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Agriculture Sector Transformation in Nepal

A Roadmap

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Foreword by Ganesh Thapa

With nearly two-thirds of the population engaged in farming, the agriculture sector in Nepal remains crucial for food security, employment, and economic growth. However, traditional practices, low productivity, fragmented landholdings, and climate vulnerabilities have posed significant challenges, necessitating a transformation in Nepal's agricultural landscape.

This book explores the transition from subsistence farming to modern, sustainable, and technology-driven agriculture. It highlights key policy reforms, technological advancements, and grassroots innovations that are driving this transformation. The insights presented here offer a comprehensive understanding of the challenges, opportunities, and future prospects of Nepal's agriculture sector.

Agricultural transformation is not merely about increasing production—it is about enhancing efficiency, resilience, and sustainability. The integration of modern agricultural technologies, digital technology, and climate-smart practices is vital to achieving a more productive and sustainable farming system. Moreover, empowering smallholder farmers, promoting agribusiness, and ensuring access to markets and financial services are critical components of this transition.

Nepal's agricultural sector faces mounting pressures due to youth outmigration, which has led to labor shortages and the abandonment of farmlands. The increasing outflow of youth in search of employment abroad threatens the long-term sustainability of agriculture, as it reduces the availability of skilled and energetic farmers to drive innovation and modernization. Additionally, climate change presents a severe threat to food production, with erratic weather patterns, prolonged droughts, and extreme temperatures disrupting traditional farming cycles. These climate-related risks exacerbate soil degradation, water scarcity, and pest infestations, further jeopardizing agricultural productivity. Over time, agriculture in Nepal has become less competitive in both domestic and export market. As a result, there has been a steady rise in food imports, which not only drains national resources but also highlights the country's growing dependence on external food supplies, posing risks to long-term food security and economic stability.

This book is structured into four major themes, encompassing 24 chapters that examine the multidimensional aspects of Nepal's agricultural transformation. Key

topics include the digitalization of agricultural extension services; strategies for commercialization of vegetable, horticulture, livestock, and rubber sub-sectors; improving local governance in agriculture; and a comprehensive operational framework for sustainable agrarian development. The book also explores agritourism prospects, high-value agricultural product certification, and pathways for improving soil fertility, irrigation, and post-harvest management.

Additionally, the book presents innovative frameworks such as climate-smart agroforestry, simulation modeling, and digital innovations in agriculture. It also emphasizes the importance of strengthening agricultural education, research, and extension services, alongside significantly increasing public resource allocation for agricultural research and development. The insights drawn from these chapters provide a roadmap for policymakers, researchers, development practitioners, and farmers to work collaboratively in transforming Nepal's agriculture sector into a dynamic and competitive force.

While this book covers a wide range of critical topics, certain gaps remain that future research and analysis should address. Key areas for further study include the socio-economic impact of agricultural digitalization, the role of artificial intelligence and digital technologies in Nepalese farming, implications of climate change on agricultural productivity, potentials for promoting climate-smart agriculture, and the scalability of successful agribusiness models. Additionally, more in-depth analysis is needed on policy frameworks that ensure equitable access of smallholders to resources, inputs and technology. Addressing these gaps will be crucial for refining Nepal's agricultural policies and driving sustained transformation.

As Nepal moves forward in its agricultural transformation, it is imperative to embrace innovation, inclusivity, and sustainability. This book is a timely and important contribution to the discourse on agricultural transformation, and I hope it will contribute to evidence based policy making.

Kathmandu, Nepal

Ganesh Thapa
Former Lead Regional Economist
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Foreword by Mark W. Rosegrant

This book is a deep and wide-ranging assessment of the agriculture sector in Nepal. It focuses on the challenges and constraints facing the sector, and seeks to identify institutional reforms, policies, investments, and other interventions that could improve the performance of the sector. Many of the chapters paint a dire picture of the current state of agriculture in Nepal. Chapter 1 identifies structural problems such as lack of coordination among key actors, weak policy formulation and implementation, and poor monitoring and evaluation of programs and policies. Other chapters note that agriculture insurance and finance reach few farmers. Investment in agricultural research and development, extension and education, water management, and rural infrastructure is inadequate. Inefficiency and high costs within value chains, including transport, communication, and transaction costs pose significant constraints to food availability and quality. These factors have contributed to a stagnant agriculture with low agricultural productivity and income growth. The chapters handle specific aspects of agriculture, with recommendations for reform in those aspects or sub-sectors. This foreword cannot elaborate on all of these, but an overall picture of needed reforms emerges by looking across the chapters. Substantial changes are needed to transform agriculture in Nepal into a dynamic, competitive, and diversified sector that can boost farmer incomes and provide improved food security more broadly.

Key policies and investments identified in the book include boosting agricultural R&D, extension, irrigation, and rural infrastructure. R&D should target not just staple crops but also high-value and export crops. Effective extension services require collaboration among government, private sector, and NGOs, using radio, mobile phones, and other technologies to educate farmers. To better target new technologies and farming systems, digital platforms should be developed to support integrated decision-making by compiling and analyzing weather, agronomic, and market data, delivering timely insights to farmers and stakeholders. Value chain innovations can make R&D investments more profitable and increase social returns. Investments in input and output markets can cut marketing margins, reduce post-harvest losses, boost production and income, and reduce hunger. Water management and irrigation efforts should improve existing systems for better efficiency and enable diversified farming while expanding irrigated areas.

Innovative agriculture insurance delivery systems, such as microinsurance and weather index-based insurance, should be pilot tested for their potential to reach greater numbers of farmers than the current system. Likewise, innovative financing mechanisms need to be explored to reach both small farmers and agribusiness. Improvement in fertilizer use efficiency should focus on developing effective and efficient fertilizer management practices that are crop- and site-specific and on integrated soil fertility management practices that combine organic and inorganic inputs. Extending this further, agro-ecological approaches that maintain species diversity in a range of productive niches, can enhance ecological processes and deliver ecosystem services that improve food security.

Two areas that should receive more attention in the book are gender-responsive policies and investment and social protection. Expanding women's access to land, finance, resources, and information—along with fairer distribution of new technology—can enhance their food production and access to food and boost overall farm productivity. Strengthening social protection in rural areas through targeted cash transfers, social insurance, tax-funded benefits, social assistance, and public works programs can improve food security by raising incomes, increasing purchasing power, and enhancing access to nutritious diets.

But overall, the chapters in this book lay out an ambitious program of institutional reform and policy and investment initiatives that can substantially improve and transform the agriculture sector in Nepal. Valuable next steps would be to do additional analysis to prioritize the policies across this rich reform agenda.

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Mark W. Rosegrant
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Preface

Nepalese agriculture possesses multiple components, including cereals, horticultural crops, and production animals, but their average productivity is low compared to the neighboring countries due to inadequate and weak policies and laws, and their weak implementation, poor functioning/performance of institutions, and incomplete federalization of agriculture sector. In light of labor shortage due to the emigration of youths, low use of improved technology, and changes in socio-economic status and dietary habits, Nepalese agriculture faces enormous challenges in transitioning from the predominantly practiced subsistence production to commercial yet sustainable agricultural production. The sector, however, has potential and such transitioning could not only fulfill domestic demands for farm products but would also contribute to transforming current agriculture into a profitable business through the export of agricultural commodities.

In the past, various agricultural policies have been formulated and implemented. However, they have failed to address serious challenges faced by Nepalese agriculture in such a way that any visible positive outcomes have been achieved. As significant effort has already been made to address one or more technical aspects of Nepalese agriculture, bottlenecks in past and current agricultural policies, their misalignments, and weak implementation have received relatively inadequate policy attention. In this context, our book aims to perform major policy revisits and integrate the knowledge from multiple agricultural sub-sectors to formulate new agricultural policies, focusing on major policy changes, governance restructures, and capacity development, considering the challenges and opportunities provided by the newly adopted federalism, with the broader goal of proposing a roadmap for the transformation of country's agriculture sector.

The idea for an urgent need of this book was proposed to the International Coordination Council (ICC) of Non-Resident Nepalese Association (NRNA) by Dr. Jagadish Timsina, who is also the Association's Agriculture Committee's Global Coordinator and is responsible for advancing Nepalese agriculture globally. The idea was promptly endorsed by the Association, and then based on a global search, the current 4-members Editorial Board was formed. Springer Nature promptly accepted our proposal for publication. All the Editors are now associated with the Agriculture

Committee. We are grateful to NRNA-ICC for providing us with an opportunity to publish this book that we believe will transform the Nepalese agricultural sector.

Our book contains a total of 24 chapters written by specialists dedicated to a range of specific agricultural commodities, university education and research institutions and systems, existing policy and government structure, and socio-economic determinants of Nepalese agriculture. We thank authors for their willingness to contribute and commitment to revise their chapter in response to Editor's and Reviewers' comments. We have been greatly benefited by the work of over 37 reviewers who provided critical and constructive comments on the drafts.

The chapters represent four major parts: (a) Agricultural Policies, (b) Education, Research, and Extension, (c) Commodity and Sector-Specific, and (d) Agri-food Systems. All chapters are oriented toward a common goal of developing a future roadmap for Nepalese agriculture, focusing on several critical elements of agriculture policy reforms in the country. These include critical analysis of historical perspectives of specific policies and plans including enabling and inhibiting factors for their effective implementation, suggestions for policy reformulations, governance restructuring, financial and legal requirements, and necessary human capacity development to address changes in policy formulations and associated implementation strategies.

We believe that this book will be a useful resource for various stakeholders. Firstly, students and researchers involved in multiple aspects of Nepalese agriculture, representing both natural and social sciences, will benefit from the agricultural roadmaps presented in the book. Secondly, it will be a solid guidebook for various governmental and non-governmental agencies and policymakers associated with agricultural development in Nepal to develop detailed roadmaps and their implementation. Finally, this book will also serve as reference material for agricultural transformation for countries that share similar economic growth, agricultural development, and geo-political challenges as experienced by Nepal. In the future, we hope this book will contribute further to developing and utilizing knowledge, skills, and competences critical for transforming Nepalese agriculture into more productive yet equally sustainable.

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Foundational Basis for Agriculture Sector Transformation in Nepal: Synthesis of Chapters and Call for National Debate

Bishnu Raj Upreti, Dinesh Panday , Prabhat Khanal, and Jagadish Timsina

Abstract Agricultural sector in Nepal has been facing unprecedented challenges and chronic problems because of combination of multiple factors. These include inconsistent or ineffective policies, inadequate or contradictory laws and regulations, weak and dysfunctional institutions, frustration among the key human resources in the sector, inadequate agricultural research and research-based education, lack of political commitment and visionary leadership, and geopolitical and geo-strategic conundrum. Addressing these challenges and problems needs new perspectives and approaches, complete restructuring of the sector, and a robust roadmap for restructuring. This chapter serves as an overview of the book and provides conceptual perspectives, approaches, and a roadmap for Nepal's desperately needed agricultural sector transformation. The wide range of topics covered in 24 chapters are grouped into four thematic areas: Policy, Institution, and Governance; Education, Research, and Extension; Commodities and Sector-Specific; Agri-food Systems. The book provides status of agricultural research, education and extension and technological progress and trends, and highlights challenges and problems in this sector. Each chapter discusses challenges and constraints faced by the specific sub-sector and provides guidelines and recommendations for the preparation of a roadmap for the transformation of the sector. Based on the analysis of diverse issues presented in various chapters, this chapter offers pathways for holistic agricultural sector reform

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in Nepal. It is anticipated that the wide range of issues presented in this chapter will serve as a conceptual basis for the broader debate among parliamentarians, political party leaders, ministers and senior bureaucrats, researchers, policy advocates, academicians, agricultural professionals, rural development workers, agri-business investors, investment banks, and students to discuss the guidelines and recommendations for development of a roadmap for Nepal's agricultural transformation. Finally, the chapter outlines other critical issues that are crucial for the transformation of the agricultural sector but not fully addressed in the book. We suggest that these issues must receive priority and be the subject of continuous discussion, research, and future publications.

Keywords Agriculture · Institutions · Laws · Performance · Policy · Roadmap · Transformation

Introduction

Nepal's new constitution (Constitution of Nepal 2015) has federalized the country into three tiers (federal, provincial and local). Under the new constitution, the responsibilities performed by the previous unitary state are assigned to three tiers, wherein most of the activities of the agricultural sector fall under the jurisdiction of local government (schedule 8 of the constitution), with only a few activities under the control of the state and federal governments. Consequently, the established patterns, procedures, human resources and institutional arrangements of the Ministry of Agriculture and Livestock Development (MoALD) at the time of the unitary state are not properly functioning now under the federal set up. Experiences over the past ten years have revealed that the three tiers of government have somewhat failed to functionalize the provisions of the Schedules 5–9 of the constitution (NLC, 2015). Consequently, staff of the federal MoALD are not willing to be transferred to provincial and local governments and that has led to overstaffing in the federal level and lack of capable human resources in the provincials and local levels. Further, because of lack of revision of the federal civil service law, provincial and local governments are not able to recruit the staff directly. Many institutional structures of agriculture (e.g., departments, centers, etc.) which must be handed over to the local governments are also not handed over yet. In this way, the agricultural sector has been adversely affected by federalization.

Nepal's agricultural sector is severely lacking relevant and competent human resources. On one hand, competent human resources are leaving the country seeking better opportunities or due to the frustration of sector dysfunctionality. On the other hand, the existing agriculture education institutions are not able to produce demand-driven, technically sound, and competent human resources. Political parties have not sufficiently prioritized or even ignored the agricultural sector. They often do not send senior politicians to the ministerial portfolios and do not allocate required resources

while leading the finance ministry and government. Hence, the nature of agriculture has remained predominantly subsistence with limited initiatives for commercialization. Consequently, the performance of agriculture and productivity of this sector is poor. Weak capacity of research institutions, lack of required agriculture infrastructures for agricultural automation, farm mechanization and marketing, poor governance and management, and poor monitoring and evaluation are contributing to poor performance of the sector.

Similarly, the agricultural market in Nepal is suffering from vested interest by elites, oligopoly, and disruptions. States' resources available for agriculture such as input subsidies and grants and services are captured by elites. Youths are not motivated to engage in agriculture. Hence, while on one hand, huge land areas have remained barren, on the other hand, the remaining pristine agriculture lands are encroached for other purposes such as for construction of business and industry infrastructures and residential buildings. Governments are not able to provide agriculture inputs such as fertilizer on time. There is weak inter- and intra-agency coordination and collaboration and existence of outdated, incomplete, or weak agricultural policies and their poor implementation. Further, increasing bio-piracy has caused loss of genetic resources, intellectual property rights have not been protected, and indigenous agricultural knowledge is rapidly eroding. There is extremely poor application of automation, artificial intelligence and digital platforms in agriculture. Finally, there is poor investment in the agricultural sector, weak engagement of the private sector, and ineffective insurance provisions.

In addition to domestic issues and challenges in Nepalese agriculture, changing global and regional geopolitical and geostrategic interests has also affected the agricultural sector. Nepal in general and the agricultural sector in particular are increasingly affected by the changing global and regional power dynamics, growing geopolitical rivalry, and divergent geo-strategic interests, as Nepal is situated in between the two rapidly emerging global powers India and China. In such situations, balancing the relationship with both and maintaining a non-alignment foreign policy have been crucial. As India has provided high subsidy to the agricultural sector and the cost of production of China is very low, Nepal is not able to compete with their agricultural products. Consequently, Nepal's agricultural market is overwhelmingly controlled by their products and Nepalese farmers are suffering from such hegemonic external agricultural market domination.

The need for transformation of the agricultural sector in Nepal has emerged from the unprecedented challenges faced by the country due to several technical, social and economic, institutional and external factors, and other interrelated causes. Many of such challenges and issues have been well recognized and addressed in recent years (Pyakuryal & Upreti, 2011; Thapa et al., 2019; Joshi & Joshi, 2021; Timsina et al., 2022). The current book has duly recognized the contributions made by these publications and has tried to fill the gaps not addressed by them. While defining the scope of the book and building upon the above studies, we realized that in addition to specific technical issues in Nepalese agriculture, we recognized that the broader issues and concerns such as geopolitical, legal, policy and institutional, and financial and governance related concerns must be considered for the transformation of the

agricultural sector. We hope that the issues and concerns and recommendations and suggestions for preparation of a roadmap mentioned in various chapters will initiate a debate and help the government and the related stakeholders in Nepal to prepare a roadmap for the transformation of the agricultural sector of the country.

Chapters Synthesis and Thematic Grouping

We summarized the key findings and lessons learnt from each chapter and grouped various chapters into four broad themes: Part I (Policy, Institution, and Governance); Part II (Education, Research, and Extension); Part III (Commodities and Sector-Specific); Part IV (Agri-food Systems).

Part I: Policy, Institution, and Governance

Upreti et al. (Chap. 1) underscored that Nepal's agriculture sector is in crisis due to weak policies, ineffective institutions, poor coordination, poor monitoring and evaluation, and complications and crises arising from the labor migration, federalization, climate change, and geo-politics. The past and current agricultural policies (both at federal and provincial levels) have been often ineffective or even failed due to several reasons. Hence, they proposed a detailed roadmap for the transformation of Nepalese agricultural and provided various ideas about how to restructure existing agricultural policies, education, research and financing institutions. There is an urgency for Nepal's agricultural sector to address (a) chronic problems, (b) constitutional requirements, (c) minimize negative effects of regional geo-political, geo-strategic and demographic dimensions, (d) ensure food security and (e) protect farmers. We anticipate that this chapter will show urgency for a need to restructure the agricultural sector and will initiate an informed debate for the broad transformation of the sector.

Joshi and Joshi (Chap. 2) analyzed the trends in public resource allocation to agriculture annual budget allocated to agricultural research and examined the factors influencing the total factor productivity growth. They suggested for a need to increase investment in public (rural) infrastructures such as irrigation, roads, and marketing and in improved technologies, and for the dissemination of those technologies by strengthening the extension system. Such investments would increase the total factor productivity in agriculture, improve and strengthen the extension system, and support smallholders in different nodes of the various value chains.

Using a mixed-methods approach, Jaishi et al. (Chap. 3) explored the agricultural service delivery (ASD) performance by local governments (LGs) across 21 municipalities in all seven provinces of Nepal. Their findings suggested that there is a need for creation of multi-level platforms that include local, provincial and federal-level representatives and agriculture, research and extension related stakeholders, and underscored the need for enhanced coordination among three levels of institutions to improve ASD, along with capacity building of local government staff.

Khanal and Pandey (Chap. 4) argued that a sovereign agri-food system that capitalizes indigenous wisdom and a modern agroecological approach can provide a safe and sure pathway for sustainable value-guided development. They emphasized the need for a paradigm shift in designing agricultural transformation policies and provided a comprehensive perspective and an operational framework for agriculture, agri-food, and livelihood systems. They further concluded that the integration of farmers' experiential knowledge, Vedic wisdom, agroecology, and Earth system justice principles in policymaking and program delivery can pave the pathway to sustainable agricultural transformation and socio-ecological development and provided several policy recommendations.

Nepalese agriculture faces various risks and vulnerabilities. Agriculture insurance can help reduce the farmers' vulnerability and risk by providing protection against crop or livestock losses due to various biotic and abiotic factors. Using the official data from the Insurance Authority of Nepal, Poudel et al. (Chap. 5) discussed the limitations and strengths of current agricultural insurance programs and insurance products in Nepal. Based on the data from field surveys in Kapilvastu and Dang districts, the study identified a wider gap between insurance premium and loss rates and suggested the need for a thorough analysis of premium rates and coverage so that the cost of premiums could be reduced. The study provided some guidelines for preparation of a roadmap for sustainable and efficient agricultural insurance programs in the country.

Despite the great contribution of agriculture to household-level food security, gross domestic product (GDP), and employment in Nepal, the sector faces persistent challenges, including outdated governance, weak institutional frameworks, and a lack of skilled human capital. Timilsina et al. (Chap. 6) stressed the need for institutional reforms and youth empowerment as key drivers of agricultural transformation. The proposed institutional reforms focus on strengthening regulatory frameworks, enhancing transparency, and fostering collaboration among government bodies, research institutions, and private stakeholders. Empowering youth through targeted education, technical training, and mentorship would be instrumental to fostering innovation and introducing modern technologies and practices. The study provided detailed considerations for preparation of a strategic roadmap emphasizing institutional governance, policy modernization, market accessibility, and digitalization to create a resilient, sustainable, and profitable agricultural ecosystem to foster economic growth and environmental sustainability.

To enhance the country's rural economy and preserve its cultural heritage, agri-tourism can leverage its diverse landscapes, traditional farming practices, and unique rural festivals. Ghimire et al. (Chap. 7) identified threats and challenges such as infrastructure deficits in rural areas, policy and regulatory gaps, financial constraints, climate vulnerabilities, gaps in hospitality, and limited market awareness in the agrotourism sector. They presented examples of successful agrotourism development in Japan, Italy, Thailand, and New Zealand and provided ideas about how they could be adapted to Nepal. They also proposed a conceptual framework tailored to country's agritourism to promote as a sustainable industry and suggested that

to realize agritourism's full potential, the country requires a dedicated national agritourism policy.

Mainali and Tuladhar (Chap. 8) provided an overview of the existing landscape of the agribusiness finance sector and the effectiveness of existing agribusiness-centered policies and initiatives in Nepal. They then explored the financial implications of transformative change and offered strategic insights for fostering sustainable agribusiness growth in the country. By identifying key challenges and opportunities, the authors provided strategic recommendations and actions required toward fostering a vibrant and resilient agribusiness ecosystem that contributes to inclusive growth, rural development, and food security in the country.

Part II: Education, Research, and Extension

Globally simulation modeling and artificial intelligence (AI) tools, such as crop and systems models, geographic information systems (GIS), remote sensing, machine learning, and digital platforms, are recognized for their role to offer transformative solutions to address various agricultural issues and challenges and modernize agriculture. Devkota et al. (Chap. 9) presented an actionable and detailed roadmap for implementing digital tools and simulation modeling in Nepal, emphasizing scalable strategies and region-specific applications to address agricultural constraints. The chapter can serve as a guide for policymakers, researchers, extensionists, and leader farmers to transform the existing low-productive agriculture into a productive, sustainable, and climate-resilient agriculture, ultimately improving food security and farmers' livelihoods. Thapa et al. (Chap. 10) provided a framework for transforming the existing agricultural extension services into an innovative extension system called 'digital agricultural extension service (DAES).' They discussed the role of digital platforms in disseminating information, technology transfer, capacity development, market management, data analytics, and decision support through real-time surveillance, advisory services, and establishing backward linkages of extension workers to research. They recommend for the implementation of the DAES platform, which serves as a framework for the transformation of extension services through digitalization, policy coherence, completeness, and collaboration among various stakeholders in Nepal.

Devkota et al. (Chap. 11) argued that all three pillars of agriculture development—agricultural education, research, and extension (AERE)—are failing to perform satisfactorily in Nepal due to the weak policy, politicization, bureaucratic control, insufficient or weak human resources, poor resource planning and weak implementation of policies and regulations. They emphasized that AERE would require structural reform and systems thinking to achieve synergies between the three pillars for the broader goal of agricultural sector transformation. Jaishi et al. (Chap. 12) provided the history of agricultural education and timelines of the establishment of various agricultural education institutions in Nepal. They also compared the course structures and students' performance and feedback in those institutions and suggested that the prevailing curriculum would need to be redesigned. They suggested a need to

restructure the current agricultural education system to produce market-driven agricultural professionals (entrepreneurs) to fulfill the demand of modern agriculture. They also suggested that agri-business incubation centers need to be established in universities which could help facilitate the transition from the subsistence farming systems to the commercialization of agriculture.

Part III: Commodities and Sector-Specific

Despite diverse climate and soil types for production of diverse species of fruit and vegetables, Nepal is annually importing them in huge quantity to meet their increasing demand. Their low production and consumption are due to limited or no commercialization, especially in the hills and mountainous areas, due to several reasons. Gautam et al. (Chap. 13) assessed current constraints and challenges in commercialization of horticulture and developed a roadmap for integration of improved postharvest management with a specific focus on packhouses and cold chain technologies with the goal of commercialization and export of horticultural crops. Timalisina et al. (Chap. 14) highlighted several challenges faced by the vegetable sector and suggested strategies to promote production, minimize dependence on imports, and achieve a trade surplus. They suggested guidelines for narrowing yield gaps and for commercializing vegetables by optimizing input use, improving value chain efficiency, strengthening institutions related to smallholder farmers, redesigning subsidy schemes, increasing investment for contextualized innovations, developing linkage of production pockets with (inter)national markets, strengthening quarantine and (phyto)sanitary measures, enhancing trade negotiations, promoting inter-agency collaboration, and developing improved policy.

Rubber (*Hevea brasiliensis*) is a high-value para or Brazilian rubber tree species with both ecological and economic benefits. Bhandari and Parajulee (Chap. 15) identified the gaps in rubber research and extension and proposed strategies for its commercialization, especially in the eastern region of the country. They proposed policy recommendations and guidelines to facilitate the expansion of the rubber production area and develop into a viable, commercial rubber enterprise. Emerging soil and water-related issues and challenges in Nepalese agriculture requires transformative strategies and interventions to manage them effectively.

Ojha et al. (Chap. 16) critically reviewed past and current legislation and policies related to soil and water management and concluded that they fall short in adequately addressing the emerging issues related to soil and water management. They proposed transformative pathways related to improved institutional quality and policy reforms that align with the present legislative and federal frameworks and prepared a roadmap, consisting of institutions responsible, institutional, policy and governance reforms, and financial requirements to tackle various soil and water-related issues in the short- and long-term. Nepalese agriculture faces multiple challenges in soil fertility and fertilizer sector. Gairhe et al (Chap. 17) identified five areas that would need immediate attention to improve soil fertility and fertilizer management in Nepal: (i) strengthening the fertilizer supply chain and markets, (ii) developing crop and site-specific fertilizer recommendation, (iii) promoting

balanced fertilization, (iv) commercializing efficient fertilizer application technologies, and (v) scaling of improved and innovative fertilizer management practices. To address these issues and to revitalize Nepal's stagnant agricultural sector, they proposed a detailed roadmap suggesting effective research and extension activities, efficient fertilizer management practices, scaling integrated soil fertility management practices involving multiple stakeholders, and improving soil health and fertilizer use efficiency strategies.

One of the key reasons for low livestock productivity in Nepal is the negligence in recognizing the importance of locally available feed sources and their use in livestock production. After reviewing the various feed sources globally and in Nepal, Khanal et al. (Chap. 18) recommended for major policy changes to improve the domestic supply of feed sources for livestock utilizing aquatic plants and algae (short term), insects (medium term), and biotechnological production of single-cell proteins (long term). They proposed developing a new Food Safety and Quality Act to deal with issues associated with governance in the feed sector by establishing a new Feed Quality Control Division under the Department of Livestock Services.

Aquaculture can play a vital role in enhancing healthy ecosystems and the rural economy, providing significantly higher returns on land and labor. Bhujel et al. (Chap. 19) reviewed the status of aquaculture research and development in Nepal and made key recommendations related to governance and planning, education, research and extension, culture types, species suitability, post-harvest handling and marketing, and specific steps to meet fish targets in different future time periods, exploiting research and development experiences in East Timor, Nepal and Thailand. They further emphasized the development of public-private sector participation at all stages of the aquaculture value chain, enabling policy environment, and emphasized on the development of public-private sector participation at all stages of the aquaculture value chain.

Part IV: Agri-food Systems

Nepal is increasingly facing food insecurity as its population and food demand are ever increasing. The current average farmers' field yields of rice, maize, and wheat are inherently low while attainable farm yields and climatic and genetic potential yields are very high. Subedi et al. (Chap. 20) identified that the factors causing low yields and large yield gaps in cereals are weather-dependent farming with no or limited irrigation facility, inadequate fertilizer use, low use of quality seeds of improved crop varieties, increased pest pressures, and various socio-economic factors. They developed a roadmap to 2040 for increasing cereal yields and food self-sufficiency suggesting for the needs of substantial investment in irrigation, fertilizer supply through in-country establishment of a fertilizer plant, adoption of improved crop and soil management practices and farmers' access to quality seeds of high-yielding varieties through efficient and innovative extension, and favorable policy and fiscal commitments from all levels of government.

Agricultural practices often combine forestry activities across Nepalese landscapes, forming diverse agroforestry systems. The application of an innovative, climate-smart agroforestry (CSAF) approach to agricultural landscapes can produce

a wide range of ecosystem goods and services. Baral et al. (Chap. 21) recommended policy and institutional reforms through development of a national roadmap based on a nexus approach to support land-sector policies and priorities, such as strengthening climate and agricultural information services; conservation and sustainable use of agrobiodiversity through site-specific crops in CSAF; development of value chains of CSAF products in partnership with the larger private sector; building capacity in CSAF technologies and practices; provision of infrastructure and other facilities for commercial CSAF, and research into the full set of ecosystem services, including carbon and ecotourism.

Pollination is an important regulating ecosystem service and plays a vital role in crop production and in conservation of agrobiodiversity. Neupane et al. (Chap. 22) highlighted the importance of pollinators in agriculture and showed serious concerns about their decline globally. They suggested that integration of pollinator management and their conservation through education, research and extension systems could reverse their decline or deficits to perform agricultural activities. They also suggested that pollination should be recognized as an important low-cost agricultural input for food production and that an evidence-based National Pollinator Strategy should be developed to safeguard pollinators and integrate pollination management into agricultural systems.

Upreti et al. (Chap. 23) discussed challenges in the current dairy sector and enabling and inhibiting factors for developing a resilient dairy sector in Nepal. They explored strategies aimed at enhancing the competitiveness, profitability, and sustainability of the sector through product diversification, efficient management practices, and innovation across financial product offerings. They emphasized the need for policy and administrative reforms to enhance productivity, promote value addition, improve market conditions and farmers' accessibility to finance, foster innovation, and strengthen governance for a sustainable dairy sector.

To fully realize the potential of high-value agricultural products (HVAPs), certification and labeling can serve as a tool for quality assurance and market differentiation. Mainali and Tuladhar (Chap. 24) highlighted the strategic importance of certification and labeling to fully exploit the potential of HVAPs for export. They provided an overview of existing certification schemes and relevant policies and regulations of different certification schemes, systematic challenges in, and opportunities for, implementation of those schemes, and identified key policies, actors, and institutional arrangements that need to be established for the effective functioning of the labeling schemes in Nepal. By giving examples of Nepal's organic-certified tea and coffee and Cameroon's GI-certified (Geographical Indication) Penja pepper, they highlighted how certification enhances market access, secures price premiums, and boosts producers' and overall national incomes. The chapter provides policy recommendations for different types of certifications schemes and calls out for policy-level improvements to align them in the agrifood sector in harmony with international standards.

Key Issues and Topics in Agricultural Sector Transformation

Despite our good intention and sustained efforts, we couldn't include many relevant and important issues or areas of agriculture, which are important for the agricultural sector's transformation. The preparation of plans and guidelines for agricultural sectoral transformation document should also consider the introduction and promotion of new technologies and providing conducive policy and favorable legal provisions for their adoption. Some of such technologies are: (1) farm automation and smart farming, (2) precision agriculture, (3) vertical farming, (4) agriculture sensors, drones and robotics, (5) automation, (6) artificial intelligence and machine learning tools, (7) advanced biotechnology, (8) soil and weather monitoring software, (9) data analytics and big data in farming, (10) GIS and GNSS (Global Navigation Satellite System), (11) minichromosomal technology, (12) Radio Frequency Identification (RFID) technology, (13) livestock biometrics, etc. Similarly, components of animal science such as animal physiology, forage and pasture, livestock production, meat science and dairy technology, animal health and antibiotics resistance, animal production, genetics and animal breeding, aquatic animal health; components of horticultural science such as floriculture, landscape horticulture, arboriculture; and components of agronomy such as weed science and agro-ecology are not addressed in this book but will need to be addressed in such document. Although rubber has been addressed, other high-value cash crops and medical herbs are not covered needing attention. The agricultural sector transformation document should emphasize technology-savvy marketing (i.e., use of digital technology to promote agricultural products and connect farmers with consumers), development of large-scale commercial agricultural marketing infrastructures, increase in agricultural investments, and consider behavioral and social issues related to agriculture. Recognizing these gaps, our team invites interested agricultural professionals to join debate on these issues and is committed to addressing these topics in the future editions to ensure more comprehensive perspectives and preparation of a robust roadmap for agricultural sector transformation.

Ways Forward for Preparation of a Roadmap: Holistic Conceptual Orientation

The ways forward proposed here for preparation of a roadmap is developed by extracting problem contexts, perspectives and recommendations from each chapter as well as experiences, reflections, and perspectives from the authors of this chapter (Fig. 1). Addressing the challenges listed in the preceding section requires total governance reform, full political commitments, new institutional arrangements, and progressive legal provisions. Further, dealing with complex challenges emerging from the regional geo-politics and power dynamics needs strong proactive foreign relations capacity (negotiation, engagement, persuasion, etc.) as well as full political

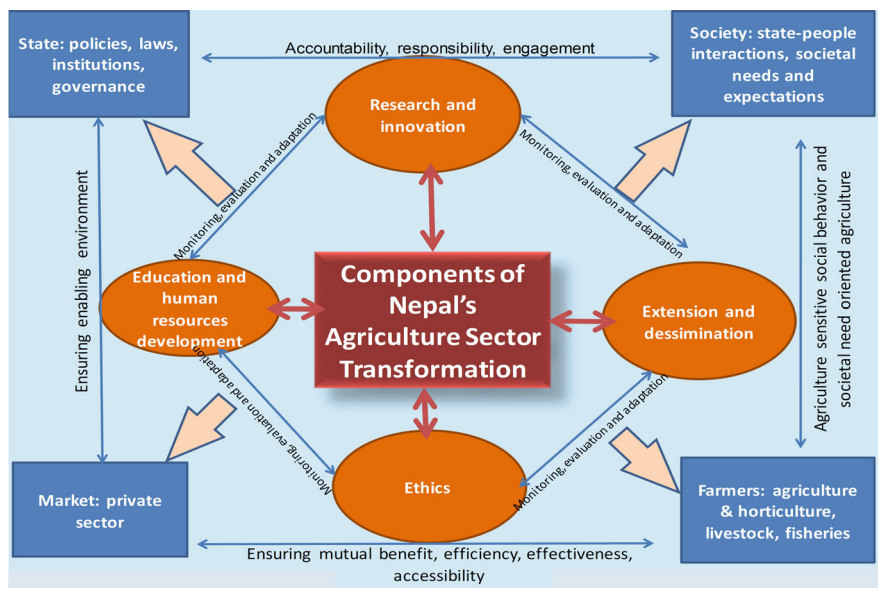


Fig. 1 Proposed framework for preparation of roadmap for agriculture sector transformation in Nepal

commitment from all political parties. Similarly, technical solutions through sound and robust scientific research, improved extension delivery systems, conducive policy environment, and favorable institutional arrangements and governance mechanisms are necessary to address the country’s complex agricultural sector problems. Restructuring the agriculture sector (Bishwakarma et al., 2020) is possible only with new ways of thinking, commitment, policies, and actions. Each of the chapters of the book has identified inhibiting factors that have inhibited the growth of the agriculture sector. Likewise, the chapters have identified enabling factors that can facilitate growth and transform the sector. Here we summarize the main inhibiting and enabling factors extracted from the various chapters.

Inhibiting Factors: Major inhibiting factors are geo-political and geo-strategic interests and pressures, market distortion and oligopoly, climate stress, adverse effects of federalized political system, dysfunctional institutional arrangements (lack of coordination and collaboration, bureaucratic, top-down, lengthy administrative procedures, failure for execution of the authorities provided to three tiers of government, etc.), failure of academic institutions to produce relevant human resources as per market need; negative effects of global change process (migration, conflict and wars, radicalism and extremism, geopolitical rivalry, etc.), biopiracy and erosion of genetic resources, loss of indigenous knowledge, ignorance and or negligence of political parties to agriculture sector, elite capture of agriculture resources (input subsidies, grants and services, etc.), lack of required agriculture infrastructures for agricultural automation and farm mechanization, poor performance of production and

productivity of agriculture sector in general and agronomy, horticulture, livestock, fisheries and other sub-sectors in particular, predominantly subsistence in nature with limited commercialization, poor research capacity and inadequate agricultural research. Other equally important inhibitors are demotivation of youth in agriculture, rampant barren lands, encroachment of fertile agricultural land for other purposes, especially housing and infrastructures, perennial failure of government to timely deliver fertilizer due to severe problem in procurement and management process; increasing loss of genetic resources, indigenous agricultural knowledge and growing bio-piracy; extremely poor inter- and intra-agency coordination with the government sector, weak collaboration between state and private sector; outdated, incomplete or weak agricultural policies and their poor implementation; failure to protect farmers' rights and poor protection of intellectual property rights; poor investment in agriculture sector; extremely poor application of agricultural automation, artificial intelligence and digital platforms; and ineffective insurance provisions. It is possible to address such inhibiting factors only through holistic reorientation, systems thinking, and complete transformation of existing policies and practices. In addition, climate change is becoming an important concern in Nepal's agriculture (DCA, 2021; Upreti et al., 2015), as many alterations in normal patterns of agriculture (such as tropical plants thriving and fruiting in sub-tropical climate, and changes in crop growth duration).

Enabling Factors: The following figure shows intricate interrelationship between four pillars—(a) state, (b) people (society), (c) market (private sector), and (d) farmers—in facilitating agricultural transformation, and these are affected by context (geopolitics, market, etc.) and interests of actors (farmers, policy decision makers, bureaucrats, consumers, traders, etc.). Systems thinking helps to understand the intricate interrelationship between four pillars, and therefore Nepal's agricultural transformation requires systems thinking, holistic perspective, enabling environment, better state-people relations, agriculture friendly societal behavior, and societal need-oriented agriculture. The synthesis of enabling factors in Nepalese agriculture shows that within these pillars, there are several enabling factors such as accountability, responsibility and engagement to promote good governance, monitoring and evaluation and, adaptation for implementation effectiveness and change.

The inhibiting factors or barriers affecting agricultural progress are related to the following four pillars. For overcoming the barriers and building the bridge for agricultural transformation, there will be a need to promote enabling factors, need to improve understanding of the complementarity among the four pillars, and need to reform each of the pillars as discussed below.

Pillar 1: State: Policies, Laws, Institutions, and Governance (Schedules 5–9 of Constitution)

The state, as regulator, facilitator and promotor, must ensure an enabling environment for agriculture sector transformation. Only conducive policy, supportive laws and regulations, responsive institutional arrangements, and implementing good governance principles into actions by the state can create an enabling environment. Hence, robust monitoring, timely evaluation and adaptation of policies, regulations (laws,

procedures, etc.), functional result-oriented institutions, competent human resources that respect and practice full accountability and responsibility, internalize and exercise engagement principles to ensure key stakeholders' participation in policy and decision-making processes to enhance ownership. Likewise, the state must ensure effective implementation of provisions listed in other pillars (2–4). The state must create an environment that promotes fair marketing, protects farmers' interests and nation's genetic resources and historical indigenous knowledge, and applies good governance principles in operation (Joshi & Joshi, 2021). Farmers are the lifesavers of Nepali people as they produce food and therefore, they must be respected. However, farmers are not properly recognized and respected by the Governments and to some extent by society as well. The state must duly recognize the pivotal role of farmers.

Pillar 2: Society: State-People Interactions, Societal Needs, and Expectations

The second important pillar of agriculture sector transformation is society. Consumerism promoted by global multinational companies and biotech industries is shaping societal behaviors, which has direct effect on agricultural sector of poor countries like Nepal. Hence, it is also the responsibility of society to perform responsible and agriculturally sensitive social behavior that promotes fulfillment of societal needs from own agriculture. So far, the role of society seems abstract but one must realize that deeper societal responsibility has a great role in saving the nation's agriculture. European Union member states in general and Scandinavian countries in particular are best examples of how society can protect, preserve and promote nation's agriculture (Prestvik et al., 2013). Society has three functions in terms of transformative agriculture. First, it should support the state for developing, promoting and implementing transformative sensitive agricultural policies, conducive legal arrangements, and effective implementation. Second, it should function as watchdog to make state accountable to people/society, to protect and prevent interests of farmers and ensure sovereignty issues in agriculture sector (Adhikari et al., 2021) as well as respect to farmers. Third, it should recognize and respect farmers and help them promote and protect their agriculture business/farm and assist them to practice ethical standards.

Pillar 3: Farmers: Agriculture and Horticulture, Livestock, and Fisheries

The third pillar of the agricultural sector and one of the key actors for agriculture sector transformation are farmers, who are often on the lower side of agriculture value chain. They are often ignored, marginalized, or neglected despite their crucial role in saving people's lives by producing food. In addition to their role in producing nutritious food, farmers also ensure mutual benefit, enhance efficiency and effectiveness of their farming, and maintain the quality and ethical standards. As discussed elsewhere in this book, the state, society and market have important role to play to protect and promote farmers whereas farmers should constructively engage with other three pillars that produce 'synergy', a badly needed aspect in Nepal's agriculture.

Pillar 4: Market: Private Sector

Private sector, often also relates with market, is another key pillar of transformation of agriculture. In Nepal, agriculture market is often either distorted, or oligopolistic,

or geo-politically dominated and therefore not fully treating farmers in a fair way. Hence, it is also the responsibility of the private sector to fully cooperate with the state and farmers to ensure fair price of agricultural products and incentivize the quality standards. The private sector has also an important role in research and innovation. The private sector needs to invest in research and education and in the promotion of large-scale agriculture for which the state must create an enabling environment. Hence, the state and private sector should work side-by-side with farmers to protect, promote and transform the agricultural sector.

The role of education and research is pivotal in bringing these important four pillars together to transform agriculture, and innovate cost effective, environmentally friendly and climatically sensitive technologies, breeds and other inputs as well as in exploring market opportunities. As has been amply demonstrated in Part II of the book, the role of education and research is fundamentally important in shaping the destiny of agriculture sector in Nepal.

Pathways: Recommendations for Preparation of a Roadmap

We suggest that the Government of Nepal should urgently start restructuring as priority national agenda. As a starting step, the government must establish an independent, high-level and fully mandated committee called High-Level Agriculture Restructuring Recommendation Committee (HLARRC) representing independent public policy experts, academicians, representatives of private sector agriculture enterprises, and senior experts from all major technical sub-sectors of agriculture. The aim of this HLARRC is to holistically examine the overall performance of existing agriculture sector and come up with operational recommendations for the government to start agriculture sector transformation. While assessing the sectoral performance the HLARRC should discuss at the ‘Agriculture, Cooperative and Natural Resources Committee’ of the Parliament and then they should be approved by the full house of the parliament to make it a broad national priority agenda.

The individual chapters presented in the book provided specific recommendations pertaining to each sub-sector. In this chapter, our intention is not to list the same recommendations here but rather to provide key recommendations that would be required for developing a broader roadmap for agricultural transformation. We offer below a proposal in the form of a set of key recommendations for restructuring the existing agriculture sector. It is not expected that all these recommendations will be implemented immediately as they will not be pragmatically possible. However, they provide a conceptual framework to initiate broader debate, discussion and engagement for effective implementation. The following recommendations can serve as the basis for HALRRC to initiate national debate for refining the roadmap for agricultural transformation of Nepal:

- (a) **Comprehensive Policy Framework:** First and foremost, a comprehensive agriculture policy that facilitates system-level reform is needed. Hence, the federal

government needs to develop a comprehensive umbrella policy that can facilitate institutional and legal reform in the agricultural sector, provide a favorable environment for the modernization of agriculture, and address all the challenges discussed in this book. The comprehensive policy must deal with the issues and concerns related to the four pillars discussed in the preceding section of this chapter.

- (b) **Institutional Reform:** Existing institutional arrangements (e.g., ministries, departments, research council and centers, Agriculture and Forestry University, Institute of Agriculture and Animal Sciences, etc.) need relevant changes in their structures, approaches, and functions. Recruitment in academic institutions should be fully transparent and merit-based and support horizontal entry at all levels to attract and retain manpower of high academic quality. Nepalese academic manpower living abroad could play a crucial role in initiating collaborative research and improving the research capacity of academic institutions in Nepal. In this context, a powerful policy body called Agriculture Coordination Council (ACC) is utmost essential to coordinate key actors and institutions such as academic, research, extension, and financial and input related organizations and ministries and departments, international development partners and different levels of government structures. The agriculture sector is directly related to the Ministry of Agriculture and Livestock Development (MoALD), the Ministry of Forestry and Environment (MoFE), the Ministry of Energy, Water Resources and Irrigation (MEWRI), and the Ministry of Land Management, Cooperatives and Poverty Alleviation (MoLMCPA) but all these are operating in silo without proper coordination with other ministries related to agriculture. Hence, it is essential to merge these ministries (except for the function of Survey Department) and make a single ministry called 'Ministry of Agriculture and Natural Resources (MoANR)'. The current ministries can be a separate department or division within MoANR to accomplish the tasks of merged ministries.
- (c) **Legal Provisions:** A strong but supportive law is essential to facilitate agricultural transformation in Nepal. At present, the existing laws and regulations are either contradictory, or unsupportive, inadequate, and ineffective.
- (d) **Governance:** Fundamental reform required in the existing governance structures and practices is the need for preconditions for the agriculture sector transformation to maintain transparency, enhance responsibility, ensure accountability, increase meaningful participation of key stakeholders, and make agriculture responsiveness to the needs of farmers, agri. entrepreneurs and nation.
- (e) **Use of Information Technology and Innovations:** There is an immediate need to introduce and use innovative advanced technologies and innovations such as drones, autonomous tractors, robotic harvesters, automatic watering, and seeding robots as well as satellite and global positioning technologies, sensors, smart irrigations, indoor and vertical farming, modern greenhouse practices, integrated pest management, micro-irrigation, plastic-culture, greenhouse cultivation, and micro-propagation, wherever appropriate. In short, precision

agriculture needs to be applied for resource use efficiency, sustainability, profitability, productivity and enhanced quality. Hence, ‘digitalization of agriculture sector’ should be an urgent priority for modernization of agriculture as has been discussed in Part II.

- (f) **Adoption of Climate-Smart Agricultural Practices:** Increasingly, Nepal needs to adapt climate-smart agriculture for which constant research and application is essential. The new agriculture policy should facilitate adaptive and climate resilient agriculture practices in Nepal.
- (g) **Farm Mechanization:** As highlighted in different chapters, farm mechanization is essential for the transformation of the agriculture sector because the currently practiced subsistence agriculture is neither attractive nor contextually relevant.
- (h) **Education and Research:** Currently, investment in agriculture research in agricultural colleges and universities is inadequate. Agriculture education provided by academic institutes at present is not fully able to meet the market demands; their graduates are largely lacking practical knowledge and updated skills. Hence, the government must ensure developing education and research systems relevant to the current changing context.
- (i) **Development of Competent Human Resources:** Developing capacity of current fragmented and demotivated human resources must be a priority of the government as at present the existing human resources available are not able to cater the needs of farmers and society.
- (j) **Protection and Preservation of Genetic Resources:** The state should develop law and regulations to protect and govern genetic resources. There is also an urgent need to start documenting and registering local species to prevent bio-piracy and extension of endangered species.
- (k) **System Perspectives and Dynamics:** The conceptual orientation of the restructuring of agriculture should follow a systems perspective. This means entailing broader social, economic, physical, and environmental processes in designing and implementing agricultural research, education and policy with a systems perspective or dynamics at a system level and not limiting to a part or a component of the system.

Conclusions

In recent decades, quite a few comprehensive books about Nepalese agriculture have been written mainly from the perspectives of natural scientists, with inadequate focus on the structural constraints such as policies, laws, regulations, institutional functionality, politics, etc. faced by the agricultural sector. In the recent past, however, some efforts have been made in dealing with pertinent issues and core policy concerns related to agricultural transformation (see “[Introduction](#)”). Considering the chronic problems and continuing underperformance of the agricultural sector, we realized the need for a holistic, system-level, in-depth, and well-informed debate on the fundamental restructuring of this sector. Building on recent studies, this book

highlights new challenges faced by the agricultural sector and provides pathways for fundamental restructuring.

We conclude that four fundamental pillars that must be considered in preparing the document for the agricultural transformation of Nepal. The first pillar is related to the role of the state, which should ensure conducive policies and laws, responsive institutions, and good governance as per the responsibilities assigned to the three tiers of government as per the constitution. The second pillar is related to society, which ensures smooth state-people relations, engagement of people in state affairs and interactions, and addresses societal needs and expectations to develop ownership of the agricultural transformation. The third pillar focuses on farmers and their concerns and commodities, and we emphasize that agricultural transformation must ensure that farmers are well protected, and their products are secure and receive deserved price. The fourth pillar is related to the market and private sector, and we suggest that agricultural transformation must ensure that the genuine concerns of private sector are addressed, and monopoly and oligopoly of agriculture market is prohibited.

Finally, in this book, we tried to cover some essential areas and issues and provided pathways and a roadmap for agricultural transformation of Nepal. We tried to prepare all chapters technically sound and at the same time stressing the need for governance, policy, legal and institutional reforms for transformation. Hence, we believe this book will be useful for policy makers, political decision makers, planners, thinkers, and high-level bureaucrats of various ministries. Finally, even though we tried to include important conceptual components and operational issues in the book, despite our efforts, it became difficult for us to cover the entire issues, concerns and topics required for agricultural transformation and for preparation of a robust roadmap. Some critically important areas (e.g., floriculture, genetics and genomics, high-value agriculture, animal agriculture) and latest technologies (e.g., farm automation, precision agriculture, agriculture sensors and drones, artificial intelligence, biotechnology, Global Navigation Satellite System) are not covered in this book. We suggest that these issues and topics be the focus of future research and publications as they will be crucial to develop a robust roadmap for Nepal's agricultural sector's transformation.

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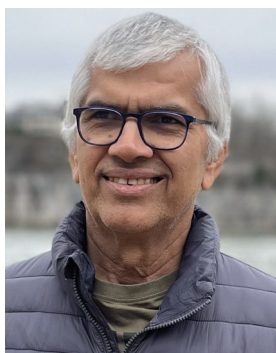


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Dr. Upreti has also served and member of different Advisory Boards e.g., CUSA of University of California at Irvine, Program Committee Member/SoA, and Program Committee Chair of Masters in Security Management Course, KUSoM/KU; Chair, South Asia School of Rural Reconstruction, Member of Board of Trustee of IFS, and many more. Dr. Upreti has taught graduate courses on conflict, public policy, security at Nepal Engineering College; KU and AFU. Dr. Upreti has supervised 2 dozen Ph.D. students and published 98 books, 3 dozen peer-reviewed articles in journals and more than 300 other articles. Dr. Upreti is frequently quoted in national and international media about Nepal's armed conflict.



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Part I
Policy, Institution, and Governance

Chapter 1

Transformation of the Agriculture Sector of Nepal: Retrospection and Outlook from Policy Perspectives



Bishnu Raj Upreti, Netra Prasad Timsina, and Yamuna Ghale

Abstract The agriculture sector of Nepal is in crisis due to several structural problems such as lack of coordination among key actors, weak policies and their implementation, poor monitoring and evaluation, and complications arising from the migration labor crisis, federalization and climate change. Further, there is unsatisfactory food production and productivity along with increasing regional geostrategic, geopolitical and geo-demographic dynamics in agriculture. Hence, the objective of this chapter is to initiate informed debate on the urgent need for transformation of the agriculture sector. While developing this chapter, we have used both primary and secondary sources of information. For primary information, we held extensive discussions with key policy and political decision-makers, experts, senior bureaucrats, academics, researchers, farmers associations and agricultural entrepreneurs in different forums such as workshops, meetings, conferences, round-tables, and one-on-one discussions. We have also reflected our own experiences and knowledge while working in agricultural policy issues and practices. For secondary data, we have extensively reviewed policies, laws, long-term strategies, and evaluation reports, as well as scientific literatures such as journal articles. As this chapter pertains to broader policy, our efforts were concentrated on capturing broader policy concerns raised by the public, media, political parties and parliament, private sectors, and farmers' associations and networks. The pressures of globalization, geo-strategic, geopolitical and geo-demographic dimensions, pandemics, armed conflicts and civil unrest in the agriculture sector, adding significant complexity. We conclude that progress in the agriculture sector is not only slow, but also failing on many fronts, such as in ensuring food security, promoting agricultural trade and protecting the rights of farmers, and have hence proposed the broader transformation of agriculture sectors.

Keywords Agriculture · Crisis · Option · Policy · Research

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1 Introduction

For the purpose of this chapter, we have operationally define ‘transformation of agriculture’, which refers to ‘a perspective that coherently and comprehensively look upon addressing power-skewed situation, integrating geopolitical and geo-strategic dimensions, technical and scientific rigor, managerial and governance dimensions, human resource aspects, reforming policy, institutional and legal frameworks, restructuring existing structures and ensuring rights and sovereignty issues in the agriculture sector of Nepal.’ Hence, it is a long-term holistic perspective that envisions fundamental change of the existing agriculture sector. The main aim of this chapter is to initiate wider debate on the need for holistic transformation of the agriculture sector from a broader perspective, going beyond business-as-usual thinking and practices.

Broader, holistic transformation may go beyond the current constitutional limit. Food is essential for everyone’s survival, and therefore, it is utmost important to develop a national consensus for the transformation of agriculture. We truly believe that the holistic transformation of agriculture is possible; thus, the perspectives shared here are implementable, if made through honest efforts with the full commitments of political decision-makers.

In this chapter, we have critically reflected on what has happened in the past three decades. Progress in agriculture is slow and unsatisfactory, and whatever changes occur in the agriculture sector are because of the pressures of globalization, commitment to international conventions and agreements, and the efforts of some innovative farmers and agri-business entrepreneurs. However, our main argument is that we could achieve more from the same resources, with time and effort, compared with current achievements. Thapa et al. (2019) published a comprehensive resource book that envisions the transformation of Nepal’s agriculture and offers possible policy options, mainly by examining macro-issues in agriculture. Their policy agenda is largely in line with our proposal for agricultural transformation.

2 Methodology

This chapter is the reflective synthesis of extensive discussions with policymakers, political decision-makers, agriculture experts, senior bureaucrats (secretaries, joint secretaries, and ex-officials) commercial farmers, subsistence farmers, agri-business entrepreneurs, and CEOs and senior officials at the Agriculture Development Bank, Nepal Rastra Bank, and other commercial banks investing in agriculture. Similarly, we have synthesized information obtained from a series of round-table discussions with provincial officials, mayors deputy mayors, and members of the federal parliament (both the Upper House and Lower House). We also extensively reviewed published and unpublished documents. The qualitative information

collected about the performance of the agriculture sector was analyzed using the descriptive-analytical approach.

3 Retrospection of Agriculture: Policy Perspective

In this section, we present the agricultural situation. Several studies have demonstrated that the agriculture sector of Nepal is facing a crisis over time (Thapa et al., 2019; Upreti, 2023). This crisis is not from a single cause, but due to numerous interrelated causes such as weak and ineffective policy, the manipulative extraction of resources by the nexus of brokers and bureaucrats, geo-strategic and geopolitical interests in agriculture (Upreti et al., 2022), lack of motivation of staff, vested interests of key domestic actors, a highly bureaucratic administration, political interference, manipulation of subsidies and services and migration, weak institutional capacities, poor resource allocations, bad governance, and other factors.

3.1 Contributions of Agriculture in GDP

Proportional contribution of the agriculture sector to Gross Domestic Product (GDP) is rapidly decreasing. According to the Nepal Economic Forum, agriculture contributed 65% to GDP in 1975, which was reduced to 40% in 2000 and by 2022 had reached only 23.95%. The total population relying on agriculture in Nepal is about 62% (Mishra, 2023). In principle, agriculture is one of the priority sectors of government, though in practice, the sector is the most ignored, highly marginalized and nearly forgotten in terms of policy, laws, resource planning and budgeting. For example, only NPR 58.98 billion (USD 445.21 million) was allocated for the agriculture sector in the fiscal year 2023/24, out of a total size of NPR 1.751 trillion (USD 13.20 billion), which is only 3.36% of the total budget (Pradhan, 2023).

The agriculture-dependent population in Nepal is also decreasing. According to the Central Bureau of Statistics CBS, , the population engaged in the agricultural sector was 73.9% in 2008, but decreased to 60.4% in 2018 (CBS, 2018). The Economic Survey (MoF, 2022) reveals that the total contribution of the agriculture sector (agriculture, forests, and fisheries) to national GDP is declining, as it was 23.9% in FY 2021/22, down from 24.9% in FY 2020/21. Similarly, the total import of agricultural and livestock products were Rs. 212.81 billion during FY 2020/21, with vegetables and pulses worth Rs. 26.74 billion, fish and readymade fish-meat worth Rs. 1.26 billion, and dairy and livestock food products worth Rs. 1.47 billion imported in FY 2021/22 (CBS, 2018). When an agricultural country relies on the import of basic food items, it is an indication that it is moving into deep crisis.

The situation of Nepal's trade deficit is also worrying (ADB, 2023). The Government of Nepal missed the opportunity to make an evidence-based futuristic agriculture plan for self-sufficiency, import substitution and export promotion. India's



Fig. 1 Map of Nepal

strategy of dominating the agricultural market of Nepal is another major threat (Acharya et al., 2021).

3.2 Geopolitical Dynamics

Geopolitically, Nepal is situated between the two largest countries in the world in terms of population. To the north, the current population of China is 1,418,967,432¹ with a geographical area of 9.6 million km², and with an open border to the south, east, and west is India, with a population² of 1,452,346,489 and a geographical area of 3.287 million km². Both countries are rising global powers. Nepal is small in comparison with these giants, as it has only around 30 million people and 147,516 km² in geographical area. Before the inclusion of Limpiyadhura, Lipulek, and Kalapani areas in the map of Nepal, the country's total area was 147,181 km², but once the Government of Nepal added these areas by amending the constitution of Nepal, 335 km² was added and the total area became 147,516 km² (Fig. 1). It is a major challenge for Nepal to manage its open border with the giant India.

Open borders between Nepal and India not only provide opportunities, but also challenges, such as illegal agricultural input and illegal food trade, cross-border crimes, illegal poaching and hunting, and open access for beggars and cheap labors

¹ As of Saturday, August 10, 2024; according to https://www.worldometers.info/world-population/china-population/#google_vignette.

² As of Saturday, August 10, 2024, <https://www.worldometers.info/world-population/india-population/#:~:text=The%20current%20population%20of%20India,latest%20United%20Nations%20data1>.

(Upreti, 2023). Further, because of the open border, Nepal's agricultural products were not able to compete with the large scale of the Indian agriculture market, storage, distribution and management capacity compared to Nepal. Further, the effects of the Indian government's protection policy of its agriculture sector, Indian hurdles in quarantine at the border, the weak negotiating capacity and commitment of Nepal's government, constraining WTO rules for trading goods and services, indirect and informal Indian restrictions on the rights of landlocked countries to free access to the sea, bilateral FTAs, not being able to utilize special privileges granted to LDCs, disfunction of the SAARC and its food bank and other agriculture provisions, the monopoly of Indian seed/food companies in Nepal's seed/agriculture sector and consequent loss of native varieties are other serious problems faced by Nepal's agriculture sector (Acharya et al., 2021).

Geostrategic tensions have also directly and/or indirectly impacted the agriculture market of Nepal. For example, high Indo-Pak tension and recent political instability in Bangladesh ousted Prime Minister Sheikh Hasina to seek asylum in India when she left the country on August 5, 2024, along with the Sri Lankan economic crisis and tension between India and Maldives, all of which have direct impacts on availability and price rates in the South Asia region and have affected the agriculture sector in Nepal. India and Nepal also have several unsettled issues related to water resources, dams, land inundations and borders, which have negatively affected Nepal's agriculture sector. Strategically important but unsettled issues between India and Nepal such as not receiving the Eminent Person Group (EPG) Report, 'Treaty of Peace and Friendship Between the Government of India and Government of Nepal', the Kalapani-Limpiyadhura-Lipulek and Susta border disputes, and the failure of India to implement agreements related to water issues have also affected the agriculture sector of Nepal. Geopolitically, Indian engagement in the civil war in Sri Lanka, tension between India and Sri Lanka on fishing rights, and Indian concerns regarding Chinese investment in Sri Lanka affect regional food markets. Tension between India and Maldives due to the Indian perception of the pro-China policy recently adapted by Maldives also alters the food system (Aryal & Droop, 2024). Hence, South Asia region is geopolitically becoming a highly sensitive zone, which is affecting regional food markets. In the past 55 years, India imposed three blockades 1961 (BS 2019), 1970 (BS 2027), 1989 (BS 2045), and 2015 (BS 2072) against Nepal (Pant, 2018), which is an example of the country's vulnerability in the future.

3.3 Chronic and Structural Problems in the Agriculture Sector

The agriculture sector is facing chronic and structural problems, such as the failure to meet people's expectations and materialize constitutional priorities due to poor governance and inappropriate aspects of the federalization process (e.g., resistance to decentralizing resources, mandates, authorities and staff from the federal level,

despite constitutional provisions and legal requirements; Adhikari, 2019; Bishwakarma et al., 2020, 2021). A mismatch between market demand and the supply of human resources, lack of coordination and collaboration between institutions (Thapa et al., 2019), inadequacy of agriculture infrastructure (e.g., warehouses and cold storage, nurseries, hatcheries and breeding centers, specialized laboratories, processing plants, sales centers, required farm machineries), and inadequate emphasis on research and innovations further contribute to the problems faced by the agriculture sector (Acharya et al., 2020; Bishwakarma et al., 2021; 2020).

The failure of the Government of Nepal to control the distorted, manipulative and oligarchic agriculture market (e.g., where only a few very large traders control the market of some commodities and cash crops such as cardamom), and Indian domination in Nepal's agriculture market are major challenges (Upreti et al., 2022). Nepal's reliance on imported food from India is one added crises in Nepal's agricultural development and even affecting national security (Adhikari et al., 2021). The exponential growth of food imports from India in the past ten years is evidence of a crisis.

Geopolitical and geostrategic concerns often affect the agriculture value chain globally. Compliance with the international and regional trade-related provisions such as the Agreement on Sanitary and Phytosanitary Measures (SPS Agreement) and Technical Barriers to Trade, biopiracy, the selective and conditional use of provisions of the World Trade Organization (WTO) (Agreement on Agriculture(AOA), Sanitary and Phytosanitary (SPS), Technical Barriers to Trade (TBT), and Trade Related Aspects of Intellectual Property Rights (TRIPS) agreement are the provisions those directly impacts on agriculture sector), agriculture trade provisions of the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) and The South Asian Free Trade Area (SAFTA) (provisions of legislative and policy related measures, assistance for improvement of national capacity on: Sanitary and Phytosanitary (SPS) measures/Technical Barriers to Trade (TBT) measures, WTO Agreement on Agriculture and Subsidies, TRIPS and Intellectual Property Rights) are some factors indirectly and/or directly affecting the agriculture sector. Father seed control through genetic modification, patenting, and molecular technologies also directly affects the indigenous seed system (Upreti et al., 2022). As Nepal is situated in between India and China, rising global power centers with opposing interests, the USA, European Union, ASEAN, and other power centers primarily focus on these two countries; hence, Nepal is one of the best places for them to make surveillance, with agriculture as an easy area for their covert engagement.

Further, India has specific interests related to Nepal's agriculture so as to maintain an Indian monopoly market of agricultural goods (Upreti et al., 2022). India obstructs exports of agricultural products such as ginger, cardamom, and vegetables in their customs offices and check-posts, raising concerns of phytosanitary measures. Heavily subsidized Indian agricultural products dominate Nepal's agriculture market because of the provision of the trade agreement between the two countries that provides agricultural products with tariff-free access to the Nepali market. Under this provision, Nepal's agriculture products cannot compete.

Similarly, India has already defined water as a strategic issue considering future scarcity.³ Therefore, in this context, for India, water is not merely a natural resource to harness optimally with care and caution but is more important to ensure for its strategic advantages. Because part of India (mainly the Ganges River Basin) is dependent on water resources drained from the Himalayas, it is of great concern of Nepal to balance India's strategic interests and meet Nepal's water needs.

In addition, China is not only expanding its geopolitical, economic, and societal influence across the globe, but also advancing in emerging biopharma and biotechnology (Algazy et al., 2022) that could have greater influence across the world. It is also forcing the US to rethink its biotechnology policy (Moore, 2020). Now, policy-makers in the United States are concerned about national security, data security, and economic competitiveness. In this situation, we do not know the impact on Nepal as China's immediate neighbor. Emerging technologies such as synthetic biology (Moore, 2020) will have greater impacts on food systems; hence, this is a concern for Nepal in general, and the agriculture sector in particular.

Globally, agriculture in general and seed in particular is seriously dominated by multinational biotech companies (Upreti et al., 2022; Panthee et al., 2023). Economically poor countries are suffering more from these companies' high-handed biotech interventions such as investment in research and innovation, monopolizing genetic resource (e.g., through patenting). For example, they have developed hybrid varieties of crops that are possible to use only once, and farmers have to buy new seed for the following crop season, repeating the same cycle again and again. Nepal is not yet able to completely save its genetic resources, and farmers are suffering repeatedly from problems related to hybrid seeds. In the long run, this issue draws serious policy concerns.

Changes in demographic dynamics (e.g., a rural to urban shift, shifts from the hills to plains/city centers, labor migration abroad, alteration in the male–female ratio, the proportion of older people) is affecting agriculture, e.g., through cultivated land turning into barren land (Ghale, 2023). Rapid, haphazard urbanization and the encroachment of fertile agriculture land through infrastructure development (e.g., the fertile agricultural lands of Kathmandu Valley and other flat plains and roadside areas disappearing) is a structural problem. Further, the recent report from National Climate Change Survey 2022 (NSO, 2022) has highlighted the potential effects, risks and huge challenges related to agriculture.

Specialized agricultural education, research and extension institutions such as the Nepal Agriculture Research Council (NARC), Agriculture and Forestry University (AFU), Institute of Agriculture and Animal Sciences (IAAS) of Tribhuvan University, and private colleges have long existed in Nepal. However, their performances are unsatisfactory. They are not operating according to their institutional objectives and the spirit of the constitution (Das et al., 2019). Their operation is highly bureaucratic, ineffective and in some cases, dysfunctional (Bishwakarma et al., 2021). The commitments of political parties through election manifestos and electoral speeches about agricultural transformation are not translated into real practices. The poor governance

³ <https://www.indiawaterportal.org/faqs/water-policies-india-past-and-present>.

and malpractices in the agriculture sector are documented in the periodic reports of the Auditor General's Office, cases fielded against agriculture officials by the Commission for the Investigation of Abuse of Authority (CIAA), the government's failure to buy required fertilizer on time and blatant delays in paying sugarcane and dairy farmers. The state of agriculture mechanization is rudimentary in Nepal. Further, land utilization as per land use policy categories is not effectively implemented. Nepal lacks proper utilization of NTFPs, medicinal herbs, high-value agriculture crops, seeds and breeds, indigenous varieties and floriculture opportunities.

3.4 Ineffective Existing Agriculture Policies

The policy in this chapter refers only to public policy of national significance and therefore does not cover short-term, small-scale policies implemented at local levels. Major policies related to agriculture are the Agriculture Development Strategy, National Agriculture Policy 2061, Poultry Policy 2068, Kharka Policy 2068, Agribusiness Promotion Policy 2063, Agro-Biodiversity Policy 2063, National Dairy Development Policy 2078, National Animal Breeding Policy 2078, National Animal Health Policy 2078 (MoF, 2022), and the Agricultural Mechanization Promotion Policy 2072 (MoLD, 2015; Joshi and Joshi, 2021). Policy has to have the capacity to provide a conceptual and operational road map (PRI, 2022), and if it is not able to provide a roadmap, perspectives and guidelines, it will fail (Muller, 2020; Rijal & Upreti, 2022). Such a conceptual roadmap can assist the government in addressing specific agriculture-related public concerns and/or deliver specific constitutional mandates as well as provide a framework for ensuring the legal, institutional, procedural, and resources (both human and financial) required to deliver the commitments contained in the policies. The effectiveness of Nepal's agricultural policies is broadly examined in this section from this perspective.

One of the authors of this chapter conducted research on effectiveness of Nepal's agricultural policies while working at the Policy Research Institute (PRI), a government think tank (Bishnu Raj Upreti was Executive Chairman of it for three years from 2020 to 2023 and was heavily engaged in reviewing public policies, comparing existing different public policies and reviewing new draft policies prepared by different ministries and government agencies and concluded that the formulation process and outcomes were weak and ineffective). Frequently raised questions during this time included why agriculture policies (both federal and provincial) are often ineffective in Nepal (PRI, 2022).

3.4.1 Bureaucratic Control and Absence of Political Leadership in Policymaking Process

Elected representatives of the people (i.e., ministers and members of parliament) are often not engaged in agriculture policy formulation process. Several elected

representatives are not able to provide vision and guidance to bureaucracy to aptly shape public policy, nor are they proactively enthusiastic or have the capacity to guide the bureaucracy in making effective public policy. Hence, public policy is entirely controlled by bureaucrats, and often lacks a political thrust. Poor understanding of policy at the political level and biased and selective interpretation of policy at the bureaucratic level are contributing to making policy ineffective (Rijal & Upreti, 2022).

3.4.2 Weak Policy Formulation Process

Nepal has serious weakness in policy formulation process (PRI, 2022), including, (a) weak proper need assessment and prioritization, (b) weak assessment of potential risks and opportunities, (c) lack of conceptual clarity, (d) tokenistic participation of key stakeholders resulting to lack of ownership, (e) a top-down and only formality fulfilling process, and others. These are often glaring weaknesses observed in policy formulation (Upreti, 2023). Proper policy formulation process often leads to the higher possibility for effective implementation, and vice versa. Weak agricultural policy is the result of a lack of proper policy formulation process, as shown in Fig. 2.

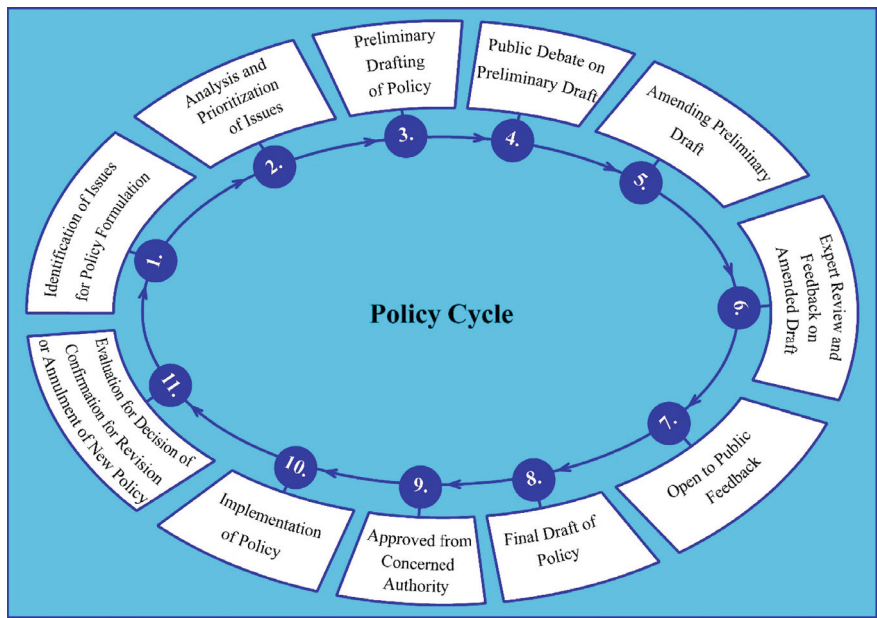


Fig. 2 Policy formulation cycle of PRI

3.4.3 Inconsistencies in Contents of Policy

The PRI study (2022) concludes that a good policy that is consistent, coherent and effective is the result of a combination of proper process, structure, and contents. One of the authors of this chapter who previously worked at PRI was engaged in assessing the effectiveness of agriculture policy and observed that the contents of policy were largely inconsistent, incomplete, and sometimes irrelevant because they were not based on evidence or research findings and did not follow the typical steps of public policy formation as presented in Fig. 2. Often, logical sequencing between (a) policy statements, (b) operational strategies, and (c) implementing guidelines were weak or missing, or very vague. Statements with similar meaning were presented as policy statements and strategies.

3.4.4 Ignorance in Legal Provisions and Requirements

Successful implementation of agricultural policy requires legal backup. However, agriculture policies are formulated without proper assessment of the legal situation. Once policies are promulgated, existing laws prohibit implementation (e.g., the forest act and the park and people act). This legal contradiction between different laws inhibiting implementation of certain policies must be assessed before finalizing policy and state clear legal provisions that are required to implement the given policy. Further, there is no provision of punishment to concerned officials if who fail to implement policy that gives impunity even if they do not take responsibility for implementing it.

3.4.5 Extremely Poor Coordination and Accountability Mechanism

Policy documents necessitate assigning specific executing and supporting institutions to effectively implement policies (Muller, 2020; PRI, 2022). However, neither clear responsibilities of officials and institutions nor accountability mechanisms or penalizing provisions are found in agriculture policies. If responsible officers are not penalized when they do not implement policies, no one will take responsibility for implementing them.

Agricultural policies are hugely complex and require the involvement and commitments of many ministries, boards, directorates, banks and financial institutions and private sectors. Lack of inter-ministerial and inter-agency coordination (e.g., the Ministerial Development Action Committee, MDAC chaired by the prime minister is the highest such mechanism, but it is not functioning) is the most important factor contributing to policy failure (Rijal & Upreti, 2022; Upreti, 2023). Implementation of agricultural policy goes beyond the existing mandate of the federal Ministry of Agriculture and Livestock Development, and the support of and cooperation from the other 12–13 federal ministries is essential. Furthermore, poor coordination and collaboration within the three tiers of government and with other actors such as

private sectors, social groups, and academic institutions is hampering the proper functioning of the agriculture sector.

3.4.6 Human and Financial Resources Provisions

Good policy always projects the human resources required to implement the policy and identifies institutions responsible for implementation (Upreti, 2023). Existing agriculture policies have no vision for the tentative requirement of financial and human resources for implementation. Without the proper projection of required resources in policy, the possibility of failure in implementation is high (Upreti, 2023). This has precisely occurred in the case of agriculture.

3.4.7 Pressure for Quick Policy Formulation

The promulgation of public policies in Nepal takes place over a very short time, leaving out important public consultation processes that ultimately lack public ownership, which makes them difficult to implement later. This is due to pressure from ministers. Proper policy formulation is a complex, lengthy and rigorous process that can easily fail if not designed properly (Hudson et al., 2019). Depending on the gravity of the issue, the timespan for a policy formulation process requires a minimum of 9 months to several years for policies' that are directly related with large number of people (e.g., agriculture, health and sanitation). Complex policies require supplementary documents (e.g., strategies, guidelines, procedures) elaborated during policy preparation to provide the background, context and other details not contained in the policies, which are missing in Nepal's agriculture policy formulation process.

3.4.8 Monitoring and Evaluation

Different agriculture policies are either inconsistent or lack clear indicators in their policy documents for monitoring and evaluation. Further, most of them include no mention of time for evaluation and do not specify monitoring and evolution responsibility (Upreti, 2023). Hence, these policies are facing challenges.

3.4.9 Lack of Accountability

One of the main reasons for the non-implementation of policy is lack of assigned accountability (PRI, 2022). Responsible officers failing to implement policy should be held legally accountable for making policy effective. So far, policy implementation comes only from the choice of responsible officials. If there is no compulsory requirement to implement policy, often, the officers responsible do not implement it.

3.4.10 Conflict Among Implementing Agencies

Nepal's agriculture policy suffers from conflict among implementing agencies (i.e., ministries/departments) and even among officials within and between agriculture agencies. Such conflicts and differences in understanding of policy provisions contribute to ineffective implementation.

3.4.11 Influence of Informal Actors

Nepal's agriculture sector is massively influenced by brokers, entrepreneurs, and other invisible actors during both policymaking and implementation. Invisible influential vested interest groups hold a large influence and are manipulating agriculture policies, practices, subsidies, and markets.

3.4.12 Lack of Institutional Memory

A serious lack of institutional memory is a chronic problem in the agriculture sector, along with the extremely poor authentic data available despite the periodic data collection system in place. Making policy without proper and relevant data is futile and risky, a challenge that the agriculture sector is facing.

3.4.13 Donor-Driven Policy in Agriculture

The influence of development partners in Nepal's agriculture sector is high. Some donors even have specific projects to support the development of agriculture policy, which should be unacceptable. These donors have huge influence in the ministry, as they provide easy financial resources and recruit former ministry bureaucrats experts to develop policy that suits the recipients and the donors but does not serve the national interests. Making public policy is a domestic political process (Upreti, 2023) and therefore it is not appropriate to engage donors in the policy formulation process.

3.4.14 Structural Difficulties for Technological Initiatives

Technology is properly and systematically used in a national scale in Nepal's agriculture sector, though some efforts in the recent past are facing hurdles due to structural bottlenecks. For example, the Ministry of Land Reform and Management (MoLRM) started the Electronic/Digital Land Record Management and Information System (LRIMS) to make land administration work efficient, accurate, and easy. However, the system is not effective due to lack of coordination with MoLD. If coordinated, the

LRIMS, a good initiative, could work more effectively in improving the performance of land and agriculture.

4 Envisioning the Transformation of the Agriculture Sector: A Pathway Proposal for Debate

Several studies have covered technical, managerial, and scientific aspects of Nepal's agriculture (Khanal et al., 2020; Panthee et al., 2023; Roka, 2017; Shrestha, 2021; Thapa et al., 2019; Timsina et al., 2022) and cover a wide range of issues in agriculture but provide comprehensive pathways for the transformation of the agriculture sector in the future. Here we deal with core concerns such as policy gaps, structural weaknesses and coordination lapses, which are essential for advancing the transformation of the agriculture sector. Lack of comprehensive long-term vision and a resistant mindset of policymakers and political decision-makers poses problems for agriculture sector transformation. It is important to critically examine the interconnection of political, economic, technical, governance, managerial, and geostrategic aspects while developing agriculture policy. Therefore, it is urgent to develop agricultural policies by integrating scientific, managerial, governance, and geostrategic aspects/concerns to avoid possible disastrous consequences in the Nepalese agriculture system.

Fundamental transformation of Nepal's agriculture sector requires new thinking, perspectives, policies and plans, legal provisions, institutional arrangements, and the allocation of human and financial resources. The "business as usual" model we have observed over the last few decades will not work in Nepal (PRI, 2022); hence, we have proposed a broad roadmap for a wider debate.

In transformative agriculture, the broader aim should be enhancing productivity, sustainability and resilience of the agriculture sector; addressing the power-skewed situation in agriculture; tackling geopolitical and geostrategic concerns in the agriculture sector; advancing technical and scientific rigor; improving managerial and governance dimensions; reforming policy, institutional and legal frameworks; and integrating rights and sovereignty issues. Further, transformation must ensure, (a) self-sufficiency, (b) import substitution, and (c) export promotion through the commercialization and mechanization of agriculture with the aim of resilience and sustainability. In this context, we discuss a roadmap for the transformation of the agriculture sector in the following sections.

4.1 Addressing Power-Skewed Relations in Agriculture

Powerful, elite and land-rich people shape and govern Nepal's agriculture sector; even though subsistence farmers and laborers are dominant in agriculture (Roka, 2017).

Further, gender discrimination is widespread in the agriculture sector (Ghale, 2023). Over the past one or two decades, the feminization of agriculture has been rapid due to the displacement of male farmers from armed conflict and/or out-migration to other countries and areas for labor work. Hence, it is necessary to change existing feudalistic, gender-discriminatory, elite-controlled power relations in the agriculture sector by changing laws and regulations, policies and practice. Highly skewed power relations in agriculture need to change with the aim of inclusive agriculture that is productivity and prosperity oriented.

4.2 Restructuring Existing Agriculture Structures

The present government, which has secured nearly two-thirds majority of the two largest political parties, has placed agriculture as a priority and made a promise to provide political stability and revision of the constitution. Therefore, it is the right time debate agricultural transformation that includes a change in vision, priorities, policies law, institutional arrangement, and human resources. This government has to take initiative for national consensus to facilitate rapid and effective implementation of an agriculture sector transformation. Therefore, political parties must work together on this issue and build a national consensus. Through either constitutional change or legal provisions, the actions outlined in this chapter are instrumental to transforming the agriculture sector.

4.2.1 Proposal for Restructuring the Existing Agriculture Sector

Agricultural sector transformation should be an urgent national agenda. Before starting the reorganization of the agriculture sector, it is appropriate to constitute an independent, high-level, and fully mandated Task Force (TF). An independent public policy expert or an academic or committed senior politician must lead the proposed TF with the representation of experts from all of the major technical subsectors of agriculture as members. The TF has to holistically assess the overall performance of the current agriculture sector and provide operational recommendations to the government for starting agriculture sector transformation. These recommendations must be discussed thoroughly at the Agriculture, Cooperative and Natural Resources Committee of the Parliament and be approved by both house in parliament to create a national priority. Following this, the government must start restructuring the agriculture sector.

4.2.2 Restructuring Existing Ministries

The higher number of ministries at the federal level means frequent bureaucratic hassles, poor coordination, and a waste of resources for administration. Hence, at the

federal level, existing agriculture-related ministries such as MoALD, the Ministry of Forest and Environment (MoFE), the Ministry of Energy, Water Resources and Irrigation (MEWRI), and the Ministry of Land Management, Co-operative, and Poverty Alleviation (MoLMCPA) must be merged to create one ministry called the Ministry of Agriculture and Natural Resources (MoANR). There should be a separate department or division within MoANR to accomplish the tasks of the merged ministries. The tasks of the Survey Department of the MoLMCPA and other non-agriculture-related technical tasks must be transferred to the Ministry of Home Affairs or another appropriate ministry. In the same spirit, all ministries related to agriculture and natural resources at the provincial level should be merged into one ministry.

4.2.3 Restructuring of Existing Agricultural Educational, Research, and Financing Institutions

The main aim of restructuring existing agricultural educational, research, and financing institutions is to develop functional integrated national agricultural education and research systems that can cater to national need. At present, Nepal's agricultural research, teaching, extension, and finance institutions are not functioning satisfactorily and therefore need to accomplish the following:

Academic Institutions

Academic institutions, e.g., the Agriculture and Forestry University (AFU) and the Institute of Agriculture and Animal Sciences (IAAS), are highly politicized. They are not fully able to cater to national needs because their academic and research quality is far below standard. Neither students, teachers, nor staff are serious about de-politicizing their institutions; rather, they are becoming part of the problem and polluting the academic environment and research ecosystem. Other branch campuses and affiliated colleges are operating haphazardly; hence, the fundamental restructuring of academic institutions is a precondition for which laws have to change first. All agriculture education institutions should be under the umbrella of AFU, with no need for a separate provincial agriculture university.

Research Institutions

Similarly, the National Agriculture Research Council (NARC), state's most resourceful apex institution responsible for agricultural research with a capacity of 63 research centers and a vast provision of human resources across the country, is heavily politicized, bureaucratized, and operationally under the shadow of the minister (and even the secretary). The enormous infrastructure (e.g., farms and research centers across the ecological belts, federal provinces, altitude zonation, climate variability) available within this institution is seriously underutilized. If this situation remains

the same, it will soon be dysfunctional. Agriculture research institutes are not able to deliver quality research outputs: for example, there is very little patenting, no drastic increase in productivity, and no food self-sufficiency. Therefore, it is urgent to restructure Nepal's agriculture research institutions.

Agricultural Financing Institutions

The performance of financial institutions engaged in the agriculture sector is poor, and seriously criticized because of their failure to serve the needs of farmers and agriculture entrepreneurs. The Agriculture Development Bank (ADB), a dedicated financial institution created to cater required service in the agriculture sector, was converted to a commercial bank. This was a strategic mistake and a great setback for agricultural development. Hence, it is urgent to bring back the ADB under the Ministry of Agriculture with a revised mandate to solely cater to the financial needs of the agriculture sector. The government provides billions of rupees directly and/or indirectly through bilateral and multilateral donors funding as subsidies to different components of agriculture annually, but their impacts are unsatisfactory. In this context, a study by Shrestha (2021:16) found that the utilization of agricultural subsidies has not been utilized properly in practice, and small and needy farmers are not being benefitted from the agriculture support policies and programs. It is found that government subsidies are heavily influenced by political power and politically influential persons. The bureaucratic complicated system, lack of transparency and good governance, and lack of proper information about the subsidy are key constraints to easy access of subsidy to the small and needy farmers. In addition, failure of anti-corruption mechanisms and degradation of the values, ethics, and morality are also significant issues of Nepal.

Transferring the ADB from Ministry of Finance to the Ministry of Agriculture and changing the mandate to cater all of the financial services needed to deliver agriculture as a one-door service is indispensable. Then, ADB must perform all investments related to agriculture (e.g., FDI, loans, subsidies, insurance), which will not only mainstream financial resources as per government priority, but also control the existing anomalies and corruptions observed in agriculture-related subsidies. This arrangement will be capable of tackling financial problems (e.g., investment as well as subsidies) in the agriculture sector. The ADB must also coordinate with other larger investments in agriculture by other commercial banks and FDI.

The existing Agriculture Input Company Limited (AIC Ltd.) is largely unable to perform its functions, especially managing fertilizers on time. Hence, it is also necessary to reform AIC Ltd. to cater efficient services that contribute to transforming commercial agriculture.

How to Restructure Existing Agricultural Education, Research, and Financing Institutions?

- (a) **Establishment of an Agriculture Coordination Council (ACC):** A powerful policy body is needed to coordinate the academic, research, extension and financial and input-related organizations to enhance the performance of the agriculture sector as a one-door service. A five-member ACC could be one of the best options, where roles will include coordinating policies, planning, legal provisions, and resources (human and financial) among agricultural educational, research, and financing institutions. An independent eminent professor or expert must serve as chair, and members of the council should be the VC of AFU, ED of NARC, GM of ADB, and the Secretary of Ministry. The main mandate of the ACC is to ensure integrated, cost-effective, and result-oriented planning, monitoring of implementation and solving the problems faced by academic, research, extension, and financial institutions to cater their mandates. This Council must also develop a long-term vision, projections of human resources needed for the agriculture sector and developing a national research strategy. The ACC should not interfere at the operational level of the AFU, NARC, ADB, and Ministry, but rather, ensure that they operate fully autonomously and on a fully complimentary basis.

As such, it will be more logical to bring all academic agricultural institutions administratively under the mandate of the ACC and restructure its current form (i.e., law, policy, strategy, human resources, curriculum, courses, operational style and teaching learning, research). Then, the NARC and AFU have to technically operate under a single national agriculture higher education and research strategy coordinated by the ACC. All research-related activities have to be implemented in an integrated and complementary way, even if the ADB, AFU and NARC operate in an autonomous way. Therefore, NARC agriculture scientists can teach in the AFU and share their research findings, and university students and faculties have to conduct research on NARC agriculture research farms spread across the country. This will be a win-win situation for both the NARC and AFU and could meaningfully contribute Nepal's agricultural transformation.

Agriculture extension, one of the essential components of the agricultural development triangle (the other two being education and research), is in a crisis at present once the established agricultural extension system (though slow and steady) is abolished after the federalization of the country. The crisis facing agriculture extension services needs to be remedied, and one right way of reviving extension services is to operate agriculture service centers in each Palika (municipality or rural metropolitan area) from the collaboration between the local government and the AFU/NARC. The AFU and NARC, operating under a national agriculture higher education and research strategy and coordinated by the ACC, must collaborate with local governments in terms of extension of research findings and innovation.

4.3 Advancing Technical and Scientific Quality

The agriculture sector of Nepal must apply innovative advanced technologies and develop the capacity to use new innovations such as drones, autonomous tractors, robotic harvesters, automatic watering, and seeding robots, as well as satellite and global positioning technologies, sensors, smart irrigation, indoor and vertical farming, modern greenhouse practices, integrated pest management, micro-irrigation, plastic-culture, greenhouse cultivation, and micro-propagation where appropriate. In this respect, capacity-building of beneficiaries is an important part of advancing technical and scientific quality. In sum, Nepal has to shift toward precision agriculture for resource use efficiency, sustainability, profitability, productivity, and enhanced quality. Applying advanced technologies and innovation in agriculture requires capacity development, conducive law, policies, and responsible institutions, which is possible only from the proposed transformation.

4.4 Strengthening Managerial, Governance, and Human Resources Requirements

At present, the agriculture sector of Nepal is weak in governance, poor in managerial aspects and undisciplined and politically divided in human resources, which are some of the major causes for the poor development of the country's current agriculture sector. Therefore, developing the capacity of fragmented and demotivated human resources, maintaining transparency, enhancing responsibility, ensuring accountability, increasing meaningful participation of key stakeholders, and making agriculture responsive to the needs of farmers, agricultural entrepreneurs and the nation.

From a broader management perspective, it is essential to shift the agriculture-dependent population to non-agriculture sectors. At present, Nepal's population relying on agriculture is about 62% (Mishra, 2023), but most subsistent farmers are not able to secure their livelihood needs (CBS, 2018). Hence, new policy has to make clear provisions for shifting the number of agriculture-dependent farmers from 62% to a lower percentage and ensure that those engaged in agriculture will be able to mechanize agriculture, develop entrepreneurship and commercialize agriculture. The strategy for reducing the number of farmers dependent on agriculture lies in the mechanization and commercialization of farms on the one hand and creating attractive employment opportunities in other sectors on the other hand.

4.5 Reforming Policy and Legal Frameworks

Reforming policy and legal frameworks are preconditions for developing a holistic national agriculture policy. The existing national agriculture policy of 2061 (2004) is outdated. Further, other dozens of thematic polices, existing institutional, and legal frameworks require reorganization to meet the spirit of the constitution of Nepal, 2015 (2072 BS). Most existing thematic or sub-sector policies of agriculture are ineffective (Roka, 2017).

Institutions in the agriculture sector are concentrated at the federal level, and are highly bureaucratic and non-responsive to change. Most staff of agriculture institutions at federal level should be transferred to the local level. Some laws and policies are outdated because they were promulgated before the constitution. In this context, the standard policymaking process (Fig. 2) and policy structure (Fig. 3) as defined by the PRI (PRI, 2022) guides to make correct policy.

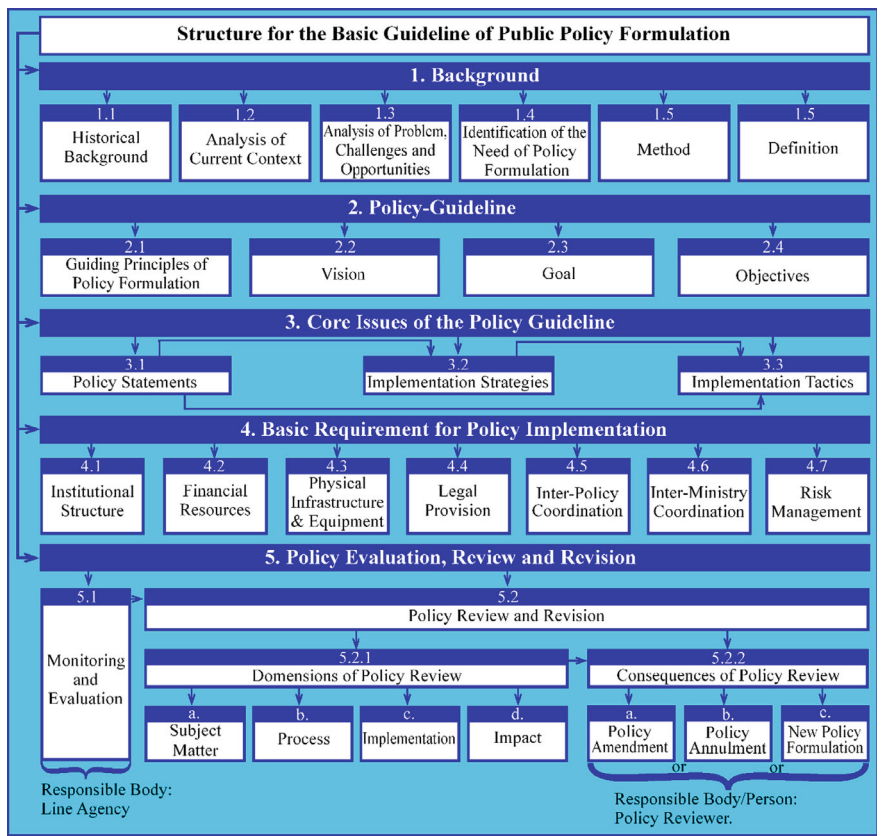


Fig. 3 Content and structure of public policy of PRI

4.6 Rights and Sovereignty Issues

Rights and sovereignty issues in the agriculture sector are poorly understood, misunderstood, or ignored. Even though the parliament has passed the Right to Food and Food Sovereignty Act, 2075 (2018) to embrace the spirit of the new constitution, its translation into action is weak. Agricultural biodiversity is increasingly being lost due to a lack of strong policy and legal provisions to protect and promote traditional agricultural systems and bioprospecting. Specific provisions of the WTO, including Intellectual Property Rights (IPRs) regimes, are also causing problems in protecting native crops, plant and animal genetic resources and local seed systems.

Nepal's commitment to plant variety protection through reformed legislative measures under the Convention of Biological Diversity (CBD) and promotional and safety measures to establish farmers' rights should be effectively executed, which is largely lacking. Hence, the priority of agriculture sector transformation should be on right and sovereignty, meaning protecting the rights of farmers (e.g., the autonomy of farmers over their genetic resources and food) and other provisions such as the United Nations Declaration on the Rights of Peasants and Other People Working in Rural Areas of the UN (2018) and the UN Covenant on ESCR (1966).

Indigenous crops are adaptive to adverse conditions such as diseases and insect-pests, and are grown in difficult conditions such as acidic or alkaline soil, dry areas, or extreme weather. Hence, Nepal must develop a crop landraces profile, and agriculture policy must address this issue. Similarly, Nepal has vast traditional knowledge on agriculture land races such as amaranth, barley, naked barley, bean, buckwheat, finger millet, foxtail millet, proso millet, and cold tolerant rice crops, along with animal breeds and traditional animal medicines. Nepal's new policy must protect, promote and make use of this knowledge.

4.7 Dealing with Geopolitical and Geostrategic Issues

Protection of agriculture from geopolitical and geostrategic interests should be part of agricultural transformation. Many countries have protected their agriculture sectors for strategic reasons. Subsidies in certain components of the agriculture value chain as part of protection is indispensable for national interests; hence, Nepal must protect its agriculture. Further, it is necessary to place top priority on agriculture in national plans, programs, budgets, technical human resources, and assigning a senior portfolio to the minister. A high priority on agriculture is needed to make the country self-food-sufficient, promote the export of agricultural products, and conserve genetic diversity.

It is also essential to incorporate food and water securities into national security provisions. Political parties need to make consensus for incorporating food and water security into national security concerns, as the failure to secure food and water will lead to national insecurity. A study by Adhikari et al., (2021) concludes that

Nepal's growing dependency on food imports is threatening the country's national sovereignty. Other issues include the unregulated flows of food from India through smuggling/illegal export.

4.8 *Natural Disasters and Climate Concerns*

A recent study found that the least developed countries (LDCs) are facing increasingly devastating impacts of climate change that are leading to loss and damage (Bharadwaj et al., 2022). Nepal is one of the LDCs suffering from the adverse effects of climate change and therefore requires additional climate finance, technology and capacity-building support to effectively implement National Adaptation Plans (DCA, 2021). Agriculture is one of the major sectors affected by climate change and therefore requires appropriate response provisions. If not timely addressed, climate concerns can be a perennial source of human insecurity (Upreti et al., 2016) and could lead to conflict and instability. Natural disasters are regularly impacting agriculture every year, e.g., the flood of September 2024 caused billions of Nepali Rupees in costs for the agriculture sector.

4.9 *Land Issues*

Land is a highly politicized, contested, complicated, and confusing issue in Nepal (Pyakurel and Upreti, 2011). Issues of squatters, landless people, peasants, ex-Kamaiya, and Haliya are used as political tools. This is being further complicated because land as a natural resource not created by human beings is constitutionalized as private property in Nepal. Conceptually, resources created by nature are not private; hence, land should be owned and regulated by the state, which should provide use rights to individuals. However, this is not the case in Nepal, and this issue is seriously affecting not only the agriculture sector, but also development infrastructure such as the construction of roads, irrigation, buildings, and urban centers.

In agriculture, a skewed pattern of land ownership with a small portion of people controlling large portions of land has implanted conflicts between landlords and small farmers and landless people. Many lands owned by land-rich individuals are either fallow, or undercultivated or use for other commercial purposes.

4.9.1 *Commercialization of Agriculture and Market Reform*

Commercialization of agriculture is a precondition for what? Nepal cannot continue its present state of agricultural development, which is largely subsistence in nature and not able to provide required food products for the nation despite billions of rupees in investment and the engagement of more than half of the country's population. Now

is the time to retrospectively analyze the reasons for this and address them. The current subsistence nature of agriculture has to shift to commercial, entrepreneurial, profitable ventures through land consolidation, accumulation or contract, farm mechanization, and agricultural industrialization. Large-scale contract farming and specialized commercial farming through cooperatives or public–private partnerships are needed to transform subsistence agriculture into commercial agriculture in Nepal.

4.9.2 Market Reform

Agricultural market reform ensures a transparent, accountable process of assembling, storage, processing, transportation, packaging, grading, and distribution of different agricultural commodities. The main aim of agriculture market reform should be to safeguard the food and nutritional security of the Nepali people, prevent monopoly and oligopoly in the agriculture market as part of agricultural reform, and systematize production and consumption. Agriculture market regulation requires a special act that ensures affordability, awareness, availability, acceptability, the choice of farmers to sell their products to anyone without obstruction, and protecting farmers from external manipulations. Agriculture market policy should focus on ensuring efficiency (both technical and economic) and effectiveness in production, distribution, and consumption.

4.9.3 Establish Rural–Urban Linkages

Conceptually, rural and urban areas are highly interdependent and complement each other. For example, rural areas produce foods and supplies to urban areas, supply labor, and provide natural beauty, outdoor recreation, and raw materials, whereas urban areas consume food produced in rural areas and provide information, imported goods, services and manufacturing to rural communities. Hence, Nepal's agriculture strategy must strengthen rural–urban linkages and functional cooperation for mutual benefits.

4.9.4 Ensure Food Self-sufficiency

One of the best ways to ensure nationwide food security is to make each local Palika food self-sufficient, which is realistically possible with the full commitments of Palikas. In this context, Palikas must have a clear policy and priority of growing local food, fruits and vegetables, or any other crops that are commercially possible in their areas. The government should emphasize the production and consumption of local food crops (e.g., if the area is suitable for buckwheat or finger millet, emphasize growing them). Palikas have to construct warehouses in each Palika, purchase products from farmers at the time of harvesting, store them in these warehouses, and

return the stored products to farmers at a time when the price of their commodity is high so farmers can get better prices and protection from manipulative traders.

4.9.5 Use Locally Produced Food Items in Government Offices

One of the best ways to promote agriculture, ensure the price of products, reduce external dependency, and motivate farmers to produce sufficient food is to make a compulsory provision of using locally produced food by state agencies. If the government makes a compulsory provision for the Nepal Army, Nepal Police, Armed Police Force of Nepal, jails, canteens of government offices, and government schools to use food locally produced within Nepal, the import of milk products, fruits, vegetables, and food items will reduce drastically.

4.9.6 Protection of Biopiracy and Biodiversity

Nepal is rich in biodiversity but losing biodiversity (MoFSC, 2014) at an alarming rate. Because biopiracy is becoming a chronic problem, Nepal must adapt stringent measures and enact strong laws and policies to protect biodiversity and prevent biopiracy. Protection against biopiracy and the preservation of biodiversity requires strong plant breeding industries in Nepal (Panthee et al., 2023).

4.9.7 Establish Organic and Chemical Fertilizer Plants

Chemical fertilizer is becoming one of the most contentious issues. It is also a source of manipulation and corruption and seriously undermining the performance of agriculture. So far, the government has not been able to provide fertilizers to meet need despite the billions of rupees allocated and invested for fertilizer purchase. Hence, Nepal has to establish its own chemical fertilizer plant as a national pride project. We have enough electricity to address the energy requirement for operating a fertilizer plant as one of the main problems; further, establishing organic fertilizer factories in each province to complement chemical fertilizer is essential to improving soil quality. A public–private-cooperative approach could be an appropriate option to establish organic and chemical fertilizer plants.

5 Conclusions

Weak and outdated policies, contradictory laws and regulations, extremely poor coordination within and between ministries, poor governance within the agriculture sector, lack of accountability and transparency, a centralized mindset, limited availability of competent human resources, extremely poorly performing existing

mechanisms, and a weak commitment of leadership are contributing factors for the poor performance of the agriculture sector of Nepal, which is not performing per the expectations of farmers as well as the government. Agriculture institutions, strategies, and action plans are not able to deliver expected results despite the huge number of human resources and the investment of billions of rupees in the sector over time. Resistance to change in the mindset of political and policy decision-makers, faulty policies (e.g., policy formulation process, structures, contents) and practices (e.g., policy implementation, governance, management) have caused poor governance of agriculture, causing the public to seriously question it (PRI, 2022). Neither monitoring nor evaluation as correcting tools are seriously used, and the performance of education, research and extension in agriculture is not satisfactory.

The changing global and regional geopolitical, geostrategic, and demographic dynamics (including the influence of India on Nepal's agriculture and the long and recent influence of China) are posing new and possibly unbearable challenge to the agriculture sector if appropriate strategic measures are not taken on time. Hence, now is the right time to start the transformation of the agriculture sector through changes in present policies, legal and institutional arrangements and implementation style, as well as organizational structures and human resource management. This means it is urgent for agricultural transformation to address, (a) sectoral chronic problems, (b) constitutional requirements, (c) minimizing the negative effects of regional geopolitical, geostrategic and demographic dimensions, (d) ensuring food security, and (e) protecting farmers.

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Chapter 2

Public Resource Allocation and Agricultural Growth: An Empirical Analysis in the Nepalese Context



Ganesh R. Joshi and Gunjan Joshi

Abstract The agricultural sector in Nepal is important in terms of providing employment and contributing to the economy. Although structural change in this sector has been observed over the years, its real growth is about 2.64% per annum. Many public policies and plan documents indicate this sector as a priority sector. However, priority is not reflected in terms of public resource allocation. This paper aims to analyze the trend in public resource allocation to the agricultural sector and examine the factors contributing to agricultural total factor productivity growth (ATFP) from 2001 to 2022. It also analyzes the annual budget allocated to agricultural research, which can add new and useful knowledge for a sustained increase in productivity. It is revealed that the compound annual growth rate of real resource allocation to agricultural research was 5.69%, which is lower than the growth of the national budget and resources allocated for agriculture. The average annual share of this sector is 7.2% of the national budget while only 3% for agriculture and livestock. Out of the share of agriculture and livestock, only about 14% is capital expenditure, which is lower than other subsectors such as irrigation, forestry and land management. Agricultural research is underfunded and has received on average only 8.9% of the budget allocated to agriculture and livestock per annum. Nepal's agricultural research receives only 0.30% of the value of agriculture gross domestic product (AGDP), which is far below the international norms of 1–2%. The ATFP growth shares about only 26% of AGDP growth, which is influenced by capital investment and expansion in roads and irrigated area. The allocation of public resources to the agricultural sector is inadequate to support infrastructure development, generate employment and improve livelihoods, and foster innovation for generating sustainable technologies tailored to diverse agro-ecosystems. Hence, if this sector is accorded priority in policy and strategies, its share of national public resources should be increased substantially for enhancing productivity and contributing to national prosperity.

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Keywords Agriculture • Allocation • Growth • Public • Resource

1 Introduction

The agricultural sector is a major sector of the Nepalese economy, consisting of agriculture and livestock, forestry, irrigation, and land management. It contributed about 48% to Gross Domestic Product (GDP) in 1990, though this has declined to about 24% in recent years; it also provides employment to 60% of people. Land holding size has decreased from 0.68 ha to 0.55 ha, while holdings below 0.5 ha in size have increased from 53 to 62%, and 12% of the land operated by agricultural holdings has declined in the last decade (NSO, 2023). Agricultural land productivity (AGDP/ha) was at about USD \$3498 while agricultural labor productivity (AGDP/labor) remained at USD \$1029 in 2021/22 (MoALD, 2023a, 2023b). Similarly, compound annual growth of real AGDP between 2011 and 2022 remained at 3.1% and cereal productivity in 2022 was 3219 kg/ha. All of these figures are lower than Nepal's neighbors (World Bank Group, 2023). The slowing growth and declining or stagnating share of agriculture draws attention to the importance of promoting sustained agricultural growth, as this sector faces many challenges, including increasing trade deficits, the outmigration of youth, low level of competitiveness, impacts of climate change, among others.

To attain the desired level of agricultural growth, all of the South Asian countries including Nepal have emphasized the importance of TFP improvements in their subsequent plan documents (Anik et al., 2017). The 20-year Agriculture Development Strategy of Nepal (2015–2035) emphasizes achieving TFP growth by facilitating access to improved technologies and ensuring the effective management of natural resources and other inputs (MoAD, 2016). Similarly, the National Agriculture Policy (NAP) 2004 envisions enhancing the livelihoods of the population through sustainable agricultural development focusing on transforming the subsistence-oriented farming system into a commercial and competitive one. The Agricultural Perspective Plan (APP, 1995–2015) was a national strategy with a cross-sectoral approach aimed at accelerating the agricultural growth rate to achieve a strong multiplier effect on employment growth, both within the agricultural sector and across nonagricultural sectors. Anik et al. (2017) mentioned that technology, finance, human, and natural capital as well as the mechanization level were the determinants of TFP change in Nepal. The average TFP level during 1980–2013 was 0.67 for Nepal, which was lower than Pakistan (0.91) and India (0.85) (Anik et al., 2017). Liu et al. (2020) mentioned that ATFP growth remained at 0.62% and a technical change at 0.68% between 2003–2016.

The agricultural sector is central to increasing income, alleviating poverty and improving the standard of living of the Nepalese people. Accelerated growth in the agricultural sector is considered a key approach for lifting about one-fifth of Nepal's population still living below the poverty line out of poverty. Agricultural-based growth is 2 to 3 times more effective at reducing poverty than similar levels of

growth originating from other economic sectors (World Bank, 2008; Christiaensen & Martin, 2018). Similarly, growth in the agricultural sector disproportionately benefits the poorest people, particularly in countries at lower levels of economic development (Ligon & Sadoulet, 2018). Most of the poverty reduction in Nepal between 2003/04 and 2010/11 occurred in rural areas and was driven by rising agriculture incomes (World Bank, 2016). However, the growth of this sector has been quite volatile in the last decades due to variation in weather and many socio-economic and technological factors.

The dismal and inadequate growth of this sector has not been able to meet increasing food demand and the livelihood needs of Nepal's growing population. In the context of the recent global and national food crisis and unprecedented rise in the price of foods, the role of this sector has further increased to address this crisis. Nepal's many public policies and plan documents spell out this sector as a priority. However, this has not been assessed in terms of public resource allocation. This paper aims to fill this gap by analyzing the trend in public resource allocation to the agricultural sector and its subsectors and analyzes the factors contributing to agricultural total factor productivity growth (ATFP) for FY 2001/02 to 2022/23. It also attempts to analyze the annual budget allocated to agricultural research, which can add new and useful knowledge for a sustained increase in productivity.

2 Methodology

Data Sources: This paper uses data published from the Ministry of Agriculture and Livestock Development (MoALD), the Economic Survey and Redbook of Ministry of Finance for different years, the National Sample Census on Agriculture for 2001/02, 2011/12 and 2021/22, and other publications of the National Statistics Office. The time series data for 2001/02–2022/23 has been used for analyzing changes in the annual national budget, the allocation to the agricultural sector and agricultural research, and total factor productivity.

Analytical Technique:

The changes in resource allocation have been analyzed using the following formula:

$y = a b^t$ or using the natural logarithm, can be written as

$$\ln y = \ln a + t \ln b \quad (1)$$

where,

y = dependent variable, i.e., national budget, allocation to MoALD and allocation to agricultural research.

a = intercept term.

t = time period as 2001 = 1; 2002 = 2 ...

To estimate the annual growth in ATFP, a growth accounting framework was adopted that allows for the marginal effects of factor growth to change over the years.

This growth accounting exercise is normally conducted in terms of labor share and capital share in the output and growth rates of these factors of production. The output growth not explained by these variables is treated as the contribution of TFP.

A Cobb–Douglas production function has been used that assumes a constant return to scale. The factor shares (labor and capital) were derived through the regression of the Cobb–Douglas production function and TFP was derived from the estimated factor shares in output and the growth of these factors of production. The production function is written as:

$$Y = e^{\delta} K^{\alpha} L^{(1-\alpha)} U \quad (2)$$

where,

Y = real AGDP, δ = constant term (shift factor), L = labor force, K = real capital, U = random error term, and δ and α are the parameters to be estimated.

Equation (2) assumes constant returns to scale [$(\alpha + (1-\alpha) = 1)$]. A logarithmic transformation of the Eq. (2) would be:

$$\log Y = \delta + \alpha \log K + (1 - \alpha) \log L + U \quad (3)$$

Subtracting $\log L$ from both sides, we get:

$$\begin{aligned} \log Y - \log L &= \delta + \alpha \log K + (1 - \alpha) \log L - \log L + U \\ \text{Or, } \log Y - \log L &= \delta + \alpha \log K + \log L - \alpha \log L - \log L + U \end{aligned} \quad (4)$$

Rearranging Eq. (3), we get:

$$\begin{aligned} \log Y - \log L &= \delta + \alpha (\log K - \log L) + U \\ \text{Or, } \log (Y/L) &= \delta + \alpha \log (K/L) + U \end{aligned} \quad (5)$$

Equation (4) is the estimating regression equation in level form. The estimating equation in growth rate form would be the following:

$$d \log (Y/L) = \delta + \alpha d \log (K/L) + U \quad (6)$$

The estimation of the regression in level form (Eq. 4) would maintain the long run relationship between the factors of production and the real output; this paper primarily makes the estimation in log form. As α gives the elasticity of output with respect to capital, $(1-\alpha)$ will give the elasticity of output with respect to labor. The output growth not explained by these two factors would be attributed to total factor productivity growth. Therefore,

$$gTF\hat{P} = gY - \hat{\alpha} * gK - (1 - \hat{\alpha}) * gL \quad (7)$$

where $gY = d \log(Y)$, $gK = d \log(K)$ and $gL = d \log(L)$, $\hat{\alpha}$ and $(1 - \hat{\alpha})$ are the estimated values of capital and labor share in output (AGDP) from the above Cobb–Douglas production function.

The data on real AGDP were obtained from the Ministry of Finance (annually published in the economic survey reports). For data on the agricultural labor force, census figures have been used, since the time series data on employed labor force are not available. Thus, data on agricultural labor force are derived by interpolation of the census data for the years 2001, 2011, and 2021 carried out by the then Central Bureau of Statistics (currently the National Statistics Office).

The time series data on capital stock (in agriculture) were not available. Therefore, for estimating the capital stock, the capital expenditure for agriculture, irrigation, forestry, and land management (AIFL) subsectors (by MoF published annually in the red book) and the annual investment made in the agricultural sector by the banking and financial institutions (BFIs) were considered. The capital stock was calculated using the perpetual inventory method. The capital stock figures were derived with the help of the equation $K_t = I_t + (1 - \delta) K_{t-1}$ where, K_t refers to capital stock at time t , I_t refers to investment in the agricultural sector (capital expenditure AIFL and BFIs investment in the agricultural sector) at time t , and δ refers to the depreciation rate. The equation $K_t = I_t / (\delta + i)$ where, $\delta = 0.08$ and i is the real interest rate $= 0.05$ was used to obtain the initial values for the capital stock (I_t).

After obtaining the figures for TFP growth in agriculture, the study attempted to examine the determinants of the growth rate, and the following regression equation was estimated.

Similarly, the determinants of ATFP have been estimated by using the following regression equation (log linear form):

$$\begin{aligned} \text{ATFP} = & a_0 + a_1 \text{Irrigation} + a_2 \text{INVEST} + a_3 \text{Road density} \\ & + a_4 \text{Literacy} + a_5 \text{PerGDP} + a_6 \text{Time Dummy} + U \end{aligned} \quad (8)$$

where

ATFP = the dependent variable, Agricultural TFP growth.

Irrigation is the ratio of irrigated area to the total cultivated area,

INVEST is the real total public investment in the agricultural sector (agriculture, forestry, irrigation, and land management),

Road density is in km per 100 sq km of cultivated land,

Literacy is the literacy rate of the economically active population in agriculture (percentage),

PerGDP is the real per capita GDP (in US\$ 2015 prices), and Time Dummy is the period dummy (1 for after ADS implementation (2015/16), 0 otherwise).

$a_0, a_1, a_2, a_3, a_4, a_5, a_6$ are parameters to be estimated and U is the error term.

The significance of the coefficient on Time Dummy would be tested to determine whether or not the Agriculture Development Strategy (ADS) implementation has significantly impacted ATFP growth rate. A positive and statistically significant value

Table 1 Mean summary statistics of the variables

Variables	Mean	Hypothesized sign
Irrigation %	41.0	Positive
Real capital budget in Agril sector (%)	3.03	Positive
Literacy %	60.0	Positive
Road density (km/100 sq km of cultivated area)	164.35	Positive
Real GDP/capita (US\$)	788.09	Positive/Negative
Time dummy (1 for:2015–2022; 0 for:2001–2014)	0.36	Positive

Source Estimated by the authors from data of 2001–2022

will substantiate the contribution of ADS implementation toward improvement in Agricultural TFP.

The inclusion of the above variables in the model is based on the review of previous literature. Several previous studies have shown that agricultural productivity is positively linked to improvements in the quality of the labor force (Avila & Evenson, 2010; Fugile and Rada, 2011) which is a proxy of the literacy rate of the economically active population. Other important determinants of agricultural growth in developing countries include general investment in agriculture (Chand et al., 2011; Rahman & Salim, 2013), infrastructural investments for road (road density) (Chand et al., 2011), and irrigation investment (Chand et al., 2011). Similarly, Enu and Attah-Obeng (2013) found a negative relationship between real GDP per capita and agricultural production, signifying that higher income levels were associated with a slower growth in agricultural TFP. The summary statistics of the variables used for estimating the determinants of ATRP growth and hypothesized relation is presented in Table 1.

3 Results and Discussion

3.1 Growth of the Economy

The overall real economic growth in Nepal remained at 4.80% per annum for the entire period (2001–2022), while the growth in the first period was slightly higher than in the second period. The AGDP growth, on the other hand, remained at 2.64% per annum. This figure was higher in the first period compared to the second period. The case with per capita AGDP was similar to that of AGDP (Table 2).

Table 2 Economic growth in different periods (percentage) in Nepal

Description	2001–2022	2001–2014	2015–2022
AGDP	2.64	4.16	2.36
NAGDP	5.75	4.81	4.93
GDP	4.80	4.58	4.25
Per Capita AGDP	2.25	3.92	1.79

Source Economic Survey (Various Years). Growth rate estimated by authors

3.2 Growth of Crops and Commodities

The agricultural sector consists of cereal crops, horticulture, livestock, fisheries and forestry. These subsectors have varying levels of contribution to GDP and AGDP. The share of cereal crops in GDP is about 6.8%, horticulture (including spice crops and potatoes) is 7.5%, livestock 5.7%, forestry 2%, fisheries 0.4% and other crops (oilseeds and pulses) 1.5%. The subsectors' in AGDP revealed that cereals share 28.25%, horticulture 31.4%, livestock 24%, forestry 8.5%, fisheries 1.5% and other crops 6.3% (MoALD, 2023a).

There are several crops and commodities under these categories. The changes in production are discussed and presented in Table 3 for 2001–2021. The growth in production and productivity is not uniform across crops. The contribution of area expansion to total production ranged from 13% for pulses to 67% for vegetables, while it was negative for paddy. The productivity growth contributing to total production was 87% in pulses, 84% in wheat, 77% in maize, 61% in sugarcane, only one-third in vegetables, and 50% in potato. The annual compound productivity growth in the case of paddy is quite high.

The annual compound growth rate of livestock and fisheries is presented in Table 4. The growth in production of all the commodities was quite impressive with the exception of mutton. The production growth of chicken was the highest, followed by pond fish culture, egg and milk. The production growth of mutton is quite low.

Table 3 Compound annual growth rate in area, production and yield of crops (percentage) from 2001–2021

Crop	Area	Production	Yield
Paddy	−0.29	1.59	1.88
Maize	0.80	3.42	2.62
Wheat	0.44	2.78	2.34
Vegetables	3.19	4.75	2.34
Pulses	0.36	2.74	2.38
Sugarcane	0.98	2.51	1.53
Oilseeds	1.87	4.57	2.70
Potato	2.00	3.98	1.98

Source Statistical Information on Nepalese Agriculture (Various Years). Growth is estimated by the authors

Table 4 Compound annual growth rate of livestock commodities and fish (percentage) from 2001 to 2021

Commodity	Production
Goat meat	3.73
Mutton	0.64
Milk	3.95
Chicken	15.00
Egg	6.32
Pond Fish	8.46

Source Statistical Information on Nepalese Agriculture (Various Years). Growth is estimated by the authors

3.3 Public Resource Allocation in Agriculture

Countries like Nepal have to increase agricultural investment, promotion of the uptake of new technologies, develop infrastructure such as roads, markets and warehouses facilities, and improve access to credit, particularly for small producers and entrepreneurs. It is also important for the government to take measures that support small farmers' access to improved inputs, support agricultural research and extension, and the generation and dissemination of knowledge about effective farming and farm management.

Investments in agriculture continue to be low despite a significant inflow of remittances and increased agricultural income. Factors contributing to the low level of investment include relatively low productive technologies that translate to low returns on investments, land fragmentation and declining farm size discouraging investments in mechanization, weak technical capacity of farmers and others. In addition, investments in the sector are also constrained by factors such as the lack of financial sector deepening. Although access to various types of infrastructure has slightly improved, there is still the need for further development of critical infrastructure such as irrigation, roads, storage and value chains.

The agricultural sector consists of agriculture and livestock, irrigation, forestry and land management. The share of total public investment of this sector and its components is presented in Fig. 1. It shows that on average, the agricultural sector received 7.24% of the total public investment per annum between 2001 and 2022. It ranged between 5.29% in 2019 and 9.25% in 2001. Similarly, the average share of agriculture and livestock (including fisheries) remained at 3% per annum, with a range between 2.27% in 2019 and 3.93% in 2001. The average share of irrigation ranged between 1.62% (2019) and 3.19% (2001), with an average share of 2.4% per annum. The public investment for forestry and land management is also fluctuating, with an average share of 1.36% and 0.47% per annum, respectively. The fluctuation in public resource allocation indicates that the government principally considers agriculture as a priority sector, but this is not reflected in resources allocation.

The allocated budget is further disaggregated into recurrent and capital expenditure. It shows that on average, only about 44% of the budget in the agricultural sector was capital expenditure between 2001 and 2022. There is quite a variation in

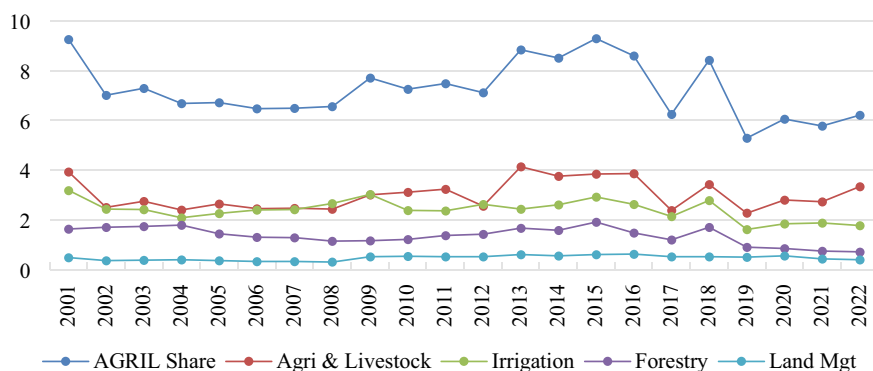


Fig. 1 Share of agricultural sector and its components in the national budget. *Source* Ministry of Finance (Redbook), various years

the proportion of capital and recurrent expenditure in different agricultural subsectors. In the case of capital expenditure, it was only about 13% for agriculture and livestock (MoALD), about 93% for irrigation, about 33% for forestry, and 22% for land management.

There is no uniformity among countries in public sector investment in agricultural research and development. As a share of the value of agricultural production at the farm gate in 2019–2022, Brazil's public sector expenditures on agricultural R&D was 0.9%, compared with 0.7% in the United States, 0.4% in China, and 0.3% in India. Public sector expenditures on agricultural R&D declined as a percentage of the value of agricultural production in all countries between 2000–2002 and 2019–2021, mainly because of the rise in the value of production. Switzerland has invested the most in agricultural innovation and knowledge systems, and is slightly above 4% of the value (average of 2019–2022) of agricultural production (OECD, 2022).

An agricultural research intensity ratio is typically used to measure the agricultural research investment effort of a country or a group of countries. It is estimated as the percentage share of investment in agricultural research in total agricultural output. The agricultural public research intensity ratio for the LDCs amounted to 0.47 compared to 1.7 for the other developing countries in 2009. Although there is no official recommendation about preferred intensity ratios for agricultural R&D investments, the World Bank has suggested a 2% target rate, while the Inter-Academy Council, focusing particularly on sub-Saharan Africa, recommended an agricultural research intensity ratio of 1.5% (UNCTAD, 2009). An intensity ratio of 0.72 was observed for global AGDP, which was spent on agricultural research. Spending averaged 0.34 of AGDP in low-income countries; 0.24% in middle-income countries other than Brazil, China, and India; and 2.81% in high-income countries (Beintema et al., 2020).

The latest share of Nepal Agricultural Research Council (NARC) in Agricultural Gross Domestic Product (AGDP) was only about 0.30% in 2022, and has never reached above 0.35%, which it did in 2001. It was the lowest (0.14%) in

2009. Compared with international norms of 1–2% of AGDP it is quite low, which is about only one-third of the lower bound of international norms. A persuasive body of empirical evidence has demonstrated that agricultural research and development (R&D) has been a major contributor to agricultural innovation, productivity increases, and poverty reduction around the globe over the past six decades. Despite the well-documented evidence that the payoffs to agricultural research are considerable, most South Asian countries continue to underinvest in agricultural R&D. Given the substantial time lag between investing in research and reaping its rewards—which is typically decades, not years—agricultural R&D requires a long-term commitment in terms of sufficient levels of sustained funding and well-staffed research agencies (Stads, 2019).

NARC's share of the MoALD budget is declining from a level of 14.74% in 2001 to only about 5.71% in 2022 (Fig. 2), which is just USD \$26.3 million. It shows that NARC is underfunded, and not sufficient for generating the sustainable and climate resilient technologies required for diverse agro-ecosystem and categories of farmers. In addition, the real annual compound growth of the research budget for NARC is quite low (5.69%) compared to the growth of the national budget (8.73%) and the total agriculture and livestock budget (9.33%) between 2001 and 2022. Empirical evidence suggests that there are high rates of return from agricultural R&D investments, making agricultural research a cost-effective way for governments to accelerate agricultural development. The return on investment from agricultural R&D remained positive for the period 2001–2011: the Benefit Cost Ratio was 4.57, while Modified Internal Rate of Return was 6.09 for Asia (Nin Pratt & Magalhaes, 2018).

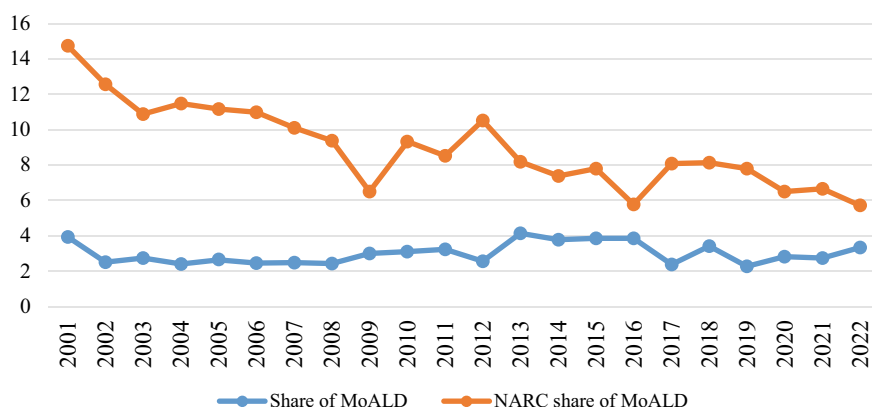


Fig. 2 Share of national budget of MoALD and NARC share of MoALD. *Source* Ministry of Finance (Redbook), various years

3.4 *Agriculture Total Factor Productivity (ATFP)*

A useful measure of the productivity of any sector is Total Factor Productivity (TFP), which measures differences in productivity that are not due to differences in use of inputs, but rather attributable to factors such as technological progress and efficiency in conversion of inputs to outputs. Capablo and Antle (1988) termed the rate of growth of TFP as a proportionate rate of output growth that cannot be explained by the growth of inputs due to the contribution of technological progress. The importance of agricultural total factor productivity growth for developing countries has long been emphasized due to its determinant role in the economic growth of low-income regions.

Investment in agricultural research and development from the public and private sectors can drive long-term TFP growth in addition to investment in public infrastructures and spill over from other sectors. In addition, TFP growth is a key indicator of agricultural sector performance and a significant contributor to economic growth. The average ATFP growth between 2001 and 2022 remained about 0.70% and the contribution of ATFP to AGDP growth was 26.4%. Fugile (2012) estimated ATFP in Nepal and found that the average annual growth of ATFP was negative for 1961–70 (−0.19%) and 1971–80 (−1.22%), while growth recovered from 1981–90 (2.34%). ATFP growth slowed down for the period from 1991–2000 (0.19%) while it again took momentum from 2001–09 with a growth of 2.49%. As per Joshi (2018), the ATFP growth remained at 0.98% between 1984 and 2014. In the first period from 1984 to 1998, which is considered the period before the Agriculture Perspective Plan (i.e., the pre-APP period), it was negative (−0.15%) while the growth rate was 1.74% in the second period from 1999–2014 (i.e., the APP period). The contribution of ATFP growth to AGDP growth was 33.5% between 1984 and 2014.

3.5 *Determinants of ATFP Growth*

To further investigate the determinants of productivity growth in Nepalese agriculture, a set of influential factors have been hypothesized based on previous literature review. The results show that variables such as the ratio of irrigated area (Irrigation) and Time Dummy were significant at 1% level, while real public investment in the agricultural sector (INVEST), literacy rate of the economically active population (Literacy), and road density were significant at the 5% level. The real per capita GDP was positive, but not significant (Table 5). All of these variables have expected sign except literacy rate (which is negative and significant). The adjusted R^2 is equal to 0.93, showing that 93% of the ATFP variation in Nepal, over the period of analysis, is explained by independent variables.

The coefficient of the irrigation ratio has been the most important variable affecting the growth of ATFP. The marginal impact of irrigation infrastructure was higher compared to other variables, as shown by the regression coefficient. In the context of

Table 5 Determinants of agricultural TFP growth from 2001 to 2022

Variable	Coefficient
Constant	−4.69
Irrigation	3.986***
INVEST	0.301**
Literacy	−3.817**
Road density	1.10**
PerGDP	0.470 ^{ns}
Time Dummy	−0.309***
Adjusted R ²	0.93

Note ***, ** and ^{ns} indicate significant at the 1%, 5% level, and non-significant, respectively

high variability of rainfall in Nepal, assured irrigation water supply complements the potentiality of biological technology such as variety, thereby resulting in increased productivity. The irrigation ratio shows that with 1% increase in irrigated area, the ATFP would increase by 3.98%. The road density variable is also an important variable for contributing to the growth of ATFP. Rural infrastructure such as roads fosters physical connectivity and promotes better integration of rural and agricultural areas with growing urban markets. It is revealed that a 1% increase in road density would result in a 1.10% increase in the growth of ATFP. These findings are consistent with the findings of Llanto (2012) and Ashok and Balasubramanian (2006).

Similarly, the financial resources allocated to the agricultural sector have been used for the development of human resources, physical infrastructure and institutions for supporting productivity enhancement. The result shows that a 1% increase in real investment in the agricultural sector would result in a 0.30% increase in ATFP growth. The literacy level among the economically active population has been contributing negatively to the growth of ATFP in Nepal: in rural areas, when people become educated, they become averse to agricultural occupations and look for other jobs (public and private) and also involve themselves in business-related occupations rather than getting involved in agriculture-related activities. The literate youth population migrated to urban areas and overseas countries in search of jobs during the ten years of conflict from 1996 to 2006, which continues even today. Agricultural activities have been the task of older people, women, and non-educated people in Nepal. This might be the reason for the negative coefficient of literacy rate on ATFP. This result is consistent with the finding of Kalamkar (2011) in Maharashtra India. The author concluded that the estimated effect of literacy was negative, which may be because of non-profitable agribusiness and the moving away of rural educated youths to non-agriculture fields.

The time dummy variable used as a policy shift variable appeared to be significant and negative, confirming the declining contribution of ADS implementation to agricultural TFP. In other words, the ATFP growth was higher in the pre-ADS period by about 0.31 percentage points compared to the post-ADS period. As ADS was prepared just before the promulgation of the Constitution of Nepal, 2015, ADS

did not consider the federal governance structure and entire agricultural institutions were restructured, and constitutionally, extension and development roles lie with the local and provincial levels. This affected entire extension system with inadequate linkages among these governments for effective service delivery. In addition, none of these governments prioritized this sector in public resource allocation.

4 Conclusion and Policy Implication

4.1 Conclusion

Nepal implemented APP and is adopting the National Agriculture Policy and strategies such as ADS with certain priorities, which were reflected in different periodic plans and annual programs. They aimed at raising productivity, reducing poverty and improving food security. Despite the implementation of policies and strategies, the AGDP and different commodity growth fluctuated over the years, and real AGDP growth remained at 2.64% per annum between 2001 and 2022. During the same period, the production growth in most crops came from productivity growth, and there was high growth in the production of some livestock products and fish. Because of the public goods nature, there is a justification of public resources allocation to agricultural sector.

The public resource allocation for the agricultural sector is also fluctuating, and the average share has been only 7.2% of the national budget per annum, while about 56% of this allocation is for meeting the recurrent expenditure. The average annual share of agriculture, livestock, and fisheries is around 3%, and 87% of this amount is for meeting recurrent expenses. This minimal allocation does not reflect the priority accorded to this sector. The most noteworthy issue is the allocation of public resources for agricultural research, which is declining and shares only about 0.3% of the value of AGDP. This amount is quite minimal given the role of science and innovation for attaining growth through technological development.

In Nepal, the focus of agricultural development should be on sustaining and accelerating growth in view of persistent rural poverty and emerging threats of food insecurity. The expansion of the area under cultivation and the intensification of input use may contribute to growth, but the best option in this regard is the improvement in productivity of factors. In Nepal, agricultural TFP growth has remained only 0.70% per annum between 2001 and 2022 which contributed only about one-fourth to AGDP growth. The analysis of the determinants of ATFP showed that infrastructural variables such as irrigation, roads and financial resource allocation in the agricultural sector are significant variables to ATFP growth. Similarly, the ATFP growth is higher for the pre-ADS period than for the post-ADS period.

4.2 Policy Implications

Nepalese agriculture is facing the challenge of accelerating factor productivity and contributing to achieving sustainable development goals. The results of the study clearly establish that investments in rural infrastructure such as irrigation and roads increase the total factor productivity in agriculture. Similarly, the investment in marketing infrastructure and supporting smallholders in different nodes of the value chain would contribute to achieving the expected goals. In less developed countries such as Nepal, agricultural productivity from public investment is important, particularly when there are diminishing factor returns and the closing land frontier. The results of this research indicated the need for further increasing investment in public infrastructures and technologies and their dissemination by strengthening extension system. Creating infrastructure in less favored areas, better management of infrastructure and the introduction of new resilient technologies can further enhance resource productivity and ATFP. Indeed, severe rural infrastructure deficiencies undermine the huge potential of the agricultural sector in Nepal to contribute to economic growth and poverty reduction. Improved rural infrastructure will reduce poverty through improved agricultural productivity and improved wages and non-farm employment. To ensure the resource needs of agriculture, it is appropriate to consider a legal measure by establishing an Agricultural Development Fund under the upcoming Agriculture Bill. Similarly, the trend of outmigration of educated people, particularly youths, to urban areas and overseas countries in search of jobs should be reversed. This can be accomplished by enhancing their skills and knowledge of entrepreneurship development in the agricultural sector, the provision of soft interest credit, material support and developing infrastructure for marketing and trade. In addition, utilizing the skills and knowledge of returning migrants and creating an enabling environment for investment in their savings is essential for contributing to the sustainable commercialization of the agricultural sector.

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Chapter 3

Improving Agriculture Service Delivery by Local Governments in Nepal: A Municipal Perspective



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Abstract This chapter explores the agricultural service delivery (ASD) by local governments (LGs) in Nepal following the country's transition to a federal system. The research assesses the compliance of agriculture governance with the Local Government Operation Act (LGOA) and explores whether LGs meet farmers needs and demands. Using a mixed methods approach, data were collected from 21 municipalities through structured interviews, focus group discussions, participant observations, and key informant interviews, and the data was evaluated against seven key worldwide governance indicators. The findings reveal that while there have been improvements in service accessibility and accountability, significant challenges remain regarding technical capacity, resource allocation, and participatory planning. The LGs significantly altered the practice of operating their roles and responsibilities, with greater autonomy on decisions that cater to their unique needs based on the LGOA. The Constitution of Nepal (2015) further empowered LGs with executive roles to devise strategies for governance that prioritize, plan, execute, and assess their actions. Results indicate that respondents perceive increased service accessibility, with a medium level of accountability (mean score of 2.58) and accurate information sharing (mean score of 2.73). However, the study also highlights shortcomings in participatory planning (mean score of 2.20) and the rule of law (mean score of 2.43). Social justice and transparency in service delivery were rated

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positively but concerns about fairness in procurement processes and the quality of services persist. Exploratory factor analysis identified three key factors influencing ASD: service delivery practices, municipal capacity, and service delivery structures. The study underscores the need for enhanced coordination among federal, provincial, and local institutions to improve ASD. To address these gaps, this study recommends capacity building for local government staff, adequate resource allocation, strengthening participatory planning processes, and promoting innovative technologies to enhance efficiency and sustainability in agriculture service delivery.

Keywords Agriculture service delivery · Agriculture governance · Local government

1 Introduction

The transition to a federal system through the enactment of the Constitution of Nepal (2015) established three tiers of government: federal, provincial, and local. Local governments (LGs) are constitutionally part of the federal system, with greater autonomy and responsibility for agricultural service delivery (ASD). The LGs in Nepal, led by elected representatives, perform administrative responsibilities at the most localized level, aiming to improve governance and enhance economic development through capacity building initiatives (Majekodunmi, 2011; Nemec, 2017; Subedi, 2014; TAF, 2017). Article 56 of the Constitution of Nepal (2015) defines local government as rural municipalities in villages, municipalities in cities or towns and district assemblies. Among the 753 local levels, there are 460 rural municipalities and 293 urban municipalities. All local levels are further divided into 6742 wards, which represent the lowest administrative and service delivery structures for local people. The LGs and their units are designed to reduce the gap between the citizens and their representatives (Acharya & Scott, 2022).

The assemblies of rural and urban municipalities hold ultimate authority, autonomy, power, and resources for policy making, development programs, and public service delivery. These assemblies' function as local legislatures to regulate services and development. The LGs faced challenges during the early federalization phase, including limited financial resources, mismatches between programs and budgeting, limited human resource capacity, inadequate service delivery infrastructures, and complex formal procedures (TAF, 2017).

Nepal's formal LG system began with the Decentralization Act of 1982, which authorized local Panchayats to manage development activities. Later, the Local Self-Governance Act (LSGA) of 1999 introduced a detailed decentralization framework (GoN, 1999). LSGA of 1999 was eventually replaced by the LGOA (2017), based on the Constitution of Nepal (2015). Schedule 8 of Constitution of Nepal (2015) provisioned executive power to the LGs under solitary rights (Jaishi & Paudel, 2020), significantly empowering them to execute 22 specific assigned functions, including the agriculture and allied sectors. The constitution also specified the concurrent

powers shared among the federal, provincial, and local governments in Schedule 9. Among the 22 exclusive powers of the local level, more than ten are directly or indirectly related to the economy, agriculture, and service delivery.

Despite these advancements, ensuring effective governance of the availability of qualified agro-technicians, infrastructure, funds, and comprehensive planning remains challenging. The Constitution of Nepal (2015) envisioned LGs as a key player in local planning, including agriculture, and with agricultural extension services under the local jurisdiction, LGs are now responsible for managing these functions. Following the local elections in 2017 and 2022 and the devolution of power, LGs are expected to fulfill their responsibilities. This transition of federal government structures aimed at empowering LGs provides an opportunity to address policy and structural weaknesses, particularly in the agricultural sector (Kyle & Resnick, 2018). Different research on ASD has reported mixed perceptions of limited implementation but increasing people's aspirations (Bishwakarma, 2022; Dahal et al., 2020; Jaishi et al., 2023).

Studying ASD within the LG framework is crucial for identifying policy-practice interface and gaps. This research assesses agriculture governance compliance with LGOA (2017) and explores its implications ASD by LGs. The study seeks to answer two fundamental research questions:

1. Do the existing institutional, legal, political, and fiscal frameworks enable LGs to fulfill ASD mandates?
2. Are LGs meeting farmers' needs and demands in line with the LGs' responsibilities and functions as per the LGOA (2017)?

2 Study Framework and Methodology

2.1 Study Framework

This chapter reviews the agriculture governance and ASD framework as shown in Fig. 1, aligning with the LGs responsibilities and functions as per the LGOA (2017). The ASD framework serves as a useful tool composed of the key factors that influence agriculture public service provided by the LG. The effectiveness of the ASD framework was examined through contemporary governance theories, decentralized theory (Subedi, 2014), the subsidiary principle, structural function theory, and a system view of governance. Ajayi (2003) emphasized the link between grassroots governance and local autonomy, providing a robust framework for evaluating ASD at the LG level.

The study framework ensures a rigorous, fair, and unbiased analysis, examining the relationships and result chains among ASD components at the local level using the theory of change (Nemec, 2017; Shahi & Sthapit, 2022). This framework (Fig. 1) evaluates agriculture governance indicators, policy documents, plans and priorities, theories and principles, ASD components and structures, and constitutional powers

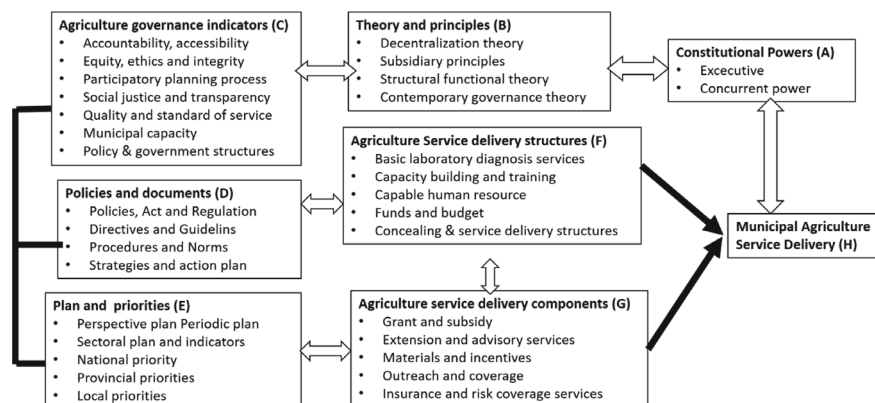


Fig. 1 ASD study framework at the municipal level

for municipal ASD. The logic of this framework is as follows: first, consider the constitutional power (A), determine the theory and principles of ASD (B), which influences the agriculture governance indicators (C), policies and documents (D), plan and priorities (E). The municipal ASD (H) is the ultimate impact of the ASD structures (F) and ASD components (G). Subsequently, the Sects. 2.2 and 2.3 explain how the principle and practice of agriculture governance influences the ASD at the local level.

2.2 ASD and Agriculture Governance

Service delivery pertains to the systems and arrangements through which governments provide their citizens with goods, services, and advisory support (Acharya and Chandrika, 2021; Dahal et al., 2020). Effective service delivery demands timely, efficient, and accountable management by the government (Bishwakarma, 2022). In Nepal, local authorities have faced challenges with service delivery due to declining capacity, ineffective procedures, and poor infrastructure (Kyle & Resnick, 2018). Similarly, Nepal grapples with issues such as inadequate capacity of local staff, poor resource allocation in agriculture, ineffective participatory planning, and limited institutional capability to expand service coverage (Pandeya, 2015). According to Pereria and Ruysenaar (2012) governance could signify a change in the meaning of government to the new methods and approach by which the community is governed. Despite the recognition of adaptive agriculture governance, LGs are still facing institutional barriers. At the crux of the challenge in agriculture governance at the LG level is the call for changing the bureaucratic culture by focusing on the outcome rather than the process and procedures. Governance structures process and procedures still rely on traditional forms of government regulation.

Agricultural development scholars emphasize the essential role of governance in advancing agricultural development (Candel, 2014; OECD, 2008; Ronaghi et al., 2020). However, despite the widespread recognition of its importance, current governance status knowledge remains fragmented and lacks a cohesive framework (Candel, 2014). Governance issues in agricultural extension and advisory services include inadequate coordination among stakeholders, power imbalances, the limited inclusion of local stakeholders, and weak accountability mechanisms. Addressing these challenges and establishing strong linkages is difficult due to resistance from those interested in maintaining the status quo (Pereria & Ruysenaar, 2012).

The OECD (2008) found weak vertical and horizontal coordination at the central level and under-resourced decentralized government bodies as the major barriers to implementing agricultural development strategies and policies. Enhancing capacity at the local and provincial levels is crucial for effective policy implementation (Kyle & Resnick, 2018). Promoting a bottom-up approach can scale up local innovations, a strategy recognized as essential elements. Pereria and Ruysenaar (2012) argued that the management of a complex agriculture system relies on adaptive governance by integrating and linking between different stakeholders operating in different roles and responsibility frameworks.

The successful integration of policies and programs into ASD hinges on two complementary aspects of governance: supply and demand (Blackmore et al., 2015). Supply side governance focuses on implementing policies and services that address the needs of smallholder farmers within agricultural and nutritional value chains (Blackmore et al., 2015). Demand-side governance refers to the institutions and mechanisms through which farmers articulate their concerns regarding good governance (Acharya & Chandrika, 2021). The current chapter analyzes the agriculture service users' and stakeholders' verdicts of how they perceive and evaluate ASD by LGs in the context of the available legislature framework and their roles.

2.3 LGs and ASD: Principles and Practice

LGs are the primary interface between communities and governance and are responsible for addressing local needs and priorities (Asaju, 2010; Keping, 2018). They perform executive, judicial, and legislative functions, supporting political participation, efficient service delivery, and decentralization against centralized governance (Adhikari, 2021). LGs are autonomous entities offering diverse services funded primarily through taxation and overseen by elected representatives. They operate within sovereign or quasi-sovereign states and share common characteristics with other governmental bodies, such as defined territory, population, organization, authority, and public service capabilities.

Several factors are associated with poor service delivery (Dahal et al., 2020). First, a basic institutional setup with limited human resources, particularly a critical shortage of technical staff, affects service delivery and program implementation.

Although federalism resulted in institutional restructuring, the change at the municipal level mainly includes administrative sections and has limited technical expertise allocated to ASD compared to the mandate. Secondly, under-resourced human capital with limited technical expertise struggle to meet farmers' needs and resolve their diversified issues in the field. Further, low-skilled technicians deliver government services inefficiently due to limited governance capacity in planning, budgeting, priority and policy setting, surveillance, and data collection. Thirdly, agriculture generally received low priority from the municipal council, leading to insufficient budget allocation compared to other sectors such as education and physical infrastructure. Ultimately, services delivered are found to be average and substandard (Jaishi et al., 2023). Service delivery is also hindered due to attitudinal behavior among elected representatives and administrative leaders. The dynamics between the two impact both the efficiency and momentum of agricultural initiatives. However, in some municipalities, elected leaders accepted ownership, coordinated with stakeholders, promoted transparency, and created a working environment, enhancing service quality (Bishwakarma, 2022).

2.4 Methodology

A sequential explanatory parallel mixed methods approach, guided by abductive reasoning and constructionist research philosophy, was employed in the study. Primary data were collected through structured interviews with 210 random service users, four focus group discussions, two participant observations, and 10 key informant interviews (KII). Sample size determination was considered based on the minimum of 5 cases for each of the items (Beavers et al., 2013). Mayors/Chairs/Deputy Chairs of municipalities, agriculture section staff and authorities of the provincial and federal ministry were taken as respondents of KII conveniently. The study covered 21 municipalities (11 rural and 10 urban), spanning all seven provinces randomly. Durgabhagwati, Chhiresornath Balephi, Indrawati, Kaligandaki, Tinau, Siyari, Baijnath, Bhairabi, Pachaljharana, and Chabispathibera were the rural municipalities considered for the study. Similarly, the urban municipalities considered for the study were Shivasatasi, Pakhribas, Dhankuta Mithilabihari, Bhanu, Sundar-bazar, Waling, Raskot, Jay Prithivi, and Suklaphanta. A workshop with municipal stakeholders was conducted to assess the compatibility of policies and procedures in the rural Kaligandaki municipality. Secondary data were sourced from literature reviews, including LGOA (2017) and other relevant studies on decentralized agriculture, service delivery, and governance.

Data collection utilized a four-point Likert-type scale, omitting neutral points to encourage decisive responses. The four-point Likert-type scale has the primary advantage of reducing central tendency bias by enforcing respondents to choose a side. The study targeted agricultural service recipients as beneficiaries, constructing seven measures of agriculture governance categorized into three broader categories:

Service delivery, municipal capacity, and enabling policy assessed based on respondents' perceptions constructed 35 items, in line with World Governance Indicators (WGI) as shown in Table 1. Kaufmann et al. (2010) and Ronaghi et al. (2020) state that WGIs permit meaningful cross-country governance comparisons. The modified seven dimensions of WGIs were used in this study to measure the ASD practice at the municipal level.

We employed a mixed method approach, prioritizing quantitative analysis embedded with qualitative observations to deepen the understanding of the phenomena as suggested by Onwuebuzie and Comb (2011). In this research, we conducted and categorized explanatory sequential design into two phases: (1) an initial quantitative instrument development and data collection phase, followed by (2) a qualitative data collection phase, in which the qualitative phase builds directly on the results of the quantitative phase. The quantitative results were explained in more detail through qualitative data appeals to researchers with quantitative solid learning (Bhattarai, 2015; Creswell, 2009; Nataliya et al., 2006).

As described above, the analysis considered World Governance Indicators (WGIs) to measure people's perceptions of ASD and governance practices. The results are summarized and presented in five major points using the value of the sum mean and standard deviation (SD). Further, factors of agriculture governance were analyzed based on exploratory factor analysis (EFA). The compatibility of the policy guidelines and regulations at the municipal level was analyzed qualitatively based on stakeholders' workshops.

3 Results

3.1 Accountability, Accessibility, Accuracy, and Equity

The analysis of perception of statements 1–5 of Table 1 is depicted in Table 2. The findings indicate how respondents perceive the devolution of power as a means to enhance the accessibility and accountability of agricultural services. The respondents feel an increased access to services in terms of physical proximity. The positive value of medium level of accountability (2.58), accurate information (2.73), access to agriculture service (3.01), digital access (2.56), and the practice of equity (2.58) confirmed that service users perceived that the devolution of power and constitutional provisions supported improving service accessibility at the LG level. During the KII, researchers also observed and felt that that LG staff are more responsive to their line ministries than to citizens. Despite the positive values, most of the indicators are below 3, showing that there is room for improvement in accountability and responsiveness toward local citizens.

Equitable distribution of agriculture services involves a fair distribution of municipal services, subsidies, incentives, and advisory support. Respondents' views on statements 6–10 showed that they perceive that municipal services were generally

Table 1 Seven measures related to ASD based on WGI used for measurement

S. No.	Dimensions	Constructs
1	Accountability of local government toward their client	1. I realized the high level of accountability of the municipal officials
		2. I feel my municipality provides accurate information to the citizens
		3. I feel my municipality provides information on accurate time
		4. I feel better access to agriculture services to the citizen
		5. I feel digital access is ever-improving in my municipality
2	Equity, ethics, and integrity on the part of ASD by the municipality	6. Municipal officials follow the principle of equity in ASD
		7. Municipal officials follow a high level of ethical integrity
		8. Municipal citizen has an equal opportunity of participation in planning and strategy setting workshop
		9. Municipal staff demonstrate good character and free of corruption
		10. Municipal staff demonstrate good character and free of hypocrisy
3	The participatory planning process	11. Municipal staff and officials strictly follow rule of law
		12. A citizen's voice is always heard and responded
		13. I have participated municipal planning workshop and meeting
		14. I have observed rule of law in providing agriculture service
		15. I feel the government-citizenship relationship is strengthening
4	Social justice and transparency of the ASD process	16. I never felt ideological discrimination in resource distribution
		17. Discriminated people are always municipal primary concerns
		18. Fair and competent procurement procedures are followed
		19. Transparent agriculture services are always practiced
		20. Discriminate people-focused programs/projects are implemented
5	Quality and standard agriculture service provisions	21. The municipality provides high-quality materials and services
		22. The municipal agricultural services provided by the are satisfactory

(continued)

Table 1 (continued)

S. No.	Dimensions	Constructs
		23. Advisory services provided by municipalities are problem-specific
		24. Precise and accurate advisory service provided by the municipality
		25. The number of technical staff is sufficient to reach the service
6	Municipal capacity to improve ASD	26. I felt that managerial capacity of municipal staff and was satisfactory
		27. I observed municipal staff with good human and facilitation skills
		28. My municipal staff have good and fair technical skills to deliver agriculture services to their client
		29. My municipality has a strong financial and investment capacity in agriculture
		30. I am very much impressed with the strategic capacity of my municipality
7	Policies and structures of local government concerning ASD	31. My municipality has good political stability over the issue of development
		32. My municipality's organizational unit, structure and resources are convenient to people and clients
		33. My municipality has sufficient policies to promote good governance and agricultural service delivery
		34. Municipalities have rules and regulation guidelines to promote governance
		35. All the agricultural service delivery units are well-equipped

satisfactory in the equitable distribution of resources (2.58), ethical integrity and honesty (2.63) (Table 2). However, the respondents felt some types of shortcomings (2.20) in equal opportunities for participation in agriculture programs and activities (Table 3).

3.2 Participatory Process and Rule of Law

The objectives of the participatory planning process are to develop comprehensive policies, programs, budgets, priorities, and strategies to optimize services at the LG level. The analysis from statements 11–15 in Table 1 shows that municipal officials generally follow the rule of law as reflected with a score of 2.65 (Table 2). However, their engagement with the public in strategy setting and sector targeting is weak, with a score of 2.01. The government-citizen relationship of municipalities is also

Table 2 Positive statements of respondents regarding agricultural governance and service delivery in their municipality

Scale items	Sum	Mean	SD
Accountability of municipal officials and staff	545	2.58	0.86
Accurate information sharing	574	2.73	0.56
Access to agriculture services	632	3.01	0.07
Digital access for service delivery	538	2.56	0.87
The practice of equity in service delivery	541	2.58	0.83
The practice of ethical integrity	552	2.63	0.80
Practice of corruption-free delivery	573	2.73	0.82
The practice of free hypocrisy	546	2.60	0.81
The practice of rule of law in service	557	2.65	0.85
No discrimination in service delivery	534	2.54	0.82
Target of the discriminate and marginal people	524	2.50	0.78
Practice of transparent service delivery	536	2.55	0.73
Discriminated focused program	527	2.51	0.76
Enactment of agri-governance policy	533	2.54	0.85
Enactment of agri-governance rules and regulation	541	2.58	0.77

insufficient, with a resulting score of 2.44. During KII, municipal officials agreed that they need to improve linkage and integration with diverse private sectors, civil society actors, and research and agriculture education institutions. According to LGOA (2017), municipalities could link and integrate with local, provincial, and federal institutions and actors based on principles of cooperation, co-ordination, and co-existence.

3.3 Social Justice, Transparency, and Service Quality

ASD must be inclusive to ensure that no one is left behind. LGs are responsible for addressing the needs of disadvantaged groups, including women, the poorest of the poor, and vulnerable people in agriculture programs and activities. This requires expanding service coverage, prioritizing equity, enhancing service quality, and broadening the range of basic services according to socio-economic strata. The perception analysis (statements 16–20) presented in Table 1 indicates that people positively agreed on corruption-free service delivery (2.73), freedom from hypocrisy (2.60), the practice of rule of law in ASD (2.65), transparent service delivery procedures (2.54), prioritization of discriminated and marginalized people (2.50), and transparent agricultural services (2.55). However, people are more concerned about the authority's fairness and competence in service procurement processes and procedures (2.32) and quality service (2.43). The findings based on people's perceptions of service quality

Table 3 Negative statements of respondents regarding agricultural governance and service delivery in their municipality

Scale items	Sum	Mean	SD
Timely information sharing	461	2.20	0.88
Equal participation in agriculture program/activities	461	2.20	0.84
Practice of address of citizen's voice	488	2.32	0.94
Participation in a planning workshop and meeting	423	2.01	0.92
Practice of rule of law	511	2.43	0.85
Government-citizen relation	512	2.44	0.80
Fair service delivery process	488	2.32	0.82
Quality service provision	511	2.43	0.85
Satisfactory service	460	2.19	0.81
Problem specific	476	2.27	0.80
Precise advisory services	514	2.45	0.81
Sufficient HR in the municipality	494	2.36	1.01
Managerial capacity of municipality	510	2.43	0.72
Facilitation skills of the municipality	521	2.48	0.69
Technical skills of municipality	478	2.28	0.81
Investment capacity of the municipality	508	2.42	0.79
Strategic capacity of the municipality	454	2.16	0.76
The political capacity of the municipality	514	2.45	0.74
Convenient service delivery structures	464	2.21	0.84

and standards and satisfactory service provisions measured through statements 21–25 in Table 1 show below-average ratings (2.5) of public service delivery.

3.4 Managerial, Fiscal, Strategic Capacity and Technical and Facilitation Skills

LGs' capabilities—including local governance experiences, institutional knowledge, skills, mindsets, and aptitudes—are crucial for successful municipal operations (Acharya & Scott, 2022). According to Kyle and Resnick (2018), inadequate human resource capacity and low investment capacity are considered responsible for ineffective ASD at the LG level. In this research, ASD concerned municipal capacity was assessed through five significant capacity dimensions: managerial capacity, staff facilitation skills, staff technical skills, municipal financial, investment and strategic capacity by scale items 26 to 30 listed in Table 1. The assessment revealed negative perceptions across all dimensions (Table 3). All of the scale items below 2.5 indicated that the study municipalities operated their ASD with below-average capacity.

3.5 Policies and Service Delivery Structures

The items related to policy and service delivery structure of the LG are presented in statements 30–35 of Table 1. The respondents agreed with the constructs related to the enactment of agriculture policy (2.54) and enactment governance rules and regulations (2.58). However, the KII and FGD discussions revealed a lack of specific guidelines and policies to connect the agriculture and allied sectors, resulting in disconnected, fragmented and ad hoc planning and programming.

In the context of ASD structures and facilities, respondents expressed their disagreements with the availability of convenient ASD structures (2.21) (Table 3). This means that the LGs have yet to develop well-equipped service delivery structures such as basic laboratory services, equipped training facilities and resources, counseling rooms, demonstration sites, and resource centers to strengthen the quality and impact of services. Similar feelings were expressed by FGD participants that municipalities lacked well-equipped service delivery structures, meaning that the quality of ASD was severely affected. Researchers also observed and felt the constraints of facilities: for example, in most municipalities, service seekers have no proper seating facilities within the agriculture section premises. There is thus a gap between respondents' expectations and actual ASD (TAF, 2017).

Nepal's experiences in implementing multiple agricultural policies related to agricultural reform suggest that patience and perseverance, with uninterrupted strong political commitment and positive engagement for implementation, are essential (Khanal et al., 2020). The Agriculture Perspective Plan (APP), Agriculture Development Strategy (ADS), and National Agriculture Policy 2004 (NAP) are the primary policy documents to date. All of these policies are considered sound in design but have significantly suffered from implementation. In many cases, they lack supporting legislation and resources for implementation. The APP, ADS, and NAP are Nepal's umbrella policies, though they require updates and modifications in the context of LGOA (2017). Some fundamental agriculture sector policies that require further refinement are the Agri-business Promotion Policy (2006), Agrobiodiversity Policy (2007), Agriculture Mechanization Policy (2014), Land Use Policy (2015), Agroforestry Policy (2019), and Gender Equity and Social Inclusion Strategy (2021). Provincial and LGs should mutually coordinate for the necessary legal arrangements to harness the opportunities specified in Annexes 7 and 9 of the Constitution of Nepal (2015).

In Nepal, legislative provisions through 55 policies, 5 strategies, 28 Acts, 11 regulations, 39 directives, 3 guidelines, and 44 procedural documents were made to achieve agricultural transformation through four categories of policies and documents. They are land tenure distribution, agriculture service infrastructure, agriculture production, and food quality standards (Jaishi et al., 2023). Article 232 (1) of the Constitution of Nepal (2015) provisions for provincial-local policy coordination between provincial and local government and local-provincial-federal policy coordination between local, provincial, and federal government. The Constitution of Nepal (2015) stands on the tri-pillar theory of cooperation, coordination, and

co-existence to operate and hold together the federalism in Nepal. Accordingly, the provincial government can sanction agricultural policies, rules, guidelines, and norms for executing the agriculture and allied sectors. Thus far, more than 92 provincial agriculture policies, rules, and regulations formulated by the seven provincial governments are in execution. The functions of agriculture and livestock are spread over the three levels of government, but a bigger role is given to provincial and local governments. Agriculture is listed as one of the concurrent powers under the three levels of government.

Additionally, EFA also showed that municipal capacity, and associated structures were major factors of ASD (Table 4). Kyle and Resnick (2018) reached a similar finding, stating that existing organizational structures, human resources, and state capacity are neither adequate nor capable of accomplishing a feat. Therefore, further improvement in service delivery practices, convenient infrastructural support, and strengthening municipal capacity are required to improve the current state of ASD.

3.6 Compatibility of Policy Guidelines and Regulations at the Municipal Level

In a stakeholder workshop in the Kaligandaki Rural Municipality of Syanja district, the LGOA (2017) guidelines and regulations on ASD were assessed through stakeholder analysis (Table 5). The study showed that Kaligandaki possesses partial constitutional, legislative, and institutional capabilities to institutionalize ASD. Of the total 54 scores, 18 scores for full, 28 for partial, and 8 for non-implementation showed that considerable work remains to be done. Effective implementation of constitutional provisions, addressing issues through legislative measures, and establishing structural, administrative, legal, institutional, and financial measures are essential to strengthen agriculture governance at the local level. The LGOA (2017) offers local government fiscal autonomy and authority to generate, collect, and mobilize resources. However, its implementation is limited in several aspects.

The stakeholders workshop revealed that Kaligandaki has made several efforts over the last eight undeveloped, with many rules and guidelines pending formulation years to enhance effective ASD. For instance, the municipality has developed sectoral guidelines and rules for agriculture with an implementation rate of up to 51.85% (Table 5). Participants agreed that livestock and veterinary services are satisfactorily implemented to support local farmers, whereas guidelines related to these fields have yet to be developed. Cooperative promotional activities were. The authorities have prioritized agricultural roads and irrigation facilities, but their action plans have yet to be finalized. Further, LGs have not fully implemented the power, authority, and responsibilities of ASD due to their limited capacity in terms of human and financial resources. Over fifty percent of the indicators were partially achieved, one-third were fully achieved, and nearly fifteen percent of the sectors

Table 4 Pattern loading factors for agriculture governance

Items	Factor		
	1	2	3
No discrimination practice	0.71		
Practice discriminating people target	0.70		
Discriminate focused program	0.67		
The practice of precise advisory	0.66		
The practice of equity in service	0.65		
Practice of good governance rules and regulation	0.62		
Practice of the rule of law	0.62		
Ethical integrity	0.61		
Transparent practices in service delivery	0.60		
Practice of fair process of service	0.60		
Accurate information	0.59		
Equal participation in the participatory workshop	0.54		
Government-citizen relationship	0.48		
Municipal facilitation skills	0.34		
Municipal managerial capacity		0.93	
Municipal political capacity		0.81	
Quality service provision		0.75	
Satisfactory service provisions			0.94
Service delivery structures			0.76
Eigenvalues	6.77	2.23	1.45
Variance %	35.64	11.71	7.61
Extraction method: Maximum likelihood. Rotation method: Promax with Kaiser normalization			
a. Rotation converged in 5 iterations			

were not achieved. Further study is needed to detect the status of agriculture-related functions and responsibilities (Table 4).

3.7 Factors of Agriculture Governance

The factors responsible for ASD were conducted through exploratory factor analysis, an appropriate methodological approach for data reduction to uncover agriculture service seeker responses using the latent characteristics of the factors. Factor analysis helps to interpret data by grouping together large amounts of data. A Kaiser–Meyer–Olkin test of sample adequacy greater than 0.6 denotes the suitability for exploratory factor analysis using maximum likelihood extraction. The pattern matrix was identified in the structure matrix for ease of factor loading interpretation. Eigen values of $\geq$

Table 5 Summary of stakeholders' responses toward the compatibility of policy guidelines at the municipality

S. No.	Sectors	Total items	NI	PI	FI
1	Preparation and implementation of rules, regulations, and guidelines	10	0	5	5
2	Livestock and veterinary service delivery	13	3	5	5
3	Agriculture cooperative development	7	2	4	1
4	Local agriculture market	10	2	5	3
5	Agriculture road and irrigation	6	0	4	2
6	Agriculture-ecology	8	1	5	2
Total items		54	8	28	18
Total score Percentage			8/54 (14.81)	28/54 (51.85)	18/54 (33.33)

NI Not implanted yet, *PI* Partially implemented, *FI* Fully implemented

1 were used to interpret the number of factors in the dataset. Three factors loaded to explain the phenomena found 6.77, 2.22, and 1.45, respectively. These three factors collectively explained 54.96% of the variance. Through factor analysis, three factors were found to influence ASD. Good agriculture service delivery practice, municipal capacity for quality ASD, and service delivery structures for satisfactory ASD were extracted as the responsible factors.

Factor 1: Good Service Delivery Practice

The good service delivery practice analysis indicates that 14 specific items contribute to this factor, collectively explaining 35.64% of the variance (Table 4). The items include: (1) nondiscrimination practice, (2) Non-discrimination practice of targeting people, (3) discriminated people-focused program, (4) practice of precise advisory, (5) practice of equity in service, (6) practice of good governance rules and regulation, (7) practice of the rule of law, (8) ethical integrity, (9) transparent practices in service delivery, (10) practice of fair process of service, (11) accurate information, (12) equal participation in the participatory workshop, (13) government-citizen relationship, and (14) municipal facilitation skills.

Factor 2: Municipal Capacity

Municipal managerial capacity, political capacity, and quality service provisions account for 11.71% of the variance (Table 4). The reliability analysis showed that the scale reliability of the three items was equivalent to 0.85. In this regard, both federal and provincial authorities agreed that the limited capacity of municipalities is a major obstacle to effective service delivery. Staffing deficits, insufficient training, and restricted resources as indicated during KII indicates the need for

specialized agricultural expertise at the local level. Acharya and Scott (2022) highlighted capacity as a significant constraint of local governments in service delivery, primarily due to the lack of technical expertise, knowledge, and technical ability of service delivery staff. This occurs mainly due to local governments' lack of adequately trained human resources and inadequate coordination with provincial and federal government structures for relevant access and support for ASD. Political representatives must also be competent enough to perform assigned roles and functions to better understand constitutional functions. Some mayor and deputy chairs agreed that their municipalities are recruiting technical human resources to address the shortage.

Factor 3: Service Delivery Structures

ASD structures for satisfactory ASD explained 7.61% of the variance (Table 4). Reliability analysis for two items was good, with a score of 0.83. Respondents reported that service delivery units' fundamental structures, such as laboratory service equipment, well-facilitated designated training venues, and audio-visual rooms for service advisory, in particular are in very rudimentary stages. FGD participants agreed that, the basic structures in municipalities for example demonstration sites, psycho-counseling rooms, and even comfort meeting rooms for service seekers are lacking. This gap is attributed to low priority and limited allocation of budget for service delivery structures.

4 Discussion

4.1 ASD in Transition

The ASD under the federal structure has resulted in a shift in governance, with various political, fiscal, and administrative exclusive rights given to local governments and concurrent rights with the federal provincial and local government. There are 35, 21, and 22 exclusive federal, provincial, and local government rights, respectively, with 15 concurrent rights shared between federal, provincial, and local governments. With 22 exclusive rights, the local government is more accountable and responsible than provincial and federal governments. The Local Government Operation Act, 2017 (LGOA) aimed to delegate six exclusive powers to support the independence of LGs. These include the power of (a) formulating annual, sectorial, and strategic plans and budgets; (b) carrying out administrative functions; (c) constituting governing structures; (d) preparing laws; (e) carrying out development projects; and (f) reviewing and evaluating their projects and programs.

While the constitutional and associated legal framework provides executive power and authority to LGs (TAF, 2017), a significant gap between governance principles and practice in ASD is evident in most municipalities. Respondents consistently criticized the quality of agriculture services and urged municipalities to revise ASD

models to meet people's expectations. FGD respondents expressed their hopes for improvement in ASD models in the days to come. During the FGD discussion, participants further claimed that despite an increase in the availability of agricultural services, LGs are unable to provide quality and responsive support. Farmers often suffer from poor technical support services, inadequate seed quality, substandard saplings, and delayed input availability. These challenges are primarily due to poor institutional capacity and insufficient research-extension-education institution linkages. The research-extension-education institutional linkage at the municipal level remains nonexistent, because research falls under federal affairs. Educational institutions are totally isolated from the community, since education-community components are missing in curricula. However, federal and provincial units may facilitate this coordination based on problems and commodity. Dahal et al. (2020) argues that decentralization and devolution of power to LGs without adequate capacity is challenging, as federalization may fail to deliver responsibilities.

Conversely, Bishwakarma (2022) revealed that LGs effectively provide agricultural services. This becomes further challenging as people's demand for specialized service and their expectations after the enactment of the new constitution have tremendously increased. Although the effectiveness and efficiency of LGs have improved, respondents still perceive that service delivery by these institutions is inconsistent with people's expectations. This perception is rooted particularly in the gap of elected representatives that persisted over a decade due to delayed elections in Nepal, and administration previously managed by deputed government staff. Moreover, LGs often face challenges in recruiting and retaining skilled staff for local agricultural extension services and making them accountable to their institutions, as the civil service structure favors federal positions due to better status and benefits. This creates an imbalance in the supply and demand for effective and efficient service delivery. The supply side must be responsive and the demand side must be active, which is lacking due to insufficient coordination between the supply and demand sides. Tables 2 and 3 summarize the people's responses of positive and negative attitudes toward municipal governance, respectively.

Among the total 35 WGI scale items, 15 rated a positive attitude, while the other 20 were rated with negative attitudes. Although the number of items for a negatively inclined attitude is higher than the number for a positively inclined attitude, the degree of inclination is less (2.01–2.48), suggesting some acceptable service quality. Analysis of positive and negative responses from Table 2 shows that service delivery in the municipality of 15 items out of 35 was perceived positively with the mean value, falling in the range of 2.5–3.01. These results indicate that there are gradual improvements in service delivery. However, it is insufficient to satisfy the expectation of the people, indicating the considerable scope for improvement in agriculture governance and service delivery.

Participatory planning and budgeting will likely be the major strategy for listening to the voice of the people (Acharya & Scott, 2022). However, assessing the inclusivity of the people's voices will remain challenging without an effective participatory framework. Dahal et al. (2020) argued that decentralization efforts should be based on understanding the spirit of basic and multifaceted planning processes rather than

superficial approaches that lack sufficient public engagement. Currently, agricultural governance practices are experiencing practical difficulties regarding most WGI indicators, which may be due to the dual role of political representatives. It is also due to the centralized mindset of bureaucracy, which primarily focuses on process rather than outputs.

4.2 Linkage and Integration Among Agriculture Research Extension and Education (AREE) Institutions at the Municipal Level

Linkage among Agriculture Research Extension and Education (AREE) institutions and farmers is key to promoting an agriculture innovation system. Studies have emphasized the importance of linkage and integration for service delivery and agriculture promotion. AREE stakeholders agreed that linkage and integration efforts improve agriculture service delivery (Jaishi et al., 2023), encouraging the sustainable agriculture innovation process and enhancing the efficiency of the agriculture system. In KII, municipal authorities, political representatives, and stakeholders participants agreed that LGs are lacking in their links with AREE institutions, resulting in fragmented agricultural development activities. However, LGOA (2017) explicitly stated that LGs are responsible for coordination among the federal-provincial institutions. LGOA (2017) explicitly stated the following 5 responsibilities that LGs can have in promoting agricultural extension to enhance service delivery.

- (a) Policy for planning, legislation, standard, implementation, and monitoring-control.
- (b) Estimating, managing, and implementing human resources for agriculture extension.
- (c) Protection and extension of agriculture technology transfer.
- (d) Extension/dissemination of agriculture information.
- (e) Linkage and coordination among federal-provincial institutions and management.

Effective integration of AREE with farmers at the community level brings the three components of the agriculture innovation system around problem areas or activities surrounding the farmers' premises (Ghimire et al., 2021; Jaishi et al., 2023). In practice, the coordination, collaboration, and partnership through AREE institutions can be done at four levels: projects, programs, activities, and events. However, these integrations must be connected to farmers' households, settlements, communities, and municipalities. Linkage and integration must be facilitated by provincial and federal AREE institutions based on the principles of cooperation, co-existence, and coordination. Integration can be at the multi-institutional and multi-government level to realize better AREE needs, objectives, activities, outputs, outcomes, and impact, as is

explicitly explained in the concurrent powers of local, provincial, and federal governments (Schedule 9) of the Constitution of Nepal, (2015). However, almost all municipal executives opined that municipal agriculture sectors are isolated, particularly by research and education institutions. They are in a dilemma and seeking multi-stakeholder platforms to link and integrate all of these AREE institutions. AREE integration at the municipality level may ease and strengthen vertical and horizontal integration for planning, designing, and advisory services. Integrated functions at the municipal level speed up the processes of generating, translating, and transmitting farmer-centric knowledge skills and training within an agriculture innovation system.

5 Conclusion and Policy Recommendations

5.1 Conclusion

The transition to a federal system in Nepal has provided LGs with greater autonomy and responsibility for ASD. However, the study reveals that despite some improvements in service accessibility and accountability, the LGs face multifaceted challenges. These include limited technical capacity, inadequate resource allocation, insufficient participatory planning processes and poor establishment of effective linkages with AREE institutions.

The LGOA of 2017 provides LGs with specific powers to develop policies, manage resources, disseminate information, and coordinate efforts with federal and provincial institutions. However, these responsibilities are not fulfilled due to limited institutional capacity and insufficient structure to enhance collaboration among AREE stakeholders. Consequently, LGs are lagging behind in building the requisite human resources, infrastructure, and administrative systems to address these challenges. LGs need to prioritize the development of multi-stakeholder platforms and frameworks to achieve stronger linkages with AREE institutions, which will allow for better service delivery in agriculture.

5.2 Policy Recommendations

This study has specific policy implications and recommends five action points for improving agricultural governance (Fig. 2).

1. To improve agriculture service delivery and service outcome, LGs must address the three factors (preconditions for improved service delivery, municipal capacity, and service delivery structures) identified by this study.
2. For efficient agriculture service delivery, LGs need to increase the amount of human resources and capacitate them.

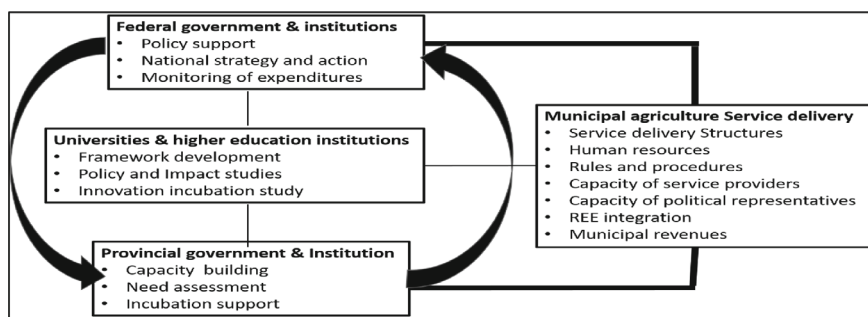


Fig. 2 Agriculture service delivery framework in the municipality

3. The LGs' own resources and revenue are essential for improving the authority and autonomy of governance. Therefore, along with the federal budget, the LGs need to execute revenue improvement plans to promote more resources for agriculture service delivery.
4. Create multi-level platforms that include local, provincial, and federal representatives and AREE stakeholders to facilitate regular knowledge-sharing, collaborative projects, and problem-solving efforts tailored to local needs.
5. Develop coordination models for planning, implementation, and monitoring programs to ensure that AREE activities align with LGs' objectives.

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Chapter 4

A Comprehensive Operational Framework for Transforming Agriculture, Agrifood, and Livelihood Systems



Nityananda Khanal and Yuba Raj Pandey

Abstract Industrial agriculture driven by a capital-centric growth model has become both the culprit and the victim of burgeoning socioecological footprints such as air and water pollution, land degradation, loss of biodiversity, climate change, food heteronomy, and socioeconomic disparity. The chronically perturbed agrifood and livelihood systems in Nepal are also clear manifestations of the discordance between delusively imitated development policies and the on-the-ground realities typified by geophysical and socioeconomic contexts. This chapter posits a comprehensive perspective and operational framework for agriculture-based socioecological transformation. The perspective and framework assimilate both a modern agroecological paradigm and South Asian eco-spiritual wisdom that pertains to agrarian economy and livelihood systems globally in general, and specifically in Nepal. We reviewed both modern agroecological and *sanatana* (a unified philosophy based on universal and primordial truths) literature and assembled cultural wisdom from authors' own recollections and conversations with knowledgeable key informants. We articulate Nepal's geographical and socioeconomic realities that dictate a self-reliant, sovereign agriculture-based economy in line with the emerging agroecological paradigm and time-tested traditional wisdom. In view of these realities, we advance the framework for a prudent, eco-friendly systems approach to managing space (S1), species (S2), seeds and breeds (S3), soils and water (S4), seasonality (S5), and stress factors (S6) with the deployment of supportive infrastructure and institutional services (S7) to develop a self-regulatory synergistic agrifood system (S8) that justifies socioeconomic objectivity (S9) and socioecological symbiosis (S10). This "S-10" operational framework covers ontological, epistemological, and axiological aspects with clear courses of action, efficient processes, and rational outcomes based on socioecological and eco-spiritual values. It identifies diverse areas for leveraging interventions

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and policy imperatives for the resilient and regenerative agrifood systems across hierarchical scales from farms to nation, traversing through a rural to urban gradient.

Keywords 10-s framework · Biodiversity · Ecoengineering · Soil · Seed · Seasonality

1 Introduction

This chapter attempts to justify the necessity of a paradigm shift in designing sustainable development policies in general and agricultural transformation policies in particular. In the following eight topical sections, it highlights the aspects of global systemic crises and the emergence of an Earth systems justice paradigm; Nepal's geophysical and socioeconomic realities implicating its self-reliant endogenous food systems; a framing of Nepalese agricultural problems to streamline leverage points for interventions; the agroecological pathway to sustainable agrifood systems; the commonality between Vedic philosophy, agroecological food systems and Earth system justice paradigms; and the prospect of the integration of indigenous wisdom and modern socioecological principles in agricultural development. It offers a comprehensive S-10 framework to identify the leverage points for transformative agricultural research and development (R &D) in Nepal, provides global relevance and financial viability of the framework, and concludes with 17-point policy recommendations.

2 Global Systemic Crises and Earth Systems Justice Paradigm

The wealth-centric, consumerist rapacity has destabilized the Earth-regulating systems and global socioeconomic orders (Fletcher et al., 2024). Corporate rapacity considers all of nature's creations, including air, water, land, ocean, space, celestial bodies, living beings, and human caliber as profit-making, marketable commodities. This led to the reckless exploitation of resources and damage to the global environment, putting the Earth's system functioning at risk of irremediable and overwhelming shifts. Six of the nine components of the Earth-regulating system, including the climate, biosphere, land use, water and nutrient cycles, and aerosols have surpassed the safe operating limits, while the remaining three components are also at increasing pressure (Rockström et al., 2024a). Global warming beyond 1.5 °C is likely to propel the 16 sub-domains of the Earth system to its tipping points, curtailing lives across the world's biomes (Rockström et al., 2024b).

Greenhouse gas (GHG) emission, land degradation, and loss of biodiversity have interactively reinforced weather anomalies and global warming (Jayaramaiah et al.,

2024). Agriculture, forestry, and other land use currently generate 22% of total net anthropogenic GHG emissions (IPCC, 2023). The coming decades will see a high frequency of hostile climatic episodes, notably, heatwaves, mega-droughts, floods, and wildfires are likely to be 7.5, 3.6, 2.8, and 2.0 times more frequent, respectively, with crop failures happening 3.0 times more frequently compared to the last six decades (Fletcher et al., 2024). By 2060, global warming manifesting as extreme heat could cause a 18–37% loss in labor productivity, 37–45% loss in health, and 12–43% loss in other resources, leading to severe perturbation on the global supply chain (Sun et al., 2024). Growing international connectivity, ecological disturbances and socio-economic imbalances have already engendered global systemic crises marked by large-scale disruptions and failures such as widespread economic recessions, social violence, wars, and disease pandemics such as COVID-19, Ebola, avian influenza, and others (Wernli et al., 2023).

South Asia in general and Nepal in particular are highly vulnerable to global climatic emergencies. Climate disruptive losses in labor productivity, health, and wellbeing in South Asia are likely to be 2.0–3.3 times higher than the global average (Sun et al., 2024). A South Asian regional analysis predicts seasonal hydro-climatic extremes with temperature increases of 1.5–7.8 °C coupled with—3.4–46.2% variation in wetness by the end of twenty-first century. Extreme seasonal anomalies are already evident in Nepal, with the Tamor, West Seti, and Budhi Gandaki river basins projected to have a higher amplitude of hydrologic anomalies compared to all of the 19 river basins studied in South and Southeast Asia (Shrestha et al., 2021a, 2021b). Examining 47 years of rainfall data from 1980 to 2020 across the elevations of Nepal, Bista et al. (2023) reported a decreasing trend of annual rainfall with erratic extremes of higher and lower rainfall in the decadal timeframe. Depletion of soil carbon stock (Suman, 2021) and the naturalization of alien invasive species (Shrestha & Shrestha, 2021) are also of concern, threatening agriculture and livelihood systems. This calls for a climate change adaptive developmental paradigm supporting a self-reliant local food systems network for the future.

A value-based, planetary commons paradigm signifying high stewardship of nature from the local to the global scale has been necessary to conserve the Earth system trajectories within safe limits (Fletcher et al., 2024; Rockström et al., 2024b). Gupta et al. (2023) proposed three key Earth systems justice criteria defining safe Earth systems boundaries (ESBs): (I) Interspecies justice, (II) Intergenerational justice, and (III) Inter-societal justice. Obura et al. (2023) stipulate a set of six concerted actions for earth systems justice: “(1) reduce and reverse direct and indirect drivers causing biodiversity decline; (2) halt and reverse biodiversity loss; (3) restore and regenerate biodiversity to a safe state; (4) raise minimum wellbeing for all; (5) eliminate over-consumption and excesses associated with accumulation of capital; and (6) uphold and respect the rights and responsibilities of all communities, present and future.” In his treatise titled “Ecosociocentrism: The Earth First Paradigm for Sustainable Living,” Upreti (2023) asserts that the crises emanated from wealth-centric anthropogenic rapacity and offers a new ethical value-based developmental framework.

Despite the scientific evidence of global crises and the emergence of an Earth system justice paradigm, the anthropogenic rapacity continues. The political influences to safeguard the interest of the fossil-fuel trade led to the unjust climate target of 1.5–2 °C in the Paris Agreement, despite the identified risk beyond 1 °C, thereby causing hindrance on the pathway to earth systems justice to phase out fossil fuels (Gupta et al., 2024). Ellis (2023) rightly asserts that the “unprecedented planetary challenges of global climate change, biodiversity loss, and so many others are not caused by a lack of human sociocultural capabilities to address them. Rather, these negative planetary conditions represent failures to address these challenges by the social groups and societies directly responsible for them.” (Ellis, 2023). It is paramount that every country and civil society should escalate their voices for planetary justice and tailor the development to socioecological realities to safeguard sustainable livelihood systems.

Growing international connectivity, ecological disturbances and socioeconomic imbalances have already engendered global systemic crises marked by large-scale disruptions and failures such as widespread economic recessions, social violence, wars, and disease pandemics (Wernli et al., 2023). Contributing to myriads of planetary crises, the industrialized agriculture driving the commoditized global food system has been overburdening peoples’ lives and livelihoods. Literature documenting the alarming agrochemical impacts on the environment, biodiversity, and public health abounds (Devi et al., 2022). A recent study conducted in the USA showed consistent associations between twenty-two pesticides and prostate cancer incidence and mortality (Soerensen et al., 2024). The annual hidden cost within the global agrifood system, largely driven by the public health burden of noncommunicable diseases such as diabetes, stroke, and cardiovascular diseases and neurological disorders is estimated to be US \$12 trillion (FAO, 2024). Thus, the prevailing chemical-driven global food system underlies syndromic issues, and its supply chains may be virtually defunct, hence reinforcing the importance of sovereign local food systems.

3 Nepal’s Geophysical and Socioeconomic Realities Implicate the Aptness of Self-Reliant Endogenous Food Systems

Landlocked boundaries, seismic sensitivity, altitudinal gradients from less than 100 to above 8800 m.a.s.l. teeming with mountains, valleys and plain terrains, natural and agroecosystem diversity, cultural heterogeneity, natural beauty, and bountiful water resources are salient realities of Nepal. The complex landscape presents both developmental challenges and niche-based opportunities. Drawing on a wide spectrum of literature, Khanal and Thapa (2023) summarized their manifestations and policy imperatives for sustainable development (Table 1).

Table 1 Salient geophysical and socioeconomic realities of Nepal and their policy implications (adapted and elaborated from Khanal and Thapa (2023))

Realities	Manifestations	Policy implications
Landlocked boundary with over 800 km to transit to Kolkata, India and 3000 km to Lanzhou, China	High transaction costs and volatility in the international trade; risk of excessive tariff, sanctions, and blockades	Promote diversified endogenous circular economy and food sufficiency approach to development; contextual integration of cleaner locally available and renewable energy options to replace import of fossil fuel while reducing wastes and hazards
Geo-tectonically active, fragile mountainous landscape and rainfall extremes	Slope instability, excessive runoff, soil erosion, landslides, and destructive scouring, flooding, and sedimentation in the valleys and plain areas damaging roads and constraining transportation	Champion spatial ecoengineering in land use and infrastructure development with minimal disturbance to land and natural drainage systems; eco-cultural conservation-based agriculture; deep-rooted horticultural plantations, and multipurpose agroforestry for slope stability; localized, sovereign food systems to minimize risky transports
Abundance of ecological diversity and renewal resource base	Availability of diverse natural food, medicines, bio-pesticides, fodder and pasture, animal bedding materials, handicraft materials, pasture and timber resources for ecologically adaptive livelihood systems	Devise policy measures incentivizing community-based conservation and sustainable utilization of resources; revitalize, incentivize and advance integrated systems such as multi-storey agroforestry, crop-livestock integration, multitrophic aquaculture; biogas-integrated farm mechanization and processing plants; local food networks
Cultural and agroecosystems diversity	A differential combination of crop and animal species and land races, seasonality, land use patterns, non-farm activities, feasts and festivals, food ingredients and preparations	Diversity-based integrated agriculture embedded in Indigenous food culture, preserving and promoting indigenous knowledge; agritourism

(continued)

Table 1 (continued)

Realities	Manifestations	Policy implications
Treasure trove of natural beauty	Bountiful leisure and recreation potential for ecotourism, cultural tourism, and agritourism	Strong policy measures for making Nepal a haven for ecotourism while promoting Indigenous cuisines and preserving cultural integrity and natural trove
Colossal water resources: 6000 rivers with annual outflow of 150 billion cubic meters	Historically delineated clusters of settlements; potential for irrigation, micro-to mega-hydroelectricity, seasonal transport routes on large rivers	Low disturbance, scale-appropriate water resources utilization for residential utility, and agri/ industrial mechanization to replace import of fossil fuel
Solar and wind energy potential: 47,628 MW of solar and 1686 MW of wind energy	Largely untapped resources for energy; solar energy sustains biomass productivity with rapid regeneration of vegetation	Regenerative, clean energy-based household utilities, rural industries, farm mechanization, and agritourism amenities

Nepal is situated on a seismically sensitive geo-hazardous landscape. Earthquakes induce landslides, avalanches, and cascading geohazards such as air blasts, outburst floods, landslide-dammed lake outbursts, and floods laden with debris, mud, and sediments causing tremendous damage in the course. The Gorkha-epicenter earthquake of April 25, 2015, and its aftershocks engendered at least 25,000 landslides, which occurred more densely at the confluence of steep slopes and high mean annual precipitation (Roback et al., 2018). Anthropogenic activities such as the construction of roads, bridges and hydropower dams, unplanned urbanization, riverside settlement, sand mining, mechanical excavation, and blasting permitted or promoted by flawed policies and poor governance have increased the significant risk of natural disasters (Gurung, 2021).

Climate change typified by erratic occurrence of extreme temperatures, rainfall, and drought has aggravated the vulnerability of infrastructure and people (Li et al., 2022a, 2022b). Agrarian communities and landless riverbank settlers are primarily vulnerable to such disasters. The Melamchi flood disaster and unseasonal late October flood of 2021 and the torrential rain and landslide disasters in July and late September of 2024 are mere representations of the warning signals signifying the discordance between the country's reality and neoliberal economic policies promoting large-scale, landscape-destabilizing infrastructure development and high intensity long-distance fossil-fuel-based land transport system. The realities simply reject the agricultural commercialization model, which stresses the specialization of production in areas of comparative advantage, and the distribution of inputs and produce through long-distance land transportation and marketing systems.

In their recent book, Bhattarai and Conway (2021) extensively discuss Nepal's geographical and socioeconomic problems, including natural hazards, international

trade obstacles and blockade by India, policy distortions, poor governance, corruption, illegitimate brokerage, smuggling, growing proselytism, and out-migration. They note that the neoliberal, growth-centric hype in governance after the 1990 political change led to the reckless privatization and spurt of corrupt business intermediaries and smugglers. Within a decade under the multi-party system, industrial growth perished from 8.7 to 1.8% growth. The chaos manifested as rampant institutionalized corruption, socioeconomic deprivation, and cultural proselytism in the country, engendering intense hopelessness among people and leading to the exodus of millions of youths for employment and emigration (Bhattarai & Conway, 2021).

Past and current agriculture developmental policies in Nepal have been guided by growth-oriented neo-classical to neoliberal perspectives. Nepal's past policies remain deficient in all three justice criteria if viewed through the lens of just and safe Earth system boundaries. Those policies do not evolve through scholarly or experiential discourse regarding on-the-ground realities, but through the adaptation of a foreign, growth-centric, resource-exploitative, profiteering economic model. The Agriculture Development Strategy (ADS) (2015–2035) and Prime Minister Agriculture Modernization Project (PMAMP) (2016–2025) incorporate some socioecological narratives (Palikhe & Adhikari, 2023); however, the growth-centric model persists in the delivery mechanism and intended outputs. Accordingly, Green Revolution-type productivist top-down policies in agricultural research and development led to shifts in societal values of frugal abundance to profiteering commercialization, thereby destabilizing the time-tested farming and complementary livelihood systems. The agricultural development model that promoted external inputs, introduced varieties/breeds, and simplified monocultural practices did not only erode Indigenous knowledge, practices, genetic resources, and agrarian culture (Dionne, 2005), but has also caused overwhelming public health burdens associated with agrochemicals (Bhandari et al., 2024). Agricultural development programs hardly align with the motto “*Krishi Mulashcha: Jeevanam*” (Agriculture is the root of life) proclaimed by the Nepal's Ministry of Agriculture. The current PMAMP delivery model comprising commodity-specialized pockets, blocks, zones, and super zones for the commercialization of cereals, vegetables, fruits, livestock, and fisheries is a live example of the continuation of such a productivist approach. The “modernization” approach underscores the import of tractors and other machinery and the adoption of high external input-based practices and modern varieties without evidence-based consideration of land capabilities, thermodynamic efficiencies of systems throughout, and socioecological impacts. Such peri-urban- and prime pocket-favored policies and practices further marginalize the market-distant, rural areas. The resultant effects are manifested with decreased diversity and sufficiency of food at the household level, and increased net import of food, feed, fertilizers, pesticides, and other agriculture-related products. It is a paradox that import trends of both agricultural inputs and outputs are increasing together (Government of Nepal, 2024), undermining food sufficiency, sovereignty, and terms of trade. Moreover, the mismatch of technology and context also leads to soil compaction, deterioration of soil structure, soil erosion and slope failure in the hilly landscapes.

The food system profile of Nepal shows grim trends. Misuse or overuse of chemical fertilizers and pesticides prevails to compensate for the decline of soil fertility and increasing pest issues. Drawing on the global evidence of linking agrochemicals with noncommunicable diseases, one cannot rule out the association between growing pesticide use and alarming trends of cancer incidence and deaths in Nepal (Shrestha et al., 2021a, 2021b). Food insecurity prevails among over half of the population, and undernourishment persists, with a prevalence of anemia among women and children and underweight and stunting syndromes among one quarter and one third of children, respectively. On the other hand, the increasing trend of consumption of ultra-processed, high glycemic food in urban areas has led to an increasingly overweight and obese population (FAO et al., 2022).

Analyzing Nepal's policy-institution-program responses from 1960 to 2020, Aryal et al. (2023) found some improvement in conventional socioeconomic indicators such as per capita GDP, population below the poverty line, economic growth rate, and human development index. However, from 1970 to 2020, the contribution of the prime endogenous economic sector—agriculture and forestry—markedly decreased from 66 to 23% while reliance on imported goods and services increased from 8.3 to 34% of GDP. Industrial contribution to GDP also declined from 21 to 12% from 2000 to 2020 (Aryal et al., 2023). The share of remittance in GDP has been around 23% for the last several years, and government records show the issuance of permits for foreign employment to nearly 6 million citizens (Government of Nepal, 2024). This substantiates the weakening trend of developmental sustainability.

Even without considering the environmental costs of Nepal's foreign trade, its economic growth measured as GDP is negatively correlated with the amount of foreign trade value. Analyzing the Economic Surveys of Nepal's Ministry of Finance from 1989/90 to 2021/2022, Dahal et al. (2024) found that a unit increase in export value caused a 0.75 unit decrease in GDP. Trade liberalization policies enacted over the years have been continuously widening the agricultural import to export ratio, resulting in the deterioration of trade balance (Shrestha, 2022). The export of unprocessed materials due to value-addition constraints and the high transaction costs associated with Nepal's landlocked, remote geosition (Acharya et al., 2020) curtail the viability of international trade. This also applies to the export of all potential agricultural commodities, implicating the need for a local self-sufficiency and domestic trade network approach to agricultural development. The disruption of the food value chain by the COVID-19 pandemic in 2020 also revealed the importance of locally self-sufficient food system network (Adhikari et al., 2021).

4 Framing Nepalese Agricultural Problems to Streamline Leverage Points for Interventions

In an effort to consolidate a set of strategies for sustainable agriculture, Khanal (2023) propounded a framework of eight action elements, including spatial bioengineering, species diversification, seed management, seasonal synchrony, soil management, stress management, systems integration, and socioeconomic objectivity, referred to as 8-S elements. In this chapter, the framework is further reorganized and its elements redefined in cognizance of resource stewardship, socioeconomic values and socioecological justice as embraced by the agroecological principles and pathways of scaling up from field production practices to the governance of agrifood systems (Wezel et al., 2020). The framework crosscuts the ontological (what), epistemological (how), and axiological (value) dimensions. In this framework, the agricultural sustainability is attainable through a prudent, eco-friendly, systems approach to managing space (S1), species (S2), seeds and breeds (S3), soils and water (S4), seasonality (S5), and stress factors (S6) with the deployment of supportive infrastructure and institutional services (S7) contributing to the development of a self-regulatory synergistic agrifood system (S8) that justifies socioeconomic objectivity (S9) and socioecological symbiosis (S10). This framework is referred to as 10-S operational framework. Using this framework, we attempt to frame the agricultural problems discussed in the previous section in Fig. 1.

It is urgent to have the paradigm shift from quick-fix sectoral silos, promoting resource-exploitative and profiteering rapacity to value-based, ethical, and systems-based regenerative dogma. The economic development policies seeking growth in GDP must be transformed into socioecological, value-guided policies that foster socioecological symbiosis. Economic growth remains the central theme of the UN Sustainable Development Goals (SDGs), and although the 17 SDGs and 169 Targets (<https://sdgs.un.org/goals>) can serve as an important basis for formulating developmental strategies at the national level, the framework relies on the market mechanism for the governance of food systems, with no accountability for food sovereignty as a fundamental human right (Guerrero Lara et al., 2023). The value-guided developmental goals foster the convergence of agricultural sustainability, food sovereignty, and One-Health, ensuring socioecological wellbeing.

5 Agroecology Offers a Just Pathway to Sustainable Agrifood Systems

The growing global socioecological issues and vulnerability of food systems have prompted competing discourses and narratives on the transition mechanisms and pathways to sustainable agriculture and food security. Recently, regenerative agriculture has emerged as a prominent narrative amidst antecedent narratives such as

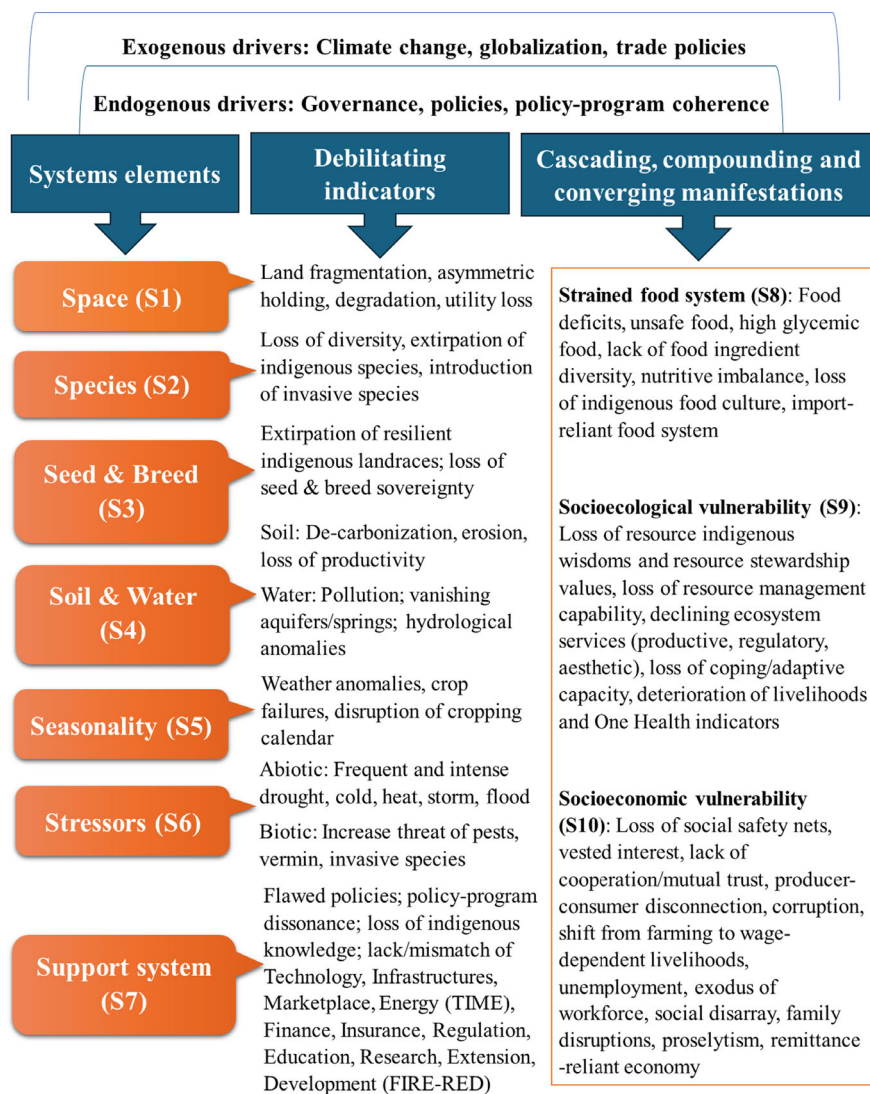


Fig. 1 Visualization of the weakening agrifood system through the lens of 10-S framework. *Source* authors' conceptualization

organic agriculture, conservation agriculture, sustainable intensification, and agroecology. All of these narratives are generally based on common ecological principles and practices for sustainability at the field scale toward enhancing biophysical efficiencies through eco-friendly practices and the redesign of production systems to balance systems tradeoffs and optimize the synergy. However, the agroecological narrative goes beyond ecological science and field practice to embrace political

activism for socioecological sustainability (Tittonell et al., 2022). Agroecology as a science, practice, and movement has been guided by 13 socioecological principles, including recycling, input reduction, soil health, animal health, biodiversity, synergy, economic diversification, the co-creation of knowledge, social values and diets, fairness, connectivity, land and natural resources governance, and participation (Wezel et al., 2020). It envisages the development of sustainable, sovereign, short-chain, and just food systems networks rooted at the community level. Unlike the quick-fix reformist narratives, agroecology has clearly charted the transformative pathway to agricultural and food systems sustainability and a way out of global systemic crises (Bezner Kerr et al., 2023; Wezel et al., 2020). Agroecology recognizes food as a vital basis of life and advocates the sovereignty of food systems. It underscores knowledge-intensive, eco-friendly practices to conserve the resource base for perpetual use.

6 *Sanatana* Philosophy Aligns with Agroecological Food Systems and Earth System Justice Paradigms

The 13 principles of agroecology and the value of food as a vital basis of life finely align with the *Sanatana* philosophy. The core essence of *Sanatana* philosophy includes care, connectedness, collective welfare, and gratitude for what nature has entrusted to us to enjoy and share with all living beings. Major scriptures such as the Vedas, Upanishads, Bhagavad Gita, Mahabharat, and the Puranas confer the *Sanatana* philosophical wisdoms and principles. The *Sanatana* philosophy covers all dimensions of knowledge and practices, including economics, social dynamics, agriculture, natural resources, livelihoods, health, astronomy, and other areas, providing foundational discourses for socioecological sustainability. Vedic philosophy underscores value-based livelihoods with frugal abundance, care, cooperation, and nurturance of nature's beings, including the sharing and sparing of space and food for wildlife. Nevertheless, a substantial portion of the world is still ignorant about and has yet to appreciate the Vedic philosophical essence and values. The agricultural sector and food security are important dimensions of Vedic economics: “Krishi Mulashcha: Jeevanam” (agriculture is the root of life), “Uttam Kheti, Madhyam Byapar, Nich Nokari” (supreme farming, mediocre trade, lowly the civil service), “Ghokanti Vidhya Dhawanti Kheti” (learning by memorizing, farming by tending), and “Subijam Sukshetre: Jayate Sampadyete” (good seed in a good field yields abundance) are some popular proverbs that epitomize the Vedic wisdoms of adorable agricultural and learning values.

The oldest treatise of the world, the Rig Veda, regards Anna (foodgrains) as the major basis of life of humans and other living beings and says that even the Gods receive necessary nutrients from them (Mandal 1, Sukta 187, Richa 1–11; referring to part, chapter and verses, respectively). The Sama Veda also regards “grain” as the Grain God and mentions that grains are produced by the Eternal Yajna (true

devotion). In this way, Vedic philosophy considers farming as the work of Yajna or the work that pleases the God. The Veda even considers that food grain originated even before the origin of God (Samaveda, 594th verse/richa/mantra). The Yajur Veda also respects and refers to food grains, including rice as God in multiple Adhyaya (chapters). The Atharva Veda also regards food grains as one of the Gods (Kanda-III, Sukta 27; where Kanda refers to as section) and mentions Bhumi (land) (Kanda 12, Sukta 1), Krishi (agriculture) (Kanda 3, Sukta-17) and grain affluency (Kanda 6, Sukta 142).

All four Vedas describe in detail various aspects of grains and agriculture, including the quality of food grains; agricultural education and technology; the development of high-yielding crops and medicinal plants; the distribution, storage, and consumption of agricultural products; caring for cows and other domestic animals; the need of the irrigation and the construction of canals to irrigate fertile land; the preparation of different medicines; nutritional drinks or juices such as the Somarasa (a juicy energy drink prepared from the juice of the somalata and other medicinal plants and grains); and nutritive grain flour. Likewise, evidence abounds for the Vedic civilization contributing to the emergence and development of the agricultural sector in human history. The Vedas describe the nutritive and ecological significance of diverse crops such as rice, barley, wheat, millets, lentil, chickpea, black gram, mung-bean, common beans, sesame seeds, leafy greens (mustard, spinach), vegetables, and fruits.

Many modern scholars often consider agricultural education and advanced agricultural technology as the achievement of efforts over the past several centuries and ignore the foundational wisdom that evolved from ancient civilizations such as the Vedic civilization. An inspirational Vedic verse says, “Oh man! Fasten the yoke with the help of a rope on the neck of oxen and connect the yoke with the plough and then till the field to sow the seeds. Get agricultural education from the farmers or experts. Develop superior varieties of crop species to produce more in a shorter period. After the crops are ready, reap, collect, and carry the produce from the field, and take your food from the produce and feed others” (Rigveda: 10:101:3; Yajurveda: 12:68 and Atharvaveda: 3:17:2). These Vedic verses emphasize the importance of practical agricultural education (Dayananda, 1935), crop improvement by breeding and seed preservation (Luitel, 2006), and the use of equipment and animal power (Upadhyaya & Pokharel, 2015) in agricultural production.

Vedas signifying agriculture as a devotion imply the investment of mind and resources. The Vedic civilization invested effort in enhancing the fertility of the arable land, adopting diverse soil and water conservation and manuring practices. Cattle dung and urine were used as fertilizer, as well as crop protectants against pests. People prepared natural compost out of cow dung, urine, animal bedding materials, plant biomass, kitchen waste, and other decaying materials in pits or trenches (Pokharel & Sharma, 2017). Bhisma in the Mahabharata, also regarded as the fifth Veda, rightly says that the livelihoods of all of the Gods, ancestors, human beings, animals, reptiles, and birds are fully dependent on food crops produced and provided by farmers (Mahabharata, Shantiparva, Rajdharmanushasan Parva, Adhyaya 89, Verse 26). This

signifies the benevolent values recognizing the coexistence of human and other living beings in nature.

Vedic society understood hydrologic phenomena and recognized the importance of water resource management. Irrigation was considered instrumental to increasing agricultural production (Rigveda: 10:101:5,6). They constructed canals to irrigate the land; preserved upstream vegetation to recharge water springs, and dug wells and ponds to collect rainwater to fulfill water needs in dry seasons. People developed and followed the rules for systems maintenance and water distribution in crop fields to mitigate potential conflicts. Society developed a system of cooperation through the exchange of labor, materials, and equipment for farming. People were also aware of the importance of the microclimatic ecosystem to conserve spring water and enhance the likelihood of timely rainfall. Figure 2 shows an example of traditional visionary ecoengineering of hamlets by a community evolved with the Vedic value system.

Vedic culture had a definite farming calendar attuned to seasonal rhythms and considered food grains as the life of human beings and other creatures (Pandeya, 2003). The Vedic cultures evolved with festive traditions of cultivating and harvesting activities. For example, the paddy planting would be accompanied by cheerful music, songs, and dances. New crop harvest would be preceded by offering samples to living creatures in the name of deities. After the harvest and storage of rice, a new harvest relishing ceremony called Nwai would be observed, with special days and times identified to perform important agricultural activities. An annual ritualistic plan of farming activities made the work itself a celebration, motivating people to perform the tasks with high enthusiasm. Some researchers and thinkers contend that the agricultural spirit of Vedic civilization was the first agricultural revolution of its type in the history of human civilization.

Vedic philosophy confers the principle of justice to farmers in agricultural taxation. If the tax rate becomes too high and farmers are unable to get a reasonable benefit on their investment, it drives the farmers away from farming as an occupation (Mahabharata: Shantiparva: 89:24, 25; (Pandeya, 2003). This results in import dependence so a country can provide food for its citizens. The safety and security of crops sown, grown, and harvested by farmers is considered the liability of the state or the government in Vedic philosophy.

The Vedic principles advocate for both the justful duties of farmers as well as justice for farmers. Vedic philosophy does not allow capable people to work themselves to unjustly appropriate earnings and property of others (Rigveda: 8:81:1; Samaveda: 728). Vedic treatises suggest that people earn or produce wealth only by walking upon the path of truth (Rigveda: 3:12:7; Samaveda:1577,1694). The Bhagavad Gita and all other ancient treatises also criticize the wealth collected through unjust practices (Pandey, 2023).

Ancient treatises such as the Vedas, Bhagavad Gita, Upanishads, Puranas, and other sources of information from the period present an advanced, just, and value-based system of farming. The generosity and justice to farm animals is reflected through the tradition of not putting them to work on days of ancestral commemorations or on certain days in the lunar calendar. Features of Vedic agriculture largely



Fig. 2 An example of traditional spatial ecoengineering strategies underscoring water harvesting, spring recharging, biodiversity nurturing, and microclimate conditioning goals in the Amarai-Jamundada hamlet in Arghakhanchi, Nepal. The Pokharis (ponds) not only served as a seasonal reservoir of water, but also helped recharge multiple water springs, providing drinking water for the community. Close to each Pokhari were *Ficus religiosa*, *F. benjamina*, and *F. benghalensis* trees, with their bases surrounded by a masonry platform called a Chautari/Chaupari for providing shade for passersby and a venue for local community meetings and events. Peripheral vegetation was strategically maintained above the water springs to help preserve water resources and stabilize and augment slope landscape for diverse uses. Multipurpose trees were planted on the field margins, terrace risers, and fence lines for harvesting edible fruits and berries, fodder, timber, bedding materials, and green manure. Modernization ignored the significance of such ancestral spatial ecoengineering, which was a key strategy of livelihood systems adaptability. In the process of modernization, the ponds were filled back, shade trees felled, and Chauparis demolished for building roads, schools, and playgrounds. Such dismantling of deliberate ecoengineering systems resulted in the disappearance of water springs, among other problems. *Source* authors' collection

align with modern agroecological principles but have not yet received proper attention in agricultural studies and research. Further research in this field can be highly beneficial for improving the sustainability of modern agricultural, economic, and livelihood systems.

7 Integration of Agroecology and Vedic Philosophy is a Way Out of the Downward Spiral

Nepal can draw upon Vedic philosophy and the agroecological paradigm for self-sustaining socioecological development. Cognizance of landscape capability and embracing an appropriate spatial ecoengineering approach can hardly be emphasized in designing developmental pathways. There is an urgency for a complete shift in the paradigm from neoliberal capitalist mimicry to a contextual ingenuous approach to sustainable developmental transformation in Nepal. The “commercialization” involving the profiteering intermediaries between producers and consumers would merely function at the latter’s cost. The territorialized food systems network eliminates the redundant value-chain steps, enabling farmers to receive higher prices and producers to receive more affordable prices (Cazella et al., 2024) while reducing environmental footprints. The short value chain potentially reduces a quarter of greenhouse gas emissions that comes from the transportation sector (Li et al., 2022a, 2022b).

In the context of Nepal, where mobility hazards abound, policies should strategize the development of territorialized short value-chain food systems networks, which reduces the need for long-distance mobility of the food trade. The current municipal Wards could be divided into a manageable food shed analogous to watershed units, with direct links to producers and consumers for local produce, and producer and consumer cooperatives can be developed for inter-network/external trades.

Nepal’s socioeconomic wellbeing relies on healthy and robust agrarian systems. Therefore, the country’s developmental planning must envision holistic trajectories centered on robustness of territorial, sovereign, and ecologically adaptive agrifood networks. As such, we propose a sovereign food system-oriented agroecological framework integrating 10 elements in agricultural development, hence “10-S” operational elements (Table 2; Fig. 3). The framework is an extension of the 8-S operational elements for sustainable agriculture originally conceptualized by Khanal (2023). We define the framework as prudent, eco-friendly, and integrated management of space (S1), species (S2), seeds and breeds (S3), soils and water (S4), seasonality (S5), and stress factors (S6), with the deployment of support infrastructure and service components (S7) to develop self-regulatory sovereign agrifood systems (S8) that rationalize socioeconomic objectivity (S9) and socioecological symbiosis (S10). This “10-S” operational framework envisages a clear course of action, efficient processes, and rational outcomes based on socioecological and eco-spiritual values and understanding of tradeoffs and synergies (Table 2). Under each “S-element,” one can categorize innovations and discoveries into (1) established innovations that require thrusts on knowledge and technology transfer aspects, (2) promising innovations that require thrusts on verification and validation, (3) potential innovations that require thrusts on more applied research to develop, and (4) unknowns and uncertainties that require exploratory and more basic research for the strategic pathways.

Table 2 S-10 framework to identify the leverage points for transformative agricultural research and development (R &D) in Nepal

Functional theme	Objectives	Leverage points for transformative interventions	Outcomes
S1 —Space: Spatial ecoengineering	Adaptive modification of physical and vegetal landscape tailored to the constraints presented by climatic, geographic, and soil conditions	Community to national scale: • Digitized land use zoning based on geomorphic capabilities such as arable agriculture, pasture and forestry, agrobiodiversity sanctuaries, wildlife parks and sanctuaries, recreation, and pilgrimage • Landscape-tailored economic diversification and ecological conservation options • Strategic locations for support infrastructures, marketplace, and institutional set-up Farm to landscape scale: • Niche-based diversification of farming systems components • Allocating safe and convenient niches for homestead, animal housing, storage, terracing, cropping, grazing, agroforestry, forestry, irrigation/drainage systems, embankment; beneficial biodiversity habitats	• Landscape stabilization • Agroclimatic moderation and microclimate improvement • Niche-based diversification • Soil and water conservation • Hazard mitigation, hygiene, and safety • Adaptation to climate change • Resiliency of agroecosystems • Bioeconomic efficiency

(continued)

Table 2 (continued)

Functional theme	Objectives	Leverage points for transformative interventions	Outcomes
S2 —Species: Species diversity and systems integration	Agrobiodiversity by design to create a multi-functional environment for enhancing landscape-carrying capacity and ecosystem services	• Integration of crops, livestock, poultry, aquaculture, apiculture, etc. • Integrative mosaics of food, feed, seed, fiber, minor niche-based and soil improving crops • Spatial and temporal arrangements based on intra- and inter-specific interactions (cultivar mixtures, various forms of intercropping, polycultures, companion push–pull cropping, crop rotations, perennial fruit crops, and multi-dimensional agroforestry) • Specialty and peripheral vegetations for economic use and ecosystem functions such as habitats for pollinators and natural enemies, beneficial macro-fauna and micro-organisms • Improving minor/ underutilized crops • Domestication of medicinal and native plants of varied uses • Integration of traditional wisdom associated with agrobiodiversity	• Niche-based economic diversification • Soil and water conservation • Microclimate moderation • Hazard mitigation • Adaptation to climate change • Resiliency of agroecosystems • Nutritional security • Circular economy

(continued)

Table 2 (continued)

Functional theme	Objectives	Leverage points for transformative interventions	Outcomes
S3 —Seed and breed: Seed and breed augmentation	Dynamic management of population evolution, adaptation, and diversity of crop species	• Decentralized participatory plant/animal breeding • On-farm seed/breed conservation • Efficacies of seed conditioning and augmentation • Seed and seedling priming: magneto-priming, microwave/UV-radiation; botanicals, bio-priming, nutri-priming, beneficial microbial seed coating; seed conditioning, seed physiology and storage techniques	• Capacity building of producers • Adaptation to climate change • Resiliency of agroecosystems
S4 —Soil and water: Soil and water resources stewardship	Management of soil, water, and ecosystem health to sustain productivity by conserving soil and water, maximizing nitrogen fixation, enhancing nutrient recycling, and enriching soil properties	Conservation: Conservation tillage, compaction remediation, strategic tillage, vertical tillage, zonal tillage, residue management, cover cropping, perennials/winter crops in rotation; contour seeding, annual/perennial strips, seeding techniques Augmentation: Legumes in rotation, green manuring, bio-tillage/large-rooted crops in rotations; organic amendments, biochar; bio-fertilizers; irrigation and drainage; belowground root and rhizosphere analysis, soil carbon dynamics Nutrient management: Nutrient dynamics studies, greenhouse gas emissions, nutrients budgeting, nutrient use efficiencies, bio-fertilizers, 4-R nutrient stewardship Carbon sequestration: Biochar, cover cropping, residue management, diversified cropping	• Climate change mitigation and adaptation • Resiliency of agroecosystems • Circular economy

(continued)

Table 2 (continued)

Functional theme	Objectives	Leverage points for transformative interventions	Outcomes
S5 —Seasonality: Seasonally synchronous activity calendars	Adapting crops, cultivars, practices to seasonal rhythms, modulating microclimatic features, and adjustment of marketing, transport, and complementary economic activities to maximize safety of lives and livelihoods	• Weather forecasting, agroclimatic modeling • Alternative back-up farm planning • Adjustment of seeding time • Selection of crops or cultivars with climate-adaptive phenology, shifting seeding time and tailoring cropping sequences in response to changing weather patterns • Development of water reservoirs, irrigation efficiency measures for critical stages of water stress • Water conservations measures: residue retention, residue/stubble/soil mulching, cover cropping • Foodbank, feed stocking, and water reservoir • Tailoring the crop marketing calendar to mitigate the need for long-distance mobility and transportation during hazardous seasons	• Climate change mitigation and adaptation • Resiliency of agroecosystems • Hazard mitigation

(continued)

Table 2 (continued)

Functional theme	Objectives	Leverage points for transformative interventions	Outcomes
S6—Stressors: Stressors smothering	Supplementing space, species, seed, soil, and seasonality management with contextual integration of stress-specific measures to mitigate abiotic and biotic stresses and perturbations	• Understand the nature of stressors; enhance their predictability for devising effective solutions: times, stage, frequency, products, and methods • Develop eco-friendly and effective management options for controllable factors • Integrated pest management involving physical, chemical, biological, behavioral, mechanical, cultural, solarization, bio-fumigation, botanicals, anaerobic soil disinfection, flaming, steaming, electrocution, application of electrostatic fields, lasers, infrared radiation, ultraviolet radiation, microwave weed treatment, mechanical weed seed crushing and other abrasive destruction measures • Agri-systems insurance, tailoring S1 to S5; solar/bio-fencing, farm-dogs, AI-security alarms, public-supported patrolling against problematic wildlife such as monkeys, porcupine, and wild boars	• Climate change mitigation and adaptation • Resiliency of agroecosystems • Hazard mitigation • Food security • One-Health attainment

(continued)

Table 2 (continued)

Functional theme	Objectives	Leverage points for transformative interventions	Outcomes
S7 —Supportive infrastructure and institutional setting	Create an enabling environment for farming communities with recognition of Indigenous knowledge and deployment of key infrastructures and institutional services conducive for a self-reliant food systems network	Community to national scale • Development of roads, ropeway, renewal energy (hydro/solar) plants, and irrigation structures (canal, reservoirs, etc.) • Research and development on locally adaptive manual, animal-drawn, and renewal energy-operated equipment for eco-friendly mechanization • Strong societal security and regulations • Institutional provision for finance, insurance informational and technological accessibility, education, research, and extension system Household to local food network scale: • Storage with environmental control, marketplace, and agritourism structures • Renewal energy-operated agro-processing plants for value addition of local produce • Subsidiary on-farm enterprises for income diversification	• Bioeconomic efficiency • On-farm self-employment • Food security • Entrepreneurship development • Resilient community

(continued)

Table 2 (continued)

Functional theme	Objectives	Leverage points for transformative interventions	Outcomes
S8 —Sovereign agrifood system	Develop an sovereign, resilient, territorial food systems network for food safety and nutritional security	• Awareness building about global systemic crises and vulnerability of industrial and corporatized food systems • Land and water resource inventory and analysis of agricultural development • Identify opportunities for bioeconomic efficiencies, and inputs substitution and redesign of agricultural systems at the municipal Ward level • Pilot food systems network model in isolated community through Living Lab approach • Scale up networks to other areas	• Food sovereignty, safety, and nutritional security • Bioeconomic efficiency • On-farm self-employment • Food security • Entrepreneurship development • Resilient agrarian community
S9 —Socioeconomic rationality	Alignment of farming systems with farmers' livelihoods, objectives and wellbeing, including income, social obligations, leisure, and recreation	• Recognize and abolish policy-bias, power asymmetry • Enact subsidy measures to promote practices that produce public goods and services • Bottom-up scaling of policy from community groups to Wards through municipalities to the national level	• Boost of morale and dignity of farmers and ethical agri-entrepreneurs • Enhance resource and environmental stewardship • Socioeconomic resilience

(continued)

Table 2 (continued)

Functional theme	Objectives	Leverage points for transformative interventions	Outcomes
S10 —Socioecological symbiosis	Enhance socioecological synergy by balancing the tradeoffs in the agrifood systems	• Analyze tradeoffs such as monoculture versus polyculture, systems integration versus specialization, risks versus productivity, crop yield versus nutritive quality, conventional versus conservation/organic production systems with respect to diverse ecosystems services and wellbeing of agrarian communities • Design economic policies to enable agrarian communities to balance tradeoffs of adopting eco-friendly agricultural practices that reduce environmental footprints and enhance social cooperation	• Climate change mitigation and adaptation • Resiliency of agroecosystems • Community resilience and wellbeing • Sustainable development

Source authors’ conceptualization and compilation

8 The 10-S Operational Framework: Globally Viable and Financially Feasible

Development policies must recognize the limitations of international trade and the significance of self-reliant economy and food systems. The discussion above has illuminated the looming crises from local to planetary scale and noted that the commercial/industrial agricultural model is a stark mismatch with Nepal’s reality. An agroecology-guided production and value-driven transformation of agrifood systems is a promising approach to food security and sustainability.

The Food and Agriculture Organization (FAO) of the United Nations has been promoting agroecology and advocating for the value-driven transformation of agri-food systems (FAO, 2024). The World Health Organization (WHO) promotes One-Health as “an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems,” recognizing the inter-linkage and interdependence among the health of humans, domestic and wild animals, plants, and the environment (https://www.who.int/health-topics/one-health#tab=tab_1). The transformative 10-S operational framework we propose aligns with the FAO’s perspectives and also contributes to the aspirational One-Health approach of the WHO. The framework also does not contravene the policies of



Fig. 3 S-10 operational framework for sustainable agricultural policies, education, research, and development. The support infrastructure and institutional setting include Technology, Infrastructure, Marketplace, Energy (TIME), Finance, Insurance, Regulation, Education, Research, Extension, and Development (FIRE-RED) with Recognition of Indigenous Knowledge Systems (RIKS). *Source* authors’ conceptualization

the World Trade Organization (WTO): “Article 20 of the General Agreement on Tariffs and Trade (GATT) allows governments to act on trade in order to protect human, animal, plant life and health. Developing countries do not have to cut their subsidies or lower their tariffs as much as developed countries, and they are given extra time to complete their obligations. Least-developed countries don’t have to do this at all” (https://www.wto.org/english/thewto_e/whatis_e/tif_e/agrm3_e.htm). There are many examples of countries adopting specialty measures, for safeguarding the interest of the nation and the protection of people, animals, and ecosystems (Echols, 2024). Agricultural policymakers tend to focus on the problems of primary agricultural production, and the strength of the food systems approach to utilizing diverse measures for socioeconomic environmental rationality remains unappreciated (OECD, 2021). It is paramount to ensure the safety of food systems against agrochemical residues, microbial toxins, toxic/anti-nutritional contaminants, and the risk of zoonotic diseases and invasive pests. Nepal lacks the resources and capacity for costly genetic and biochemical analyses, extensive testing for pesticide residues, and the health of living materials for effective quarantine during importation (Chaulagain et al., 2022). Thus, the most feasible approach for Nepal is to adopt an exclusion principle and develop a risk immunity approach by mitigating the unrestricted material flow, which is possible by strengthening territorial food system networks. With a clear vision and sound governance, Nepal can justify and implement its approach to

a value-driven transformation of agrifood systems for safeguarding One-Health and people's livelihoods.

Agroecological transformations of varied forms and degrees are gaining momentum in several countries around the world (Monjane & Rosset, 2024; Ong et al., 2024; Wezel et al., 2024). The 10-S framework is a comprehensive elaboration of agroecology and a concrete portrayal of the approach to the value-driven transformation of agrifood systems. Many of the action elements in the framework such as management of species (S2), seeds and breeds (S3), soils and water (S4), seasonality (S5), and stress factors (S6) are incremental, requiring only a reorientation of thinking and program design on the part of support institutions. Due to the incremental nature of the field-scale leverage points in our 10-S framework, most of them can be implemented under the ADS and PMAMP, thereby redirecting existing programs toward agroecological pathways. With proper training, strategies, and procedures of a comprehensive developmental framework, ongoing programs can be seamlessly transitioned in more positive and aspirational directions. In the light of increasing trends of geoclimatic disasters in Nepal, the management of space herein referred to as spatial ecoengineering (S1) has been a growing intersectoral felt need. It is imperative to instantly adopt spatial ecoengineering in developmental planning to safeguard people's lives, property, and resources. Thus, the prime call of the proposed framework is a paradigm shift for appropriate cognizance of reality, analysis of problems, and launching transformative solutions, rather than the continuity of quick-fix reformative measures and perpetual down-turn of the system. The prevalent three-tier of government requires rigorous vertical and horizontal communications for common understanding and coordination to appreciate the gravity of the issues and promising solutions. Without sound governance, any policy and program can fail, as epitomized by the case of climate adaptation plans (Gentle & Mainaly, 2024). We do not anticipate any impediments of governance structures for the implementation of co-development initiatives, provided sound governance prevails.

9 Conclusions

Sovereign agrifood systems that capitalize Indigenous wisdom and a modern agroecological approach provide the only safe and sure pathway for sustainable value-guided development. Policies and practices should be judged by the dichotomy of whether they foster or undermine social metabolism, functional connectivity of ecosystems services, and civic citizenship recognizing socioecological interdependence. We should not forget the signal that COVID-19 provided: the safest strategy for all crises, including pandemics, is to have self-reliant, local food networks. Nepalese consumers have been increasingly aware of food safety, and there seems to be a clear preference for frugal, sufficient, quality food over the abundance of unsafe foods. Thus, substituting toxic inputs with eco-friendly practice can enhance the well-being of both producers and consumers. The "10-S" operational framework crosscuts the ontological (what), epistemological (how), and axiological (value) dimensions

and envisages clear course of actions, efficient processes, and rational outcomes based on the cognizance of tradeoffs and synergies with respect to socioecological and eco-spiritual values. The integration of farmers' experiential knowledge, Vedic wisdom, agroecology, and Earth system justice principles in policymaking and program delivery can pave the pathway to sustainable agricultural transformation and socioecological development.

9.1 Policy Recommendations

Drawing on the discussions in the above sections, we put forward the following policy recommendations:

1. Adopt the 10-S framework in policy formulation for agricultural education, research, and co-creation of innovations and development programs.
2. Integrate traditional wisdom and modern scientific knowledge in designing and executing agricultural systems innovations. Student interns can be encouraged to document oral stories, compile new and pre-existing documentation of traditional wisdom, and analyze the analogy with modern agroecology and relevant sciences. A course on traditional wisdom in agriculture and natural resources management can be a worthwhile addition in the curriculum.
3. Recognizing the power asymmetry among stakeholders, consult the vulnerable groups to acquire their perspectives prior to hosting multi-stakeholder forums in policymaking and program design.
4. Foster innovations in manual, animal-drawn, and regenerative energy (solar, electric, and biofuel)-driven equipment.
5. Promote on-farm research with the Living Labs approach (Knickel et al., 2023) for the co-creation of innovations for operational efficiency, eco-friendly input substitution, and the redesign of farming systems.
6. Promote student internship programs to serve in the rural agricultural areas in the Living Labs approach for real-world learning opportunities for students and the injection of innovative ideas into the programs.
7. Subsidize only those agri-entrepreneurship-related investments that contribute to the wellbeing of communities and environmental health. Do not subsidize those that benefit individual families or have negative socioecological externalities.
8. Incentivize the gradual substitution of external synthetic inputs (fertilizers and pesticides) with locally available and eco-friendly alternatives.
9. Subsidize biodiversity-based agriculture and food systems, and promote Indigenous or underutilized food crops, resource conservation, and cooperative initiatives.
10. Incentivize the integration of diverse components in farming systems rather than single specialized practices that do not synergize systems outputs or do not produce ecosystem services.

11. Provide support to diversify local economies through value addition (household/community-based small agrifood processing industries powered by renewal energy), community-based agritourism (homestay, local/organic food fairs, etc.), fair marketing (through community-based cooperative marketing, micro-financing, local haat-bazaar, etc.), and local food networks (by re-connecting producers and consumers through short-chain markets) underpinned with publicly funded infrastructures (roads, irrigation, storage, marketing, and collection centers) and institutional services.
12. Within territorial food networks, promote the mechanism of personalized and digitalized intra- and inter-network communications and transactions by issuing a subsidy card per household for travel, transport, and Internet subscriptions.
13. Devise intra-network accounting of farmland area; itemized agricultural production; and the number of producers, consumers, and visitors accounting for food sufficiency and estimates of food import and export.
14. Part-time farming/entrepreneurship/service can be the most sustainable value-oriented livelihood model for the majority of Nepal. So, foster on-farm or intra-food network value addition, agritourism, and bioenergy generation enterprises. Encourage local human resources development for public service for their stability, effective contributions with their territory-based expertise and minimizing administrative costs of frequent relocations.
15. For management and operational efficiency, promote individual farmer and food network level land consolidation plans by reducing the number of parcels and increasing single-parcel farming operations per household. Waiving title transfer charges for up to 1–3 ha depending on the land use capability class and land value may incentivize farmers for land consolidation. Discourage inter-regional land holding (hill and Terai; rural and urban locations) through taxation measures to mitigate absenteeism from the arable land.
16. Existing local administrative units called Wards can be subdivided into food shed communities (analogous to the watershed concept) to establish local food networks based on the convenience of community members.
17. Encourage inter-network collaborations to declare organic agriculture zones with the establishment of publicly funded labs and factories for bio-fertilizers, bio-pesticides, and phyto-pesticide production.

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Chapter 5

Agricultural Insurance Programs in Nepal: Challenges, Opportunities and Way Forward



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Abstract To address the higher risk faced by producers in agricultural production and sales from the farm gate, the government of Nepal launched an agriculture insurance program in the fiscal year 2013/14 with a significant subsidy on insurance premiums. After 10 years of the program's implementation, this study found that agricultural insurance covers 4.4% of total farmer participation and 3% by insured value to agricultural gross domestic product (GDP). This indicates that a thorough review of agricultural insurance policies, programs, and outcomes in Nepal is urgently needed to assess the effectiveness of public investment and identify areas for improvement. The aim of this chapter is to examine the features and performance of the programs, the significance of the program in the context of risk coverage, status of claim settlements, technical challenges, and other implementation problems. Additionally, the study analysed the outcomes of the crops and livestock insurance programs in comparison to a huge public investment, primarily in the form of an insurance premium subsidy to producers. This study has also assessed and presented lessons learnt from similar agricultural insurance programs overseas. Recommendations and the way forward from this study could be helpful in supporting policy guidance to provide a roadmap for sustainable and efficient agricultural insurance programs in Nepal, thereby supporting the overall transformation of agriculture in the country. The study identifies a wide gap between insurance premium and loss rates: premium rates need to be properly analysed, and coverage level cautiously reduced from 90%, which would reduce the cost of premiums. Additionally, to reduce the huge government stake in agricultural insurance, there is a need to prioritize crop and livestock species for providing premium subsidies and focus on climate-resilient insurance programs.

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Keywords Agricultural insurance · Claim settlement · Insurance premium · Multi-peril risks · Stake

1 Introduction

Agriculture remains the mainstream of Nepal's economy, as it contributes 24.1% of total GDP (MoALD, 2023). However, the industry is exposed to various risks and is highly dependent on the weather. Agriculture insurance can help reduce this vulnerability for such households and enterprises by helping to reduce the vulnerability of primary producers, households and enterprises by providing protection against crop or livestock losses due to natural disasters such as drought, floods, hailstorms, pest attacks, disease outbreaks and other extreme events. It aims to reduce the financial risk and uncertainty faced by farmers and help them manage their production and income more effectively. Furthermore, agricultural insurance improves access to credit for households and businesses as institutional lenders such as banks and cooperatives prefer to lend money to farmers who have insurance coverage for their products. This ultimately helps farmers to expand their operations and invest in new equipment or technology. Insurance has become even more important as extreme weather events and climate change have increased the risks and uncertainties in agriculture-based enterprises.

Nepal is vulnerable to natural disasters, including climate-induced ones such as floods, landslides, wildfires and droughts, and non-climatic ones such as earthquakes and epidemics. These disasters not only cause the loss of lives and private property, but they also destroy physical infrastructure and disrupt economic development. Making matters worse, the impacts of Nepal's climate vulnerability and extreme weather events are unevenly distributed among its people and have especially higher impacts on the lives and livelihoods of smallholder farmers. Such unique circumstances made the Nepal government form a strong commitment to sustainable development goals 2030, and in its subsequent programs and strategies to promote commercial farming, requiring development of appropriate insurance products and effective implementation of risk management tools such as crop or livestock insurance by farmers as priority programs for the country.

The Crop and Livestock Insurance Directives 2013 have opened the door to commercial insurers to start agriculture insurance. The Insurance Board of Nepal then introduced agriculture and livestock insurance products for cereals, vegetables, fruits and livestock starting on 15 January 2013. As per the Directives, crop insurance covers production cost, including the purchase of seedlings, fertilizers and the labour charges incurred until the crops are ready for harvest. Livestock and poultry insurance provides coverage to all types of cows, oxen, buffalo, yak, female yak, sheep, goat, swine, chicken and ducks based on the sum insured fixed by the insurance board. Maximum and minimum sum insured, age limit, amount of premium and commission are clearly specified by the insurance board. For all types of loss, insurers will provide 90% compensation of actual loss and 10% should be borne

by the client. The government of Nepal has emphasized the importance of investing both in financial inclusion for smallholder farmers and in risk management tools that help them cope with multi-peril risks, including climate-related threats. As a key stakeholder of agricultural insurance, the Insurance Board of Nepal requires non-life insurance companies to sell at least 5% of the total insurance policies in agriculture, livestock or the primary production sector. Further, the federal government of Nepal provides an 80% subsidy on the insurance premium.

Another initiative launched by donor-sponsored projects is microinsurance. Microinsurance is insurance specially designed to protect low-income households from the risks they face in their daily lives. The Insurance board has been promoting the expansion of microinsurance. In addition to the government's subsidies (of up to 75%) on agriculture and the special issued set of microinsurance directives, the Government of Nepal has mandated that insurance companies have at least 5% of their total portfolio in microinsurance. These initiatives have increased the focus on the sector. One example of such microinsurance is a UK aid program called Sakchyam. The Sakchyam Access to Finance for the Poor Programme (Sakchyam) was part of an agreement between the Governments of Nepal and the UK. The programme was implemented by the Louis Berger Group and worked with the public and private sectors to leverage access and facilitate financial sector development in Nepal through a Challenge Fund mechanism.

Being a complex business, agricultural insurance requires highly technical expertise, both in the development and operational phases. At present, private insurance markets have proven to be efficient, without public intervention, for dealing with non-systemic risk and large farmers. On the other hand, commercial insurance may not be useful for systemic risks or smaller farmers. Thus, the first and foremost role of governments should be to address market and regulatory imperfections to encourage participation by the private insurance and reinsurance industry (Mahul & Stutley, 2010). Despite livestock insurance being effective in risk management, several factors play a crucial role in insurance adoption that are still overlooked. The total number of dairy animals, farmers' memberships, extension agent contacts and knowledge of subsidy on premiums are inevitable factors affecting livestock insurance adoption (Kandel & Timilsina, 2018). In addition, cattle breed, loan access, income from livestock and the number of cattle reared were major factors affecting livestock insurance adoption in Nepal (Subedi & Kattel, 2021). Thus, identifying and understanding the factors that influence farmers' decisions to adopt livestock insurance as a risk management strategy is inevitable to upscale its adoption (Chizari et al., 2003).

A study conducted in the Surkhet district of midwestern Nepal concluded that while 86.7% of farmers perceived livestock insurance as effective, 64.4% adopted it. Moreover, 62.1% of the insurance adopters had insured their livestock within the current year, which shows that the insurance has increased in popularity. Most of the surveyed farmers had some knowledge of insurance need, but when asked about the reason for not insuring their livestock, some stated that livestock insurance was for large farmers only, whereas others mentioned that they had low levels of satisfaction from insurance companies for not having enough coverage and suitable insurance product choices (Nepali, 2021). Another study by Dangi (2022) stated that

among several agricultural insurance products, livestock insurance coverage was the highest, with about 95% in 2014, and more than 75% in subsequent years based on the sum-insured, clearly suggesting that livestock insurance coverage is more successful among agricultural insurance products. In comparison, crop insurance was adopted for cash crops such as bananas and vegetables. Another study on livestock insurance illustrated that 90% of respondents found the process of insuring their animals and claiming compensation to be easy. This was due to the availability of local technicians and agents assisting them in filling out the forms as well as carrying them to the company office, though 10% of respondents stated that the process was difficult because of their limited access to the representative and the long commute to the company office. In some cases, there was no mutual understanding between an insurance company and the farmer on the valuation of improved animal breeds, which are often costlier than the existing common breeds (Adhikari & Bidari, 2018).

1.1 Rationale and Objectives of the Study

In the 10 years since the introduction of agricultural insurance in Nepal, there have been several private companies working to provide insurance products to farmers. The trend depicted in publications and reports so far has shown that despite the significant premium subsidies offered and disbursed by the Government of Nepal, other enterprises, with the exception of livestock, have less insurance appeal. The livestock subsector, which contributes 24% of total agricultural GDP, covered 89.05% of the total insured value of agricultural insurance in 2022/23, while the crop sector covered only 10.95% (Insurance Board, 2023). There could be several obvious and underlying causes behind this sectoral imbalance in insurance uptake. The government of Nepal has given higher priority to agricultural insurance by providing higher subsidies (75–80%) on insurance premiums. There are limited studies found in the literature to cover the progress and constraints of agricultural insurance programs in Nepal.

This study aims to assess the factors behind the different speeds of adoption of agricultural insurance among various agriculture subsectors and enterprises. Furthermore, this study aims to examine the features and performance of available agricultural insurance products, the significance of the program in the context of risk coverage, the state of claim settlement, technical challenges in claim settlement, and other implementation issues faced by primary producers. At the policy level, this review study aims to analyse the current state of policies and guidelines that are favouring or obstructing adoption. It will identify and analyse underlying problems in this sector of the economy, which will provide recommendations to government and other stakeholders that enable them to address these issues through policy or program interventions.

1.2 Types of Agricultural Insurance Products in Nepal

Globally, there are several types of agricultural insurance products offered so that producers have choices to suit their customized needs. However, such choices are limited in Nepal's agricultural insurance product market. Two most common insurance products are traditional multi-peril insurance and weather index-based insurance. The multi-peril insurance in the case of crops is based on production costs coverage and production value coverage, while in the case of livestock it is based on loss values.

Multi-peril insurance (MPI): This insurance product covers many risk factors that affect crop loss. In Nepal, the word "peril" means diseases and pests, drought, flood, hailstones, snow, frost, windstorms, landslides, earthquakes, poisoning by pesticides, loss due to wildlife and other disasters. The premium for crops, livestock and birds is 5%, for fish it is 2%, for fishponds it is 1% and for broiler it is 1.25% for each batch. Likewise, 7% of the premium is approved for value-based MPI in ginger and forage. In multi-peril insurance, there are two categories for crop insurance: the first category insurance covers the production costs, while the second category covers the value of the production. In both cases, the insurance covers 90% of the insured amount (DoA, 2018).

Weather Index-based insurance: As a risk management strategy, weather index-based insurance is applied in risk-prone areas in the region to reduce the adverse impacts of climate hazards. This product is new in Nepal and is typically popular in apple farming based on the rainfall index. It pays out based on the triggered value, which is calculated using historical data and a predetermined index. Rainfall index-based insurance is one of several types of index insurance that covers low rainfall risks that may affect the apple yield in a determined area. For example, the index may use historical data to project the expected amount of rainfall in a specific area and calculate the value of the insured yield. If the level of rainfall is lower than predicted by the index, payouts to farmers, based on less than the trigger amount, will be made even if farmers do not face yield loss. Therefore, such a straightforward product design makes it easy to understand, enhances transparency, helps to avoid disputes and may reduce costs for insurers.

2 Methodology

This study primarily applied quantitative analysis techniques using official data received from the Insurance Authority of Nepal. The data mostly received are an annual sum of the number of policies issued, the total value of insured and the indemnity paid to farmers in the last 10 years for both crop and livestock sector separately. In addition, we also used survey data from fields in 2 districts, namely Kapilbastu and Dang, taking 142 sample farmers. The farmers were selected purposefully, covering different economic strata, ethnicities, and genders. The study took the information

on farmers' perceptions of risk, coverage, field-level problems faced by farmers and improvement suggestions. Moreover, the study also considered past research findings and covered discussions that they raised.

3 Results and Discussion

3.1 Farmers Perceptions About Risk and Their Participation in Insurance

The field survey conducted in Kapilvastu and Dang districts revealed a high risk of high rainfall and diseases in the crops and livestock grown by farmers (4 out of 5 scale). Most smallholder farmers reported that they are not informed about crop insurance (only 25% informed), while the majority of well-off farmers were found to be informed about the crop and livestock insurance programs (about 75% informed). A smaller number of smallholder farmers were found to be involved in this program; likewise, farmers were not found to be involved in crop insurance but were involved in livestock insurance. Farmers reported that they had insured mostly buffalo, cows and pigs due to the higher investment and greater fear of loss in the animals compared to crops. Another reason for the lack of crop insurance is a management problem. Insurance companies were found hesitant to offer crop insurance in the survey areas.

3.2 Agricultural Insurance Policy, Programs and Procedures

The insurance program in Nepal is regulated by the Insurance Act 2022, with amendment in 2024. Currently, there are 35 insurance companies, including 14 life insurance, 14 non-life insurance, 2 re-insurance and 5 micro-insurance companies providing insurance service under the regulation of the Nepal Insurance Authority, an arm of Nepal Government's Ministry of Finance (MoF, 2024). The Nepal Insurance Authority is responsible for developing insurance policies for different crops and livestock in collaboration with the Department of Agriculture and the Department of Livestock services under the Ministry of Agriculture and Livestock Development. Agriculture insurance began in 2013 with government-approved premium subsidies for crop and livestock insurance. According to the Crop and Livestock Insurance Directive 2013 guidelines, livestock sectors (cow, buffalo, sheep, goat and pig), poultry sectors (hen, duck, ostrich, pheasant), fish farming sectors (fish, trout and fish pond), and crop production sectors (vegetables, mushroom, paddy, potato, fruit, banana, cardamom, ginger, turmeric, tea, coffee and citrus fruits) are worth insuring. Insurance will cover losses in those sectors caused by natural disasters (e.g., fire, lightning, earthquake, flooding, landslides, drought, storm, hailstorm, frost and snow), unexpected or accidental external factors, diseases, and pests. Initially the

government provided a 50% subsidy on insurance premium, which has increased to 80% since September 2022. In addition to the subsidy provided by the federal government, many provincial and local governments provide additional subsidies to the premium for crop and livestock insurance. For instance, in Gandaki province, farmers receive an 80% subsidy from the central government and a 20% subsidy from the provincial government.

The “Crop and Livestock Insurance Directives 2013” was upgraded in 2022 as the “Agriculture, Livestock and Medicinal Herb Insurance Directive 2023”. Premium rates for most products range from 5 to 7% based on cost of production and value. However, the premium rates are 8% for apples, 1% for fishponds, 2% for ostriches, and 1.25% for broilers. Agents now receive 10% of the premium rate as a commission charge for each product, and there is a 15% discount on the overall premium value for insuring on an organisational basis. There is also a provision of accident insurance that is compulsory for farmers, as per which the insured farmer has to pay 500 Rupees per year, and in case of an accident they would receive payment up to 2 lakh Rupees. For loss estimation, external agents should be hired as evaluators for more than 2 lakh of insured crops. The government has set a maximum subsidy limit of ten million dollars for an insurer. In the event of total loss, farmers will receive up to 90% of the sum insured or 10% less than the total value, whichever is less, and in the case of partial damage, compensation is based on the damage loss evaluation report.

3.3 Progress on Issuing Insurance Policies, Sum of Insured Value and Coverage by the Insurance Program

The number of crop insurance policies issued in Nepal has been steadily increasing over the past ten years. In the first year, there were only 23 crop insurance policies issued, but this number grew to 8,325 in the fiscal year 2022/23. This represents a growth of almost 362 times over the 10-year period. In the livestock sector, the number of insurance policies issued was 983 in the first year, which increased to 160,457. This growth represents an almost 163-fold increase over the same period (Unpublished data Nepal Insurance Authority, 2024).

Figure 1 shows that the value of insurance coverage is also increasing in both sectors. The value of crop insurance coverage was 7 million NRs in the first year, and rose to almost 4852.4 million NRs, a growth of about 691 times, which seems encouraging. The same pattern of growth seemed to occur in the livestock sector as well: Fig. 2 shows that the livestock insured value was 295.6 million NRs in the first year and reached 39,460.77 million NRs.

In Fig. 3, we can observe that the insured value of fruits shows good progress compared to cereals and vegetables. If we exclude the abnormal increase in cereals in 2018/19, the progress of vegetables and cereals is similar. The decline in 2022/23 was due to a delay in reimbursement of premium subsidies from the government to the private insurance companies. Due to a dispute with the government, insurance

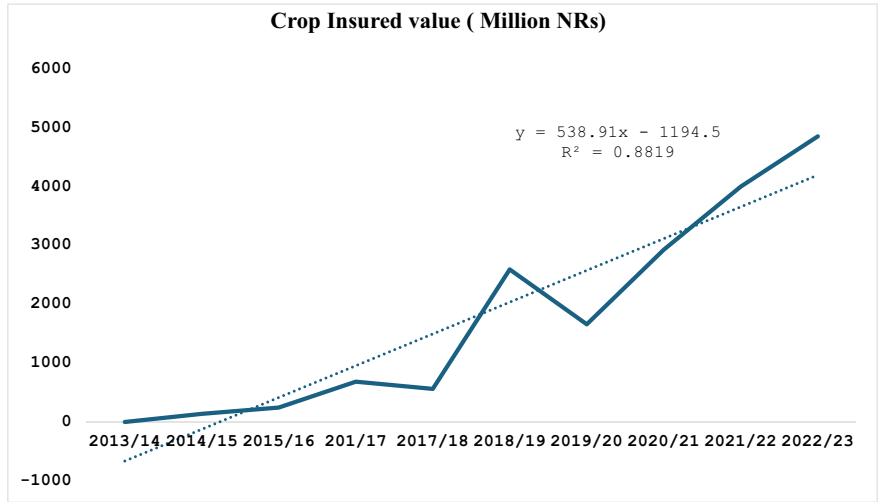


Fig. 1 Value of crop insurance policies issued in the past 10 years. *Source* Nepal Insurance Authority, 2024

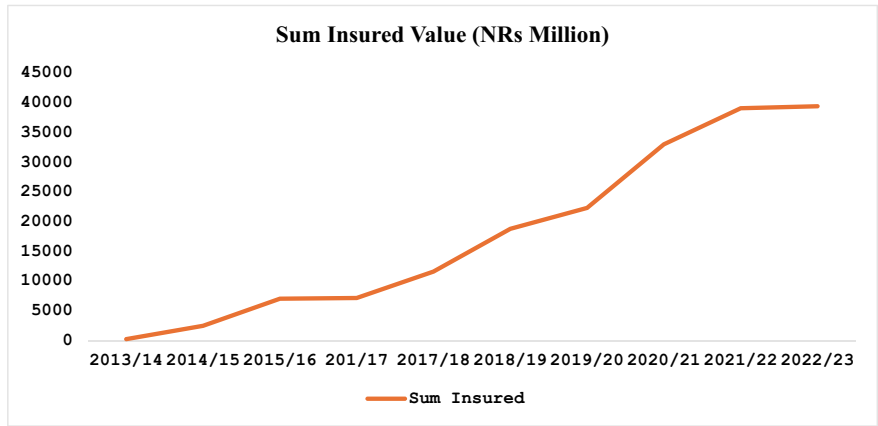


Fig. 2 Value of Livestock insured in the past 10 years. *Source* Nepal Insurance Authority, 2024

companies stopped issuing insurance policies and declined the total value of the insured amount. The good progress in fruit crops could be due to the high-risk perception of farmers towards bananas and apples, which are commercially grown these days. In the case of banana farming, the problem of lodging due to summer winds is observed frequently. Likewise, good progress is seen in the weather index insurance scheme in apple farming.

One of the positive developments, we observed in this study is that the total sum of agriculture insurance (both the agriculture and livestock sectors) makes up

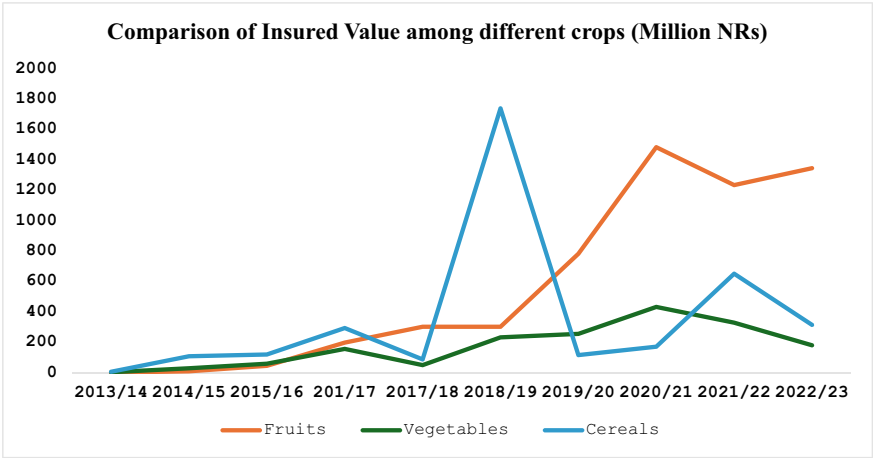


Fig. 3 A comparison of insured value of different crops (Million NRs). *Source* Nepal Insurance Authority, 2024

NRs 44,313.16 million out of 1,510,348.7 million AGDP) is almost 3% of the total agricultural Gross Domestic Product (AGDP), which is an acceptable achievement for the agriculture insurance program in Nepal as shown in Fig. 4. Based on farmers’ involvement, the insurance coverage figure is about 4.4% (NSO, 2023). In India, the World Bank (2007) reported that 12.7% of farmers participated in the Kharif crop and 4% in the Rabi crop in 2005. Because India has a long history of agriculture insurance programs compared to Nepal, for a less experienced country such as Nepal, covering almost 3% of the value of agricultural GDP and 4.4% by farmers’ involvement in the agricultural insurance can be considered acceptable progress.

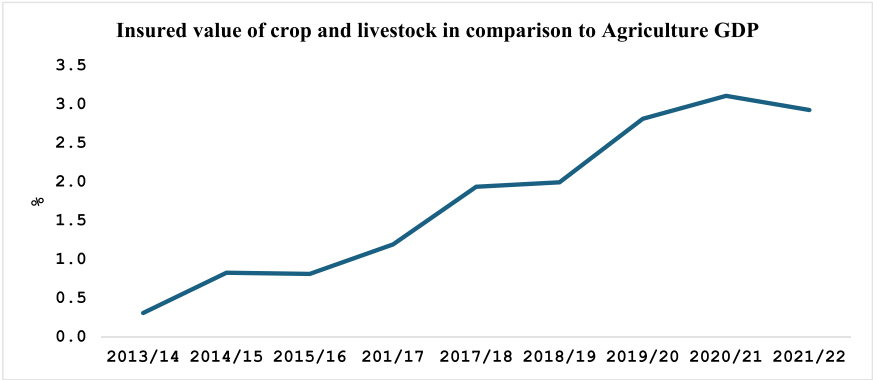


Fig. 4 Percentage of insured value of crop and livestock in comparison to agriculture GDP in the past 9 years. *Sources* Ministry of Finance, 2024 and Nepal Insurance Authority, 2024

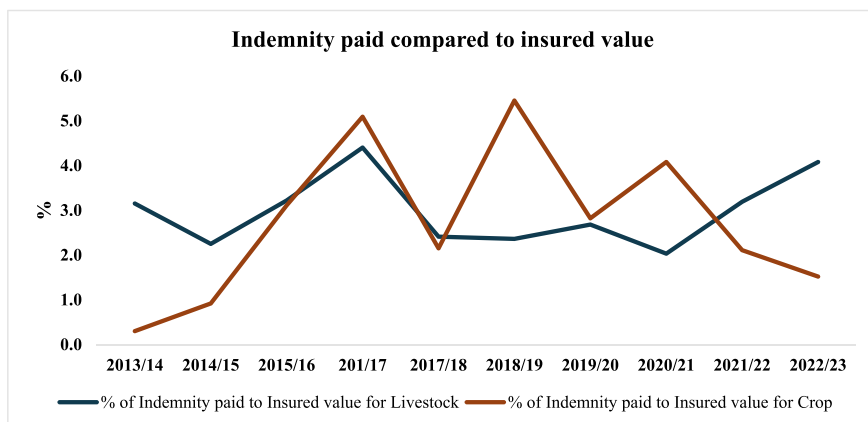


Fig. 5 Percentage of indemnity paid compared to the insured value in the past 10 years. *Source* Nepal Insurance Authority, 2024

3.4 Status of Claims Paid to Farmers

The average claim payment or indemnity payment in the last 10 years is about 3% in the livestock sector and 2.8% in the crop sector, as shown in Fig. 5. This statistic broadly shows that there could be an almost 3% risk among insured in both sectors. According to the sample of farmers from the survey, farmers face many hurdles in the claim application process, leading to delays or sometimes no payment for claims. Therefore, the claim or indemnity payment would increase if the hurdles in the application process and non-payment issues are resolved.

3.5 Status and Challenges for Adoption of Agricultural Insurance

Agricultural insurance has yet to be introduced on a large scale in a systematic and organized manner, as insurance coverage is only 4.4% of total farmers according to the National Sample Census of Agriculture Report, 2023 (NSO, 2023). The adoption of agricultural insurance in Nepal faces various institutional, financial, operational, and technical challenges. Among them, technical challenges include low awareness and knowledge among farmers, lack of a comprehensive policy framework, and a low level of interest in private insurance companies for offering agriculture insurance products. Technical challenges primarily arise from issues in data collection and management, risk assessment, technology adoption, and infrastructure. Reliable data on weather patterns, crop yields and historical losses are often lacking, and variability in data collection methods leads to inconsistencies. The availability of quality time series data on actual agricultural production and productivity is also a challenge

for estimating the insurance value of products. Developing accurate risk models is complex due to diverse climatic conditions and the increased frequency of extreme weather events caused by climate change. Moreover, the low penetration of advanced technologies such as satellite imaging and GIS, coupled with farmers' limited digital literacy, hampers effective monitoring and risk assessment. Infrastructure deficiencies, such as poor roads and limited internet connectivity, further hinder the efficient delivery of insurance services, especially in remote areas. Efficient damage assessment for timely claims processing is also challenging without advanced tools, and preventing fraudulent claims requires sophisticated algorithms.

Insurance companies in Nepal are found to be reluctant to invest in agricultural insurance due to its high risk and their limited financial resources. Additionally, they have less exposure to international practices and lack the essential knowledge and expertise in design, rating, and implementing agricultural insurance. Similarly, most farmers possess very limited knowledge about agricultural insurance, resulting in low demand. Farmers do not adopt insurance for various reasons, including lack of awareness, lack of premium-paying capacity, complex documentation, lack of faith in the scheme/agency, lack of access to insurance companies, and the small number of commercial farmers. Likewise, difficulty in documentation, valuation, and claim procedures are major challenges faced by farmers in insuring their crops and livestock.

4 Conclusions

This study showed that there are technical, managerial and legal problems faced by stakeholders during the implementation of the insurance programs. Field-level surveys showed that most farmers, especially smallholders are unaware of insurance programs. In some cases, insurance companies show unwillingness to offer insurance policies, and in many cases, farmers or producers encounter hurdles during the application of loss claim processes. Difficulty in documentation, valuation, and claim procedures are major challenges frequently faced by farmers.

Although the overall coverage of agricultural insurance programs is quite low—almost 4.4% on farmers' participation basis and by 3% on insured value to agricultural GDP basis—progress in the livestock sector in the issuance of insurance policies, insured value and claim amount is far better compared to the crop sector. The total insured value of the livestock sector was almost 9 times higher than that of the crop sector in 2022/23. Some of the reasons of preference for livestock insurance to crops insurance by farmers, found by the study, is livestock are considered higher value investment and can be sold more easily in comparison to crops—the higher the investment, the greater the fear of loss. The average indemnity payment compared to the insured value in the past 10-year period is almost 3% for both the crop and livestock sectors.

4.1 Policy Implications

The agricultural insurance program has shown slow progress despite substantial investment in premium subsidies by government of Nepal. Therefore, the agricultural insurance programs should be critically reviewed, and future government subsidy programs should focus on priority crop and livestock products. Similarly, a technical review of the risk factors, loss assessment, and claim submission processes is essential, and insurance programs should be designed accordingly. Moreover, management problems at the field level observed by the study team, such as the reluctance on the part of insurance officers to issue insurance policies to agricultural products, the deliberate creation of hurdles in the claim application process and delay in claim settlement should be addressed in the agricultural insurance policy directives initiated by the relevant government agencies such as the Department of Agriculture and the Ministry of Agriculture and Livestock Development.

4.2 Way Forward

1. By comparing the premiums paid by farmers and the indemnity paid to farmers, noticeable gaps are observed (i.e. the premium is 5% or more and indemnity is about 3.05% on average over a 10-year period), which can be reduced through proper analysis of the risks.
2. The insurance coverage level for all insurance products is 90%, which is the main reason behind the higher premium rate. The current study suggest that the coverage level could be reduced from 90% to a reasonable level based on contemporary studies.
3. The issue of fraudulent insurance policies and disbursement of premium subsidy amounts to such policies have remained a major concern among insurers during this study. This issue can be mutually managed by establishing a proper monitoring mechanism and punishing those found to be committing fraud.
4. As climate change impacts are more obviously affecting agriculture in Nepal, there should be a greater focus on implementing climate-resilient programs by the government and I/NGOs.
5. The government's investment in premium subsidies is high because it currently provides coverage for all geographical areas including many crop and livestock species. Therefore, subsidies on premiums should be limited to priority crops and livestock that are considered risky and grown in specified areas.

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Chapter 6

A Roadmap for Agricultural Transformation in Nepal: Addressing Policy for Youth Empowerment and Institutional Quality Improvement



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Abstract Agriculture remains a foundation of Nepal's economy, contributing significantly to GDP and employment. Despite its significance, the sector faces persistent challenges, including outdated governance, weak institutional frameworks, and a lack of skilled human capital. This study highlights the need for institutional reforms and youth empowerment as key drivers of agricultural transformation in Nepal. Proposed reforms focus on strengthening regulatory frameworks, enhancing transparency, and fostering collaboration among government bodies, research institutions, and private stakeholders. Empowering youth through targeted education, technical training, and mentorship is critical for fostering innovation and introducing modern practices to the sector. The study outlines considerations for preparation of a strategic roadmap emphasizing institutional governance, policy modernization, market accessibility, and digitalization to create a resilient, sustainable, and profitable agricultural ecosystem in Nepal. Nepal can unlock its agricultural potential by integrating these priorities to foster both economic growth and environmental sustainability.

Keywords Agricultural ecosystems · Market accessibility · Mechanization · Policy · Youth

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1 Introduction

Agriculture is a fundamental sector for economies, food security, income, and employment for a significant portion of the population globally (Rahut et al., 2022). It is particularly crucial for rural livelihoods, poverty reduction, and sustainable development in many countries (Kumar et al., 2005). In Nepal, agriculture is the primary source of livelihood and contributes to almost one-third of the country's GDP (FAO, 2023). Agriculture Census-2021 indicates that about 62% of the population is engaged in the agriculture sector with 32% of farmers as female, and only 45% of which sustaining from agriculture, indicating the predominance of subsistence farming. The country's topography and ecology are highly varied and divided into three broad physiological areas: the mountainous region, the hilly region, and the lowland tropical terai region (Krupnik et al., 2021). The diverse climatic zones allow for cultivating a more comprehensive array of crops, including rice, maize, sugarcane, oilseeds, and pulses, where the staple crops are cultivated predominantly in the Terai region. In contrast, maize, millet, and barley are predominant in the hilly areas (Krupnik et al., 2021).

Nepal's agricultural sector must prioritize three key pillars: human capital investment, innovation, and knowledge and technology spillovers. Agricultural development depends on advancing human capital and leveraging innovation to transform the sector. A critical pathway for innovation lies in knowledge and technology transfer, which serves as a catalyst for the growth of high-value agriculture (Dhoj, 2018). High-value agriculture, often facilitated through contract farming, has gained popularity for its ability to link smallholder farmers with large-scale markets. In such arrangements, contractors, such as supermarkets or agroprocessing firms provide farmers with essential inputs like seeds and pesticides, guidance on modern cultivation techniques, and assured purchasing terms at pre-agreed prices. This system not only disseminates advanced knowledge but also fosters international technology transfer. In the past, when agricultural practices were simpler, it was easier for farmers to learn by observing others, copy techniques, and adopt new methods (technology transfer and imitation). However, as farming has become more complex that requiring specialized knowledge, advanced techniques, and high-value products like organic or export-quality produce, it has become harder for farmers to independently learn or adopt these practices without additional support or training. Conversely, lack of skill development and low adoption of modern agricultural practices are crucial bottlenecks to engaging youths in agriculture. Traditional education systems push youths not to adopt practical and innovative farming techniques or engage in agribusiness and agri-tech industries in Nepal. Moreover, despite the availability of resources such as arable land and renewable water, high outward migration creates a shortage of human resources in the agricultural sector. Nepal's agricultural sector currently suffers from institutional inefficiencies and limited stakeholder coordination. Key issues include a lack of coherence in agricultural strategies, inadequate implementation of existing policies, and bureaucratic obstacles. For instance, resource allocation and service delivery disparities under the decentralized federal governance system

hinder progress. Nepal must invest in agricultural technology, infrastructure, and human capital to spur economic growth and move towards a more market-oriented agricultural sector to unlock its agricultural potential (Rahut et al., 2014).

To address these gaps, this chapter first examines the challenges of Nepal's agricultural sector and tries to provide pathways and a roadmap for agricultural transformation in Nepal. Nepal can tap into its potential to drive innovation, adopt modern technologies, and implement sustainable farming practices by providing young people with the necessary skills, knowledge, and resources. Focusing on institutional and policy reforms and youth empowerment is essential for ensuring the long-term success and growth of the agriculture sector in Nepal.

2 Human Resource and Institutional Challenges

Nepal faces a dual challenge of labor shortages in agriculture due to high youth outmigration and weak institutional frameworks that hinder effective resource utilization and economic transformation. While abundant natural resources like arable land and water offer potential for agricultural growth, systemic issues such as low productivity, inefficient governance, and limited institutional support exacerbate dependence on remittances. Addressing these challenges requires fostering institutional reforms, building human capacity, and adopting modern agricultural practices.

2.1 *Human Resource Challenges*

A significant human resource deficit plagues the agricultural sector in Nepal, which is marked by migration trends, as young and non-disabled individuals leave rural areas searching for better opportunities. Nepal faces a significant challenge with high levels of outward migration, where unskilled youths from rural areas predominantly migrate to Gulf countries and India for employment, while educated and skilled youths tend to move to destinations like the United States, Canada, Australia, Japan, and Europe. This trend has led to a rapidly aging farming population and a labor shortage during peak agricultural seasons, resulting in delays in planting and harvesting, reduced productivity, and land abandonment (Thapa et al., 2019). For example, in hilly regions like Kavre, Lamjung, and Kaski, significant portions of arable land remain fallow due to the lack of manpower (Paudel et al., 2023). The migration of youth from rural areas reflects broader systemic issues such as low farm profitability, limited access to credit, and societal perceptions of agriculture as an unattractive career (Maharjan & Knerr, 2019).

As per the World Bank, Nepal ranks as the fourth-largest recipient of remittances globally as a percentage of GDP for 2017–2022 (Table 1). Usually, high-remittance-receiving economies rely heavily on outward migration due to limited domestic economic opportunities. However, these economies vary widely in their

natural resource endowments (Table 1). While few of them are rich in resources, others face significant constraints in resource availability. Among the top 15 high-remittance-receiving countries, Nepal stands out, ranking first in population size, arable land area, and total renewable internal freshwater resources, and second in forest coverage.

These data highlight a paradox that Nepal struggles to create sufficient domestic employment opportunities despite being resource-rich. Its abundant natural resources, particularly land and labor, traditionally considered foundations of economic growth, have not translated into robust job creation within the country. Moreover, despite the high natural resources (arable land, water, and forest) required for agriculture, Nepal's agriculture suffers from low inputs and a low productivity nexus. This persistent shortfall has driven a large segment of the youth population to seek work abroad, reflecting the challenges of leveraging domestic resources to foster sustainable economic development through agricultural transformations.

Figure 1 shows the world's trend of natural progression of economic transformation often follows a path from agriculture to manufacturing and, eventually, to

Table 1 Natural resources of high-remittance receiving economies

Country name	Remittances, % of GDP: average (2017–2022)	Total population: 2022	Arable land (hectares): 2021	Forest area (sq. km): 2021	Renewable internal freshwater resources, total (billion cubic meters): 2021
Tonga	37.86	106,858	20,000	90	N/A
Tajikistan	32.54	9,952,787	838,000	4,248	63.46
Kyrgyz Republic	30.75	6,974,900	1,287,400	13,336	48.93
Nepal	23.69	30,547,580	2,113,700	59,620	198.20
Honduras	22.79	10,432,860	1,018,000	63,383	90.66
El Salvador	22.73	6,336,392	721,000	5,794	15.63
Samoa	22.61	222,382	11,290	1,612	N/A
Lesotho	22.19	2,305,825	429,000	345	5.23
Bermuda	21.65	63,595	300	10	N/A
Lebanon	19.87	5,489,739	139,300	1,439	4.80
Jamaica	19.63	2,827,377	120,000	6,008	10.82
West Bank and Gaza	18.63	5,043,612	41,900	101	0.81
Gambia, the	18.63	2,705,992	440,000	2,369	3.00
Haiti	18.50	11,584,996	1,005,000	3,442	13.01
Comoros	17.37	836,774	65,000	325	1.20

Note N/A refers to not available

Data Sources World Development Indicators (WDIs), November 2024

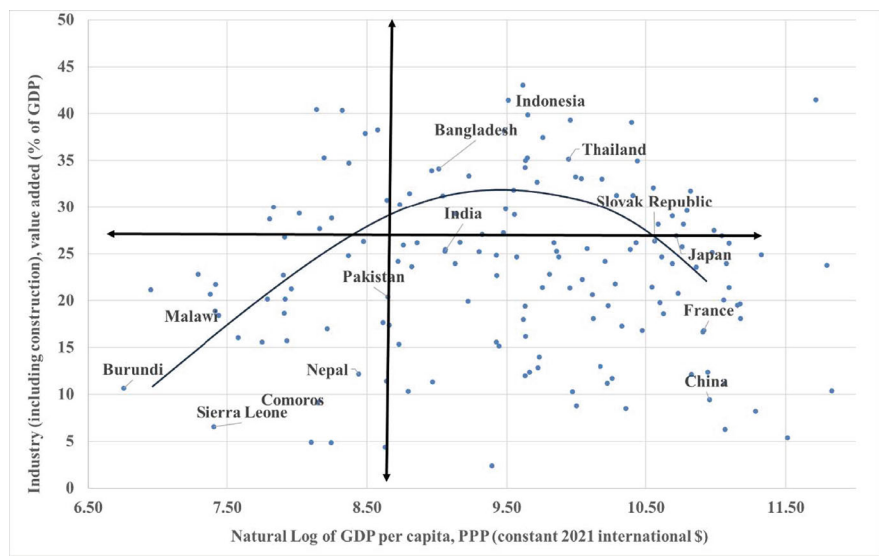


Fig. 1 Economic transformation pathways moving from agriculture to services. *Source* Authors creation using data from World Development Indicators (WDIs)

higher-productivity services. However, this trajectory is not the case for Nepal, where workers are leaving the agricultural sector and moving abroad for employment. This creates a significant emptiness in the labor market, as Nepal struggles to transition toward a robust manufacturing sector. Additionally, traditional service industries, such as tourism, tend to have lower productivity and contribute less to sustained economic growth. Given these challenges, Nepal’s most viable pathway lies in transitioning toward high-value agriculture and leveraging its labor force within the agribusiness sector. Policymakers must focus on fostering innovation, promoting technology transfer, and transforming agriculture into a business-oriented model. Therefore, by building human capacity and enhancing productivity through modern agricultural practices, Nepal can retain its labor force, strengthen its agricultural base, and establish a foundation for long-term economic development. This approach not only addresses labor outmigration but also ensures that the agricultural sector contributes meaningfully to national growth.

2.2 Institutional Quality and Governance Challenges

Weak institutional frameworks and governance inefficiencies afflict Nepal’s agricultural development. Rapid outward migration is deeply connected to the quality of

institution.¹ Robust institutional systems are pivotal in channeling domestic resources into productive economic activities.² Good quality institutions promote transparency, good governance, and efficient resource allocation, ensuring effective and optimum utilization of domestic resources for sustainable development. Conversely, weak institutional frameworks often result in inefficiencies, corruption, and the suboptimal use of available resources. Strengthening institutional quality through enhanced governance, robust legal frameworks, and anti-corruption initiatives could magnify the developmental impact, fostering long-term economic growth and resilience. However, Nepal has experienced significant institutional shifts over the past few decades. The establishment of multiparty democracy in the 1990s marked the beginning of economic and financial liberalization. However, a decade-long civil war, coupled with the royal massacre in 2001, destabilized the country, ultimately transitioning its political system into a federal democratic republic in 2008, ending over two centuries of monarchy. The institutional quality of Nepal deteriorated sharply during the civil war (1996–2006), coinciding with a surge in outmigration (Fig. 2). These disruptions caused structural shifts in outward migration around 2002 and a noticeable decline in institutional quality till 2005. Political instability persisted until the promulgation of a new constitution in 2015. Due to these factors, Nepal's institutional quality, other than political stability, voice, and accountability, has been paralyzed even after the peace accord in 2006. The economy has shifted from a "subsistence-based agricultural economy" to a "remittance-based consumption economy" in recent decades.

Figure 2 shows that Nepal's overall institutional quality has gradually improved since 2006, driven mainly by political stability, voice, and accountability, though progress remains uneven. Institutional quality measured using an index derived from six worldwide governance indicators ranges from -2.5 to $+2.5$, with higher scores reflecting stronger institutions. Key determinants of institutional quality, such as the rule of law, control of corruption, regulatory quality, and government effectiveness, have not been significantly improved even after the improvement of political stability since 2006. Consequently, remittance inflows are surging since there is limited optimism about the return of migrant workers to actively participate in the country's economic activities as institutional challenges continue to deter reintegration. Therefore, until and unless we do not put our efforts into strengthening the overall institutional performance of the nation, there is less chance of human resource development and transformation of the agricultural sector so that Nepal could lower its dependency on external sources such as remittances.

¹ The overall institutional quality index is derived by adding six key indicators from the Worldwide Governance Indicators dataset: (1) Control of Corruption, (2) Government Effectiveness, (3) Political Stability and Absence of Violence/Terrorism, (4) Regulatory Quality, (5) Rule of Law, and (6) Voice and Accountability.

² There are soft and informal institutions, that represents norms, values, customs, and cultural practices which shape individual and social behavior in a society. Also, there are formal institutions, which are determined by written laws and regulations. However, soft institutions depend on unwritten rules, trust, and social order to influence governance and economic and social interactions.

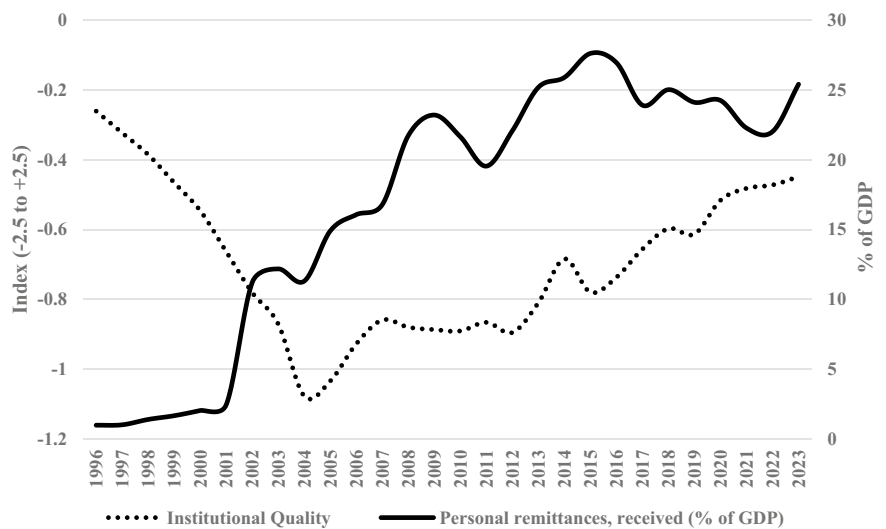


Fig. 2 Remittances and Institutional Quality Index. *Data Sources* World Development Indicators (WDIs) and Worldwide Governance Indicators (WGIs) 2024

The absence of a stable government framework has resulted in inefficient resource allocation, lack of accountability, and heightened challenges in agricultural sector development. When soft and formal institutions, such as governance systems and regulatory mechanisms, fail to function effectively, hard institutions like the Agricultural Universities, Council for Technical Education and Vocational Training (CTEVT), and the Nepal Agricultural Research Council (NARC) which are critical for developing skilled human resources and advancing agricultural research suffer from underfunding and lack strategic direction. Similarly, the Department of Agriculture (DOA) faces significant limitations in providing farmers with effective extension services and technical support. Nepal’s agricultural sector urgently requires better coordination among government agencies, increased funding, and enhanced extension services to promote innovation and support marginalized farmers. Unclear and poorly enforced regulatory frameworks further exacerbate the problem, creating uncertainty for farmers and investors. This often leads to irrational decisions, such as prioritizing cash crops over staple cereals despite rising demand (Gyawali & Khanal, 2021). These challenges require a stable governance, improved institutional frameworks, and clear, enforceable regulations that encourage rational decision-making and the adoption of sustainable agricultural technologies. To achieve meaningful transformation in Nepal’s agricultural sector, it is essential to focus on three key areas: institutional reform, human resource development, and a robust policy and advocacy environment.

3 Addressing Challenges for Transforming the Agriculture Sector

Transforming Nepal's agricultural sector requires an integrated approach encompassing institutional reforms, human resource development, and policy advocacy (Muchová & Raškovič, 2020). Strengthening institutions through transparent regulatory frameworks, modernized agricultural education, and enhanced research capabilities is essential for fostering innovation and improving efficiency. Concurrently, it is necessary for targeted human resource development and leveraging digital tools to equip the workforce for a technology-driven agricultural landscape. Also, policy reforms are needed for addressing land fragmentation, market access, and financial constraints in improving productivity, reducing inefficiencies, and empowering farmers through cooperative models (Holden et al., 2009).

3.1 Institutional Reforms

Agricultural R&D in Nepal is primarily managed by public institutions under the Ministry of Agriculture, with insufficient human resources, infrastructure, and funding to meet diverse client needs. Institutional reforms are central to transforming Nepal's agricultural sector for addressing inefficiencies. Effective institutions foster social order through democracy, rule of law, political stability, regulatory quality, and property rights, which are essential for creating a predictable and supportive environment for agricultural development (Chong & Calderón, 2000). Clear and transparent regulatory frameworks eliminate ambiguity, enabling stakeholders to plan investments, implement operations, and develop strategies effectively. Such frameworks also ensure accountability, efficient land administration, accessible irrigation systems, sanitary standards, and robust infrastructure development. Enhancing transparency in regulatory processes builds trust among stakeholders, empowering them to contribute to policy improvements through feedback and participation (Kaufmann & Weber, 2010).

Nepal must prioritize the modernization of agriculture via education and research to strengthen its agricultural sector. Agricultural universities should align their curricula with local challenges and foster partnerships with international institutions to introduce advanced technologies. Similarly, the CTEVT should tailor its programs to market demands and expand access in rural areas to develop a skilled agricultural workforce. Key institutions like the NARC and the DOA require targeted reforms, including increased funding, advanced research infrastructure, and enhanced extension services. The DOA, for instance, must employ trained personnel, use digital tools for outreach, and improve monitoring systems to ensure the timely availability of quality agricultural inputs and reduce market distortions.

Transparent regulatory systems are also critical for ensuring the availability of inputs like fertilizers and seeds while mitigating hoarding and market inefficiencies. Strengthening infrastructure, such as storage and transportation facilities, and promoting cooperative marketing models can improve market access for farmers and ensure fair prices. Institutional reforms can create a positive feedback loop, where improved governance supports agricultural transformation, and agricultural growth reinforces institutional quality through increased economic activity and tax revenues. Drawing lessons from East Asia, Nepal can adopt targeted policies, including clustered agro-industrial development, contract farming, and public–private partnerships, to enhance farm-level efficiency and drive sustainable agricultural development. Additionally, with growing population pressures and diminishing arable land, reforms should prioritize land-saving technologies and functional land rental markets to optimize resource allocation and boost productivity.

3.2 Human Resource Development

Human resource development (HRD) is pivotal for transforming Nepal's agriculture sector by building a skilled workforce capable of adopting and implementing innovative technologies and practices (Mottaleb et al., 2019; Rivera, 1995). Despite its importance, significant gaps persist in Nepal's agricultural HRD, as highlighted by the Strategic Vision for Agricultural Research 2011–2030 of the NARC. The NARC's report focuses on strengthening research infrastructure, capacity building, demand-driven research, PPP, and farmer involvement. It stresses leveraging innovations such as digital tools, mobile applications, and efficient communication systems to improve agricultural extension services. Moreover, a recently released High-Level Education Commission Report 2019 by the Ministry of Education, Science, and Technology of Nepal recommended comprehensive recommendations to the government to include agriculture curricula at secondary level education. Additionally, it proposes a unified integrated service commission for recruiting university faculty and staff and restructuring the University Grants Commission into a Higher Education Commission to manage research fund. Also there is a need for quality accreditation, institutional ranking, and performance evaluations every five years while advocating for transforming Tribhuvan University Kirtipur Campus into a research hub. Other suggestions are the competitive selection process of professors, regular curriculum updates, periodic school performance evaluations, and free education through open secondary schools for out-of-school learners. These recommendations are vital for creating human capital that is essential to transform and modernize the agriculture sector.

Integrating STEM (Science, Technology, Engineering, and Mathematics) with agricultural education is another transformative strategy. As noted in the commission report and the NARC report, this integration fosters technological literacy, critical thinking, and problem-solving skills essential for agricultural innovation (Sirajudin et al., 2021). Therefore, by engaging students in STEM-driven agricultural learning

environments, productivity can improve and perceptions of agriculture as a viable career choice can be enhanced. Research shows that linking STEM with agriculture increases student engagement and fosters positive attitudes toward the field (Conroy & Walker, 2000). However, the NARC Vision Report identifies significant weaknesses in the extension component of agricultural education. Poor connectivity between research and extension services hampers the development and dissemination of agricultural technologies, slowing sectoral progress. Challenges such as inadequate service coverage, insufficient infrastructure, weak evaluation systems, and poor data management compound the issue (Masanja et al., 2023). To address these challenges, the commission report recommends modernizing extension services by improving infrastructure, enhancing monitoring mechanisms, and fostering better stakeholder coordination. A recent study indicated that the farm sector of Nepal is suffering from demand-driven technologies, extension services and essential inputs like credits and markets. While private sector engagement is encouraged, weak coordination hinders effective PPP. Strengthening institutional capacities and fostering stakeholder collaboration are vital for sustainable agricultural advancements. Policy reforms and resource-sharing mechanisms are essential to improve research and extension linkages under Nepal's federal system.

Modernizing Nepal's agriculture necessitates prioritizing HRD and innovation strategies tailored to the nation's agro-ecological conditions. Key approaches include precision farming, hi-tech floriculture, integrated nutrient management, post-harvest management, mechanization and commercialization, as highlighted in the NARC's report. These initiatives aim to equip the workforce with the skills needed for a technologically advanced agricultural landscape (Manikandan & Abdullah, 2016). Promoting agri-entrepreneurship is also vital, as it combines innovation with business models to address food security, environmental sustainability and rural poverty. Integrating entrepreneurship education into agricultural curricula at all levels, as recommended by the commission report, will empower students to navigate evolving agricultural markets and capitalize on emerging opportunities effectively. Digital agriculture plays a pivotal role in this transformation. The NARC Vision Report emphasizes the importance of ICT and digital tools for streamlining research, enhancing extension services, and improving farmer decision-making. Globally, digital technologies have demonstrated their potential to boost productivity, expand market access, and enable real-time data management. However, rural Nepal faces significant challenges, including limited digital literacy and inadequate ICT infrastructure. Young individuals often bring innovative perspectives, digital literacy, and a readiness to adopt new practices. Coordinated efforts are essential to bridge these gaps, ensuring technological access and providing comprehensive ICT-based training to foster widespread adoption of digital agriculture and youth engagement.

3.3 *Policy Reform and Advocacy*

Transforming Nepal's agriculture sector requires policy reform and advocacy, such as a legal framework for land reform. The weak land reform policies are leading to land fragmentation, which is especially prevalent in hilly regions and exacerbated by haphazard urban planning (Niroula & Thapa, 2007). Rapid urban expansion without proper planning divides agricultural land into smaller and less productive plots while failing to regulate land use effectively. Disputed land ownership also further degrades land use efficiency (Stein & Suykens, 2014). To address such land fragmentation, proposed reforms should consolidate landholdings through land pooling mechanisms and cooperative farming models. These farming methods and mechanisms help to enhance agricultural productivity. It is necessary to resolve land ownership disputes and land fragmentation issues through combined legal, technical, and economic processes by forming a clear legislative framework (Latruffe & Piet, 2014).

The agricultural sector cannot progress without proper access to markets and finance. Effective policies must be established to address these challenges, requiring serious government attention. Inadequate governance and poor infrastructure hinder market linkages, while insufficient financial services undermine farmers' abilities to produce, transport, and store their products. Improving road infrastructure is costly and time-consuming for the government; however, prioritizing policies that facilitate the delivery of farmers' produce from rural areas to markets is essential. Temporary government-led transportation services could provide a solution in remote areas where market transportation services may not be viable. Such policies can help reduce farmers' costs and enhance agricultural and market efficiency. Another policy advocacy is investing in modern warehouses and cold storage units, which can preserve perishable goods and minimize post-harvest losses. The government should invite private companies to provide these services, and then with public, private, and government ownerships. Improving market information systems through digital platforms can provide farmers real-time data on market prices, demand trends, and best practices. Farmer cooperatives and producer organizations can be crucial in enhancing market access. These cooperatives can amplify farmers' collective bargaining power, allowing them to negotiate better prices and access larger markets. Establishing direct linkages with buyers reduces dependency on intermediaries and ensures fairer market prices for farmers (Mtonga, 2011). Financial access challenges for farmers in Nepal are equally pressing. Agriculture requires significant initial investment, but many rural farmers lack access to banking services. Therefore, promoting microfinance institutions (MFIs) and developing schemes that can strengthen the investment capacity is essential (Dossou et al., 2020).

4 Considerations for Preparation of the Roadmap for Agricultural Transformation Through Youth Empowerment and Institutional Quality

Laborde et al. (2018) defined agricultural transformation as the process over which the agrifood system evolves from subsistence-oriented into a system that is commercialized and off-farm-centered. Each country has followed its distinct path to achieve agricultural transformation, although similarities may be exhibited in some cases. For instance, Korean agricultural transformation is characterized by market liberalization, agriculture commercialization, and crop diversification. A key area that the country focused on was bridging the rural–urban income gap, addressing environmental concerns, and ensuring food safety. The state played a crucial role by heavily investing in agriculture and promoting farm mechanization by providing farm machinery to farmers. Significant investments were made in research to develop high-performing crop varieties, enhancing agricultural productivity and sustainability. National universities offered extensive training to extension workers to further support this transformation, building a robust knowledge base for agricultural research and extension services.

Likewise, several key initiatives and policies have significantly impacted the development that drove Thailand's agricultural transformation. One primary strategy was reducing farmland and labor taxes, easing financial burdens on farmers, and encouraging investment. Establishing an agricultural research system and providing higher education opportunities abroad enhanced farm knowledge and innovation. Compulsory primary education ensured rural populations had access to basic education. The country also invested substantially in rural infrastructure, such as roads and irrigation systems, to improve efficiency. The Bank for Agriculture and Agricultural Cooperatives (BAAC) provided affordable credit to farmers, facilitating financial stability. The government promoted biotechnology through scholarships and university investments, leading to the rapid development of new crop varieties. Looking at the successful stories of Korea and Thailand, Nepal should adopt a comprehensive and innovative approach to drive the transformation.

Therefore, the transformation of Nepal's agricultural sector requires a strategic focus on three pillars: innovation, human capital investment, and learning from abroad. Innovation, driven by the introduction of improved technologies and management practices, forms the backbone of initiatives ranging from high-value agriculture to sustainable farming practices. To effectively adopt and integrate these innovations, investing in the human capital of key stakeholders including farmers, agricultural researchers, extension workers, cooperatives, agroprocessors and distributors is essential. These players serve as the bridge between innovative ideas and their practical implementation in Nepal's agricultural landscape. Learning from successful international models, particularly from East Asian countries, highlights the importance of providing technical and managerial training through both public and private sector initiatives. This approach not only enhances the capacity of farmers and

entrepreneurs but also strengthens the role of supporting institutions like cooperatives and agroprocessors. Nepal can drive sustainable agricultural transformation, bolster rural livelihoods, and contribute to national economic growth by embedding these principles into its development strategy.

To promote innovation, it is important to improve financial inclusion that provides farmers with the resources necessary to invest in infrastructure and sustain farming operations. Tailored financial schemes, such as micro-loans, crop insurance and savings plans, can effectively address the unique challenges faced by smallholder farmers (Paudel et al., 2019). Additionally, developing mobile banking platforms can enhance access to financial services, especially in remote areas (Paudel et al., 2023). Establishing agricultural risk management programs to deliver weather forecasts, pest alerts, and other critical information can help farmers mitigate risks and make informed decisions, thereby strengthening the sector's resilience (Ma et al., 2022). Therefore, by integrating advanced education with accessible financial tools, Nepal can build a robust agricultural foundation that supports innovation in agriculture.

Youth empowerment is vital for human capital investment that can support agricultural transformation with innovation, resilience, and adaptability (Arslan et al., 2020). Youth are more likely to embrace technology and innovative practices, critical for increasing productivity and sustainability. However, socio-economic barriers often discourage youth participation in agriculture. Overcoming these barriers involves providing necessary education and training through specialized agricultural programs in universities and vocational training centers, integrating practical training and internships, and facilitating access to resources such as land, finance, and technology (Chinsinga & Chasukwa, 2018). Policy interventions should ensure secure land tenure and equitable access to land for young farmers, while financial inclusion strategies should provide microloans, grants, and crop insurance schemes (Higgins et al., 2018). Establishing innovation hubs and incubators can foster agricultural startups and agri-businesses led by young people.

Youth education is foundational for agricultural transformation, equipping young people with technical skills, knowledge, and entrepreneurial abilities. We should create more entrepreneurs through the education system. For example, vocational training centers could offer hands-on skills in agro-business management and sustainable farming, complemented by internships with experienced farmers to bridge the gap between theory and practice. The agriculture sector should appeal to the youth and provide enough employment opportunities. Nepal can establish agro-industrial zones and support value-chain development to address the migration of young people abroad. For instance, promoting agribusiness startups and mechanized farming through PPPs can generate jobs while ensuring fair wages and labor protections. Establishing youth councils at all governance levels can enable young voices to shape agricultural policies. Mentorship programs, where experienced farmers guide young entrepreneurs, and cooperative farming initiatives can further enhance their leadership and engagement. Political instability and rural risks, such as crop failure or natural disasters, deter youth participation. Addressing this requires programs like crop insurance, disaster risk reduction, and equitable resource access, ensuring safety and stability, especially for young women in rural areas.

Youth can learn from abroad and play a central role in this transformation process through adapting innovation and modern agricultural techniques. Young people are more likely to embrace technology and innovative practices, critical for increasing productivity and sustainability. They can also effectively utilize mobile applications for market information, weather forecasts, and modern agricultural instruments through their familiarity with digital devices. Additionally, their adaptability to new ideas makes them ideal candidates for experimenting with sustainable farming practices, such as organic farming, regenerative agriculture and agroforestry. Youth empowerment includes facilitating access to land, finance and technology resources. This would give the youth capital, saving channels, and risk mitigation mechanisms essential for their agricultural ventures. Furthermore, supportive infrastructure and institutional frameworks are pivotal in enabling youth participation in agriculture. Innovation hubs can also provide training and seed funding, creating an ecosystem that supports innovation and business development.

5 Conclusions

In conclusion, the agricultural transformation in Nepal hinges on youth involvement, market integration, value chain development, agro-ecological practices, agricultural education, financial inclusion, and institutional reforms. Institutional reforms and youth empowerment are critical for driving agricultural transformation in Nepal. The development of agroprocessing industries must be prioritized as the cornerstone of rural industrialization, creating much-needed jobs and addressing urban overcrowding. To achieve this, a coordinated strategy is essential, ensuring harmony between advancements in agricultural technology and the growth of agroprocessing clusters. Government support for emerging high-value agricultural areas and agroprocessing industries is particularly vital, as it can harness Nepal's comparative advantage and stimulate rural economic growth.

Empowering young farmers through training in cultivation techniques, input procurement, and marketing can help them transition from being labor providers under contract farming to becoming entrepreneurial farmers capable of independent decision-making. This shift from "production contracts" to "market contracts" and not only enhance farmers' incomes but also foster resilience and innovation in the sector. Engaging the youth in agriculture through modern, technology-driven approaches and providing them with access to credit, training, and entrepreneurial opportunities, Nepal can build a vibrant, sustainable agricultural sector that supports rural livelihoods while contributing to the nation's broader economic development goals. Agriculture in Nepal highlights the potential for integrated development strategies focused on knowledge transfer and human capital investment and development. While general education, infrastructure development, and access to credit remain critical, targeted investments in training decision-makers, such as farmers and small-scale entrepreneurs can provide a "fast track" to impactful outcomes. Given Nepal's limited resources, prioritizing human capital development in these areas can unlock

significant economic potential. This is particularly relevant for empowering rural communities and fostering growth in both agriculture and small-scale industries, paving the way for sustainable development and poverty reduction across the country.

Young people are important to the agricultural sector, as they bring innovation, adaptability and a readiness to adopt modern farming practices. Young farmers can make significant contributions to the industry by addressing socio-economic barriers through education, training and improved access to resources. Although new technologies from developed countries can be replicated by adapting their fundamental concepts, the quality of institutions cannot be copied or borrowed, and there is no automatic transfer of these advantages. Future research should concentrate on innovative models for engaging youth, the effects of digitalization and mechanization on smallholder farms, and the effectiveness of various institutional reforms. Such research can inform the development of tailored strategies to address the unique challenges of Nepalese agriculture and its youthful workforce.

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Chapter 7

Prospects of Agritourism on the Socio-Economic Landscape in Nepal



Him Lal Ghimire, Jagannath Tiwari, and Bharat Raj Gautam

Abstract Agritourism in Nepal presents significant potential to merge tourism with agriculture, enhancing rural development through sustainable practices. Nepal's diverse landscapes, traditional farming techniques, and rich cultural heritage create an ideal foundation for agritourism, yet challenges persist due to infrastructure deficits, regulatory gaps, and limited stakeholder coordination. This chapter proposes a conceptual framework tailored to Nepal's agritourism, distinguishing core activities such as farm stays and harvest festivals from peripheral activities such as cooking classes and handicraft workshops. This framework aims to support a sustainable agritourism model that integrates local cultural events and agricultural practices, offering visitors authentic rural experiences while benefiting communities. Drawing from successful international models—including Japan's Sixth Industrialization and Italy's agritourism districts—a roadmap is outlined to guide agritourism development in Nepal. The roadmap phases include initial planning, infrastructure enhancement, community training, pilot projects, and continuous monitoring. Additionally, a policy analysis reveals gaps within Nepal's existing agriculture and tourism policies, underscoring the need for a national agritourism policy that aligns with rural economic goals. Through agritourism, Nepal can generate employment, promote cultural preservation, and foster environmental stewardship. This chapter concludes that a well-coordinated, Nepal-specific agritourism strategy could serve as a catalyst for socio-economic transformation, empowering rural communities and contributing to Nepal's broader sustainable development objectives. To enhance Nepal's rural economy and preserve cultural heritage, agritourism can leverage the country's diverse landscapes, traditional farming practices, and unique rural festivals, setting it apart as a culturally rich destination. However, to realize agritourism's full potential, Nepal requires a dedicated national agritourism policy. Such a policy would address

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infrastructure gaps, coordinate stakeholder involvement, and support sustainable development, ensuring that agritourism becomes a pillar of rural economic growth.

Keywords Agritourism · Nepal · Policy framework · Rural economy · Sustainable development

1 Introduction

Agritourism, which combines tourism with agricultural activities, is an increasingly relevant strategy for rural development worldwide. Agritourism, an intersection of agriculture and tourism, has gained increasing global relevance as countries strive to diversify rural economies, foster cultural exchange, and promote sustainable development (Schilling et al., 2012). Tourism helps to empower local communities and build capacity, which in turn improves their livelihoods, while empowerment is a multidimensional concept that includes economic, social, political, and psychological empowerment (Nyaupane & Poudel, 2011). Tourism is one of the fastest growing and most important economic sectors in the world, providing benefits to both host communities and destination areas. When properly planned and managed, sustainable tourism can improve livelihoods, promote inclusion, protect cultural heritage and natural resources, and foster international understanding. The tourism industry is essential for the growth of developing economies, with the potential to create millions of jobs and promote entrepreneurship and innovation (The World Bank, 2019). Tourism is an expanding worldwide phenomenon, and it has been observed that by the next century, tourism will be the largest industry in the world. Tourism has long been familiar in Nepal (Ghimire, 2014), and agritourism can be an essential component of Nepalese tourism, transforming the societal landscape and bringing real-life changes to rural communities.

Agritourism plays a crucial role in sustainable development and rural transformation. With declining agricultural productivity and living standards, many countries support agritourism as a way for farming families to pursue supplementary or alternative income (Awan et al., 2016). Nepal, with its rich natural beauty, diverse climates, and unique cultural heritage (Ghimire, 2017), is exceptionally well-suited for agritourism, which could play a transformative role in its socio-economic landscape (Khanal & Shrestha, 2019). One of the key impacts of agritourism in Nepal is its contribution to the socio-economic landscape of rural communities. By opening their homes and farms to tourists, local farmers can generate additional income, supplementing their earnings from agriculture. Furthermore, agritourism has created new employment opportunities in rural areas, particularly for women and youth. As farms diversify their offerings to cater to tourists and visitors, there is a growing demand for guides, cooks, and other hospitality staff, providing a boost to local employment rates and reducing rural–urban migration. Nepal is well-positioned to benefit from agritourism.

In Nepal, agriculture has traditionally been a dominant economic sector, employing around 62% of the population and contributing 23.92% to the national GDP in the fiscal year 2023/24 (MoF, 2024). However, factors such as youth migration, lack of modern farming practices, and climate change have posed significant challenges to rural development. Agritourism offers an alternative approach to reinvigorate rural areas by attracting tourists to participate in farm-related activities, thereby providing additional income streams for local communities and preserving traditional practices (Mahaliyanaarachchi, 2016). The integration of agritourism within Nepal's existing rural economy could foster resilience against economic vulnerability and environmental threats, promoting sustainable growth.

Nepal possesses abundant potential and resources for the growth and development of agritourism. The country boasts outstanding natural beauty and diverse geographic areas, including climates, ecosystems, and topographies ranging from high mountains to mid-hills and Terai. It has rich biodiversity and varied topography, encompassing plains, mid-hills, and high mountains. Nepal ranks 49th in the world for biodiversity, and there are over 22,000 species reported from Nepal, accounting for 1.3% of global biodiversity (NBRCC, 2024). These attributes make Nepal well-suited to meet the global demand for green adventure and ecotourism products, which ultimately align with agritourism offerings that can be produced in abundance across the nation. The growth of tourism is closely linked to increasing consumer demand for specific products and services, and one of the key impacts of agritourism in Nepal is its contribution to the socio-economic landscape of rural communities. Agritourism creates a symbiotic relationship where agricultural practices enhance tourism experience and tourism provides economic support to agriculture, ensuring its sustainability and growth. Agritourism is one of the most crucial parameters to improve the nation's economy and the sustainable development of rural communities in a country like Nepal, where the major occupation is farming and there are numerous potential as well as established tourist destination hubs (Khanal & Shrestha, 2019).

This chapter aims to evaluate the current state of agritourism in Nepal, identify key challenges, and propose practical models to harness the sector's full potential. Agritourism in Nepal faces several challenges, including limited infrastructure, regulatory gaps, and financial constraints for rural farmers. These obstacles hinder the sector's growth despite Nepal's strong potential for agritourism. To address these challenges and enhance agritourism's impact, this analysis draws insights from successful international models, such as Japan's integrated agricultural approach and Italy's agritourism districts. These examples offer adaptable strategies that emphasize sustainable growth, community involvement, and policy cohesion, which can guide Nepal's own agritourism development. Additionally, this chapter highlights the potential of agritourism to strengthen socio-economic resilience in rural Nepal, focusing on its benefits for income diversification, cultural preservation, and sustainable agricultural practices. Furthermore, it identifies policy and structural gaps and examines strategies that could facilitate a thriving agritourism sector, ensuring alignment with local needs and international standards. By addressing both challenges and opportunities, this chapter seeks to contribute to the policy debate on agritourism and provide a roadmap for sustainable rural development in Nepal.

2 Methodology

This chapter employs a qualitative research approach, integrating secondary data from a range of academic publications, policy documents, government reports, and case studies relevant to Nepal's agritourism sector. The methodology follows three key steps: a comprehensive literature review, policy analysis, and a contextualized conceptual framework development.

2.1 Literature Review

An extensive review of literature on agritourism, rural tourism, and sustainable development was conducted to gather insights on the benefits, challenges, and strategic pathways relevant to agritourism.

2.2 Policy Analysis

Policy documents, including Nepal's Agriculture Development Strategy (2015–2035), Tourism Vision 2020, and National Agriculture Policy 2004, were examined to assess existing institutional support and identify gaps in agritourism-specific provisions. This analysis emphasizes the lack of a dedicated national agritourism policy, which is essential for structured development and effective implementation at both local and national levels (MoAD, 2015; MoTCA, 2009).

2.3 Conceptual Framework Development

Based on Chase et al. (2018), a conceptual framework for agritourism tailored to Nepal's socio-economic and cultural context was developed. This framework outlines core and peripheral agritourism activities, emphasizing local resource utilization, sustainable practices, and stakeholder involvement. It seeks to capture the unique agricultural and tourism intersections in Nepal and provide a roadmap for policy formulation and practical application.

This methodological approach provides a comprehensive understanding of Nepal's agritourism landscape, identifying both immediate and long-term interventions necessary for its growth. A multi-faceted methodology is employed, including an analysis of international agritourism models and their adaptation to Nepal's context. Through this approach, we highlight key regulatory gaps and emphasize the need for a cohesive national agritourism policy. The comparative analysis of

international models—such as those from Japan, Italy, Thailand, and New Zealand—offers adaptable strategies that inform Nepal’s agritourism framework, emphasizing sustainability and community involvement. Thus, this methodology not only assesses Nepal’s current agritourism landscape, but also provides actionable insights for policy and structural development in the sector.

3 Conceptual Framework for Agritourism in Nepal

The conceptual framework for agritourism is crucial for understanding how agritourism activities are categorized and implemented. Chase et al. (2018) propose a framework that divides agritourism activities into **core and peripheral activities** based on their connection to agricultural production and their location (on-farm vs. off-farm). Core activities, such as direct farm sales, farm tours, and agricultural festivals, are deeply tied to agricultural production and typically occur on farms. Peripheral activities, such as cooking classes and cultural events, while related to the rural experience, do not necessarily depend on active agricultural involvement.

In adapting Chase et al.’s (2018) framework to Nepal, it is essential to incorporate activities that resonate with Nepal’s agricultural diversity, traditional practices, and rural lifestyles. The framework for Nepalese agritourism emphasizes a blend of **traditional farming practices, biodiversity, and cultural heritage**, which are central to the Nepalese rural experience. Unlike in some regions where agritourism primarily involves commercial farming operations, Nepal’s agritourism centers around small-scale, community-based agriculture, often with a focus on organic practices and sustainable land use.

Nepal’s agritourism conceptual framework includes the following categories, adapted to local needs and contexts:

3.1 *Core Activities (On-Farm, Directly Related to Agriculture)*

- **Farm Stays:** Staying on local farms to experience Nepalese rural life directly, often with hands-on participation in daily agricultural tasks.
- **Farm Tours:** Guided tours that showcase Nepal’s traditional and organic farming practices, such as terracing and rotational cropping.
- **Harvest Festivals:** Cultural festivals associated with crop cycles, such as rice planting and harvest festivals, where tourists participate in traditional agricultural celebrations.
- **Direct Farm Product Sales:** Opportunities for visitors to buy locally produced items such as tea, honey, and organic fruits directly from farms, often with a focus on high-value products.

3.2 *Peripheral Activities (Off-Farm or Indirectly Related to Agriculture)*

- **Culinary Experiences and Cooking Classes:** Tourists learn to cook traditional Nepali dishes using farm-fresh ingredients, blending agritourism with cultural exchange.
- **Handicrafts and Traditional Arts:** Workshops in rural villages that focus on making crafts from locally sourced materials, such as bamboo and wool.
- **Nature and Ecotourism Activities:** Activities that emphasize Nepal's biodiversity, including birdwatching, hiking, or tours of botanical gardens that showcase native plants and their agricultural significance.
- **Cultural Events and Folk Performances:** Off-farm events that highlight the cultural and historical aspects of rural Nepal, such as folk dances or storytelling sessions related to agricultural heritage.

By distinguishing core activities, such as farm stays and harvest festivals, from peripheral activities, such as culinary workshops and ecotourism, the framework captures Nepal's agritourism potential. This approach enables the integration of local culture and agriculture, directly supporting goals of economic diversification and cultural preservation in rural Nepal.

4 **Agritourism Policy Issues in Government and Non-Government Documents**

Agritourism in Nepal is influenced by various government policies and strategies; however, these documents often lack a unified approach specific to agritourism, creating barriers to its sustainable development. Key government documents, including the **National Agriculture Policy 2004**, **Agriculture Development Strategy (ADS) 2015–2035**, and **Tourism Vision 2020**, touch on related areas, but fall short of providing a cohesive framework for agritourism. Here, we examine each document's contributions and limitations in promoting agritourism (Table 1).

Nepal's agritourism sector would benefit from a dedicated agritourism policy that addresses these policy gaps, provides financial incentives, and establishes clear guidelines for agritourism development. Such a policy could outline the roles of different stakeholders, offer training and financial support for rural communities, and set standards for sustainable tourism practices. The lack of a cohesive agritourism policy hinders the sector's growth, as current documents only partially address agritourism's needs. By establishing a dedicated agritourism policy, Nepal can provide a structured framework that promotes economic resilience, cultural preservation, and sustainable development in its rural areas.

Table 1 Agritourism policy review: content, relevance, and gaps analysis

Policy	Content	Relevance	Policy gaps
National agriculture policy 2004	This policy emphasizes modernizing agriculture and improving rural livelihoods but does not address agritourism explicitly	While agritourism could contribute to rural income diversification, the policy does not establish guidelines or incentives for integrating tourism with agriculture	There is a need to extend the policy's scope to support agritourism activities, such as farm stays, direct sales of farm products, and rural cultural exchanges
Agriculture development strategy (ADS) 2015–2035	The ADS focuses on transforming Nepal's agriculture sector through modernization, commercialization, and sustainability	Agritourism aligns with ADS objectives by offering an additional revenue stream for farmers and promoting sustainable practices	The ADS does not provide a clear pathway or support mechanisms for agritourism. Integrating agritourism into the ADS could facilitate access to funding and training for rural entrepreneurs
Tourism vision 2020	This document outlines Nepal's goals for increasing tourist arrivals and revenue, with a focus on sustainable tourism and rural inclusivity	While Tourism Vision 2020 acknowledges rural tourism, it lacks specific provisions for agritourism and does not detail how agriculture and tourism can complement each other	Developing agritourism-specific goals within this vision would align tourism growth targets with rural development objectives, promoting a balanced approach that leverages Nepal's agricultural diversity
Non-governmental initiatives and support	NGOs and INGOs have launched projects aimed at rural tourism, agricultural sustainability, and community empowerment	These initiatives often provide training, funding, and technical assistance to rural communities, indirectly supporting agritourism	A coordinated approach that brings together NGOs, local government, and private stakeholders is missing. Formal partnerships and defined roles for NGOs in promoting agritourism would improve resource allocation and project sustainability

Source Authors prepared from (MoAC, 2004; MoAD, 2015 & MoTCA, 2009)

5 Fundamentals of Agritourism

Agritourism serves as an innovative approach to rural development, blending agricultural practices with tourism to create unique experiences for visitors while generating income for local communities. This form of tourism allows tourists to engage directly in the agricultural lifestyle—whether through farm stays, participation in agricultural activities, or the purchase of locally produced goods. **In the Nepalese context, agritourism holds significant potential, offering opportunities for sustainable development and preservation of rural culture and heritage.** Nepal's varied landscapes and traditional agricultural practices provide a strong foundation for agritourism, positioning it as a strategic approach to enhance socio-economic growth in rural areas. Agritourism is rooted in core principles such as income diversification, cultural preservation, and sustainable farming practices.

Agritourism products refer to the goods and services that are offered to visitors at agritourism destinations and the agricultural goods supplied to hotels, restaurants and resorts. These products can vary widely depending on the specific focus of the agritourism operation and local agricultural practices. Agritourism products are available year-round and are easy to find due to their abundant availability. Figure 1 shows the following components of agritourism.

Agritourism in Nepal aligns with several core principles of sustainable development

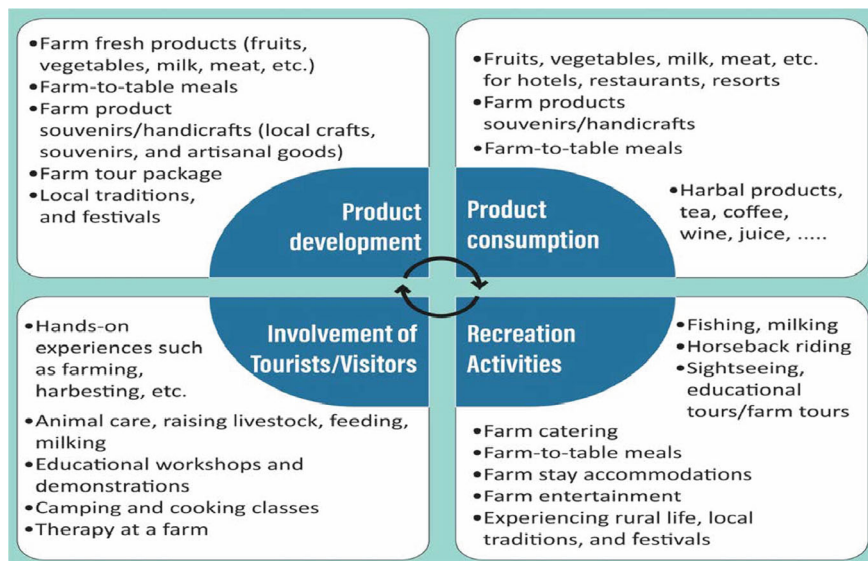


Fig. 1 Components of Agritourism. *Source* Authors creation

5.1 Economic Diversification

By encouraging local farmers to diversify their income streams through tourism, agritourism reduces dependency on conventional agriculture alone. This economic resilience is essential in Nepal, where small-scale farming is predominant and vulnerable to external shocks.

5.2 Preservation of Cultural Heritage

Agritourism allows visitors to experience Nepal's rich agricultural traditions and practices, fostering cultural exchange while helping to preserve traditional knowledge.

5.3 Environmental Stewardship

Sustainable agritourism promotes environmentally responsible practices, emphasizing organic farming and eco-friendly methods that benefit both the ecosystem and the tourism experience.

In recent years, global agritourism has expanded significantly, and Nepal can leverage this trend by building a sector rooted in its unique cultural and agricultural heritage. However, establishing a successful agritourism industry requires a clear framework that addresses both policy and practical challenges, including infrastructure development, capacity building, and community engagement. In this regard, agritourism can play a crucial role in Nepal's rural transformation by integrating tourism with agriculture in a way that benefits both sectors.

6 Prospects of Agritourism in Nepal

Agritourism has become a growing sector globally, bridging the gap between agriculture and tourism and promoting rural development through sustainable practices (Schilling et al., 2012). Defined in the current context as the business of establishing farms as travel destinations for educational and recreational purposes, agritourism encompasses a variety of on-farm activities, including direct marketing (e.g., farm markets and pick your-own operations), educational activities (e.g., school tours and winery tours), entertainment (e.g., corn mazes and hayrides), outdoor recreation (e.g., hunting and fishing), and accommodations (e.g., bed and breakfasts) (Schilling et al., 2012).

In Nepal, agritourism is at a nascent stage, yet it holds substantial potential due to the country's rich biodiversity, traditional farming systems, and diverse cultural heritage. *Nepal's agritourism sector provides unique experiences such as tea plantation tours, paddy plantation tours, yarsagumba collection, honey hunting, mango festivals, orange festivals, organic farming activities, homestays, and hands-on agricultural experiences that attract both domestic and international tourists* (Table 2).

The economic benefits of agritourism extend beyond direct revenues. Multiplier effects include increased demand for local products, job creation, and enhanced infrastructure. Using GDP contribution as a model, we identify factors such as visitor spending, employment, and local product sales that contribute to the larger economy.

Despite its challenges, agritourism in Nepal presents considerable prospects. *With effective policy support, Nepal's agritourism could enhance income diversification, preserve cultural traditions, and promote sustainable land use* (Ghimire, 2017). Nepal's diverse climates and agricultural landscapes make it suitable for various agritourism products. *Addressing current policy and infrastructure gaps is essential to unlocking agritourism's potential. Establishing a national agritourism policy, creating infrastructure support programs, and offering training to local farmers and entrepreneurs are key steps for fostering agritourism's growth.* Additionally, agritourism could benefit from integrating eco-friendly practices and focusing on organic and traditional farming methods, both of which align with Nepal's sustainable development goals. For instance, in Ilam, agritourism initiatives have led to job creation through tea plantation tours, which attract both domestic and international tourists. This not only boosts local income but also helps retain youth in agricultural roles by making farming more economically viable (Table 3).

As shown in Table 4, agritourism in Nepal generates multifaceted benefits that extend beyond individual farmers to include visitors and the broader rural community. For farmers, agritourism provides essential income diversification and skill development opportunities, reducing reliance on traditional agriculture. Visitors benefit

Table 2 Benefits of agritourism in Nepal

Category	Components	Examples
Accommodations	Rural homestays, eco-friendly lodges, traditional farmhouses	Experience Nepali culture through stays
Activities	Farm work experiences, organic farming workshops, tea plantation tours, nature and wildlife tours	Participate in local agriculture, explore biodiversity
Products	Organic produce, handcrafted goods, processed agricultural products	Purchase locally made honey, cheese, textiles
Educational experiences	Sustainable farming practices, cultural festivals, culinary workshops	Learn about organic farming, join festivals, cook traditional dishes

Source Authors compilation/creation

Table 3 Socio-economic impacts of agritourism in Nepal

Impact category	Description	Example in Nepal
Employment creation	Generate jobs in rural areas, reducing urban migration and providing income for local communities	Local guides, homestay operators, craft artisans
Youth engagement	Encourages young people to participate in agriculture and tourism, reducing youth outmigration	Youth involvement in eco-tourism activities and farm management
Cultural preservation	Promotes the preservation of traditional practices and local festivals, showcasing Nepalese heritage	Traditional farming practices, cultural festivals such as Tihar
Environmental sustainability	Encourages eco-friendly practices that align with tourism, such as organic farming and waste reduction	Organic farms, sustainable water use in agritourism sites
Community empowerment	Increases community pride and ownership, empowering locals to take part in tourism and economic planning	Community-managed tourism programs and cooperative ventures
Economic diversification	Provides an alternative income source, reducing dependence on traditional agriculture alone	Income from tourist activities, sale of local produce and crafts

Source Authors compilation

from immersive cultural experiences and educational opportunities that connect them to rural lifestyles and sustainable practices. At the community level, agritourism contributes to job creation, cultural preservation, and environmental sustainability, as it supports eco-friendly farming methods and conservation. These benefits collectively position agritourism as a catalyst for socio-economic resilience in rural Nepal, highlighting the sector’s potential to foster sustainable development.

The future of agritourism in Nepal looks promising, with several key factors contributing to its growth and development (Table 5).

Nepal’s unique biodiversity and rich cultural heritage present substantial opportunities to create a niche agritourism market. Furthermore, growing government interest in sustainable tourism opens the door for establishing formal agritourism policies that support rural economic growth and environmental conservation.

Table 4 Benefits of enhancing agritourism

Stakeholder	Benefit	Description/Examples
Farmers	Income diversification	Additional revenue from agritourism services and processed goods (e.g., cheese, honey)
	Skill development	Learning hospitality and tourism management
Visitors	Cultural experience	Hands-on activities in traditional farming, attending local festivals
	Educational opportunities	Workshops on organic farming and traditional Nepali cooking
Community	Job creation	New jobs as tour guides, cooks, or artisans
	Cultural preservation	Showcasing and preserving traditional practices
	Environmental sustainability	Promoting eco-friendly practices that align with rural conservation goals

Source Authors compilation/creation

Table 5 Prospects for the growth and development of agritourism

Key factors	Description
Sustainable rural development	Significantly contribute to rural development by creating jobs, especially for locals and farmers. Retain people in rural areas and reduce migration to cities amidst ongoing urbanization
Value addition and diversification of income sources	Agritourism offers farmers value addition and diversification of their products and a source of income beyond traditional agriculture
Educational opportunities	Provides a platform for educating the public about organic farming, sustainable agriculture, and biodiversity conservation. It also offers hands-on learning experiences for schools, colleges, and families interested in rural life and agricultural practices
Preservation of heritage and culture	Allows visitors to experience Nepalese culture, cuisine, and traditions, helping to preserve and promote the country's rich cultural heritage and preserve Indigenous knowledge, crafts, and artistic expressions
Market demand and source market	There is a surge in demand, especially among urban dwellers who yearn for organic, health-conscious food and a meaningful connection to nature • Domestic Tourists: This segment includes urban families interested in experiencing rural life, school groups on educational tours, and various organizations seeking team-building retreats • International Tourists: Key segments include eco-tourists, adventure travelers, and cultural enthusiasts from countries such as India, China, the United States, Japan, and Europe. These tourists seek authentic, eco-friendly experiences that offer insight into Nepalese rural traditions and lifestyles
Environmental sustainability	Emphasis on organic practices that protect the environment while attracting eco-conscious tourists

Source Authors assumption/creation

7 Adopting International Models for Agritourism Development in Nepal

Agritourism supports economic resilience by creating jobs, reducing poverty, and diversifying income. In Nepal, agritourism can play a pivotal role in stabilizing rural incomes and reducing youth migration. It also facilitates knowledge exchange, promoting both local pride and agricultural innovation. Agritourism worldwide has seen considerable success through structured models that integrate local culture, agriculture, and sustainable tourism. Nepal can look to other countries' successful agritourism practices as models, adapting these strategies to fit local needs. This would not only improve the agritourism experience for visitors but also offer new value-added income opportunities for Nepal's rural communities. With the right investment, Nepal's agritourism sector can become a significant contributor to both rural development and the national economy. Coordinated efforts among government bodies, local communities, and private stakeholders will be essential to realize these goals. This section highlights four international models—each offering unique strategies that Nepal can adapt to enhance its agritourism sector.

7.1 *Japan's Sixth Industrialization Model*

The “Sixth Industrialization” model in Japan integrates agriculture (primary sector), processing (secondary sector), and tourism services (tertiary sector) to maximize the value of agricultural products. By adding stages of processing and direct marketing, this model enables farmers to generate income from not only raw produce, but also value-added products and tourism experiences (Yasuda, 2017).

- **Adaptation for Nepal:** Nepal can adopt this approach by promoting farm-based processing and direct sales, such as converting locally grown fruits into preserves or juices, and marketing these products through farm stays or local tours. For example, tea and honey producers could add tasting experiences or interactive workshops, drawing tourists while enhancing income potential.

7.2 *Italy's Agritourism Districts*

Italy's agritourism districts emphasize authentic experiences tied to local food, culture, and eco-friendly practices. Designated agritourism zones allow Italy to capitalize on unique regional products and heritage, making it easier for tourists to plan agritourism-focused trips and for local governments to streamline agritourism policies (Sonnino, 2004).

- **Adaptation for Nepal:** Nepal could create regional agritourism zones such as Ilam (tea), Mustang (apples), or Chitwan (organic vegetables), each highlighting

the area's unique agricultural offerings. This zoning approach would simplify marketing efforts and attract tourists to experience Nepal's agricultural diversity. Additionally, these zones could serve as pilot regions for agritourism-focused infrastructure and policy support.

7.3 Thailand's Community-Based Agritourism

Thailand's model focuses on community-based agritourism, empowering local communities to manage tourism activities and retain economic benefits locally. This approach promotes cultural exchange and sustainable tourism, with visitors participating in traditional agricultural activities and local customs (Pongponrat & Chantradoan, 2012).

- **Adaptation for Nepal:** Nepal's rural areas, rich in tradition and community spirit, are well-suited for community-based agritourism. By establishing community-led agritourism cooperatives, Nepal could ensure that profits stay within local communities. Such cooperatives could organize farm stays, traditional cooking classes, and festivals, creating immersive experiences that directly benefit the community.

7.4 New Zealand's Farm Stay Model

New Zealand's farm stays offer visitors a hands-on agricultural experience, typically involving activities such as animal care, crop harvesting, and seasonal farm work. These farm stays are family-oriented and provide a blend of relaxation and educational experiences (Telfer & Wall, 2000).

- **Adaptation for Nepal:** Nepal could adopt New Zealand's farm stay model in regions where visitors can participate in seasonal farming activities. For instance, in rice-growing regions, tourists could experience rice planting and harvesting, while in orchard-rich areas, they could join in apple or orange picking. This model would allow tourists to connect with Nepal's agricultural cycles and experience the rural lifestyle authentically.

By adapting successful international agritourism models, Nepal can create a unique, sustainable agritourism sector that leverages its natural and cultural assets. Implementing elements from these models—value-added processing, agritourism zoning, community-based management, and immersive farm stays—will position Nepal as a distinct agritourism destination and promote socio-economic resilience in rural areas.

8 Threats and Challenges of Agritourism in Nepal

While agritourism in Nepal holds immense potential, *despite its many promising elements, several challenges hinder its full development. These include inadequate infrastructure, lack of a clear national agritourism policy, limited awareness among local farmers, and insufficient support for rural entrepreneurs* (MoAD, 2015). Existing tourism policies, such as the Tourism Vision 2020, make only brief mentions of rural and sustainable tourism without specifically addressing agritourism needs (MoTCA, 2009). *In addition, issues such as gender disparity, weak institutional coordination, and the underutilization of local resources have limited the benefits that agritourism can bring to rural communities.* Addressing these challenges is essential for developing a sustainable and resilient agritourism sector. This section examines major threats and challenges to agritourism in Nepal, categorized into infrastructure, policy, financial, environmental, human resources, and market awareness issues.

8.1 Infrastructure Limitations

- Nepal's rural infrastructure is underdeveloped, with limited road access, unreliable electricity, and scarce basic amenities in many agritourism-eligible areas. These limitations restrict tourists' access to rural farms and increase transportation costs. Inadequate infrastructure also affects the comfort and safety of agritourism facilities, making it difficult to attract and retain visitors. Developing road networks, reliable power, and clean water systems in rural areas is essential for promoting agritourism effectively.

8.2 Policy and Regulatory Gaps

- Nepal currently lacks a cohesive, nationally recognized agritourism policy. This absence results in fragmented support, inconsistent regulatory standards, and unclear guidelines for stakeholders, making it difficult for agritourism businesses to operate efficiently. Without a structured framework, agritourism providers struggle with legal compliance, funding, and resource allocation. A well-defined agritourism policy is crucial to streamline processes, standardize practices, and foster investment across the sector.

8.3 Financial Barriers for Local Farmers

- Many farmers in Nepal face difficulties in accessing capital to establish or upgrade agritourism facilities. From constructing accommodations to integrating eco-friendly practices, the costs involved in setting up agritourism are substantial. Financial institutions are often hesitant to lend to rural ventures due to perceived risks and limited collateral. This lack of financial support prevents many interested farmers from participating in agritourism, thereby restricting the sector's growth.

8.4 Climate Vulnerabilities and Environmental Threats

- Nepal's agriculture is highly vulnerable to climate change, and agritourism is no exception. The impacts of extreme weather events—such as landslides, floods, and erratic rainfall—can disrupt farming cycles and compromise tourist experiences. Agritourism's reliance on seasonal agricultural activities makes it sensitive to climate fluctuations, which can negatively affect yields and the availability of authentic farm experiences. Mitigating climate risks through sustainable practices is essential for agritourism's longevity.

8.5 Skills Gap in Hospitality and Tourism Management

- Many rural communities lack the necessary training in tourism and hospitality, affecting the quality of services offered to tourists. Agritourism activities require skills in areas such as customer service, safety protocols, and cultural presentation. Without sufficient training, local providers may find it challenging to meet tourist expectations, which can lead to unsatisfactory experiences. Building human resource capacity through skill development programs is vital to creating a skilled workforce in agritourism.

8.6 Market Awareness and Promotion Deficits

- The agritourism sector in Nepal suffers from limited visibility in both domestic and international markets. Unlike mainstream tourism offerings, agritourism lacks cohesive promotional strategies and marketing efforts that highlight its unique experiences, such as tea plantation tours, traditional farming methods, and cultural festivals. The absence of strong branding and promotion means that many potential tourists are unaware of Nepal's agritourism potential. Targeted marketing

campaigns and digital platforms could help raise awareness and attract a broader range of visitors.

Addressing these challenges requires a coordinated effort involving policy reforms, infrastructure development, financial support, climate resilience measures, skill development, and effective marketing. By overcoming these obstacles, Nepal can unlock the full potential of its agritourism sector, transforming it into a pillar of sustainable rural development.

9 Roadmap for Socio-Economic Transformation Through Agritourism

This roadmap for agritourism development promotes a structured, incremental approach to integrating agritourism into Nepal's rural economy, and includes the following phases (Table 6).

This roadmap helps ensure structured, phased progress, aligning with Nepal's agritourism goals. Each phase builds on the previous one, beginning with planning and ending with monitoring, creating a sustainable transformation process in rural Nepal. Implementing this roadmap will not only strengthen Nepal's agritourism sector but also contribute to the broader goal of socio-economic resilience, empowering rural communities through diversified income streams and sustainable practices.

10 Conclusions

Agritourism offers Nepal a powerful opportunity to bridge tourism with agriculture, fostering socio-economic transformation in rural areas while preserving the country's cultural and environmental heritage. With its diverse landscapes, traditional farming practices, and rich cultural customs, Nepal is uniquely positioned to leverage agritourism for sustainable development. This paper has examined the potential of agritourism in Nepal by exploring its fundamentals, presenting a conceptual framework tailored to Nepal's context, and analyzing both international models and Nepal-specific challenges.

The adapted **conceptual framework for agritourism** in Nepal differentiates core activities, such as farm stays and harvest festivals, from peripheral activities such as cooking classes and handicraft workshops. This distinction allows agritourism stakeholders to develop offerings that are both authentic and sustainable, catering to tourists' desire for immersive experiences. The framework also emphasizes integrating local cultural events and traditional farming practices, making Nepalese agritourism distinctive and valuable on the global tourism map.

The chapter has also identified a range of **threats and challenges** that must be addressed for agritourism to thrive in Nepal. Key issues include infrastructure

Table 6 Roadmap for socio-economic transformation through agritourism

Phase	Timeframe	Key actions	Goals
Phase 1: planning and assessment	Year 1	– Conduct a national assessment of agritourism potential – Develop a national agritourism policy framework	Establish baseline understanding and formal policy support
Phase 2: infrastructure development	Years 1–2	– Improve rural infrastructure (roads, electricity, water) – Develop basic tourism facilities (lodging, sanitation)	Increase accessibility and ensure a comfortable experience for tourists
Phase 3: capacity building and training	Years 1–3	– Provide training for farmers on hospitality and safety – Establish agritourism cooperatives for community-based management	Empower locals with skills and organization for managing agritourism
Phase 4: pilot projects and implementation	Years 2–3	– Launch pilot agritourism projects in high-potential areas (e.g., Ilam, Chitwan) – Establish model farms with guided activities	Demonstrate agritourism viability, create working examples for scaling
Phase 5: marketing and promotion	Years 2–3	– Develop a national agritourism branding campaign – Use digital platforms and social media for targeted marketing	Attract domestic and international tourists, increasing visibility and demand
Phase 6: expansion and diversification	Years 3–4	– Scale successful pilot projects to new regions – Diversify activities to include additional experiences (festivals, handicrafts)	Broaden agritourism offerings and expand to more rural areas
Phase 7: monitoring and evaluation	Years 4–5	– Regularly monitor socio-economic impacts – Collect feedback for continuous improvement – Adjust policies as needed	Ensure sustainable growth, make adjustments based on feedback and lessons learned

Source Authors forecast

deficits in rural areas, policy and regulatory gaps, financial constraints faced by local farmers, climate vulnerabilities, skill gaps in hospitality, and limited market awareness. Addressing these obstacles will require a cohesive national agritourism policy, targeted investments in infrastructure, training programs for local communities, and cohesive marketing strategies to increase Nepal's visibility in the agritourism sector.

Drawing on successful international models, this paper presents a roadmap for the **socio-economic transformation of Nepal through agritourism**. From Japan's Sixth Industrialization model to Thailand's community-based tourism, these examples offer actionable insights that Nepal can adapt to enhance agritourism's resilience and inclusivity. Implementing such strategies in a phased approach—starting with planning and assessment, and followed by infrastructure development, community capacity building, pilot projects, and ongoing monitoring—will establish a sustainable growth pathway for Nepal's agritourism sector.

This paper underscores that, when developed thoughtfully, agritourism can serve as a catalyst for rural development in Nepal, generating employment, enhancing cultural pride, and promoting environmental stewardship. By connecting farmers, tourists, and communities, agritourism can foster mutually beneficial relationships that support economic resilience and contribute to sustainable development goals. With concerted efforts from policymakers, local communities, and private stakeholders, agritourism has the potential to become a pillar of Nepal's rural economy, promoting prosperity while preserving the nation's invaluable agricultural and cultural heritage. Establishing a cohesive national agritourism policy is essential to ensuring the sector's success. By addressing regulatory gaps, fostering community involvement, and promoting sustainable practices, such a policy can position agritourism as a cornerstone of Nepal's rural economy.

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Chapter 8

Enabling Transformational Change of Nepalese Agriculture Through Agribusiness Financing Restructuring in Nepal



Kiran Mainali and Deepak Ratna Tuladhar

Abstract The credit and financial accessibility to agribusiness and smallholder farmers are urgently required for rapid agricultural transformation, through which farming practices can be modernized, productivity can be increased, market access of the products can be improved, and sustainable livelihoods for rural communities can be ensured. This chapter aims to provide a comprehensive situational analysis of agribusiness in Nepal, focusing on the status and potential aspects within the banking sector, microfinance institutions (MFIs), and cooperatives. By examining various agribusiness-centered policies and initiatives, the chapter explores the financial implications of transformative change and offers strategic insights for fostering sustainable agribusiness growth in Nepal. The chapter provides an overview of the existing landscape of agribusiness, contribution of agriculture to the national economy, and key challenges of the agribusiness sector, and then discusses the existing agribusiness financial landscape of Nepal. The effectiveness and financial implications of agribusiness-centered policies and initiatives such as the Agriculture Development Strategy (ADS) (2015–2035), Specialized Investment Fund (SIF) 2019, Foreign Investment and Technology Transfer Act 2019, Agri-business Promotion Policy 2006, Agriculture, Livestock, and Medicinal Herb Insurance Directive 2022, National Land Use Policy 2015, Unified Directives to bank and financial institutions (BFIs) and MFIs, and Integrated Procedural for Interest Subsidy on Concessional Loan 2018 are appraised, and their specific provisions related with agribusiness financing are reviewed. Additionally, to achieve rapid agricultural transformation, the development of tailored financial products for smallholder farmers and agribusinesses, alongside strengthening digital financial infrastructure to enhance accessibility needs to be prioritized. **Furthermore, emphasis on strengthening governance structures and institutional capacity within agricultural finance sectors needs to be provided for the financial producer/ service effectiveness and its better implementation.**

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Keywords Agribusiness · BFI · Economic growth · Financial products · Institutions · Smallholder farmers

1 Introduction

Agriculture has been one of the sought-after sectors for Nepal's economic growth and has been prioritized in its plans, policies, annual budget, and programs (Adhikari, 2015). Despite its crucial need, demand, and importance showcased by different government and non-government sectors, this sector faces several challenges in terms of access to inputs, mechanization, market, information, price, and most importantly finance (Gyawali & Khanal, 2021). To address these core constraints there should be a systemic approach operating in multiple facets simultaneously to structure and minimize the long-term deficit and increase the global competitiveness of Nepalese agriculture. One such implemented approach, as also highlighted in the Agricultural Development Strategy (ADS), is to structure and reform the financial sector to make it more robust and agri-lending friendly and be able to provide necessary capital, and risk management tools and develop innovative financing solutions that are designed for the diverse nature of agriculture in Nepal (MoAD, 2015).

In current practices, Nepalese farmers largely depend on formal and informal sectors for credit facilitation. The formal sector includes Nepal Rastra Bank (NRB) licensed Bank and financial institutions (BFIs), microfinance institutions (MFIs), and cooperatives (Pandey, 2022). Conversely, the informal sector includes the farmer group, women groups, personal lenders, etc. The government has set some long-term plans for agricultural commercialization and competitiveness in the agriculture sector; however, the state of which is reported poor due to a lack of credit access to the smallholder farmers and enterprises related to the sector (Bhandari, 2024). The availability of credit to the agricultural sector is impacted by a multitude of constraints like poor coverage of the agricultural credit facilitation, high interest rates which is not within the payment limit of the people engaged within the sector, unfavorable principal repayment terms that act as a deterrent, and lastly, collateral requirements which are often not valued in case of properties of farmers or small and medium enterprises (SME) located in the rural regions of the country. Despite the governmental efforts to increase private sector investment, the loan amount expended in the commercialization and modernization of agriculture remains low. Mid-year estimates of agriculture sector loans provided by commercial banks, development banks, and finance companies during the year 2022 were NRs. 350,134.8 million, 31,529 million, and 6563.5 million, respectively (MoALD, 2023). The amount of investment by the development banks in agriculture is low in comparison with the commercial banks. As of mid-July 2023, commercial banks provided 29.71% of their total loan to the specified sectors including agriculture (12.89%), whereas development banks and finance companies provided 25.28 and 21.75 percent, respectively, of their total loan in the specified sectors including agriculture, SME, and energy sector (NRB, 2024). As reported by Giri (2023), the banks often adduce risk as the

primary reason for the limited growth of agricultural investment. Similarly, higher operational costs of BFI branches, poor physical infrastructures, and credit policies like credit ceiling, the short grace period for perennial crops, collateral-free loans, etc., are the major identified discouraging factors to investing in the transformation of agriculture.

This chapter focuses on the current landscape of the agri-finance sector in Nepal, communicating the different types of financial services that are effectuated and can be leveraged by the private sector to expand their investments and collectively contribute to the agrifood system investment that the country requires for holistic agricultural sector development. In addition, it analyzes and examines different existing policies and frameworks that influence the agri-finance sector and how they can create an enabling environment for the agrifood system development of Nepal. Lastly, based on the review of existing policy structures, the chapter proposes actionable policy recommendations and strategies to stimulate the agrifood system transformation in Nepal.

2 Current Financial Landscape for Agribusiness in Nepal

The banking sector in Nepal was formalized in 1937 with the establishment of Nepal Bank Limited to provide financial services to Nepalese citizens. Meanwhile, Nepal Rastra Bank (NRB), the central governing bank of Nepal was established in 1956, under the Nepal Rastra Bank Act 1955 to supervise, promote, and direct the functions of commercial banking activities (Kalika, 2019). The Banks and Financial Institutions Act (BFIA) 2017, commonly referred to as BFIA 2017, is the current key piece of legislation that directs the functioning of banks and microfinance to ensure its sound operations while maintaining sustainable financial progress in the country (Pokharel, 2018). Under this umbrella law, the BFIs have been divided into various categories based on their scope, capital requirements, and functions. This includes commercial banks, development banks, finance companies, and microfinance institutions. In Nepal, the **microfinance institutions** constitute the largest share (51%) with 57 institutions, followed by **commercial banks** at 18% (20 banks). Similarly, **development banks** and **finance companies** each account for 15% (17 institutions each), while **infrastructure development banks** make up the smallest portion, representing just 1% (1 bank). Each type of financing institution is under specific functioning legislation. Each of these individual financing entities plays a critical role in providing financial services to the agribusiness sector, by providing credit, insurance, and other financial products to the agricultural sector as mandated by the BFIA 2017.

For the promotion of financial accessibility to priority sectors like agriculture, BFIA comprises specific provisions related to dispensing agricultural loans to fuel economic development. To ensure priority sectors like agriculture receive sufficient funding for their growth and development, the NRB has mandated Banks and Financial Institutions (BFIs) to allocate 15% of the total credit portfolio. Similarly, with the

motivation to support small agribusiness and farmers, NRB also has fixed different criteria for loan disbursement including the principal repayment provision, interest rates, and collateral requirements specific to the agricultural sectors. As per the fiscal policy of Nepal, agricultural micro, cottage, small, and medium-scale industries will receive a five percent interest subsidy meanwhile industries operated solely by women will get a six percent interest subsidy (The Annapurna Express, 2024). As small farmers are bereft of traditional means of collateral, the act also addresses these concerns and directs the BFIA to encourage the use of alternative forms of collaterals to facilitate the process of loan disbursement. The BFIA serves as a cornerstone in ensuring the financial products offered by the private sector reach the priority sectors like agriculture for its commercialization and rapid growth in the country.

2.1 The Role of Commercial Banks

Commercial banks in Nepal are the largest financial service providers, holding most the country's financial assets. As of 2024 there are 20 commercial banks in Nepal, with a combined total asset value exceeding NPR Rs 7.468 trillion (myRepublica, 2024). Despite their dominant position in the financial sector, commercial banks have historically been cautious in lending to the agriculture sector. This reluctance stems from the perceived high risk associated with agricultural lending, due to factors such as income volatility, fragmented landholdings, and susceptibility to climate-related events (Pradhan et al., 2019).

To encourage greater involvement of commercial banks in the agribusiness sector, the NRB has mandated that these institutions allocate at least 15% of their total loan portfolio to agriculture (NRB, 2024). This directive has led to an increase in agricultural lending, though it remains concentrated in lower-risk segments such as agribusinesses with established supply chains and collateralizable assets. As of 2024 mid-July, agricultural loans accounted for approximately 12.89% of the total loan portfolio of commercial banks (NRB, 2024). Further to limit the lateral dissemination of commercial banks currently 36% of the commercial bank branches are in Bagmati Province, with 71% of the branches in Bagmati Province located in Kathmandu Valley alone showcasing the unfamiliar concentration of commercial banks.

However, the access to credit for smallholder farmers and smaller agribusinesses remains limited. High collateral requirements and complex loan approval processes are significant barriers (Gupta et al., 2016). Addressing these issues requires the development of alternative collateral systems, such as warehouse receipts or contract farming agreements, and the simplification of loan processes to make credit more accessible to those who need it most. Also, evidence of bad loans or failure to recover the loan amount that was provided as credit in financing agriculture and agribusiness reported from the banks disinterests the banking authorities from further investment. The Agriculture Development Bank Limited (ADBL) reported a strikingly high loan loss rate of 34% invested in agriculture, drastically exceeding the rates of other banks.

Nepal SBI Bank Limited (NSBL) and Himalayan Bank Limited (HBL) also exhibit comparatively high losses at 18% and 16%, respectively. In contrast, the remaining banks demonstrate much lower loss rates, generally ranging from 9 to 13%, with Prabhu Bank showing the lowest at 9%. These data suggest a considerable variation in risk management and loan portfolio quality among commercial banks in the context of agricultural lending, potentially contributing to a reluctance within the banking sector to further invest in agriculture-related businesses and individuals.

2.2 *Microfinance Institutions (MFIs)*

Microfinance institutions (MFIs) are essential providers of financial services to low-income households and smallholder farmers, especially in rural areas where access to formal financial services is limited. As of 2023, there are 90 licensed MFIs in Nepal, serving over 4 million clients with a total loan portfolio of NPR 200 billion (MFIN Nepal, 2023). MFIs typically offer small loans, savings products, and micro-insurance, tailored to the needs of their clients.

MFIs have been particularly successful in reaching rural farmers and small agribusinesses through group lending models, which reduce the risk of default by leveraging social capital. However, the high interest rates charged by MFIs—ranging from 18 to 24% per annum—can be a significant burden for borrowers although the NRB has provisioned a maximum interest rate of 15%. These interest rate levels are attributed to higher operating costs including monitoring and supervision costs (NRB, 2008). Additionally, MFIs face challenges such as limited access to wholesale funding and high operational costs, which constrain their ability to scale up and offer more competitive financial products.

Similarly, the **non-performing loans (NPLs) in the microfinance sector from 2014 to 2024, compiled from NRB reports, are increasing on a yearly basis** (Yadav, 2024). NPLs were high from **2014 to 2016**, peaking at **14.42%**, before steadily declining to **6.18% by 2020**, due to improved credit management and economic factors. However, since **2023, NPLs have been rising again**, reaching **8.37% in December 2023** and to **8.81% in 2024**, indicating potential repayment challenges, economic distress, or shifts in lending practices. This reversal suggests emerging risks in microfinance loan recovery that warrant further analysis (Yadav, 2024).

2.3 *Cooperatives*

Cooperatives play a crucial role in Nepal's rural economy, particularly in mobilizing resources for agribusiness development (Neupane et al., 2018). There are 31,450 registered cooperatives and a membership base exceeding 7.3 million individuals,

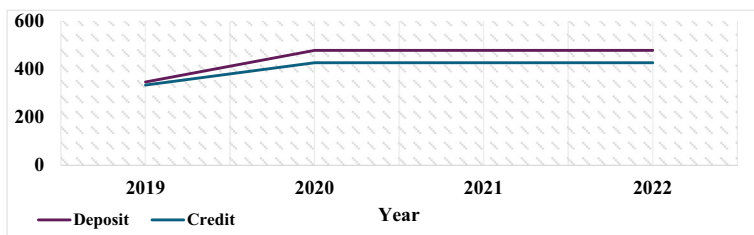


Fig. 1 Year-by-year variation in total cooperative deposit and credit value. *Source* Complication of Data from NRB, Banking and Financial Statistics (https://www.nrb.org.np/contents/uploads/2024/06/FSR-2022_23-2.pdf)

and cooperatives provide a range of financial and non-financial services, including credit, savings, input supply, and marketing (Prasain, 2024).

Agricultural cooperatives have been instrumental in organizing smallholder farmers, facilitating access to markets, and improving product quality. For example, dairy cooperatives have helped smallholder producers in Nepal increase their income by providing better access to markets and negotiating fair prices with buyers. Rizal (2021) indicated that one of the determinants for poverty alleviation in Bagmati and Gandaki Province of Nepal was because of the high contribution of cooperatives. Despite their successes, cooperatives in Nepal face several challenges that limit their potential impact. These include limited access to capital, weak governance structures, and a lack of technical and managerial capacity. Moreover, many cooperatives are heavily reliant on external funding and struggle to achieve financial sustainability.

A cooperative's asset value has been one of the major indicators of the economic status of cooperatives. Since 2016 (except 2019), the asset value of cooperatives in totality has not changed. Further, from 2020 up to 2022, the NRB reports suggest that the deposit and credit of cooperatives have stayed idle. This is to be noted that when an industry indicator stays idle for more than 2 years in a row there is a systemic risk of failure. As such in the years 2021, 2022 NRB during its Financial Stability Report made the following remarks in the report "In the absence of prudential regulation, the cooperative sector faces the risk of financial irregularities, which may affect the stability of the financial system through direct and indirect linkages-2021" and "With the growth of cooperatives and increase in capital and credit, its risk is also increasing. Credit risk, operation risk, and market risk are major inherent risks of the cooperative sector (Fig. 1)."

2.4 Alternate Finance

One of the breakthroughs unfolding within the financial sector is the development of alternative finance mechanisms and the endorsement of these financial institutions by different regulatory organizations. Private equity firms have been enlisted as a

source of alternative financing mechanisms and are registered under the SEBON. Additionally, angel investors, through various incubation and acceleration-led initiatives financed and supported by development partners in Nepal, have shown their interest in supporting innovators within the agrifood system ecosystem in Nepal.

3 Policy Framework and Enabling Environment

A supportive policy environment is essential for the transformation of the agribusiness sector in Nepal. Several key policies have been enacted to promote agricultural development and attract investment in agribusiness. These policies aim to create an enabling environment that encourages innovation, enhances productivity, and ensures the sustainability of agricultural practices. Some of the key policies relevant to agricultural credit facilitations are outlined and discussed below:

3.1 Agriculture Development Strategy (2015–2035)

The Agriculture Development Strategy (ADS) is a long-term strategy aimed at transforming Nepal's agriculture sector into a competitive, sustainable, and inclusive industry. The ADS of Nepal (2015–2035) includes several financial products and services to support the agricultural sector. These include affordable agricultural credit, crop and livestock insurance, subsidies for inputs, microfinance services, and investment funds like the Innovation and Agri-entrepreneurship Fund (INAGEF). These measures aim to enhance productivity and sustainability, ensuring farmers have the necessary resources to thrive.

The strategy emphasizes the need for increased investment in agriculture, particularly in areas such as infrastructure development, research and extension services, and financial services. It also highlights the importance of creating a conducive policy environment supporting private sector agribusiness investment. The implementation of the ADS is expected to have a significant impact on the agribusiness sector, provided that adequate financial resources and effective coordination among stakeholders accompany it. The ADS strategy also identifies establishing matching grants to promote agro-enterprise innovation (includes innovation funds and agro-entrepreneurship programs targeted to youth, women, disadvantaged, groups, and disadvantaged areas) (MoAD, 2015).

3.2 Specialized Investment Fund (SIF) Regulation 2019

The Specialized Investment Fund (SIF) 2019 was established to promote investment in priority sectors, including agriculture and agribusiness. The fund provides financial support to projects that have the potential to generate significant economic and social benefits. The SIF aims to de-risk investments in high-potential but underserved sectors by offering concessional loans, grants, and equity investments.

For the agribusiness sector, the SIF presents an opportunity to attract private sector investment and scale up innovative projects through private equity and venture capital funds. Although the regulation does not delineate any specific aspects of funding related to agriculture, the provisions of venture funds and hedge funds open the possibility of investment in agriculture and agriculture-based industries. The criteria mentioned in the SIF regulation also inhibit private sector funding through fund management mechanisms. Investment of at least NPR 150 million (about USD 1.14 million) is compulsory to start a fund where the fund manager, who runs the fund, must invest at least 2% of that amount, which is NPR 3 million (about USD 23,000), because of these small agribusinesses fail to meet the minimum investment of NPR 735,000 (about USD 5,600) set for this investment purpose. However, the success of the SIF depends on the ability of financial institutions and agribusinesses to utilize the available funds effectively. This requires capacity-building at both the institutional and enterprise levels to ensure that projects are well-designed and implemented.

3.3 Foreign Investment and Technology Transfer Act 2019

The Foreign Investment and Technology Transfer Act 2019 (FITTA) was introduced to attract foreign investment and facilitate technology transfer in key sectors, including agriculture. The act provides a framework for foreign investors to invest in agribusiness ventures in Nepal, with provisions for repatriation of profits, protection of intellectual property, and dispute resolution.

The FITTA is expected to play a critical role in bringing much-needed capital and technology to the agribusiness sector. Initially, foreign direct investment (FDI) in the agriculture sector of Nepal was restricted. However, the Ministry of Industry, Commerce and Supplies (MoICS) of the Government of Nepal, through a notification dated 4 January 2021, has amended the Schedule of Foreign Investment and Technology Transfer Act, 2019, effectively allowing foreign investment in primary sectors of agriculture (UNCTAD Investment Policy Hub, 2021). Through partnerships between domestic and foreign investors, the act can help accelerate the adoption of modern agricultural practices and technologies. Despite of this progress, to fully realize the potential of FITTA, there is a need for clear guidelines and streamlined processes to facilitate foreign investment in agriculture.

3.4 Agri-Business Promotion Policy 2006

The Agri-business Promotion Policy 2006 is a key policy framework that outlines the government's vision for the development of the agribusiness sector in Nepal (Mishra & Paudel, 2023). The policy aims to create a conducive environment for perpetuating the growth of agribusinesses by promoting investment, improving infrastructure, and enhancing access to markets.

Other goals of this policy include increasing agricultural productivity, promoting value addition, enhancing the competitiveness of Nepali agribusinesses in domestic and international markets, and attempting to reduce poverty through commercial agriculture development. Special emphasis also has been provided to the development of public–private partnerships (PPP) to equitable share investment and other resources in the development of agriculture.

The agribusiness policy also has outlined provisions for loan disbursement relying on the gestation period of the agribusiness, promotion of human resources through elaborative agriculture and related education, channelizing at least 20% of the tax revenues generated from the agri-markets for the development of the market and interest subsidies on loan for agriculture transport vehicles which is also reflected in the national budget. To ensure the effective execution of the Agri-business Promotion Policy focused on securing private investment, there is a need for concerted efforts among various stakeholders including government agencies, financial institutions, development partners, and agribusiness operators. The policy still does not address issues of agribusiness insurance and proper financing mechanisms, and therefore, depending on the feedback received from the stakeholders, the policy should be periodically reviewed and updated to incorporate evolving market dynamics and opportunities.

3.5 Agriculture, Livestock, and Medicinal Herb Insurance Directive 2022

The Agriculture, Livestock, and Medicinal Herb Insurance Directive 2022 was introduced to promote the adoption of agricultural insurance as a risk management tool for farmers and agribusinesses. According to Acharya et al. (2024), this directive has ensured that all farmers of each geographical location have access to agriculture and livestock. As of now, 14 life insurance, 14 non-life insurance and 2 re-insurance companies, and 7 micro-insurance companies are providing insurance services in Nepal (NIA, 2022). This directive mandated all the non-life insurers to provide insurance to agriculture, livestock, and medicinal herbs and further required these companies to allocate 5% of the total insurance sold annually to this sector. The directive provides guidelines for the development and implementation of insurance products that cover various risks, including crop failure, livestock mortality, and natural disasters.

By reducing the financial risks associated with agricultural activities, the directive aims to encourage greater investment in agribusiness and improve the resilience of farmers to climate-related shocks. Although agricultural insurance has been expanding in Nepal with directives formalized by the government, the success of agricultural insurance in Nepal depends on the development of proper, affordable, and accessible insurance products as well as better competencies of the insuring companies in managing and mapping agriculture-related risks.

3.6 National Land Use Policy 2015

The National Land Use Policy 2015 provides a framework for the sustainable use of land resources in Nepal. This policy aims to address critical issues related to land fragmentation, degradation, ownership, and tenureship related to land. Private sector investment for agribusiness and access to credit is only ascertained through long-term land tenureship, and therefore, this policy emphasizes securing land tenure for farmers.

3.7 Unified Directives to BFIs and MFIs

The Unified Directives issued by the NRB provide guidelines for the BFIs and MFIs in terms of their lending practices, risk management, and financial reporting. Such a directive issued by NRB intends to ensure the stability of the financial sector, promoting financial inclusion and access to credit specifically in priority but underserved areas like agriculture.

The directives require BFIs and MFIs to allocate a certain percentage of their loan portfolio to priority sectors, including agriculture (Table 1). Further, the NRB in the directives has provisions for concessional loans for smallholder farmers and agribusiness operators, to reduce the cost of credit for marginalized groups and stimulate investment in agriculture for its overall economic growth. Despite the issuance of this directive, NRB has been imposing fines on commercial banks as they fail to meet credit thresholds on the priority sectors specified in the directives (Shrestha, 2022). Therefore, the success of these directives relies on the effectiveness and capacity of banks to manage risks associated with lending in agriculture. There is also a need for checks and balances of commercial banks to ensure they righteously dedicate the funds to priority sectors as mentioned in these directives.

Table 1 Unified directive for allocation of agricultural loans to different financial categories as defined by NRB

Priority	Institution	2020/21 (%)	2021/22 (%)	2022/23 (%)	2023/24 (%)
Agriculture	A	11	13	15	15
Agriculture, SME, energy, tourism	B	16	17	19	20
Agriculture, SME, energy, tourism	C	11	12	14	15

Source Pandey (2022). Extracted and complied from NRB Unified Directive

3.8 Integrated Procedural for Interest Subsidy on Concessional Loan 2075

This procedure has been effectuated by the government for the planned implementation of agriculture-related loans for agribusiness. In this procedure, the government provides an interest subsidy of 5% of the agriculture loan for up to 50 million commercial agriculture and livestock loans, and 2% for more than 50 million. Similarly, as reported by Kathmandu Post (2017), loans up to 1 million in credit can be issued on group guarantee. The revised form of these guidelines also requires agribusiness to be insured to take benefit of these concessional loans.

4 Challenges in Financing Agribusiness Transformation

As the financing issues are deeply entrenched in Nepalese agriculture, the process of transformation of the agribusiness sector in Nepal confronts systematic challenges. Despite the government directives, regulations, and policy concentration on agricultural finance, BFI is reluctant to invest in the agricultural sector. The envisaged goals of commercialization, mechanization, export promotion, and import substitution are priorities of the government and are only possible with properly designated investment and funds in agriculture (Lamichhane, 2022). However, the sector faces challenges which include high perceived risk, inadequate collateral, high cost of credit, limited access to insurance, and weak institutional capacity.

4.1 High Perceived Risk

According to Maurer (2013), the agricultural sector is often regarded as a high-risk sector by the financial sector due to inherent issues like weather conditions, pest infestation, and unexpected market-related fluctuations. Formal financial institutions often exhibit disinclination to invest in agriculture and its related activities due to

these primary risk factors linked to it, which makes it difficult for smallholder farmers who are often financially illiterate to avail the services offered by formal banking institutions.

4.2 Inadequate Collateral

Another important reason commercial banks show their disinterest in financing agribusiness in the country is the lack of adequate collateral (Mathema, 1988). Most of the smallholder farmers in Nepal lack possessions of valuable assets or entitlement of prized land which could be used as collateral and security in exchange for the loan amount. Even in the case of ownership of assets or lands for collateral, the valuation of the assets inhibits the process of acquiring financing from the formalized banking institutions in Nepal.

4.3 Credit Ceiling

The ceiling of agricultural loans for the cooperatives is limited to NPR. 10 million. The ceiling amount considering the volume of transactions and scope of work of the cooperatives is too minimal. In case of an increment of the credit ceiling for the cooperatives, they will be more actively invested in installing cold storage and post-harvest operations through mechanization, go-downs, or agri-input purchases facilitating overall sectoral growth in the long term.

4.4 Limited Access to Insurance

The reliance on monsoon-based farming for major commodities, pest infestation, natural disasters, vagaries of climate, and non-assurance of market makes Nepalese agriculture vulnerable and fragile. Despite such challenges, agricultural insurance companies are reluctant to insure crops and livestock in Nepal, as they fail to estimate accurate risk estimation due to damage to the crops or mortalities of the livestock. Due to this issue and the lack of confidence of farmers on insurance of the market only a small percentage of farmers are covered by insurance products which raises systematic issues in agriculture.

4.5 *Weak Institutional Capacity*

BFI in Nepal show inadequacy in terms of technical expertise and capacity to assess and manage risks related to agriculture lending. Therefore, BFIs usually prefer to understand liquidity position, repayment capacity, debt–equity ratio, profitability, managerial quality and strength, performance record, sector of loan, market competition, size of the loan, and quality of collateral security, before handing out the outlays as agricultural loans (Adhikari, 2022). The lack of capacity of commercial banks is a significant barrier to increasing the flow of credit to the agribusiness sector.

5 Exploring Innovative Finance and Alternative Finance

Since the conventional financing mechanisms in Nepal are failing to deliver rapid agricultural sectorial transformation, to overcome the challenges of financing agribusiness transformation, it is essential to explore innovative and alternative financing mechanisms. These mechanisms can play a crucial role in de-risking investments and mobilizing additional financial resources in agribusiness.

5.1 *Blended Finance*

In the case of high-impact and priority sectors like agriculture, blended finance is an innovative financing approach that unites the funding from the public or any philanthropic sources with commercial capital to de-risk investments. As agriculture sectors and related investment are deemed to be risky, the blended financing approach can counteract this understanding and encourage private sector investment in numerous agribusiness projects. As the country has ambitions to execute large-scale agricultural projects, the provision of blended finance in the policies can be particularly effective in financing large-scale agribusiness projects with demand huge initial capital investment. To illustrate, the scope of blended financing can be practically applied to projects like storage facilities or the development of modern irrigation systems that will enhance agricultural productivity and increase the market outreach of the products.

5.2 *Crowdfunding for Agribusiness*

Crowdfunding has recently been applied as a financing mechanism that allows individuals or organizations to raise capital investment from several people through online platforms. According to Filimonova et al. (2019), the sphere of agriculture

often meets difficulty in receiving financial resources from traditional sources for financing innovative and investment projects, and crowdfunding can be a useful alternative funding mechanism to finance agribusiness and rural areas development projects. Crowdfunding can be used to finance innovative agricultural projects, such as the development of new crop varieties or the adoption of sustainable farming practices. Additionally, crowdfunding can help build a community of supporters around a project, which can be valuable for marketing and business development.

5.3 Value Chain Financing

Value chain financing refers to the provision of financial services along the agricultural value chain spanning from the input suppliers to the farmers. The competitiveness of the agricultural sector and its efficiency can be improved by providing value chain financing at different stages of agricultural operations. For reference, input suppliers can provide agricultural credit to the farmers to assist in their purchase of seeds, fertilizers, and other necessary inputs. Meanwhile, processors can also fund farmers to conduct their agriculture practices for a guaranteed supply of the produce. Overall, value chain financing can be used to develop agribusiness clusters, improve economies of scale, and empower all actors within the chain for the sector's holistic development.

5.4 Digital Finance Innovations

Digital financing innovations, such as the facilitation of loans through digital platforms, hold enormous potential as alternative financing mediums to revolutionize the way financing solutions are being delivered in the agriculture sector. By leveraging digital technologies, financial institutions can reduce the cost of delivering services, improve access to credit, and enhance overall financial inclusion. One such initiative has already been seen with the collaboration of Kheti and NMB Bank through the rollout of a financing product called NMB Kheti Karja is a collateral-free, quick, paperless, and hassle-free digital loan product designed for the farmers who are a part of agri-tech platforms. Through this paperless and hassle-free initiative, agribusiness can avail the loan amounts ranging from NPR. 10,000 to the maximum amount of NPR 2,00,000.

5.5 Climate Finance

Under the Paris Agreement, developed countries have committed to mobilizing USD 100 billion per year by 2020 to support climate action in developing countries. Nepal,

as a signatory to the Paris Agreement, is eligible to access this funding to support its climate change adaptation and mitigation efforts. To access climate finance under the Paris Agreement, Nepal must develop robust project proposals that align with its Nationally Determined Contributions (NDCs) and demonstrate the potential for high-impact climate action. Additionally, Nepal needs to strengthen its institutional capacity to manage and implement climate finance projects, including improving its financial management systems and monitoring and evaluation frameworks.

Climate finance can prove pivotal in transforming Nepal's agribusiness sector by streamlining the funds for the adoption of climate-resilient agricultural practices, improving access to climate-smart technologies, and building the capacity of farmers and agribusinesses to adapt to dynamic scenarios resulted due to climate change. For example, climate finance can be leveraged to promote the development of drought-resistant crop varieties and climate-smart irrigation systems and support the transition to regenerative agriculture practices by sharing the funding received with the farmers. To negate the adverse consequences of climate change, climate finance can also be used to finance insurance or other risk management measures within the agribusiness.

6 Institutional Capacity-Building for Agribusiness Financing Transformation

The successful and smooth transformation of the agribusiness sector in Nepal requires a strong institutional capacity at all levels and among various actors and enablers, ranging from government institutions to financial institutions linked within the agricultural chain. Institutional financial mechanism is a prerequisite for developing the required skills, knowledge, and systems that are needed to robustly implement policies, make financing more accessible, and deliver finance-related services effectively.

6.1 *Building Capacity in Government Agencies*

The role of government agencies is critical for the overall agricultural sectorial development through the implementation of policies that support agricultural transformation. Different government structures—local, provincial, and federal—play distinct roles in organization of the agribusiness finances. **Local governments** are mainly responsible for direct support to farmers, implementing agricultural programs, facilitating access to credit, and coordinating with cooperatives and microfinance institutions. **Provincial governments** are accountable on formulation of regional agricultural policies, capacity-building initiatives, and ensuring alignment between local needs and federal strategies. Lastly, **the federal government** oversees national policy formulation, regulatory frameworks, govern the flow of capital in agribusiness and

large-scale financial programs while ensuring coordination among provinces and international financial partners. Despite this, many government agencies in Nepal are confronted with challenges specific to capacity, delivery of technical expertise in projects related to agribusiness financing, constrained financial resources, and weak liaison between different layers resulting in inconsistent coordination mechanisms. According to Joshi and Joshi (2021), weak governance within and between the governments, the private sector, and local communities' results in bad policy or bad policy implementation. To effectively aim at remedial measures for these challenges, targeted capacity-building focusing on improving the technical skills of government officials, strengthening financial management systems, and enhancing coordination among government agencies and other stakeholders should be prioritized. Governmental agencies need to be equipped with all the necessary tools, skillsets, and knowledge to functionally deliver agribusiness and financing-related services to the concerned small-scale farmers and agribusiness operators.

6.2 Strengthening Financial Institutions

Financial institutions like BFIs are the bedrock for propelling growth in the agricultural sector, by provisioning the financing services required for investment in commercialization, and mechanization of the traditional agricultural functional setup within the country. Despite their fundamental role in providing credit facilities in high-priority and underserved sectors like agriculture, the BFIs still is in shortage of key technical persons and guidelines for effectively assessing and managing the risks linked with agricultural lending. This inability of the BFI to assess limits the flow of credits to agribusiness, negatively impacting farming communities' socioeconomic capacity and other social-economic pillars of the country. Training programs and activities need to be formulated to banking professionals focusing on agricultural financing, risk assessment, and credit management to empower the capacity of financial institutions. Similarly, financial institutions should be encouraged either through directives or policies to devise specialized financial products focused on the emerging needs of agribusiness like value chain financing and digital financing hassle and collateral-free loan mechanisms to stimulate long-term agriculture sectorial development.

6.3 Building Capacity in Agribusinesses

Agribusiness themselves should also enhance their ability and competency to manage their daily operations, search methods of financial accessibility, and compete in the market with stress induced by domestic and international markets. Agribusiness needs to be trained in core functional areas such as business management, financial planning, market analysis, and strategy to market their products. Agribusiness also

needs to be receptive to new technologies and sustainable global practices focused on advancing productivity and sustainability. Training programs, technical assistance, and access to finance for investment in new technologies should be promoted among agribusiness to enable them to deliver and be a vital cog in sectorial transformation.

7 Mainstreaming Finance as a Nation-Building Tool

Finance is an impactful tool for overall nation-building and the well-being of its citizens. The provision of financial services is key to driving economic growth, reducing poverty, and developing society. Through mainstream investment in high-priority economic sectors of the country like agriculture and agribusiness, financial mechanism aids in building a resilient nation.

7.1 The Role of Finance in Economic Growth

In the context of agribusiness, finance can support the development of new enterprises, the expansion of existing businesses, and the adoption of new technologies and practices to endorse productive and resilient agricultural practices. However, to ensure the maximization of the impact of finance on agribusiness growth, the financial resources should be funneled down among the farmers equitably and seamlessly. Achieving this is a challenging task as it requires robust financial management systems, transparent governance, and effective monitoring and evaluation mechanisms of the existing directives or regulations related to provisioning financing products and solutions among agribusinesses.

7.2 Leveraging Finance for Systemic Investments

Systemic investments are those that have the potential to create long-lasting change by addressing the root causes of poverty and inequality. In the agribusiness sector, systemic investments can include the development of infrastructure, the promotion of sustainable agricultural practices, and the strengthening of value chains.

By leveraging finance for systemic investments, Nepal can create the conditions for sustained economic growth and development. For example, investing in irrigation infrastructure can improve agricultural productivity, increase food security, and reduce vulnerability to climate change. Similarly, investing in value chains can enhance the competitiveness of Nepali agribusinesses and create new opportunities for income generation.

7.3 *Finance as a Tool for Poverty Reduction*

Finance and financing solutions offered can significantly boost poverty reduction by providing access to credit to underserved yet priority sectors like agriculture and the smallholder farmers and rural entrepreneurs reliant on it for their daily economic activities. For this to turn into reality, it is essential to promote financial inclusion and develop financial products and services that are accessible and affordable for all. Through better-developed financial products through rigorous consultation, Nepal can empower its agriculture sector for the overall development of the country and attain the envisaged goals of commercialization, export promotion, and import substitution shortly. Modern digital tools like digital financial services need to be leveraged effectively to overcome the any barriers faced by the agribusiness operators in the rural regions of the country.

8 Graduating from LDC

Before concluding this chapter, it is important to understand the country's evolving financial and economic landscape, as it undergoes a significant transition from a financial perspective. In 2015, Nepal surpassed the LDC graduation threshold, and in 2018 it became eligible for graduation but deferred and was subsequently recommended for graduation in 2021. Nepal will graduate in 2026, and we must investigate the different aspects of graduation and what it means to the financial flow. Post-graduation the country's financial landscape is expected to change, with a major reduction in access to concessional loans and grants. This will create a need for the development of innovative financing mechanisms and stronger public and private partnership mechanisms to activate international investments. So, the next dialogue for food system transformation and the role of financial services will be to develop an inclusive and resilient financial ecosystem to build on the losses of graduation and capitalize on the opportunities it can induce.

9 Specific Policy Recommendations

See Table 2.

Table 2 Specific policy recommendation using gri-finance for agricultural transformation

Policy areas	Recommendations
Financial interest rates and loan portfolio	Differential interest rates for priority sectors like agriculture and agribusiness
	Develop refinancing schemes with lower interest rates for rural and marginalized farmers
Capital flow	Easier access to FDI in sustainable and green agribusiness to give impetus to sustainable local economy generation
	Develop policies to channel remittances to productive investments, such as infrastructures and entrepreneurship.
Financial governance	Regulatory oversight to ensure transparency and accountability in financial institutions
	Strengthen intergovernmental coordination to align monetary and fiscal policies effectively
	Increasing the access to capital in rural and underserved areas through modern means of digital banking and microfinance.
Climate finance and blended finance	• Establish green financing mechanisms to support climate-resilient agriculture and agribusiness • Promote subsidies or low-interest loans for investments in sustainable farming practices • Public–private partnership (PPP) models to de-risk investments in key sectors • Utilize donor and development funds and grants to galvanize the investment from the private sectors to de-risk investment

Source Author formulated

10 Conclusions

With regulations comes more streamlined policies that de-risk investments. With the country evolving toward a more saving-based economy rather than an investment economy, financial service providers, such as the commercial banks and micro-finance institutions, have had limited strategic investments for agrifood system transformation in Nepal.

The policy level input has been placed, and the government of Nepal time and again comes with innovative financial support services through incentives and subsidies within the agribusiness financial sectors be it mandating investments in agribusiness by commercial banks or providing interest subsidies in validated agri-loans.

The transformation of Nepal's agribusiness sector is a complex and multifaceted process that requires coordinated efforts from all stakeholders, including government agencies, financial institutions, agribusinesses, and development partners. By addressing the challenges in financing agribusiness transformation and exploring

innovative and alternative financing mechanisms, Nepal can unlock the potential of its agribusiness sector and create the conditions for sustained economic growth and development.

Climate finance, institutional capacity-building, and the mainstreaming of finance as a nation-building tool are key components of this transformation. By strategically investing in agribusiness and leveraging finance for systemic investments, Nepal can achieve its development goals, reduce poverty, and build a more prosperous and resilient nation.

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Part II
Education, Research, and Extension

Chapter 9

A Roadmap for Transforming Nepalese Agriculture Through the Application of Simulation Modeling and Digital Innovations



Krishna Devkota, Jagadish Timsina, Dinesh Panday, and Upendra Singh

Abstract Nepal's agriculture faces multiple challenges, including low productivity, fragmented landholdings, climate vulnerabilities, and inefficient resource utilization. These challenges not only hinder agricultural productivity but also threaten food security and the livelihoods of millions of smallholder farmers. Simulation modeling and artificial intelligence (AI) tools—such as crop models, Geographic Information Systems (GIS), remote sensing, machine learning, and digital platforms—offer transformative solutions to address these issues and modernize agriculture. This chapter presents an actionable roadmap for implementing these tools in Nepal, emphasizing scalable strategies and region-specific applications to address agricultural constraints. It focuses on optimizing resource use, enhancing yield forecasting, improving climate resilience, and empowering farmers through data-driven ICT-enabled agro-advisory services. It provides insights into financial and operational frameworks necessary for technology integration, with specific emphasis on provincial-level implementation and stakeholder capacity building. The roadmap highlights key requirements, including the development of robust data and computational infrastructures, capacity building for stakeholders, and the integration of crop modeling and digital tools into national agricultural policies. It also identifies barriers to scaling up those tools across diverse agroecological zones. The chapter underscores the need for fostering collaboration across public and private sectors to enhance productivity, sustainability, and resilience in agriculture. We hope that the

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insights and recommendations provided in this chapter serve as a guide for policy-makers, researchers, extensionists, and leader farmers for transforming agriculture into productive, sustainable, and climate-resilient, ultimately improving food security and farmers livelihoods.

Keywords Crop modeling · Digital agriculture · Geographic and information systems (GIS) · Climate-smart agriculture · Machine learning in agriculture · Sustainable agricultural practices

1 Introduction

Agriculture remains a cornerstone of Nepal's economy, supporting more than two-thirds of the population and serving as a critical pillar for economy, food security and rural livelihoods. However, the sector faces significant challenges, including low productivity, reliance on traditional practices, fragmented land holdings as well as vulnerability to climate change. These challenges are further exacerbated by limited adoption of advanced agricultural technologies, constrained by inadequate policy support, weak institutional frameworks, and gaps in skilled human resources (Krupnik et al., 2021). Consequently, transformative tools—such as crop simulation models, geographic information systems (GIS), remote sensing, machine learning (ML), artificial intelligence (AI), digital twin technologies, and digital platforms, including ICT-based agro-advisory services—remain underutilized, despite their demonstrated potential to enhance productivity, optimize resource use, and strengthen climate resilience (Devkota et al., 2022).

Nepal's Diverse agroecological zones, combined with the increasing impacts of climate variability, underscore the urgent need for adopting these technologies to bridge yield gaps, promote climate-smart practices, and drive sustainable agricultural growth (Devkota et al., 2022; Pandey, 2012). Widely used crop modeling techniques and digital tools—such as the Decision Support Systems for Agro-technology Transfer (DSSAT), Agricultural Production Systems Simulator (APSIM), ORYZA, CropSyst, and AquaCrop—have demonstrated success in developed countries, improving resource efficiency and building climate resilience. However, their effective implementation in Nepal faces significant structural and systemic challenges.

While the existing legal frameworks support agricultural development, they lack comprehensive provisions for the integration of simulation models and digital tools into national strategies. Moreover, the policy environment offers limited incentives for innovation and fails to establish guidelines to align these technologies with extension systems and research institutions. Institutional fragmentation further hinders progress, as research and extension services often operate in silos, limiting the coordination and capacity required to adopt and operationalize these technologies for Nepal's unique agroecological conditions highlights the need for targeted capacity-building programs.

Notable studies, such as Devkota et al. (2022), have provided a comprehensive analysis of crop modeling applications in agricultural research. Similarly, Timsina and Humphreys (2006a, 2006b) evaluated and highlighted diverse applications of DSSAT, particularly CERES-Rice and CERES-Wheat, models demonstrating their relevance for addressing climate change impacts in South Asia's rice–wheat systems, including Nepal. For a deeper understanding of the role and potential of crop simulation models in South Asia, readers are encouraged to explore these studies. Expanding the scope of these models, alongside locally developed digital tools like GeoKrishi, Krishi Guru, Smart Krishi, and Digitally Enabled Seed Information system (DESI) is essential to maximize their potential benefits across country's diverse agricultural contexts.

This chapter critically examines the role of crop simulation models and emerging and established digital tools to transform Nepalese agriculture by addressing barriers related to policy, legal frameworks, institutional structures, and human resources. It emphasizes scalable pathways to leverage the country's existing digital platforms and explores strategies to overcome their current limitations. Despite their promise, these initiatives remain limited in scope and impact in Nepal. Key pathways include aligning legal and policy frameworks to incentivize innovation, fostering public–private partnerships to build infrastructure, and integrating digital tools into national research and extension systems. Investing in human resource development through targeted training programs and establishing dedicated research centers will be crucial to adapting and applying these tools effectively. Additionally, region-specific strategies for deploying these tools are vital to ensure their scalability and relevance to local conditions. By creating an enabling environment through institutional reforms, policy alignment, and collaborative initiatives, Nepal can unlock the transformative potential of simulation models and digital tools, achieving a more productive, sustainable, and climate-resilient agricultural sector. This roadmap provides actionable strategies for policymakers, researchers, and practitioners to accelerate the integration of these technologies, advancing agricultural development on a national scale.

2 Simulation Modeling and Digital Tools with Transformative Potential

This section explores the potential simulation modeling and digital tools appropriate for Nepalese context, emphasizing their role in enhancing efficiency and sustainability across diverse agroecological zones.

2.1 Crop Simulation Models

Figure 1 provides a comprehensive system-based framework showing how crop simulation and AI models and digital tools interact with key agricultural components to inform decision-making. The framework integrates biophysical such as climate, soil, genotype, irrigation and agricultural technologies and socio-economic dimensions including demographics, land use, markets, and income levels with scenario modeling such as climate change, policy, science-policy integration, and develop socio-technical bundle solutions. Diverse data sources—such as from field experiments and remote sensing to environmental, ecological, and policy are combined using digital tools, machine learning, and big data analytics. These feed into integrated models that simulate the interaction of agricultural systems at multiple scales, from gene and plant level to field, landscape, and watershed levels. The outputs generated include insights on crop productivity, food and nutrition security, precision farming, and resource use efficiency (land, water, nutrients, SOC, biodiversity). The framework also supports climate change adaptation and mitigation strategies, improved decision support systems, and alignment with Sustainable Development Goals (SDGs), highlighting the potential of data-driven, integrated solutions in sustainable development. In Nepal, models such as DSSAT, APSIM, EPIC (Environmental Policy Integrated Climate), and others have been utilized to analyze yield gaps of major crops like wheat, rice, and maize (Table 1). For instance, DSSAT has been applied to evaluate nitrogen management strategies in rice and wheat systems, offering evidence-based recommendations to improve efficiency while minimizing environmental impacts (Devkota et al., 2024; Timsina & Humphreys, 2006a, 2006b). Similarly, APSIM has provided insights into maize yield improvement under varying management scenarios, emphasizing site-specific nutrient and water management (Gaydon et al., 2017).

2.2 Geographic Information Systems and Remote Sensing

GIS and remote sensing technologies are powerful tools for spatial analysis and monitoring agricultural systems. Their applications include:

Precision agriculture: GIS enables the creation of soil nutrient and moisture maps, guiding site-specific fertilizer application and irrigation scheduling.

Risk mapping: Remote sensing, using platforms like Sentinel-2, allows real-time monitoring of crop health, drought risk, and pest outbreaks. For example, GIS-based drought mapping in Terai region has helped prioritize water resource allocation (Devkota et al., 2022).

Climate monitoring: Combining GIS with historical and real-time weather data provides actionable insights for climate-smart agriculture.

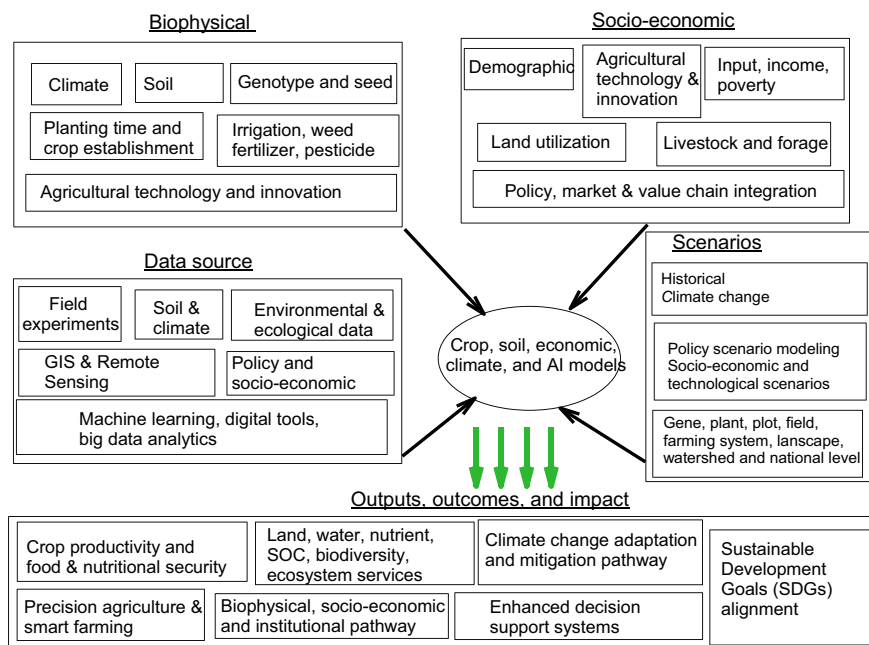


Fig. 1 Integrated framework for the use of biophysical, socio-economic, climate and AI models to support agricultural systems and sustainability goals (Modified from Devkota et al., 2022). SOC = Soil organic carbon; GHG = Greenhouse gas emission

However, the adoption of GIS and remote sensing remains limited due to cost barriers and a lack of technical capacity in Nepal. Subsidizing those tools and integrating their use into provincial agricultural departments could significantly enhance their adoption.

2.3 Machine Learning and Artificial Intelligence

Machine learning and artificial intelligence (AI) have emerged as critical tools for analyzing complex datasets, predicting trends, and optimizing decision-making in agriculture. Their applications in agriculture include:

Yield prediction: ML algorithms analyze satellite imagery, weather data, and historical crop yields to predict outcomes with high accuracy. This approach can help mitigate risks and improve planning. It can also be combined with model-generated yields to refine predictions.

Pest and disease monitoring: AI-driven tools identify pest infestations and diseases using image recognition and recommend timely interventions. For instance,

Table 1 Application of crop models for assessing yield, resource use, and climate risks across major crops in Nepal

Parameters studied	Models used ¹	Crop	References
Yield gap/trend analysis/ energy use/GHG emissions	EPIC	Major grain crops	Basukala and Rasche (2022); Devkota et al. (2024)
	APSIM	Wheat	Devkota et al. (2024)
	CEREC-Rice	Rice	Jha et al. (2019)
	DSSAT	Rice	Amgain et al., (2021, 2022); Timsina et al., (2021, 2022)
	AquaCrop	Maize	Sedhai et al. (2023)
Soil and water management	AquaCrop	Rice, wheat Maize	Shrestha et al., (2013a, 2013b)
Climate risks	APSIM and DSSAT	Rice, wheat	Darai (2019)
Crop yield	APSIM	Wheat	Campolo et al. (2021); Kaini et al. (2022), Gaydon et al., 2017
	SWAT	Rice, wheat Maize	Palazzoli et al. (2015)
	DSSAT	Maize, wheat	Laborde et al. (2019); Rai et al. (2011), Devkota et al. (2016); Timsina et al., (2021, 2022)

convolutional neural networks (CNNs) have been used in South Asia to detect diseases in rice crops with over 90% accuracy (Islam et al., 2023).

Market intelligence: AI-based systems analyze market trends and provide farmers with recommendations on when to sell their produce for maximum profit.

2.4 ICT-Based Platforms

Information and Communication Technology (ICT)-based platforms, such as GeoKrishi, Smart Krishi, Krishi Guru, and DESIS, are vital for disseminating timely and actionable information to farmers. Such platforms provide:

Weather advisories: Delivering localized weather forecasts enables farmers to plan planting and irrigation schedules effectively.

Pest alerts and crop management tips: ICT platforms inform farmers about emerging threats and recommend best practices for pest and disease management.

Market connectivity: Real-time price information and market demand updates and empower farmers to make informed selling decisions.

2.5 *Economic Modeling and Decision-Making Tools*

Economic modeling tools, combined with crop models, can support policymakers and stakeholders in designing cost-effective and evidence-based interventions. Their applications include:

Cost–benefit analysis: Evaluating the economic feasibility of adopting new technologies or practices, such as precision agriculture tools.

Policy simulations: Predicting the outcomes of subsidy programs or pricing policies on farmer incomes and productivity.

Risk assessment: Quantifying economic risks associated with climate variability and market fluctuations.

Existing models, such as DSSAT, can perform economic analysis and risk assessment.

3 Applications of Crop Modeling and Digital Tools in Nepalese Agriculture

3.1 *Yield Forecasting*

Crop modeling, ICT-based agro-advisory tools, remote sensing, GIS, and advanced technologies like ML and AI offer actionable insights for yield forecasting. Crop growth models have demonstrated 15–20% improvements in yield through site- and soil-specific recommendations. For instance, the Smart Krishi App has been downloaded over 100,000 times, helping increase crop yields by 10–15% (GeoKrishi, 2024). Integrating Sentinel-3 SLSTR imagery, soil data, and topographic features with ML models like XGBoost has shown superior accuracy and cost-efficiency in crop yield estimation (Sahbeni et al., 2023). Combining remote sensing with meteorological data and ML has also enhanced rice yield estimation accuracy to 92% in the Terai region (Islam et al., 2023).

3.2 *Yield Gap Analysis*

The existence of high yield gaps—defined as the difference between potential yield under optimal management and farmers’ field yields—is a significant barrier to enhancing agricultural productivity in Nepal. Crop models like DSSAT have been instrumental in analyzing yield gaps in rice and wheat, offering insights into productivity constraints and measures for improvement (Devkota et al., 2015, 2016, Krupnik et al., 2021; Timsina et al., 2006a, 2006b). Similarly, APSIM has been applied to maize yield gap studies, emphasizing the role of improved management and technology adoption (Devkota et al., 2024; Timsina et al., 2021).

3.3 Resource Optimization

Efficient resource utilization is essential for sustainable agriculture, where challenges like fragmented landholdings, water scarcity, and inefficient fertilizer use prevail. DSSAT, APSIM, AquaCrop, and Nutrient Expert have shown improvements in irrigation and fertilizer use efficiency, optimized fertilizer recommendations in maize farming, and reduced energy use and greenhouse gas (GHG) emissions (Devkota et al., 2016, 2024; Shrestha et al., 2013a, 2013b; Timsina et al., 2021). The GeoKrishi platform has further enabled farmers in Terai region to reduce fertilizer usage by 20% through soil nutrient mapping and precise recommendations (GeoKrishi, 2024). Remote sensing tools like Sentinel-2 have achieved over 85% accuracy in monitoring crop health and predicting yield outcomes, supporting better resource allocation (Sahbeni et al., 2023). Machine learning algorithms have also proven effective in predicting cereal yields and explaining their variability (Timsina et al., 2021) and predicting pest outbreaks, reducing pesticide use by 15% (Thorat et al., 2023). These innovations reduce resource waste, carbon footprint, and environmental impact, contributing to sustainable agricultural practices.

3.4 Climate Resilience and Adaptation Strategies

Simulation modeling and digital tools offer critical means to predict, mitigate, and adapt to the adverse effects of climate change. DSSAT, APSIM, and AquaCrop simulate crop performance under varying climatic scenarios, enabling predictions of yield outcomes and identifying adaptive strategies for each of those scenarios. For instance, DSSAT has been used to predict rice yields in central Terai region under changing climatic conditions, emphasizing the need for climate-resilient rice cultivars (Amgain et al., 2021; Devkota et al., 2022; Timsina et al., 2021). APSIM has been applied to study climate change impacts on maize and wheat across Asian countries, including Nepal, providing strategies for adaptation and mitigation (Gaydon et al., 2017). AquaCrop has demonstrated its utility in evaluating water requirements for wheat and maize under future climate scenarios, suggesting improvements in irrigation efficiency (Shrestha et al., 2013a, 2013b). GIS-based risk mapping identifies vulnerable areas while remote sensing enables early warning systems. These technologies support designing adaptation strategies, including developing climate-resilient crop varieties, adjusting planting schedules, and improving soil and water management.

3.5 Soil Health and Fertility Management

Maintaining soil health and fertility is fundamental to achieving sustainable agriculture. However, widespread challenges such as soil degradation, nutrient depletion and imbalance, erosion, and insufficient data and testing infrastructure hinder progress. Advanced digital tools and crop simulation models offer innovative solutions by simulating nutrient dynamics, predicting long-term soil health, and enhancing soil organic matter management. These tools diagnose soil issues, optimize fertilizer use, and promote sustainable practices tailored to diverse agroecological zones. Integrating simulation modeling with GIS, remote sensing, and mobile-based platforms can make soil health management more accessible and provide targeted fertilizer advice. Key strategies like site-specific nutrient management (SSNM), integrated soil fertility management (ISFM), and the adoption of climate-smart practices can significantly improve soil health and ensure accurate nutrient recommendations and sustainable practices. Crop simulation models such as DSSAT have been calibrated and validated to simulate nitrogen dynamics in maize and rice fields in several districts of Nepal, demonstrating optimized nitrogen management for higher yields and reduced environmental impact (Bhusal et al., 2010; Timsina et al., 2021). Similarly, the Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) model, endorsed by the Nepalese government, provides site-specific fertilizer recommendations for various crops, enhancing productivity (CIMMYT, 2022). These models not only identify nutrient deficiencies or excesses but also ensure that crops receive appropriate nutrients at the right time. By integrating crop simulation models, GIS, ML, and remote sensing into soil health management, Nepal can create a resilient agricultural system that supports productivity while protecting natural resources. These efforts will be instrumental in addressing current challenges and building a sustainable foundation for future agricultural growth.

3.6 Pest and Disease Management

Pests and diseases are major constraints to agricultural productivity, causing losses that often exceed 30% of potential yields in staple crops such as rice, wheat, and maize. Climate change further exacerbates these challenges by altering pest dynamics and increasing the frequency of outbreaks. Digital tools and crop simulation models offer innovative solutions to predict, prevent, and manage pest and disease risks, reducing losses while minimizing reliance on chemical inputs. For example, the spread of the tomato pest *Tuta absoluta* was modeled using a network-based approach to assess the impact of regional trade on its dissemination (Venkatramanan et al., 2020). However, the country faces challenges such as invasive pests, excessive pesticide use, and limited early warning systems. Decision-support platforms can accelerate the integration of strategies such as Integrated Pest Management (IPM), biocontrol agent evaluation, crop rotation guidance, and precise pesticide application

to reduce overuse and mitigate environmental impacts. Key actions for sustainable pest management include:

- Integrating GIS and remote sensing with national pest monitoring networks to issue timely alerts.
- Equipping stakeholders with tools and knowledge for implementing IPM and decision-support systems.
- Investing in research and promoting the use of natural predators and biopesticides to reduce chemical dependency.
- Establishing regulations to limit pesticide overuse and incentivize sustainable practices.
- Piloting digital tools and crop models in pest-prone areas to evaluate their scalability and effectiveness.

Efforts in the mid-hills, with the use of Farmers' Field Schools and agricultural extension programs, have already demonstrated success in promoting IPM. Transforming these initiatives into digital-learning platforms can further empower farmers to adopt economically and environmentally sustainable practices. By leveraging digital tools, simulation models, and ML, the country can modernize pest and disease management, reducing crop losses and fostering sustainable agricultural development.

3.7 Water Use Efficiency and Irrigation Management

The country faces pressing challenges in water management, including erratic rainfall, limited irrigation infrastructure, and inefficient water use practices, which are exacerbated by the impacts of climate change. Efficient water use is vital for agriculture, particularly in regions with constrained water resources. Crop simulation models and digital tools provide innovative solutions to optimize irrigation management and enhance water use efficiency.

Models such as CROPWAT and AquaCrop have been effectively utilized to assess the impact of climate change on crop water requirements. For instance, these models aided the development of water-efficient irrigation strategies in the Kamala River Basin in southeast Nepal (Dawadi et al., 2022) and minimized water usage while maximizing maize productivity in Chitwan, central Nepal (Shrestha et al., 2013a, 2013b). These tools enable the prediction of future water needs, ensuring crops receive adequate water without wastage.

Technologies like IoT devices, including soil moisture sensors and automated irrigation controllers, further enhance real-time water management. GIS and remote sensing-based approaches can support deficit irrigation, conservation agriculture, and improved canal efficiency. Key interventions for sustainable water management include:

- **Promoting efficient technologies:** Policies should encourage the adoption of drip and sprinkler irrigation systems, with subsidies for smallholder farmers.
- **Capacity building:** Training extension workers and farmers on using simulation models and digital tools to manage water resources effectively.
- **Infrastructure investment:** Modernize irrigation systems and improve existing infrastructure to minimize water losses.
- **Pilot programs:** Implement projects in water-stressed areas to demonstrate the effectiveness of tools like AquaCrop and IoT systems.

3.8 Strengthening Supply Chain and Market Linkages

Efficient supply chain management and robust market linkages are vital for ensuring the profitability and sustainability of agricultural activities. Crop models and digital tools play a pivotal role by providing accurate predictions of production volumes, harvest schedules, and market demand. This information enables farmers, traders, and agribusinesses to make informed decisions regarding production planning, storage, transportation, and marketing strategies. Strengthening these linkages can significantly enhance market access, reduce post-harvest losses, and improve the economic viability of agriculture (Kafle et al., 2022).

3.9 Empowering Communities for Technology Adoption

The integration of ICT with DSS and agro-advisory services has transformative potential to enhance agricultural practices and productivity. ICT-based platforms, leveraging advanced tools such as crop models, GIS, remote sensing, and mobile applications, provide farmers with timely, location-specific, and actionable information for better decision-making. These tools empower farmers to make informed choices on planting dates, irrigation management, fertilization strategies, pest and disease control, harvesting times, and market decisions. Combining crop models with extension services and digital tools—such as mobile apps, SMS-based advisories, cloud platforms, interactive voice response (IVR) systems, and GIS and remote sensing—ensures access to reliable, locally tailored advice. Weather-based advisories, pest alerts, crop management tips, and market updates in local languages promote inclusivity and encourage broader adoption, ultimately improving farming outcomes.

Crop models also demonstrate the benefits of modern agricultural technologies, such as precision agriculture tools, improved seed varieties, and mechanization. By highlighting their positive impacts on yield, resource efficiency, and profitability, these models motivate farmers to adopt innovative practices. Integrating ICT-based platforms into teaching, research, extension services, and policymaking is essential

to accelerating the adoption of advanced agricultural technologies and driving the transformation of agriculture.

4 A Roadmap for Developing and Implementing Crop Modeling and Digitalization in Nepalese Agriculture

As stated earlier, the integration of crop modeling and digital tools has potential to revolutionize Nepalese agriculture as such tools offer opportunities to address challenges such as fragmented landholdings, low productivity, and climate vulnerabilities while promoting sustainable agricultural growth. However, developing and operationalizing such a roadmap requires targeted actions to address existing gaps in infrastructure, human resources, policies, and collaboration frameworks. This roadmap outlines the critical steps needed for successful implementation, focusing on human resources, institutional capacity, policy integration, financial investments, and governance mechanisms.

4.1 *Building Human Resources and Capacity Development*

Building skilled human resources is fundamental for effectively implementing advanced modeling and digital tools. Targeted capacity-building efforts should include:

Educational program: Universities should update their curricula to include courses in quantitative techniques and evaluation and mathematics for agriculture graduates. In addition, training in crop modeling, GIS, remote sensing, and data analytics would be necessary. Partnerships with international institutions can provide access to cutting-edge tools and global best practices. [Click or tap here to enter text.](#)

Training program: Government and private-sector stakeholders should conduct hands-on training sessions for extension agents and policymakers, focusing on the practical application of modeling tools. Programs should be tailored for diverse stakeholders, ensuring inclusivity and accessibility to local languages.

Retention strategies: To address the brain drain of skilled professionals and ensure long-term sustainability, education, research and extension institutions must provide incentives for in-country teaching, research and extension. At the same time, universities should update curricula to include modeling and digital tools and methodologies, while collaboration with international institutions can provide access to the latest innovations and training opportunities. Additionally, strategies to retain trained professionals within the country are essential. Providing career development opportunities, competitive salaries, and research grants can mitigate the loss of skilled talents to international institutions.

4.2 *Equipping Academic, Research, and Extension Institutions*

Modernizing Nepal's academic, research, and extension institutions is essential to support the adoption of modeling and digital tools. Key initiatives include.

High-performance computing (HPC): Institutions should invest in HPC systems capable of running complex simulations, such as climate impact modeling and advanced AI algorithms. These systems are essential for processing large-scale datasets and generating actionable insights.

Dedicated research centers: Government and private sectors should establish centers for modeling and digital tools within universities and agricultural institutions. These centers can then focus on calibrating and validating simulation model such as DSSAT, AquaCrop, and APSIM for location-specific conditions (Khatri-Chhetri et al., 2017).

Improved soil and plant analysis labs: Government and private sectors should conduct nationwide laboratory assessments and introduce quality control measures to ensure the accuracy of soil and plant data. High-quality data is critical for building reliable models and improving decisions related to crop management practices.

Extension support systems: Government and private sectors should equip extension services with user-friendly digital tools and modeling outputs, enabling them to deliver science-based recommendations to farmers efficiently.

4.3 *Policy and Institutional Integration*

The integration of modeling and digital tools into agricultural policies and systems is critical for their large-scale adoption (Devkota et al., 2022).

Incorporating modeling and GIS in national strategies: Embed simulation modeling and GIS tools within frameworks such as the Agriculture Development Strategy (ADS) 2015–2035. Policymakers should emphasize the role of these tools in addressing yield gaps, resource optimization, and climate resilience (Government of Nepal, 2015).

Subsidies and incentives: Introduce subsidies for ICT-based platforms, precision agriculture tools, and modeling tools to enhance accessibility for smallholder farmers.

Data governance: Develop policies that address data sharing, privacy, and ownership, ensuring collaboration and trust among stakeholders. Clear regulatory frameworks will foster innovation and public–private partnerships.

4.4 Strengthening Data Infrastructure and Computational Systems

High-quality, multi-dimensional datasets are the foundation of simulation modeling and digital tools.

Comprehensive data collection and standardization: Establish national databases covering soil properties, hydrology, cropping patterns, socio-economics, and climate variables. Standardized collection methods will ensure consistency and compatibility across platforms. Collaborate with organizations like CGIAR (Consultative Groups for International Agricultural Research) and AgMIP (The Agricultural Model Intercomparison and Improvement) to avoid redundancies.

Real-time monitoring systems: Deploy IoT (Internet of Things) sensors, automated weather stations, and remote sensing platforms to gather real-time data on soil moisture, temperature, nutrient levels, and vegetation health. Tools like Sentinel-2 and Landsat are effective for monitoring large-scale land use changes and crop health.

Cloud computing and data sharing platforms: Utilize cloud platforms for real-time data analysis and collaboration. Cloud systems ensure scalability and accessibility while supporting cybersecurity measures to protect sensitive data. Develop interoperable open-access platforms to facilitate access by researchers, extension agents, and policymakers.

4.5 Collaboration and Regional Networking

Collaboration across disciplines and borders is crucial for maximizing the potential of modeling and digital tools. Key initiatives include:

Public-private partnership: Leverage private-sector expertise in GIS, AI, and remote sensing to develop user-friendly applications. Besides partnerships among Nepal Agriculture Research Council (NARC), Department of Agriculture (DoA), agricultural universities (e.g., Agriculture and Forestry University, Tribhuvan University), partnership with Agritech companies can facilitate the deployment of AI-powered crop monitoring and productivity enhancement systems.

Centers of excellence: Establish multidisciplinary hubs under a center of excellence to foster innovation, focusing on the integration of modeling tools with decision-support systems tailored to Nepal's diverse agroecological contexts.

Regional networks: Engage with regional initiatives such as the South Asian Association for Regional Cooperation (SAARC) to share resources, knowledge, and best practices.

4.6 *Pilot Projects and Demonstrations*

Pilot projects provide an opportunity to test and refine modeling and digital tools before scaling up:

Regional pilots: Conduct field trials in representative agroecological zones to validate various crop models and digital tools. Such validations would help increase resource use efficiency. For instance, pilot studies on water use efficiency in the Terai using AquaCrop demonstrated water savings of up to 30% without yield losses (Shrestha et al., 2013a, 2013b).

Monitoring and evaluation (M&E): Develop robust frameworks to assess the effectiveness and scalability of pilot programs. Feedback loops will ensure continuous improvement of tools and methodologies.

4.7 *Financial and Governance Frameworks*

4.7.1 **Securing Funding and Institutional Collaboration**

Adequate funding and national and international collaboration are essential for the success of pilot programs.

Government budgets and mobilizing resources: Allocate specific funds within national and provincial agricultural budgets to support initial infrastructure and operational needs. Secure funding from national budgets, international donors, and initiatives like Prime Minister Agriculture Modernization Project (PMAMP), Food and Nutrition Security Enhancement Project (FANSEP), Nepal Seed and Fertilizer Project (NSFP), Agriculture Development Strategy (ADS) Implementation Support Program.

International support and national and international collaboration: Collaborate with organizations like FAO, CGIAR, World Bank, and ADB for technical assistance and financial grants. The Ministry of Agriculture and Livestock Development (MoALD) should co-ordinate with global organizations such as the FAO, CGIAR, International Fertilizer Development Center (IFDC), World Bank and the Asian Development Bank (ADB) to access cutting-edge technology, technical assistance and expertise, and funding. In addition, funding needs to be sought, and resources shared through SAARC and other regional networks.

Public-private partnerships (PPPs): Engage private-sector entities to co-finance technological development and deployment.

4.7.2 Infrastructural and Operational Costs

A minimum level of infrastructure and operational costs is required to institutionalize the crop modelling and digitalization in agriculture across provinces. Key estimates include:

Infrastructure costs

- *High-speed computers, servers:* These are essential for running crop models like DSSAT, APSIM, and AquaCrop with large input data sets and producing large outputs. Each research and extension center would require a setup costing approximately US\$ 100,000 per province.
- *Weather monitoring stations:* Real-time, localized data is critical for model calibration. Installing a network of 10 stations per province would require approximately US\$15,000 per station.
- *Remote sensing and GIS tools:* To facilitate precise data collection and analysis, each province would need remote sensing and GIS software and tools, estimated at \$50,000 per unit.
- *Laboratory and field equipment:* These are necessary for soil and crop analysis and would require an estimated cost of USD\$ 100,000 per province.
- *Total infrastructure cost:* High-speed computers and servers + weather monitoring stations + remote sensing and GIS tools + Laboratory and field equipment = US\$ 100,000 + 150,000 + 50,000 + 100,000 = 400,000 USD/Province.

Operational costs

- *Staffing:* Hiring and training researchers, extension workers, and data analysts. Assuming a team of 20 specialists at an average salary of \$20,000 per year, the annual staffing cost per province would be about \$400,000.
- *Capacity-building training programs:* Continuous professional development and capacity-building workshops for stakeholders would require an estimated cost of about \$100,000 per year per province. UGC Nepal, ICIMOD, and FAO Nepal can give training on these topics.
- *Maintenance and upgrades:* Regular maintenance of infrastructure and periodic upgrades, including lab supplies would require an estimated cost of \$100,000 per year per province.
- *Data acquisition:* Purchase of satellite imagery, climate data, and other necessary datasets can be estimated at \$50,000 per year per province.
- *Total operational cost per province:* = 400,000 + 100,000 + 100,000 + 100,000 = 700,000 USD

Total initial financial requirements: $400,000 + 700,000 = 1,110,000$ USD per province, which will be around 7,770,000 USD for 7 provinces.

Subsequent annual costs (operational only) will be $700,000 \times 7 = 4,900,000$ USD per year.

4.7.3 Governance Framework for Piloting

Governance ensures the coordinated deployment of crop modeling systems and fosters accountability and stakeholder engagement. A multi-tiered approach is critical to address provincial diversity while maintaining national coherence.

Central co-ordination committee

- Establish a National Crop Modeling Coordination Unit (NCMCU) under MoALD. This unit will be responsible for overseeing the deployment of crop modeling and ICT-based systems, setting modeling standards, managing funds, and ensuring synergy across provinces.
- The NCMCU will work closely with provincial agricultural departments to tailor crop modeling efforts to the specific needs of each region.
- Engages international donors, research institutions, and private partners for resource mobilization and technical support.

Provincial crop modeling centers

- Each province should establish a Provincial crop modeling center (PCMC), reporting to the NCMCU. These centers will be the primary hubs for research, data collection for model calibration and validation and analysis, model deployment, and develop farmers' advisories.
- The PCMCs will be responsible for local data collection, model calibration, and providing real-time decision support to farmers and policymakers.

4.7.4 Stakeholders' Engagement

- Develop a governance framework that ensures the involvement of key stakeholders, including farmers' associations, private Agritech companies, academic institutions/stations, national research stations, NGOs, universities, and private-sector partners.
- Regular workshops, training sessions, and knowledge-sharing platforms should be organized to build the capacity of local governments, extension workers, and farmers in utilizing crop models.

4.7.5 Monitoring and Evaluation

- **Performance tracking:** Regular assessments of pilot sites to evaluate model accuracy, adoption rates, and economic impacts.
- **Adaptive framework:** Use findings from pilots to refine tools, build additional functionalities, and expand deployment.
- **Annual reviews:** Conduct annual impact evaluations led by the NCMCU to measure progress and align future investments.

4.7.6 Steps for Implementation of a Pilot Project

Piloting crop modeling tools involves phased implementation, focusing on building trust and demonstrating tangible benefits to stakeholders.

Phase 1: Establish pilot sites

- Identify representative agroecological zones in each province to serve as pilot sites.
- Set up infrastructure, including weather stations, high-speed computing systems, and remote sensing capabilities.
- Train local personnel in using simulation models and digital tools.

Phase 2: Model calibration and deployment

- Calibrate and validate models using localized data, including soil profiles, climate records, and crop management practices.
- Begin providing tailored recommendations to farmers, such as optimal planting dates, irrigation schedules, and pest control strategies.

Phase 3: Stakeholder engagement and feedback

- Involve farmers, extension agents, and policymakers in evaluation and testing of modeling and digital tools at pilot scales through workshops and interactive platforms.
- Use their feedback to refine user interfaces and improve the accuracy of outputs.

Phase 4: Expansion and scaling

- Expand successful pilots to additional districts within provinces, guided by lessons learned.
- Ensure financial and technical support from both provincial and national governments.

5 Conclusions

Nepal's agricultural sector faces critical challenges, including low productivity, climate vulnerability, and resource inefficiencies, which demand urgent and innovative solutions. This study underscores the transformative potential of modeling and digital tools—such as crop simulation models, GIS, remote sensing, digital twin technologies, and AI—to address these challenges. By enabling data-driven decision-making, optimizing resource use, and enhancing climate resilience, these tools pave the way for sustainable and modernized agricultural practices. The proposed roadmap outlines essential steps for developing and implementing crop modeling systems tailored to diverse agroecological zones. Key requirements include building robust

data infrastructures, equipping research and extension institutions, fostering interdisciplinary collaboration, and integrating these tools into national policies. The financial framework, governance structures, and phased piloting strategies presented in this chapter offer a practical guide for scaling modeling technologies across the country. Additionally, training researchers, extension agents, and farmers in utilizing these tools, coupled with strategies to retain skilled professionals, is crucial for long-term success. Active stakeholder engagement, policy alignment, and resource mobilization—both at national and provincial levels—are vital to ensure sustainability and widespread adoption. By leveraging digital innovations and fostering collaboration among public institutions, private stakeholders, and international organizations, Nepal could revolutionize its agricultural systems. The insights and strategies presented here serve as a foundation for transforming Nepalese agriculture into a climate-resilient, resource-efficient, and sustainable sector, ultimately contributing to national food security and economic growth.

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Chapter 10

Digitalization of Agricultural Extension Service in Nepal: A Framework for Transformation



Manita Thapa, Annie R. Specht, Binod Ghimire, and Sagar Ghimire

Abstract The agricultural sector in Nepal is vital to the economy, contributing around 24% of gross domestic production and engaging 50.4% of the population. Effective extension services provide a foundation for enhancing agricultural competitiveness but face challenges such as limited reach, conventional practices, and inadequate responses. These challenges stem from the fundamental characteristics of Nepalese agriculture, including diseconomies of scale, scattered production, succession threats due to aging and outmigration, distorted supply chains, and dysfunction of the coordinated mechanism among three government tiers. Considering this decentralized structure, this chapter aims to provide a framework for innovating existing extension service mechanisms through the integration of digital platforms. It outlines the role of digital platforms in disseminating information, technology transfer, capacity development, market management, data analytics, and decision support through real-time surveillance, advisory services, and establishing backward linkages of extension workers to research. The chapter examines policies regarding digital agricultural extension, explores perceptions toward digital platform use among extension workers, and provides effective strategies for their integration into the system. In line with the National Sustainable Development Goals (2015–2030) and Digital Nepal Framework, 2019, the chapter proposes a digitally enabled platform that serves as a framework for transformation of extension services through digitalization, policy coherence, completeness, and collaboration. From the analysis of existing context and author experiences, it calls for exploration beyond conventional boundaries and contributes to the landscape of current working modality.

Keywords DAES model · Digitalization · Extension service · Extension workers

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1 Agricultural Extension in Nepal

1.1 Background

The agricultural sector in Nepal is vital to the nation's economy, contributing around 24% of gross domestic production (MoALD, 2022) and employing over half (50.4%) of its population (MoF, 2023). Farmers primarily reside in rural areas, operating subsistence farms with inadequate infrastructure and limited access to extension services, with only 25% of farming households benefiting from extension programs (Ghimire et al., 2021). On top of that, there is a significant gap between front-line extension workers and farm households, with a ratio of 1:1328 (Thapa et al., 2025; Timsina et al., 2023). Extension services are most effective for enhancing the competitive capacity of the agricultural sector and hold relevance for the sector's transformation through the integration of digital solutions.

In this chapter, we propose a digitally enabled platform for delivering extension services that we refer to as the Digital Agricultural Extension System (DAES). The chapter consists of six sections, and we begin by reviewing the past and present plans, policies, and approaches employed by the agricultural extension system of Nepal. Section 2 discusses the current extension system, including gaps and challenges, and Sect. 3 presents survey results on the perceptions of extension workers toward the use of digital extension tools. Based on these perceptions, we propose a DAES platform, its rationale and significance, roles for several actors, coordination mechanisms, and the strengths, weaknesses, opportunities, and threats (SWOT) in Sects. 4 and 5. Lastly, we conclude by urging implementation of DAES for the improvement of extension service efficiency.

1.2 Policies, Programs, and Approaches

1.2.1 Periodic Plans

To date, Nepal has implemented ten five-year and five three-year plans. These plans have consistently prioritized agriculture, with strategies aimed at enhancing production and productivity through improved technologies and knowledge transfer. Since the first plan, efforts have been made to reach farmers through various means such as demonstrations, publications, and two-way communication between farmers and research centers via extension workers. Subsequent plans introduced agricultural fairs and media-based programs with the use of technology such as audio-visual aids, video films, radio broadcasts, and television programs. With the advancement of information and communication technologies (ICTs), recent plans have focused on leveraging the internet, toll-free services, and computerized systems, with digitalization of services to enhance the efficiency of service delivery. Despite these extension efforts, the performance of the agricultural sector remains unsatisfactory,

with a sectoral growth of just 2.5% and an agricultural trade deficit of NPR 257.5 billion (MoALD, 2022).

1.2.2 Agriculture Perspective Plan (APP)

The Agriculture Perspective Plan (APP), implemented from 1995 to 2015, aimed to stimulate agricultural growth, commercialization, and poverty reduction in Nepal. The plan promoted the adoption of agricultural technologies and participatory approaches in extension. However, it did not specifically focus on digitizing agricultural extension services, which limited its capacity to effectively use digital tools and broaden the outreach of these services.

1.2.3 Agriculture Policy, 2004

The National Agricultural Policy of 2004 sought to transition subsistence farming into competitive and commercially viable farming business through the adoption of suitable technologies. The policy envisions using farmer groups for on-site extension services, implementing package programs, and employing ICTs for agricultural extension. It also advocates for fee-based services and encourages participation from private, cooperative, and non-governmental sectors, but this vision has largely remained unfulfilled due to implementation issues.

1.2.4 Agriculture Development Strategy (ADS)

The Agriculture Development Strategy (ADS) from 2015 to 2035 emphasizes decentralizing extension services to Community Agricultural Extension Service Centers at the village level. It aims to enhance responsiveness to farmers and agro-enterprises by building the capacity of existing human resources and promoting the adoption of ICTs to disseminate technical and market information. Despite this forward-looking approach of decentralization and ICT integration, ADS faces implementation issues, as it was not framed in alignment with the current federal structure. Similarly, limited resources, poor coordination, and lack of internalization at the provincial and local levels are additional issues. Despite being halfway through its timeline, ADS has yet to achieve its desired outcomes.

1.2.5 Agricultural Extension Approaches

The Nepalese government has employed several agricultural extension approaches, including conventional extension, training and visit system, integrated rural development, the tuki approach, farming system research and extension, and block production programs. Additionally, strategies such as the commodity group approach,

pocket package, projectization, contract and partnership, and farmers' field school are being adopted. However, these approaches heavily rely on manual roles, and lack the integration of digital tools. The availability of tools and techniques also constrains the capability of extension workers. No single approach suits all services, leading to the adoption of commodity and region-specific methods. Despite the emphasis on written, spoken, and visual communication, digital extension tools remain underutilized in existing approaches.

1.2.6 Government Interventions and Programs

Formal institutional development in the agricultural extension system began with the establishment of Krishi Adda in 1921, followed by the Department of Agriculture (DoA) in 1951 and the Agriculture Information Section within the DoA in 1965. Over the years, communication channels including agricultural magazines, radio programs, and publications such as Krishi Diary, agricultural bimonthly, and booklets were introduced. Additionally, an audiovisual program was launched on Nepal Television in 1989. However, the effectiveness of these efforts remains limited due to poor access to information technology and low literacy among farmers and extension workers. Extension service through toll-free call centers was initiated in 2015, but implementation is hindered by limited reach, the absence of visual guidance, and coordination problems. Furthermore, more than 20 agriculture-related mobile applications have been developed in Nepal (Magar, 2020), but they often go unnoticed by users and lack updates, leading to low use by agricultural technicians, farmers, and other stakeholders. Thus, providing sustainable service and promoting adoption remains a greater challenge.

1.3 Provisions in the Constitution of Nepal

Article 25 (4) of Nepal's constitution presents a commitment to increasing agricultural productivity and modernization through the promotion of commercialization while ensuring environmental protection. The restructuring of the agricultural sector into three tiers of government initiates the decentralization of extension services, aiming to provide quality support to farmers (Ghimire et al., 2021). At the federal level, responsibilities include policy development and implementation, international trade regulations, and food quality standards. Provincial authorities are tasked with disease control, promoting agribusiness, and seed quality assurance. Local entities are primarily responsible for providing front-line extension services. However, there is a lack of coordination mechanisms between these three tiers, leading to overlapping and duplication of roles and responsibilities.

1.4 Provision in the Digital Nepal Framework 2019

The 2019 Digital Nepal Framework aimed to drive innovations across eight sectors through eighty digital initiatives. Agriculture was identified as a priority sector in this framework, with the inclusion of eleven specific digital initiatives. These initiatives include eHaat Bazaar (a local online marketplace), precision agriculture, agricultural tools sharing, digital disbursement for minimum support price and subsidies, digitization of land records, small irrigation projects, smart livestock and wildlife management, Televet medical center, an input and output product quality tracking system, an education and training program for farmers, and state-of-the-art knowledge centers and government agriculture centers. These initiatives envision a comprehensive approach to digitizing Nepal's agriculture within a national framework, outlining key activities for innovation. However, the framework overlooked the roles of local and provincial governments as well as grassroots-level stakeholders. Weak institutional capacity and the absence of immediate intervention have hindered its implementation over the past five years, stalling progress. For effective implementation, the framework still requires the development of a functional structure and robust frameworks for collaboration to digitize agricultural extension services and the entire sector.

2 Current Agricultural Extension System of Nepal

The public agricultural extension service in Nepal has positively impacted farmers' knowledge and practices, contributing to the improvement of the sector's productivity and commercialization. A previous study revealed that farmers who regularly receive extension services tend to achieve higher productivity than those who do not (Adhikari & Nepal, 2016), and the extension system has empowered farmers to adopt more efficient and sustainable farming practices through the dissemination of modern agricultural techniques, providing access to improved seeds, fertilizers, and irrigation technologies. The system has also facilitated addressing new and emerging topics such as marketing, environmental sustainability, pest diagnosis, risk management, and resiliency to climate change.

In addition to bureaucratic organizations, agricultural universities, research institutions, and the private sector are also contributing to extension efforts. Universities are connected to extension through initiatives such as Learning for Entrepreneurial Experience, where students engage directly with farmers and enrich their educational experiences. Some universities have initiated Agriculture Science Centers and Kishan Call Centers to provide localized support, training and resources to farmers. The Nepal Agriculture Research Council (NARC) is also trying to reach farmers directly through activities such as the NARC technology village and NARC call center, and provide farmers with access to innovation and management practices.

The role of the private sector is mainly seen in terms of input management, mechanization, the marketing of agricultural products and value addition. However, each of these stakeholders faces challenges: research institutions and universities face budget constraints and have limited outreach services, which restrict their ability to meet the diverse needs of farming communities, while the private sector is not enough in itself to provide complete supply chain solutions, as they primarily focus on product sales.

After Nepal transitioned to a federal structure in 2015, agricultural extension services became the primary responsibility of local levels, while the federal and provincial levels were tasked with regulatory functions, policymaking, infrastructure development, and research (Kyle & Resnick, 2016). Even after nearly a decade of such provision, federal and provincial agricultural entities continue to provide extension services, while the local level remains insufficiently equipped (Bishwakarma et al., 2022). Apart from structural shifts, new challenges are emerging in the agricultural sectors, leading to large yield gaps between the current and achievable yields.

The extension system struggles with insufficient human resources and technical expertise. This is evident from the fact that the federal, provincial, and local extension systems have 12, 37 and 29% vacant positions, respectively, and that most of the positions at the local and provincial tiers are filled on short-term contracts with limited field-level experience (Timsina et al., 2023). These issues are further compounded by the fundamental characteristics of Nepalese agriculture, including diseconomies of scale, scattered production, succession threats due to aging and outmigration, distorted supply chains, and dysfunction of the coordinated mechanism among the tiers. In addition, the current focus of extension service is primarily administrative and subsidy distribution, rather than information and technology transfer (Timsina et al., 2023). This limits the capacity and expertise of extension workers to provide core technical support, further widening the gap.

Besides the above issues, the extension system lacks a functional coordination mechanism among its tiers, leading to program duplications, confusion, and gaps in service delivery (Bishwakarma et al., 2022; Timsina et al., 2023). Thus, the quality of extension service is often questionable, as most of the programs are distribution-based, fail to connect the entire agricultural value chain, lack systematic monitoring and follow-up systems, and insufficiently focus on the needs of service recipients (Shrestha, 2011). The current methods of technology transfer have also been criticized for linear knowledge transfer, neglecting farmers' organizations, and local knowledge (Glover et al., 2017). There is limited space to collaborate various interconnected stakeholders, including farmers, credit and input providers, buyers, researchers, and development organizations in collective problem-solving efforts.

Thus, current extension approaches are not sufficient to address the evolving issues and needs of wider audiences, leaving a significant gap between service providers and recipients. This necessitates the development of an integrated digital service system that is cost-effective, capable of widespread information dissemination in a short timeframe, provides real-time information, is accessible to all, and supports informed decision-making (Thapa, 2023; Timsina et al., 2023).

3 Perceptions of Digital Platform Adoption Among Extension Workers

This section aims to highlight the perceptions of extension workers toward the integration and use of digital systems in agricultural extension services. Before recommending DAES for implementation, we sought to understand how extension workers perceive digital services and gather preliminary insights on the acceptability of such a digital advisory system. To explore this, we conducted a quantitative survey using a structured questionnaire. A stratified purposive sampling method was employed to select extension workers from all three tiers of the extension system and across the seven provinces of Nepal. The study approval was granted by the Institutional Review Board of The Ohio State University (#2024E0596). The survey instrument was developed using Google Forms and administered through online platforms. A total of 207 complete and usable responses were collected.

3.1 Preferred Types of Digital Tools

Figure 1 presents the perceptions of the respondents regarding the types of digital tools useful for providing extension services. A majority of the respondents mentioned the need for digital tools that provide integrated extension services rather than scattered or isolated ones. Particularly, a higher percentage of local extension workers (73.20%), indicated their preference for a system that provides integrated service. This inclination is understandable, as they are frontline extension workers who directly interact with farmers and require digital tools for effective agricultural extension services.

3.2 Perception Scores on DAES Functions

We calculated the perception index based on the respondents' response to fifteen positive statements about the applicability and functionality of digital tools in the extension system. Sampled extension workers were asked to rate their agreement on a 5-point Likert scale ranging from "strongly disagree" to "strongly agree" for each statement. Five representative statements and their corresponding participant responses are presented in Table 1. The overall perception score, calculated across all 15 statements, is also included. Perception index values ranged from 0.50 to 0.96, where higher values indicate a more positive perception toward the digital system. The mean perception score was 57.58, with a perception index of 0.75, suggesting the positive perceptions of respondents toward digital extension service integration. Extension workers strongly agreed that the digital extension tools reduce the time

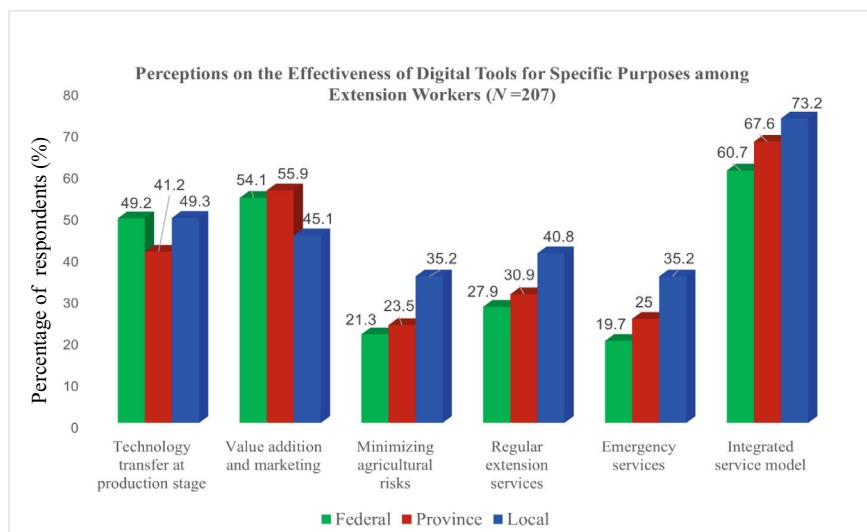


Fig. 1 Extension workers' perceptions on the types of digital tools needed for extension services. Source Author's Survey in 2024

required for service delivery and enhance service coverage, as well as improve the quality of service.

4 Rationale and Significance of Digital Extension System

Section 3 shows that extension workers demand an integrated system and hold a highly positive perception toward adopting digital extension services. Therefore, there is a need to develop digitally enabled web-based integrated platforms operated collaboratively by three government tiers and related stakeholders to facilitate adoption and functionality. Before discussing this, we need to understand why such systems are in high demand.

The necessity of meeting farmers' needs to scale up information and technology dissemination is paramount. This requires empowering farmers through effective extension services. The effectiveness depends on human capacity, information content, delivery process, and technology (Bhattacharyya et al., 2021). The challenges faced by smallholder farmers, including unpredictable weather and limited access to information and financial services, demonstrate the need for innovative solutions. While traditional extension services have struggled to effectively address this issue, the emergence of digital technologies presents an opportunity for improvement.

The solution to overcoming the discussed shortcomings lies in a digitally enabled extension service (Bhattacharyya et al., 2021). Technologies in the world are advancing at a faster rate. These technologies impact countries, populations, and

Table 1 Perception score on functionality and applicability of the DAES ($n = 207$)

S. No.	Statements	<i>SD</i>	<i>D</i>	<i>N</i>	<i>A</i>	<i>SA</i>	<i>M</i>	<i>Std. dev</i>
1	Digital extension system reduces the time required for service delivery	23	3	4	105	72	3.97	1.20
2	Digital extension system enhances the service coverage	15	2	8	117	65	4.04	1.02
3	Digital tools can deliver the right information at the right time	5	9	8	135	50	4.04	0.82
4	The use of digital tools in extension helps to improve the quality of service	1	8	23	130	45	4.01	0.73
5	I am willing to encourage farmers to use digital technology to get agricultural services	6	2	11	135	53	4.10	0.78
Perception parameters		<i>M</i>		<i>Std. dev</i>		<i>Max</i>	<i>Min</i>	
Overall perception score		57.58		5.94		73	38	
Perception Index (PI)		0.75		0.07		0.96	0.50	

Note SD = Strongly disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree, M = Mean, Std. dev. = Standard deviation

Source Author's Survey in 2024

markets globally, including Nepal and its agricultural sector, necessitating the adoption of new extension approaches, methods, and tools to meet the evolving needs of farmers and agri-entrepreneurs (Ghimire et al., 2021). Digital platforms for agricultural extension encompass a range of technologies, including mobile apps, websites, messaging services, social media, remote sensing tools, and others that facilitate technology transfer, capacity development, market management, data analytics, and decision support. These platforms leverage ICTs to reduce transaction costs, provide tailored advice to farmers, and facilitate direct interactions with related stakeholders. For example, predictive analytics and machine learning algorithms can offer personalized recommendations based on data related to weather forecasts, soil conditions, and market prices (Rajkhowa & Qaim, 2021).

Digital platforms serve as electronic bridges between farmers, extension organizations, research institutions and other stakeholders. The COVID-19 pandemic also increased the importance of digital services, providing extension organizations with an avenue to switch to these systems. They offer several advantages, including

reduced transaction costs and improved information quality and extension effectiveness (Thapa et al., 2025). They facilitate connecting farmers to input markets, enhance bargaining power, and increase access to personalized information and technologies. Digital services have the potential to positively impact farmers' cropping patterns, input intensities, yields, sales volumes, and incomes.

Efforts to digitize extension services in Nepal have been initiated, but they remain fragmented across different sectors. For example, the Agricultural Information and Training Center (AITC) publishes digital resources on agricultural packages and practices, the Seed Quality Control Center adopted Digitally Enabled Seed Information System (DESI) for monitoring seed quality and availability, and NARC has developed a knowledge management system to provide digital access to research publications and launched the digital soil map of the country. Some initiatives at the provincial level include a short message service for agro-advisory from the ministry of the government of Gandaki Province, while local efforts such as Pokhara Metropolitan City's farmer's identification and classification aim to reduce service duplication and streamline the extension efforts system. Additionally, private sector initiatives include mobile applications such as Smart Krishi and Krishi Ghar to provide agriculture-related updates, and the Kalimati Fruits and Vegetable Market website disseminates daily vegetable and fruit price information. All of these initiatives are equally important, though many of these systems remain non-operational, and users lack either awareness or sufficient knowledge for their effective use, as they are scattered and not integrated. As digital technology is becoming cheaper, better, and more accessible, it seems rational to use it for extension services, particularly in a developing country like Nepal. Therefore, it is essential to integrate existing digital infrastructures and systems to make them functional, dynamic, and accessible for all.

The use of multiple digital platforms, some with overlapping functions and potential untapped synergies, presents a challenge as well as an inherent characteristic of diverse extension systems. From an evolutionary perspective on innovation, one might argue that the presence of multiple digital platforms fosters competition, driving rapid improvement leading to the survival of the most effective ones. However, in the context of limited resources, the benefit of this approach is open to debate. From the viewpoint of innovative systems, there is a scope for enhancing collaboration within an integrated digital platform through resource sharing among the three tiers of extension, along with involvement from universities, research institutions, and private sectors. Such collaborations could address both the developmental and maintenance costs of platforms by combining the strengths of all stakeholders, including collective demand articulation, advisory services, and database management.

Our proposed model is not an isolated system, but rather a holistic platform that integrates not only digital initiatives within the agriculture sector, but also other major governmental initiatives. For example, DAES utilizes both the National Identification Number (NID) and the farmers' registration number, which helps to verify farmer identities and facilitates the delivery of agricultural programs, subsidies, and advisory services in a way that minimizes fraud and reaches registered farmers more

effectively. This will ultimately lead to differentiated services to meet the specific farmer's needs.

5 Framework for the Digital Extension Service

In this section, we propose a digitally enabled platform called DAES (Fig. 2) as a framework for transformation that facilitates the digitalization of extension services. This initiative is in line with the Digital Nepal Framework 2019, where our proposed model offers a viable solution for digitizing agricultural extension services. Here, we advocate for the establishment of an all-in-one or integrated web-based digital platform operated collaboratively by all three governmental tiers and related institutions, providing one-door information access. The need for such an approach was also emphasized by Thapa (2023) and Timsina et al. (2023), stressing the need for a technology-centric and participatory extension system. We acknowledge that using such a platform requires a certain level of digital literacy among users but also contend that a single integrated platform would be more reliable and user-friendly compared to managing multiple scattered systems. The basic components of the platform and their functionalities are discussed below.

5.1 *Components of DAES*

5.1.1 Database Management

DAES begins with a user manual to walk all users through the platform. The system is designed for the registration and organization of information of all actors involved. The core function starts with registration, where each actor is required to create an account. Actors include extension workers, researchers, faculty representatives from academic institutions, farming actors (farmers, agro-farms, farmer groups, cooperatives), and market actors (input suppliers, exporters, importers). Upon registration, they are assigned a unique identification number, and their information is recorded in the DAES database. Farming actors provide personal and farming information, including land holdings, farm size, and production details. Farmers' contact details are accessible only to their respective local governance, while farming information is available to actors of all tiers. Service recipients such as farmers, traders, and other stakeholders within the agricultural value chain can access the profile and expertise of extension workers, facilitating appointments for consultations. The database facilitates data compilation regarding farming activities, including but not limited to area, production, farm size, productivity, and trade status. It enables farmers to connect with traders and other market actors to sell products and purchase inputs.

DAES also incorporates a digital tracking system for agricultural product marketing. Moreover, it provides notifications and updates on farming practices based

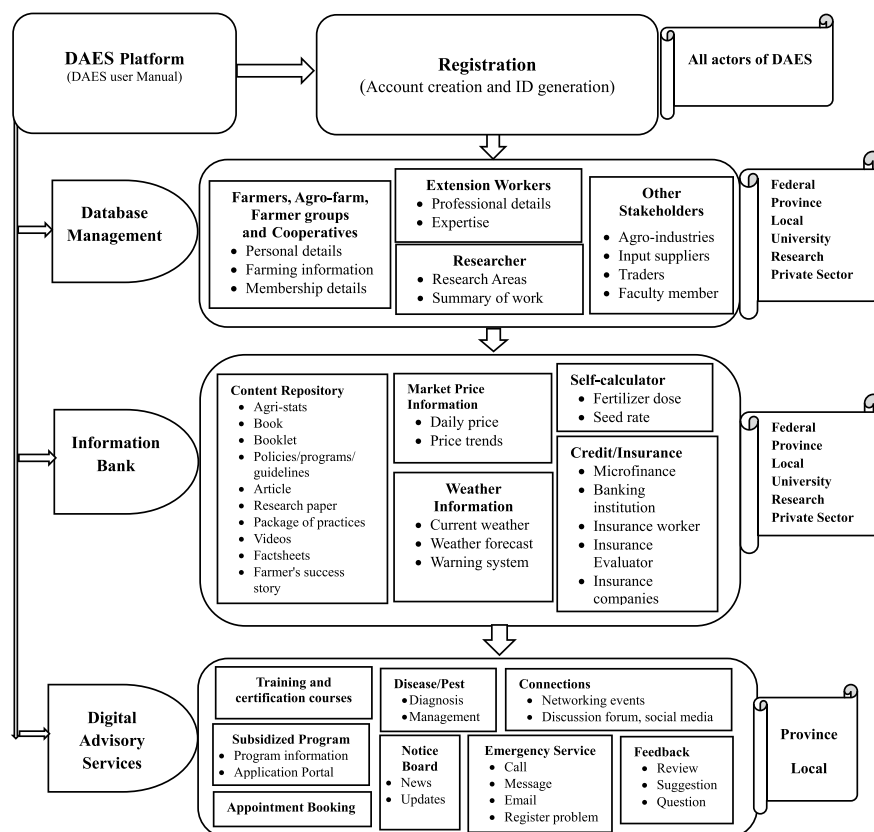


Fig. 2 Layout of DAES platform

on cropping seasons and stages, offering guidance and recommended practices for crop and animal husbandry management that facilitate timely decision-making and planning. The data analytics tools will help to track the activities of all of the actors and functionalities in the system, and the database is a powerful tool for estimating and ensuring the availability of seeds, fertilizers, pesticides, and other inputs as well as identifying the needs and preferences of all of the actors involved. Administrative oversight at three tiers manages data governance, with each level assigned responsibility for managing data and service provision within their respective areas of operation. This promotes cooperation and effectiveness in extension efforts, leading to better service delivery.

5.1.2 Information Bank

The primary components of the information bank in DAES include content repositories housing agricultural statistics, published resources, videos, blogs, webinars, research findings, and other recommended packages of practices for all agricultural products and processes. Price information, including daily commodity prices and price trends, will be accessible. It will help farmers to make decisions about the selection of commodities, price determinations, harvesting schedules, and so on. This information will be updated by the respective markets and facilitated by the federal and provincial ministries. Weather information from all of the meteorological stations will also be available, including weather forecasts. In the event of adverse weather forecasts, platform users will be notified via SMS services.

Since this platform is mobile-friendly, users can seek the required information whenever necessary. In addition, farmers will have access to the self-calculating platform for seed and fertilizer, which enables them to determine the recommended dose of fertilizer based on the information about the cropping area and crop details, as well as seed rates based on cropping area and varietal information. This section also provides information on credit institutions, insurance companies, insurance evaluators, and workers, along with procedures and provisions for credit and insurance facilities. In this decentralized mechanism of the data repository, specific personnel at each organization will be assigned to update data and maintain the accuracy and relevance of the information. Legal provisions for auditing the uploaded information are required to be developed and implemented. Additionally, feedback from users and experts will be collected for the continuous validation and improvement of the data and information in the repository.

5.1.3 Digital Advisory Services

This section includes a range of services that are designed to support farmers and other stakeholders in the system. Farmers can schedule appointments with extension workers to receive consultation services, selecting them based on their expertise. Additionally, users can apply for training and certification courses, with virtual participation options available. Training programs will be accessible on the platform, provided by implementing entities. Emergency services will be facilitated through the portal, allowing farmers to report issues via call, text, email, or by registering problems directly on the platform and receiving responses therein. Disease and pest diagnosis services are available, enabling users to upload images of affected areas for management recommendations. Information on subsidized programs and their implementation procedures is provided, allowing users to apply for programs through the platform. A networking section enables connections through forums and social media platforms, facilitating communication among users. Feedback, suggestions, and queries regarding platform usage can also be submitted, ensuring continuous improvement. This section primarily involves implementing entities, predominantly at the provincial and local levels.

5.2 Coordination Mechanism in DAES

DAES integrates a functionality that facilitates coordination among three tiers of the agricultural extension system and other related stakeholders (Fig. 3). They are connected digitally with access to respective roles and responsibilities. The digitally coordinated DAES platform enables real-time information exchange and dialogue among those concerned. These channels include chat forums, discussion boards, and virtual meetings, allowing stakeholders to share updates, exchange ideas, and seek feedback on ongoing initiatives. For instance, federal authorities can provide policy directives to provincial and local entities, while local extension workers can report field observations and receive technical support from the provincial and federal government.

5.2.1 Data Sharing and Integration

Data sharing and integration involves the compilation and exchange of agricultural information across three tiers. This process is operated through standardized data formats and protocols as they are made consistent with the different databases. For example, agricultural statistics, research findings, and market price information collected from local levels, research institutions, and markets, respectively, can be aggregated and analyzed at the provincial and federal levels to inform policy decisions and resource allocation.

5.2.2 Standardized Information Access

This functionary involves the designing of uniform protocols for accessing agricultural information across all levels. This ensures that all actors of the system have

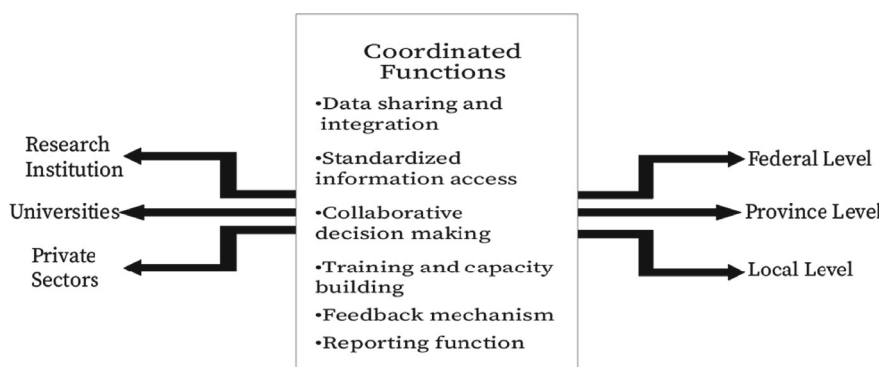


Fig. 3 Coordinated roles within DAES

equitable access to information and resources regardless of their geographical location or administrative jurisdiction. For instance, federal policies, provincial programs, and local farming practices can be accessed through a single interface, maintaining consistency and efficiency in service delivery.

5.2.3 Collaborative Decision-Making

This involves engaging all actors in joint discussions and deliberations to formulate policies and strategies. Through this participatory approach, decisions are informed by diverse perspectives and local knowledge, leading to contextual interventions. Multi-stakeholder forums and working groups within the platform's discussion forum facilitate this function.

5.2.4 Training and Capacity Building

Training and capacity-building programs are designed to enhance the skills and knowledge of extension workers and other actors, including farmers. These programs include online courses, webinars, and skill-building workshops designed to meet the specific needs and priorities of all of the actors involved. For example, federal authorities can provide administrative training to employees, provincial levels can offer technical training on new agricultural technologies to extension workers and large agribusinesses, and local entities can deliver field-based training on best practices in crop management and livestock husbandry to farmers.

5.2.5 Feedback Mechanism

DAES is a dynamic framework rich in its interactive features. The embedded feedback feature in the platform enables stakeholders to provide input on the quality and effectiveness of extension services and policies. Feedback from platform actors is collected through online surveys, feedback forms, and suggestion boxes, allowing users to share their experiences, concerns, and recommendations for improvement. For example, farmers can provide feedback on the relevance of advisory services received from extension workers, helping to identify areas for improvement and innovation.

5.2.6 Reporting Function

The reporting mechanism reflects transparency, accountability, and effective communication among three levels. Each level updates their annual programs, budget allocations, and current progress status on a regular basis. This allows concerned actors

to track implementation, understand resource allocation, and hold extension workers accountable.

5.3 Implementation of DAES

To expedite extension service delivery and prevent regression, it is essential for all stakeholders to collaborate in designing and developing the proposed platform. Alongside this, implementing a digital literacy program for users to enhance platform functionality are essential. So, for the implementation of the proposed platform, the first step involves the development of a digitally enabled platform as shown in Fig. 2 that integrates the functionalities and databases of all stakeholders. Following this, an intensive DAES literacy program should be conducted, targeting extension workers, educators, researchers, farmers, traders, and other actors to enhance their digital skills. This literacy initiative should be conducted before making the system functional. Finally, the DAES platform needs to be operationalized by activating it to deliver extension and other associated services. The platform's performance should be monitored regularly, and feedback should be gathered for continuous improvement of the system. Table 2 presents the role of the federal, provincial, and local extension tiers in the DAES platform.

For effective implementation, a legal provision needs to be established to mandate the integration of DAES into the operations of all agricultural entities at the federal, provincial, and local levels. The focal agency for DAES at the federal level (for example, AITC) will take the lead in overseeing the system's development, operations, and functional rollout. The center should be allocated with an adequate budget to provide training and capacity development for research institutions, agricultural universities, and extension services so they can fulfill their responsibilities effectively. Moreover, certain unit at universities (for example, the Directorate of Extension), NARC (for example, the Socioeconomics and Agricultural Policy Division), provinces (for example, Agricultural Training Centers), and the local level (for example, IT sections) will function as focal institutions for the implementation of DAES in their respective system. Each institution will assign focal personnel on a rotational basis to provide essential information and support through the DAES. This team will be responsible for addressing issues on a real-time basis.

5.4 SWOT of DAES

DAES is a transformative initiative expected to significantly change the extension system across all tiers and related sectors. Therefore, challenges during its development, installation, and implementation are inevitable. However, the platform's long-term outcomes and opportunities far outweigh these initial hurdles. Regular updates and refinements of DAES enhance its efficiency in service delivery. Table 3

Table 2 Role of the three tiers in the DAES platform

Level	Database management	Information bank	Advisory service
Federal	• National farming profile • Federal extension workers profile • Researcher profile • Exporters profile • Importers profile • Academic faculties profile	Content repository • National agri-stat • Book/ Articles • Booklet/Factsheets/ Infographics • Policies/programs/ regulations/ guidelines • Blogs/Podcasts/ Webinars • Research paper	Training and certification courses • Employee administrative training Regulatory services Policy support
Provincial	• Provincial farming profile • Provincial extension workers • Subject matter specialist • Traders • Processors • Industries • Input suppliers	Content repository • Provincial agri-stat • Policies/programs/ guidelines • Videos • Factsheets Market price information • Commodity wise • Daily basis • Price trends Credit • Microfinance • Banking institution Weather information • Current weather information • Weather forecast • Warning Insurance • Insurance agents, evaluators, and companies	Connections • Networking events • Discussion forum • Social media Training and certification courses • Employee technical training • Value chain stakeholder training Subsidized program • Program information • Application portal Disease/Pest • Diagnosis /Management
Local	• Farmer database • Agri-farm database • Group database • Cooperative database • Local trader database • Local extension workers database	Content repository • Package of practices • Videos • Factsheets • Farmer's success story Self-calculator • Fertilizer dose • Seed rate	Emergency service portal • Call • Message • Email • Problem registration Training and certification courses • Farmer level Disease/Pest • Diagnosis/Management Subsidized program • Program information • Application portal

Table 3 Strength, Weakness, Opportunity and Threat (SWOT) of DAES platform

Strengths	Weaknesses
Demand: Strong desire and positive perceptions among front-line extension workers for digitally enabled integrated service systems Scalability: Extends services to remote and rural areas that were previously uncovered Information access: Provides timely and relevant agricultural information to farmers and stakeholders Efficiency: Improves communication, data management, and resource allocation Market Linkages: Facilitate market information, price updates, and input management	Digital illiteracy: Limited skills in using digital tools among farmers and extension workers Infrastructure: Poor digital infrastructure, including electricity and network connectivity Technical support: Insufficient technical support system in the current agricultural extension Investment: High initial cost associated with digital tools and services
Opportunities	Threats
Innovation: Advancements in digital technology and fast growth of internet users provides avenue for the integration of digital tools Policy Support: Supportive policies and allocation of budget foster the adoption Capacity Building: Digital literacy and training programs can empower farmers and extension workers Partnership: Collaboration with private sectors and development partners can facilitate resources and expertise	Resistance to change: Traditional extension system's reluctance to adopt DAES Privacy and security risks: Susceptible to cybersecurity threats, including data loss and privacy issues Digital divide: Socioeconomic disparities in access to technology and resources, leading to inequalities among farmers

presents the associated strengths, weaknesses, opportunities, and threats of the DAES platform.

6 Conclusion and Recommendations

The synopsis and digital framework outlined in this chapter provide policy guidance for stakeholders involved in agricultural development. The survey findings revealed that extension workers strongly demand a digitally enabled, integrated extension system and hold a highly positive perception toward adopting such. This necessitates the development and implementation of the proposed platform. The identification of stakeholder needs, collaborative assessments and development of solutions are integral components of the framework. We believe that adoption of the DAES improves accessibility to information, supports process facilitation, and serves as a one-door platform for knowledge sharing through joint problem-solving efforts, collaborations, and the promotion of knowledge integration. Additionally, it enables prompt responses to issues, manages agricultural databases, and incorporates user feedback

for continuous improvement. The timely flow of information can empower farmers to sustain their agribusinesses. Overall, these digitally enabled extension services will serve as a holistic approach to the sector's transformation, driving productivity, service delivery, and innovation.

The success of DAES is highly dependent upon collaboration among multiple actors and stakeholders, and there are certain limitations for making the system functional. The implementation of DAES requires a high level of dedication from the responsible organizations and focal personnel, particularly during initial design and implementation stages. The development of the system itself and capacity building of the institutions and stakeholders requires the allocation of an adequate budget. Furthermore, there may be challenges related to aligning the DAES with local and provincial agricultural strategies, which could lead to potential alienation of the system from the specific needs and priorities of various communities.

While DAES is not a blueprint or panacea, it serves as a collaborative framework that unites all concerned stakeholders for the betterment of extension advisory services. Instead, it is a dynamic platform that serves as the starting point and can be continuously updated based on changing needs of extension services. Therefore, we highly recommend that the government and related institutions collaborate to allocate the necessary budget, establish legal provisions, and assign focal agencies to make the proposed DAES functional.

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Chapter 11

Agriculture Education, Research, and Extension: Review and Outlook of Agricultural Advancement in Nepal



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Abstract Despite its crucial role on the contribution of the agricultural sector in the country's economic development and associated improvement in people's livelihoods, agricultural performance in Nepal is ineffective, leading to widespread food insecurity and lack of employment creation mainly due to the underperformance of agriculture education, research, and extension (AERE). The agriculture sector lacks the necessary commitments, infrastructure and resources required for its development, and the relevance of current agricultural education is in question. Development of agriculture is impossible without competent, committed, skilled and visionary human resources, which must be produced from education institutions. Agriculture research, another pivotal area, is not able to contribute at the desired level. Likewise, agriculture extension, a means to communicate knowledge and research findings to farmers, is in jeopardy due to bureaucratic manipulations. Hence, all three pillars of agriculture development (agriculture education, agriculture research, and agriculture extension) are collectively failing, as is evident by Nepal's growing food imports every year. There are several reasons for the underperformance of AERE such as weak policy (e.g., from the institutions responsible for agricultural research, extension and education being placed under different ministries; incoherent

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vertical functional linkages), politicization, bureaucratic control, underfunding (only 0.04% of the country's annual budget is allocated to research across all areas of agriculture, including livestock); insufficient or weak human resources, poor resource planning and weak implementation of policies and regulations. Under this context, in this chapter, we discuss the current state of AERE and identify gaps with the goal of enhancing the future performance of the agriculture sector. We argue that a paradigm shift is needed in AERE, which requires a stronger dedication from all key stakeholders.

Keywords Agriculture · Education · Research · Gaps · Policies

1 Agriculture Education, Research, and Extension (AERE): Policy Gaps

Agriculture Education, Research, and Extension (AERE) is the foundation of the agriculture sector (AS) in Nepal. The AS provides employment and livelihoods to 60.4% of the population (CBS, 2018), contributes 24% to the country's GDP, employs around 66% of the workforce, and accounts for 50% of total national exports (NRB, 2023). AERE should support other allied subsectors, including food, feed, and livestock production, processing, transport, marketing, and service activities to create a multiplier effect on Nepal's overall economy (Thapa & Gaiha, 2014). Thus, the AERE inefficiencies in subsectors of AS are equally responsible for the underperformance of the AS and contribute to food insecurity, social imbalance, and developmental regression. Despite its enormous stake on the national economy and people's livelihood, the AS in general and the performance of AERE in particular are facing several challenges and hindering growth and productivity in this sector. Some of the AERE gaps within AS are presented below.

1.1 Low Agriculture Productivity: Underperformance of AERE

Nepal's agricultural productivity remains below its potential (FAO et al., 2024; FAO Nepal, 2023). Less relevant education, weak research, and poor extension services result in outdated farming practices, inadequate access to necessary agriculture input and modern technologies, and limited knowledge production and dissemination, which are part of AERE. Consequently, AERE is responsible for low agriculture productivity.

Subsistence farming is still the main characteristic of the Nepalese agriculture system. AERE is intended to focus on enhancing productivity of major staple crops such as rice, maize, wheat, millet, pulses, and livestock farming for milk, meat and

wool production, and the integrated livestock and crop system. Instead, low productivity of AS has contributed to food insecurity in the country. Because agriculture research institutions (ARIs) have not able to develop high productivity landraces and animal breeds, the productivity of major staple crops in Nepal is far below the world average: for example, rice 3.5 mt/ha, maize 2.5 mt/ha, and wheat 2.7 mt/ha compared to the global averages of 4.6, 5.8 and 3.4 mt/ha, respectively. Similarly, Nepal's average milk production per cow is 1500 L/yr compared to the global average of 2200 L/yr (FAO et al., 2024).

AERE is not yet able to contribute to shifting from monoculture, subsistence farming, and export-oriented high-value low-volume agriculture products, which has created agricultural imbalance and a lack of balanced diet (FAO et al., 2024). Agriculture research institutions must have the capacity to develop varieties that are resistant to droughts, floods, and other stresses to address food shortages both during normal periods and during times of natural calamities and disasters. Nepal's average per capita calories of 2200 per day are below the global average of 2500 cal per day (WFP, 2020) and serve as evidence of underperformance of AERE. It is sad to report that Nepal ranks 69th in the global hunger index where approximately 26% of children under five years old suffer from inadequate diet and malnutrition (UNICEF et al., 2023) despite so many ARIs operating in Nepal.

1.2 Climate Change Impacts and AERE

Nepal is highly vulnerable to climate change and unpredictable weather patterns, resulting in seasonal shifts in cropping patterns, floods, landslides, droughts, range expansion of insect and disease pests, increased pest severity, and crop failures (Ghimire et al., 2020). In such situations, the role of AERE in general and ARIs in particular are even more prominent in coping with climate stresses. However, not much has been observed in addressing these climate change impacts. If productivity is decreased due to a decrease in soil fertility and the imbalanced use of chemical fertilizers, AIRs have to provide options. AERE has not yet been able to internalize that only a multisectoral, holistic approach to developing adaptive resilient cultivars and livestock breeds to changing climatic condition can address the effects of climate change in agriculture. Thus, specific and targeted policies are required to addressing this situation and respond scientifically to the challenges posed by weather variabilities and climate change.

1.3 Technology Gap and Agriculture Research Institutions (ARIs)

Agriculture research institutions are not able to provide demand-driven technologies and resources to farmers and agricultural entrepreneurs, and agriculture extension institutions (AEI) are not able to provide required extension services (Babu & Sah, 2019; Bishwakarma et al., 2020, 2021). Appropriate adaptive and innovative technology in agricultural inputs such as seeds, fertilizers and irrigation enhance agricultural production and productivity. However, ARIs are not able to harness demand-driven technologies for enhancing production and productivity. Improved germplasms and animal breeds are not sufficiently available, are unaffordable and their quality is questionable. AERE is not able to develop technologies for an amicable solution, and huge gaps exist.

1.4 Collaboration and Collaboration Gap in AERE

Coordination and collaboration among AERE institutions and other key stakeholders determines the overall performance of AS. This performance largely determines the overall functions of related organizations/institutions. However, at present, AERE institutions are operating in a sectoral, segmented, and isolated manner. Currently, research and development (R&D) efforts are primarily performed by public sector institutions such as the Nepal Agricultural Research Council (NARC), Department of Agriculture (DOA) and Department of Livestock Services (DOLS) under the Ministry of Agriculture and Livestock Development (MoALD). The Institute of Agriculture and Animal Science (IAAS), Agriculture and Forestry University (AFU), and other agricultural colleges, dedicated for education, also invest in agricultural research and extension as part of their graduate education program and outreach service. However, there are wider gaps in coordinating and collaborating among all institutions operating in AS. When operating collaboratively with existing human resources, infrastructure, and other allied resources, government agencies and universities can be mobilized to enhance the productivity of AS. When these publicly funded AERE institutions are not properly collaborating, it is an unrealized dream to expect collaboration between public AERE and the private sector in agriculture R&D. In many countries, limited public–private partnerships are thriving, while in Nepal, they are rudimentary. Another collaboration hurdle is administrative arrangements, as AERE institutions are placed under different ministries and operate in a vertical way. Collaboration not only promotes a more efficient, inclusive, resilient, and sustainable agrifood system for enhanced production and better nutrition, but also drastically reduces overlaps and duplications in functions and resources that have not yet been realized by policy makers and political decision-makers.

2 AERE Evolution, Functions, and Performance in Nepal

2.1 *Agriculture Education Institutions (AEI)*

The first School of Agriculture was established in 1957 under the Ministry of Agriculture. It was upgraded to the College of Agriculture in 1968 for training Junior Technical Assistants (JTA) and Junior Technicians (JT). It was further upgraded to Institute of Agriculture and Animal Science (IAAS) under Tribhuvan University in 1972 and relocated to Rampur, Chitwan in 1974. Two additional constituent colleges under IAAS were established: the first campus was established in Sundarbazaar, Lamjung District in 1975 and Paklihawa campus in Rupandehi District was established in 1978. IAAS was responsible for training students up to the undergraduate level (B.Sc.Ag.).

In addition, the Council for Technical Education and Vocational Training (CTEVT) was established in 1989 to train technical and skilled human resources, including short-term trainings and pre-diploma and diploma programs in different disciplines of agriculture, livestock, and veterinary sciences. Vocational training centers under CTEVT are running across the country and focusing on practical agricultural skills. In 2000, two private colleges affiliated with Purbanchal University began undergraduate programs in agriculture and veterinary science. The Himalayan College of Agricultural Sciences and Technology (HICAST) was established in 2000, which has provided education in Agriculture, Science, and Technology under Purbanchal University. IAAS had started master's programs in various disciplines of agriculture, livestock, and veterinary sciences and Rural Sociology-Extension.

The establishment of Agriculture and Forestry University (a state-owned technical university) in 2010 with its mission to undertake educational, research, and extension activities in the field of agriculture, animal science, veterinary science, aquaculture, forestry, and related disciplines became the milestone and new era in the agriculture education system (Ministry of Education, Science, and Technology, 2010).

Currently, Purbanchal University (PU), Kathmandu University (KU), Mid-western University (MWU), and Far-western University (FWU) all offer undergraduate programs in Agriculture. Madhesh Agriculture University (MAU) was the first provincial Agriculture University established (2021) by provincial act. Currently, 32 central, constituent, and private academic institutions under seven universities annually enroll 2300 undergraduate students in agriculture, veterinary science, and fisheries, while more than 500 students are enrolled in postgraduate programs at AFU, IAAS, HICAST, and Nepal Polytechnic Institute (NPI). However, such uncoordinated, haphazard offering of courses by multiple institutions without proper assessment of the human resources needed for the country risks the production of unemployed graduates and a waste of state resources. The sad reality is that despite the rapid expansion of academic institutions in agriculture, the AS is decreasing and Nepal has to rely on importing food. There exists a significant gap between the curriculum and the lack of a practical and impactful research environment that hinders the development of well-trained skilled agricultural professionals.

Though much was expected from the AFU in integrating teaching, research and extension for the holistic and synergistic delivery of robust agriculture education in the country, performance in the past sixteen years has been extremely poor. The AFU is not able to produce the competent human resources required for the modernization and commercialization of agriculture. Instead, dirty politics from the bickering cadres of political parties have resulted in burning university buildings, pouring black color in the face of a university professor and garlanding his shoes, attacking students, university closure and damage to the academic environment (Das et al., 2019). Similar politicization and obstruction of the academic environment is common in other agriculture education institutions.

Agricultural curricula across all agricultural academic institutions are not responsive to market demand; often, they are neither adequately theoretical, nor appropriately exposed to hands-on experience and research-based teaching, and are neither innovative nor modern technology-oriented. Further, the following gaps exist in the Nepalese agricultural education system, including:

- (a) lack of satisfactory practical, hands-on, experiential learning opportunities in students, primarily due to the lack of laboratory and field research facilities and equipment,
- (b) some courses lacking rigor in content and teaching while other courses are outdated, misaligned with the scope of the course, or have expectations that are not clearly presented in the curricula,
- (c) several courses are taught by instructors appointed from other campuses, universities, or government or even private sectors because campuses are not fully staffed with the required number of teaching faculty,
- (d) the temporary absence of faculty members on study leave without proper arrangement for these temporary vacancies pose additional strains on teaching,
- (e) teaching faculty members lack sufficient training on effective teaching methodology, appropriate use of statistical methods in social versus biological science research, and the use of globally available literature on teaching and research,
- (f) lack of reliable and consistent sources of funding for research, graduate student commitment in research, and research productivity measured in terms of refereed publication and measurable impact,
- (g) lack of commitment of teaching faculty on student education and no mechanism for assessing faculty accountability,
- (h) postgraduate student research lacks a standardized protocol for selecting research committees, members and the roles each should play in student research, thesis preparation, and publication,
- (i) university management and administration not enforcing existing rules or lacking adequate, enforceable regulations for students, faculty members, and university staff required for academic sanctity.

2.2 *Agriculture Research Institutions (ARIs)*

Though Nepal's traditional agricultural heritage and learning-based Indigenous practices trace back centuries and these farming practices have been passed down through generations, modern agriculture research is relatively new in this country. Formal agricultural research began with the establishment of the Department of Agriculture in 1959, as the department had also focused on improving crop varieties, soil management, and pest control.

During the 1970s, more organized agriculture research gained momentum once international collaborations began introducing improved fruits, cattle breeds, and modern agricultural practices. The most significant milestone was the establishment of the Nepal Agricultural Research Council (NARC) in 1991 as an autonomous organization under the Nepal Agricultural Research Council Act, 1991 to conduct agricultural research for uplifting the economic well-being of Nepalese people. Since then, the NARC has commenced research, with some successes. The main two areas of focus have been, (a) crop improvement, where efforts are focused on developing high-yielding crop (e.g., rice, wheat, maize, and vegetable) varieties; and (b) livestock improvement research promoting better breeds, disease control, and efficient management practices. Some achievements have been made by introducing exotic cattle breeds and crossbreeding programs to improve milk and meat production.

Even though some progress has been made in crop and livestock development research, NARC suffered from poor management, weak implementation of policies, and limited and/or inappropriate use of available resources, politicization and influence of political interests, lack of motivation and commitment of scientists and unhealthy competitions among human resources. Despite the huge potential for collaboration with international universities and research institutes, NARC was not able to harness enough potential for knowledge exchange, technology transfer, and joint research projects.

Still, NARC and its affiliated institutions shape Nepal's agricultural research landscape even though there are agriculture EIs such as AFU and IAAS. However, their role in advancing agricultural knowledge, technology, and practices and making the country self-sufficient in agriculture is not yet satisfactory. MoALD did not realize the importance of autonomy of NARC, and political and bureaucratic interferences have jeopardized its mandate.

Provincial Agricultural Research Directorates (DoARs) as decentralized agriculture research centers are strategically located across Nepal's diverse agro-ecological zones and unable to fulfil their core mandates. Their functions are conducting region-specific research to address farmers' problems, to develop technology suitable to local conditions, to develop high-yielding crop varieties and significantly contribute to crop improvement, soil management, and livestock productivity. However, there have not been any significant improvements in these areas.

Meanwhile, private sector engagement in agriculture research is still rudimentary, and performance is poor. No substantial results have been observed from private sector agriculture research. The private sector is weak in agriculture compared

to other sectors such as service and tourism. RIs are unable to meet the national requirements of developing cultivars of improved rice, wheat, maize, and vegetables that are high-yielding, resistant to pests and disease, drought-tolerant, and climate-resilient. Similarly, livestock RIs are not able to meet the national need of enhancing livestock productivity, executing successful breeding programs, controlling disease and improving animal management practices. Research Institutions (RIs) in Nepal face multiple problems (Chhetri & Subedi, 2017; Ghimire et al., 2020; Kandel & Shrestha, 2022) in executing research functions in agriculture. There are several main reasons for the underperformance of RIs, though the following points are important to consider related to enhancing the capabilities of such institutions:

- (a) low investment in research infrastructure, equipment, and human resources,
- (b) insufficient skilled researchers,
- (c) poor governance and management of RIs,
- (d) poor coordination and lack of collaboration culture as they often aim to skip collaborating with EIs,
- (e) discretionary and ineffective capacity-building programs,
- (f) poor understanding of research by policy makers and political decision-makers,
- (g) lack of modern laboratories, experimental farms, cutting-edge technology, and data management systems,
- (h) lack of a culture of collaborative and integrated research, etc.

2.3 *Agriculture Extension Institutions (AExI)*

Agriculture extension is a crucial yet highly neglected function within the agriculture sector in contemporary Nepal. Agriculture extension service was better in the past, with dedicated institutional arrangements such as departments, agriculture offices in districts and service centers at the local level. Unlike the semi-autonomous nature of different institutions in agriculture education and research, agriculture extension was directly administered by the Ministry. Once the country was federalized in 2015, the responsibilities of the District Agriculture Development Office (DADO) were transferred to the local government. However, there was huge resistance to transferring human resources, and local governments were not able to continue the agriculture extension function; hence, the already missing link has become permanently broken. Senior officials of MOALD created this situation, and if MoALD had transferred enough staff to the local level, the situation could be different today.

2.4 *Agriculture Education, Research, and Extension (AERE) Policy in the Past*

In the past, AERE was part of a set of general broad agricultural policies rather than having separate laws and policies. Certain institutions were established at specific

times (e.g., the Department of Agriculture in 1959; NARC in 1991), and one unique characteristic and or limitation of past policies in agriculture is “standalone,” “work alone” or “lack of complementarity” between the AERE, which has seriously undermined the principle of interrelated functioning of “education-research-extension” in AS. It was difficult to find policy orientation towards integrating “agriculture education-agriculture research and agriculture extension,” except in the Agriculture Development Strategy (ADS) (2015–2035). The ADS has nicely envisioned the interrelationship between the three components (“agriculture education-agriculture research and agriculture extension”). However, this document was not fully implemented due to a lack of federal perspective (as it was finalized before promulgation of the constitution). Now, after 9 years of approval of the ADS, the MoALD, with the support of donors such as the UNDP and USAID, is revising it, for the main reason that the “agriculture education-agriculture research and agriculture extension” is not proper functioning in a mutually reinforcing and complementary way due to the policy lacuna.

3 Reforming Agriculture Education, Research, and Extension

The problematics discussed in section two of this chapter clearly demonstrate that the “business as usual” style of operation existing in the AS for so long cannot and should not continue if “agriculture education-agriculture research and agriculture extension” to be relevant. It must be changed in terms of structural, functional and mandatory provisions addressing the land-grant concept at the agricultural university level as well. The seventy-five years of history of agriculture development has amply demonstrated that the agriculture sector is not able to perform satisfactorily, despite some positive initiatives and achievements. While absorbing 60.4% of the population (CBS, 2018; IFPRI South Asia, 2020), it is able to contribute only 24% to the country’s GDP, which is decreasing over time against the increase in investment in agriculture (NRB, 2023).

3.1 Procedures for AERE Transformation

In this section, we discuss these transformative changes, but do not claim that our proposition is the only option. However, we do emphasize that broader, deeper and informed debate is needed to reform existing ARER—debate that our proposition can provoke. Only informed, constructive, and forward-looking debate can help policymakers and planners to opt for transformative agriculture, which is the thrust of this chapter.

The following propositions or broad guidelines will help to shape the debate to facilitate the restructuring of AERE in Nepal:

- (1) Review all existing laws and policies related to agriculture education, research, and extension; identify strengths, weaknesses, and gaps; and identify areas of change.
- (2) Formulate an umbrella policy and umbrella law for agriculture sector transformation that clearly articulates the operation of agriculture academic institutions, NARC and other agriculture research institutions, and extension organizations under a single umbrella. These revised policies and laws should address the main reasons for the underperformance of the agriculture sector such as extremely poor governance, weak institutional arrangements and legal provisions, domination by geopolitical and geostrategic interests, and lack of commitment of political decision-makers and politicians.
- (3) Formulate law and policy to regulate the agriculture education system and all agricultural education institutions under a single umbrella AFU. This policy should develop appropriate regulatory bodies to oversee research, teaching, and extension activities and promote public–private partnerships to foster innovation and extension in agriculture and allied areas.
- (4) Formulate law and policy for agriculture research that ensures the autonomous operation of the national agricultural research system under the coordination and research management of an apex body (called the National Agriculture Council). This agriculture council can allocate resources for NARC, AFU and other research institutions, and both NARC and AFU could operate autonomously but collaboratively to ensure a seamless environment for research students and faculty members of all academic institutions to conduct research on NARC farms while NARC scientists teach and train graduate students at academic institutions with full reciprocity.
- (5) Agriculture extension service has to operate through the Service Centers of academic and research agriculture institutions in collaboration with local governments as outreach centers. Agriculture academic institutions should be capable of providing required agriculture experts for local, provincial, and federal governments, the private sector, and non-governmental sectors. The purpose of agriculture extension is to disseminate new research findings and innovations to farmers and bring feedback from stakeholders to research systems.
- (6) All of these efforts will have the central goal of identifying and selecting an improved, suitable model that meets the needs of Nepal's agriculture sector.

3.2 Focus of AERE Reform for Future

AERE reform should focus on (a) complementarity among education, research, and extension organizations/functions, (b) competency (which should be required to be

relevant), (c) being demand driven, (d) innovation, (e) cost-effectiveness, and (f) resourcefulness.

3.2.1 Education Institutions (EIs)

One of the possible ways of integrating education, research, and extension is to opt for a modified land-grant model, as part of the broader transformation of the agriculture sector. All three pillars (education-research-extension/community services) of the land-grant model exist in Nepal's current agriculture systems, though they are fragmented and uncoordinated. Now, they must be reorganized as per the federal system and six focus areas identified earlier (complementarity, competency, being need-based, innovation, cost-effectiveness, and resourcefulness).

The restructuring of various scattered institutions is a precondition of making AERE functional, efficient, need-based, and competent. In this process, it is essential to review all laws related to AFU, TU/IAAS, PU/HICAST, NPI, KU, MWU, FWU, MAU, and other agriculture institutions based on the review formulate umbrella law and policy to regulate the agriculture education system under the umbrella of AFU where all agricultural education institutions come under a single operational policy. Efforts have been made in the past to develop strategies on the restructuring of AFU to bring all agricultural education institutions under one umbrella (Das et al., 2019), though it was not possible to bring all agricultural education institutions under AFU because of existing laws and the divergent interests of key stakeholders and decision-makers.

The existing operational style of the AFU will not be able to make itself relevant, which means that restructuring is a must. When restructuring the AFU, policymakers have to examine the other institutions providing agriculture education and whether they are able to meet the six criteria (i.e., complementarity, competency, being need-based, innovation, cost-effectiveness, and resourcefulness). And, if they are not able to meet these criteria, these institutions must be brought under a single policy framework for legal provision and cost-effective operation.

3.2.2 Research Institutions (RIs)

At present, agriculture RIs are operating either under the administration of the NARC or to a lesser extent by academic institutions. However, there is an apparent lack of coordination and collaboration within the agriculture RIs and between RIs and EIs that is resulting in the duplication of work and a waste of public resources. Hence, this situation must end. The best way to end this situation and enhance their performance is to develop a national agriculture research policy to formulate law and regulations related to agriculture.

Agriculture RIs have to collaborate with academic institutions and local governments to establish Outreach Service Centers (OSCs) and disseminate research findings through these centers. Therefore, these OSCs will receive the findings, fresh

knowledge, and practical skills to share with farmers creating strong farmer-OSC relations and effective dissemination.

Nepal's agricultural research should examine smallholders' access to credit, technology, markets, and cooperative farmers groups and provide findings to solve problems. The research program should also focus on climate resiliency to address Nepal's vulnerability to climate change and suggest adaptive policies. Government efforts should extend to strengthening farmer-responsive research and extension services. At the heart of decentralization lies the concept of farmer-responsive research and extension services. Research institutions must closely collaborate with local farmers and understand their needs, challenges, and aspirations. By involving farmers in participatory research, research institutions can ensure that solutions are context-specific and practical.

In the future, Nepal's agricultural research system must focus on sustainable productivity enhancement, diversification, and value addition; climate adaptation and mitigation; research capacity building; innovation; technology adoption; community engagement; climate-resilient crop varieties and livestock species; efficient water management; soil health; precision agriculture; leveraging technology for optimal resource utilization; exploring alternative crops suited for local agro-climatic conditions, agroforestry, organic farming, and non-traditional livestock; developing climate-smart practices to cope with extreme weather events; developing drought-tolerant crops, flood-resistant varieties, and resilient livestock breeds; promoting carbon sequestration through agroforestry and sustainable land use, the agriculture value chain, and market promotion.

It is also equally important to establish innovation hubs for agri-tech startups and conduct research on the blockchain, AI, and remote sensing (Sishodia et al., 2020) for precision agriculture.

3.2.3 Agriculture Extension

At present, agriculture extension services are provided by the network of agriculture offices throughout the country under the Agriculture Knowledge Center (AKC; formerly the Department of Agriculture) but are facing tremendous problems and not functioning properly (Bishwokarma et al., 2021, 2022). In fact, the integration of academic institutions, NARC research centers, and AKC offices as postulated herein should develop into a unique land-grant model for resource sharing and greater efficiency across all provinces of the country.

Outreach Service Centers (OSC) of agriculture academic and research institutions provide agriculture extension in collaboration with local governments. Agriculture academic institutions should be able to provide required agriculture experts for the local, provincial, and federal government, the private sector, and non-governmental sectors. The purpose of the agriculture extension disseminated through OSC is to disseminate new research findings and innovations to farmers and bring feedback from stakeholders to research systems. The main function of OSCs is to disseminate

research findings directly to farmers, facilitating knowledge transfer and providing farmers' feedback to research and academic institutions.

3.2.4 Integration of Education, Research, and Extension: Systems Perspective

So far, Nepal's AERE is operating independently and is therefore unable to produce the desired results. Hence, it is necessary to work from a Systems Perspective (Checkland, 1981). It has been proven that the operating in a synergetic manner works better compared with a disconnected set of operations (Checkland & Scholes, 1990; Jaishi et al., 2023). Facilitating sustainable agriculture requires systems thinking (Roling & Wagemakers, 1998). The interconnectedness of agriculture education, research, and extension (Fig. 1) is one way of enhancing collaboration among AERE institutions to achieve a productive, efficient, and sustainable agriculture system (Fig. 2).

In a systems perspective, coordination among various institutions of AERE is key, and therefore an apex body called the National Agriculture Council (NAC) is proposed. The NAC would ensure autonomous operation of the national agricultural

Fig. 1 Interconnectedness of AERE pillars in a model mimicking the land-grant agriculture development system

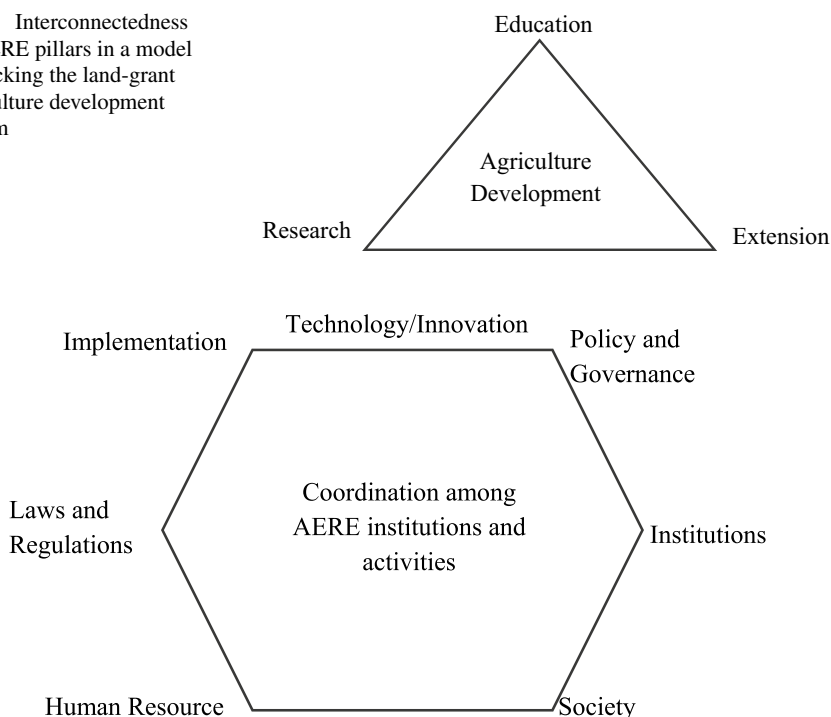


Fig. 2 Coordination of developmental parameters for the integration and synergy of agriculture education, research, and extension activities for agricultural development

research system under the coordination and research management of NAC. The NAC allocates resources for NARC, AFU and other academic and research institutions, and both NARC and AFU operate autonomously but collaboratively to ensure cooperation, the exchange of scientists, students, research students and faculty members of all academic institutions to conduct research on NARC farms while NARC scientists teach and train graduate students at academic institutions. They would publish their research findings jointly and disseminate findings that are relevant to farmers through OSCs and policy-relevant findings to the policymakers reporting through NAC. This is called an operation under the principle of reciprocity, which develops mutual trust among academic and research institutions.

AREE must engage and collaborate with private sectors and industries for agricultural research under the arrangement of public–private partnerships. NAC has to establish a National Agricultural Research and Development Fund (NARDEF), as well as create Agricultural Mechanization-Innovation Centers (AMIC) to facilitate research and innovation. The main functions of AMICs are to promote modern farming practices, provide training, demonstrations, and access to farm machinery and ensure access to tractors, harvesters, other farm machines, and irrigation equipment that enhances productivity and reduces labor-intensive tasks. Regional research centers under the NARC operating across the country should cater to the need of specific agro-climatic conditions and work in close collaboration with local stakeholders, including farmers, OSC extension workers, and community-based organizations. These regional centers must serve as specialized research centers for applied research, technology transfer, capacity building, ensuring soil health, pest management, and crop diversification in the region by engaging local scientists, extension officers, and farmers. In this context, they also serve as a bridge between research and in-field implementation of research.

Agriculture research should conceptualize from a systems perspective rather than conducting compartmentalized research. Hence, the strategic priority of AERE is to strengthen the Agricultural Research System. The NAC has to develop plans for (a) knowledge transfer (Thapa et al., 2019; UNCDF, 2020), (b) implementation of research findings, and (c) impact assessment by involving key stakeholders such as farmers, women, and youths. The concept of citizen science and farmer-led innovation networks are more relevant to serve farmers, and this is possible through a participatory action-oriented transdisciplinary research approach.

4 Conclusions

As Nepal moves forward, a holistic approach that integrates traditional wisdom with cutting-edge science is crucial, which is possible only through structural reform and the systematic thinking of research and academic institutions within the broader framework of agricultural sector transformation (see Chap. AB 10 for a detailed account on sectoral transformation). In this chapter, we have quickly examined Nepal's existing agricultural research-teaching-extension landscape, which is neither

effective nor efficient. It is surrounded by complex problems that require fundamental change in Nepal's AERE. In this context, we have proposed a way forward that unlocks the full potential of Nepal's agriculture sector and addresses numerous challenges: only then can we foster a system perspective in the agriculture sector of Nepal. At this juncture, it is urgent to begin a process of identifying alternative policy options, imitating informed debate by bringing all key stakeholders together. Nepali policymakers and key agricultural stakeholders have to come together to find a common strategy to address the chronic problem of agriculture education, research and extension that contribute to broader agriculture sector transformation.

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Chapter 12

Structuring Nepal's Agricultural Education Toward Commercialization



Ajay Jaishi, Janarjan Adhikari, Roshan Subedi, and Kumar Lama

Abstract Agricultural education is the most emphasized sector in producing graduates who contribute to enhanced agricultural productivity. Establishment of the first agriculture school in Nepal in 1957 AD was a milestone to developing agricultural professionals entailed to remodel the prevailing subsistence farming system to a commercial farming system. To date, 35 different agriculture colleges established through Nepalese universities produce almost 2154 graduates per year. A significant number of graduates reflects the positive impact of national agriculture policy that at the same time lacks in connecting those graduates in evolving commercial agriculture, raising concerns about the efficacy of agricultural education. In this chapter, we emphasize plotting the prevailing agriculture education system and possible connections among agriculture stakeholders to realize a synergetic effect to transform the agriculture sector in Nepal. In addition, a brief history of formal agricultural education, a review of the academic curriculum of different universities, and their development pattern through comparative studies reflects the inside story of Nepalese agricultural education. Results from individual surveys, key informant interviews, and focus group discussions with agriculture experts are utilized to configure the future direction of Nepalese agriculture education with an aim of transforming the existing subsistence agriculture system to a modern agriculture system. The chapter also suggests an amendment to be made in the current agricultural education system to develop market-driven agricultural professionals and fulfill modern agricultural demand.

Keywords Agriculture professional · Agriculture policy · Education · National modern agriculture

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1 Introduction

Education is the fundamental element of social and economic development and has significant positive impacts on a nation's prosperity, particularly in developing nations (Zolfaghar, 2015). In Nepal, agriculture contributes about 24% of total gross domestic product and employs 60.4% of the total labor force (MoALD, 2023). Agriculture extends beyond food production and supports an enormous workforce, including farmers, educators, researchers, extension workers, agribusiness professionals, and ultimately consumers. Agriculture graduates and farmers are key contributors to enhancing agricultural productivity (Mansour & Shahien, 2023), and educational institutions and universities are central to research in various agricultural fields and providing extension services and technical guidance to farmers (Jaishi, 2022a, 2022b; Spiertz & Kropff, 2011). These institutions play a vital role in the success of development and extension services for adapting new agricultural technologies. Notably, education institutions are working to produce experts and professionals to understand the complexities of agriculture, overcome challenges, and lead the agricultural development of the country (Gurung & Azad, 2013).

Formal agriculture education in Nepal began with the aim of generating skilled human resources for rural agricultural development (MoALD 2024). Generally, academic institutions provide two categories of education in agriculture: short-term commodity-specific trainings offered by the Council of Technical Education and Vocational Training (CTEVT) and long-term graduate programs offered by universities. In particular, 296 institutions under the CTEVT with an annual capacity of producing 11,840 skilled individuals in various subsectors of agriculture are currently operating in Nepal (CTEVT, 2024). At the same time, 35 different colleges belonging to central and provincial universities producing 2194 graduates each year in agriculture have been established to date (Maharjan & Dhakal, 2023; Research Survey, 2024) as shown in Fig. 1. The rising number of agriculture institutions throughout the country was noted after the enactment of the federal system in Nepal.

Inadequate human resources in the agricultural extension and research sector may explain the growing number of new agricultural academic institutions in Nepal, which enroll approximately 2000 students annually in bachelor's degree program (Gauchan & Paudel, 2012; Ghimire et al., 2021; Timalsina, 2021). Unfortunately, very few graduates from Nepalese universities are noted in agribusiness sectors, whereas these sectors are mostly led by students trained in Israel, Malaysia and other foreign agricultural universities (Pun, 2019). These foreign-trained individuals are driving growth and innovation in agriculture commercialization, highlighting a gap in the Nepalese agricultural education system in producing graduates who pursue careers in agribusiness. On the other hand, youth motivation in agriculture is declining in Nepal, with only a few youth passionate in involving themselves in farming (Khanal et al., 2021). This declining trend of choosing the service sector instead of farming has been noted since 2000 in low- and middle-income countries (Maiga et al., 2020).

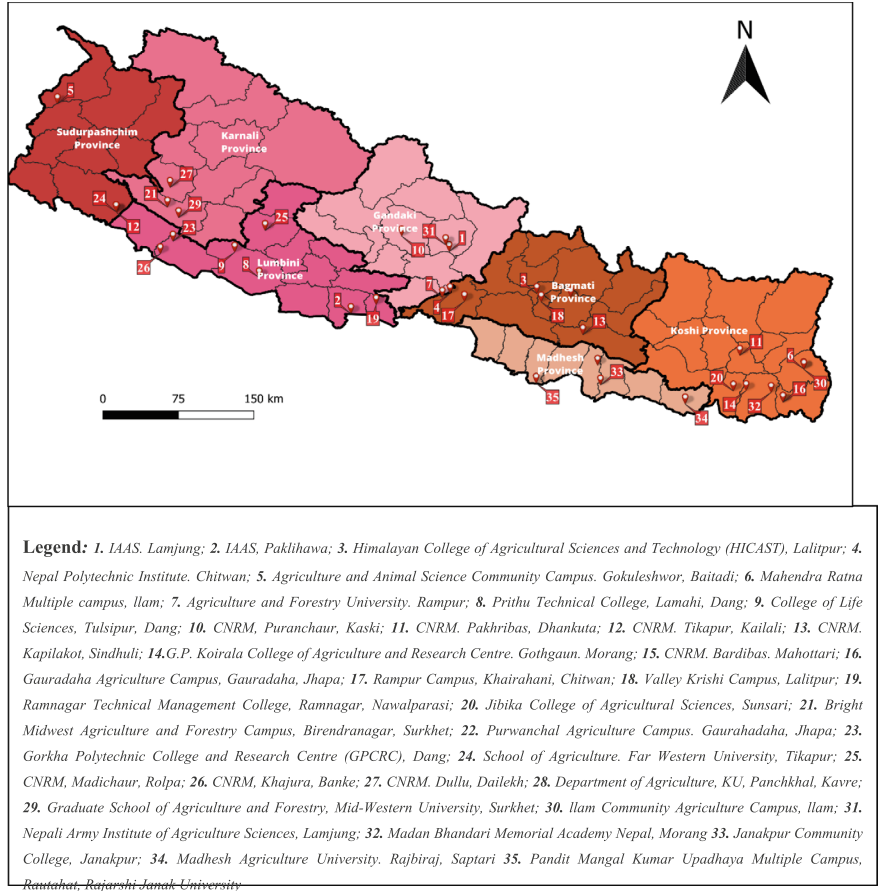


Fig. 1 Distribution of agricultural universities, constituents, and private colleges in Nepal. CNRM: College of natural resource management; IAAS: Institute of agriculture and animal science. *Source* authors compiled

In recent years, there has been a noticeable decline in student enrollment in Nepalese universities, whereas the number of students leaving the country for higher education has been on the rise (MoEST, 2023). According to the Ministry of Education, Science and Technology (2023) in Nepal, the number of students receiving No Objection Certificates (NOCs) increased by approximately 171% from 44,812 in 2021 to 121,499 in 2022. Agriculture education sectors are not an exception to this downfall trend of student admission; the migration of agriculture graduates to pursue higher studies or for job opportunities is 52%, and the major reason for migrating abroad has been the prevailing poor higher education system (Kattel & Sapkota, 2018; UGC, 2018). Many agriculture education institutes prioritize student number over quality, maintain age-old syllabi with minimal updates, lack adequate classroom infrastructure and laboratory facilities and have higher student to faculty

ratios (Amgain & Adhikari, 2022; Paudel et al., 2013). Moreover, excessive course curriculum at the undergraduate level has preoccupied the student mindset, and as a result, students are deprived from deep learning of subject matter and have limited extracurricular involvement. The prevalence of primitive evaluation methods is forcing students to read teachers slides and notes instead of exploring and developing their own intellectual capabilities (Gurung & Azad, 2013; Paudel et al., 2013; Pun, 2019). The government's uncoordinated decision to establish the Agriculture and Forestry University (AFU) within the Tribhuvan University (TU) premises without a formal property transfer has intensified conflicts among university stakeholders. Moreover, politically motivated disputes among students and ongoing administrative challenges have progressively eroded the quality of agricultural institutions (Timalisina, 2021). It has been well established that the agriculture teaching and learning process requires laboratory facilities and extensive field work for enabling the transformation of the prevailing subsistence farming into commercial farming. Our survey revealed that top ranked graduates frequently opt for social science over other biological sciences due to the convenience of conducting research through surveys, given the inadequate functioning of laboratories required for biological research.

This book chapter is intended to review and analyze the cause of the deteriorating Nepalese agriculture education system. We delved into the different agriculture education institutions established in Nepal, differences or similarities in curriculum and conducted a survey with faculty and undergraduate students to discover their approach to the teaching and learning process, laboratory facilities, and laboratory and field work in different agriculture institutions in Nepal. Additionally, key informant interviews with agriculture professionals in Nepal and scholars in foreign countries were carried out to integrate their views in relation to agriculture education and their profession. This chapter recommends the reformation of the prevailing curriculum and the structural transformation of agriculture education institutes in Nepal.

2 Agriculture Education in Nepal: A Timeline

The advent of agriculture education in Nepal dates back to 1957 with the establishment of the School of Agriculture under the Ministry of Agriculture located at Putali Bagaicha, Kathmandu. Later, the School of Agriculture was upgraded to the College of Agriculture and began the Intermediate of Science in Agriculture (I. Sc. Ag) program in 1968 to produce Junior Technicians (JTs). In 1972, the college was upgraded to the Institute of Agriculture and Animal Science (IAAS) under TU. Since the establishment of IAAS, agriculture programs have expanded in different parts of central Nepal and other universities have simultaneously launched undergraduate and post-graduate programs in agricultural science (Fig. 2).

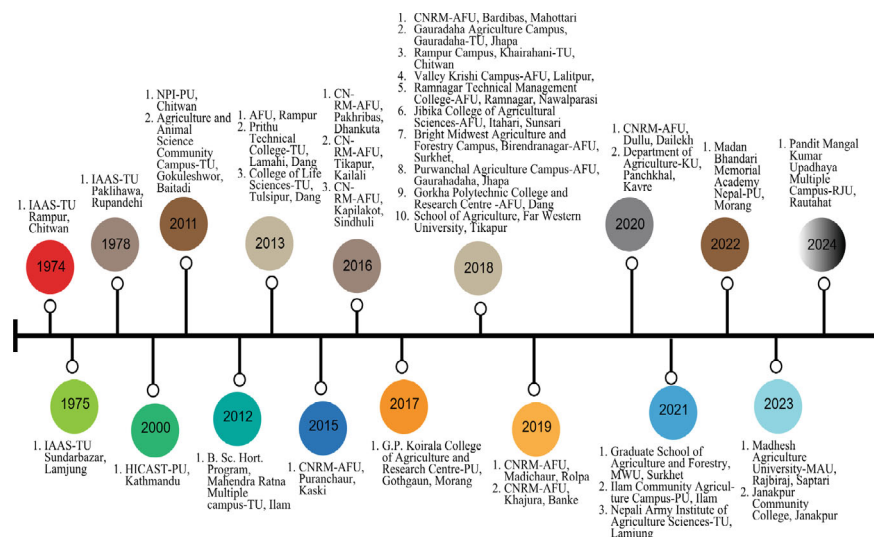


Fig. 2 Timeline of the establishment of agricultural education institutes in Nepal. All agricultural constituent and affiliated colleges of Nepalese universities are listed based on establishment date. *Source* authors drawn

- **Tribhuvan University (TU):** In 1974, IAAS was transferred to Rampur, Chitwan as a central campus, with two satellite campuses in Sundar Bazar, Lamjung, which was established in 1975, and Paklihawa, Rupandehi, which was established in 1975. For a four-year bachelor's, both Lamjung and Paklihawa campus conducted only two years of B. Sc. Ag., and the remaining two years were completed at the central campus in Rampur. From 1975 to date, TU further expanded agriculture programs in the Chitwan, Lamjung, Jhapa, Baitadi, Dang, and Ilam districts of Nepal, adding four constituents as well as four affiliated colleges (Fig. 2).
- **Purbanchal University (PU):** Agriculture education at PU began through an affiliated college: the Himalayan College of Agriculture Science and Technology (HICAST) in 2000 at Bhaktapur, beginning with undergraduate programs. Nepal Polytechnic Institute (NPI), Chitwan, Ilam Community Agriculture Campus, Ilam, Madan Bhandari Memorial Academy Nepal, Morang, and Janakpur Community College became affiliated with PU in 2011, 2021, 2022, and 2023, respectively. Importantly, the G.P. Koirala College of Agriculture and Research Centre was established at Morang by PU as a constituent campus in 2017 to offer B. Sc. Ag. and B. Sc. Agriculture Engineering degrees.
- **Agriculture and Forestry University (AFU):** Agriculture and Forestry University was established in June 2010 at Rampur, Chitwan, with the idea of bringing agriculture and forestry education under a single umbrella to meet the national demand of producing quality graduates. The IAAS Rampur, Chitwan, and the Institute of Forestry in Hetauda, both under TU, were joined to AFU. This establishment followed the land-grant model, where the federal government allocated

state-owned land to build the new university and its colleges (Amgain & Adhikari, 2022; Das et al., 2019). From 2015 to 2020, AFU established seven constituent campuses across all of the provinces of Nepal. In addition, AFU provided private affiliation to seven colleges in 2018. Apart from the teaching institutions, Agriculture Science Centers (ASC) were established in 2019 at Palung, Makawanpur and Ghyalchok, Gorkha to conduct agricultural research and extension programs under the Directorate of Research and Extension (DoREx), AFU.

- **Other Universities:** Recently, the School of Agriculture was established under Far Western University (FWU) in 2018, and Kathmandu University (KU) started a B. Sc. Agriculture under the Department of Agriculture at Panchkhal, Kavre in 2020. The Graduate School of Agriculture and Forestry in Surkhet was established under Mid-West University and Madesh Agriculture University, Rajbiraj and started a B. Sc. Agriculture in 2023. Similarly, Pandit Mangal Kumar Upadhyaya Multiple Campus, Rautahat, affiliated with Rajarshi Janak University (RJU), recently initiated the B. Sc. Agriculture program starting in 2024.

3 Comparing the Undergraduate Agriculture Course Structure of Nepalese Universities

Agricultural courses for undergraduates require content from different science disciplines to fulfill farmers' needs (Kunkel et al., 1996). Appropriate instruction can contribute to higher farm production by increasing technical efficiency and farmers' decision-making capacity (Pudasaini, 1983). The curriculum of IAAS, TU, being the oldest in Nepal, has been developed in response to evolving national demands as envisioned by the Ministry of Agriculture and Livestock Development (MoALD) of Nepal. Subsequently, other institutions established after IAAS, TU have adopted similar patterns in their courses, with minor modifications (Amgain & Adhikari, 2022). Generally, the undergraduate curriculum offers 157–170 credit hours of courses, with a maximum of 40% practical classes (Table 1). Interestingly, the newly established Madhesh Agriculture University has only 19% weightage in practical classes, though its curriculum offers 170 credit hours in the B. Sc. Ag program. This significant difference shows a gap in hands-on learning opportunities for students at Madhesh Agriculture University compared to their peers at other institutions. The variations in curriculum could be designed according to their availability of resources and the interest of the University, which might have an impact on the quality of agriculture education in Nepal. Although the agriculture education curriculum has been revised in AFU and TU, only minor adjustments have been made to ensure the eligibility criteria for the public service commission examination of Nepal. A survey conducted with undergraduate students from AFU and TU revealed that 43.9% and 33.3% of students, respectively, believe in the need for curriculum improvement (Research Survey, 2024).

These students recommended to update and contextualize the current curriculum to better align with the evolving demands of the job market. This indicates a clear need

Table 1 Course structure and the weightage of major agricultural courses in the current curriculum of B. Sc. Agriculture programs in different Nepalese universities

Percentage of course weightage in curriculum								
Major Courses	AFU	TU	FWU	PU	MWU	KU	MAU	RJU
Horticulture	10	12	12	16	11	9	9	10
Agronomy	9	12	7	5	9	10	9	9
Plant protection	11	11	13	14	7	7	15	13
Soil science and agri-engineering	6	12	8	11	7	6	7	14
Plant breeding	6	6	7	5	4	4	4	8
Extension and related courses	7	7	7	4	5	4	3	8
Agriculture economics and project planning	8	11	11	8	8	8	6	9
Animal science	15	11	14	11	13	8	12	9
Sustainable agriculture				7				0
Organic agriculture				2		2		1
Climate smart agriculture						1		0
Precision agriculture						2		2
Other courses	28	17	22	15	36	39	34	16
Total	100	100	100	100	100	100	100	100

Note: *AFU:* Agriculture and Forestry University, *TU:* Tribhuvan University, *FWU:* Far-western University, *PU:* Purbanchal University, *MWU:* Midwestern University, *KU:* Kathmandu University, *MAU:* Madhesh Agriculture University and *RJU:* Rajarshi Janak University
Source Research Survey, 2024

for major curriculum reform to remain relevant and effective in preparing students for future challenges. Alternatively, key informant interviews with 36 faculty members across the seven universities disclosed revisions of curriculum within the last four years. In examining the curriculum, it is evident that newly established universities have incorporated emerging subjects to meet market demands. For instance, Far Western University and Rajarshi Janak University offer an organic agriculture course, Purbanchal University offers courses in sustainable and organic agriculture, and Kathmandu University includes organic, climate-smart, and precision agriculture-related courses (Table 1). We surveyed students from seven universities to understand the motivation provided by the current curriculum, and among 155 respondents, 67% feel that the curriculum encourages scientific and innovative learning. Although universities offer courses on enterprise development, 54% of students believe these courses do not adequately promote entrepreneurship due to shortcomings in their implementation (Research Survey, 2024).

4 Declining Enrollment and Rising Migration of Agriculture Graduates

The B. Sc. Agriculture in Nepal is a four-year undergraduate program pursued after completing 10 + 2 science, I. Sc. Ag or an equivalent qualification with a minimum of 50% marks in each subject for English, Physics, Chemistry, Biology, and Math, or a C+ grade (2.0–2.4 CGPA/GPA). At present, eight different universities in Nepal offer seats for 2154 students in B. Sc. Agriculture, varying in their intake capacity. The AFU offers 934 seats (584 for central and constitute colleges, and 350 for affiliated colleges), followed by 548 seats in TU (300 for the constitute college and 248 for affiliated colleges), 384 seats in PU (96 for central and 288 for affiliated colleges), 110 seats in FWU, 48 seats in MWU, 50 seats in MAU, 30 seats in KU, and 50 seats in RJU.

Despite agricultural science in Nepal being historically positioned as a secondary or tertiary choice after medicine and engineering, student enrollment in the prevailing agricultural colleges was almost 100% in the past, leading to the rising trend in establishing agricultural colleges in Nepal (Timilsina, 2021). However, recent trends show a noticeable decline in the number of applicants to agricultural universities, constituted and affiliated colleges (Fig. 3). In the last five years, the number of applicants to AFU and IAAS-TU has fallen by 62% and 72.9%, respectively. As a result, around 75% of the total affiliated agricultural colleges are on the verge of closing. Meanwhile, most of the constituted colleges are struggling to fulfill their number of seats (Research Survey, 2024).

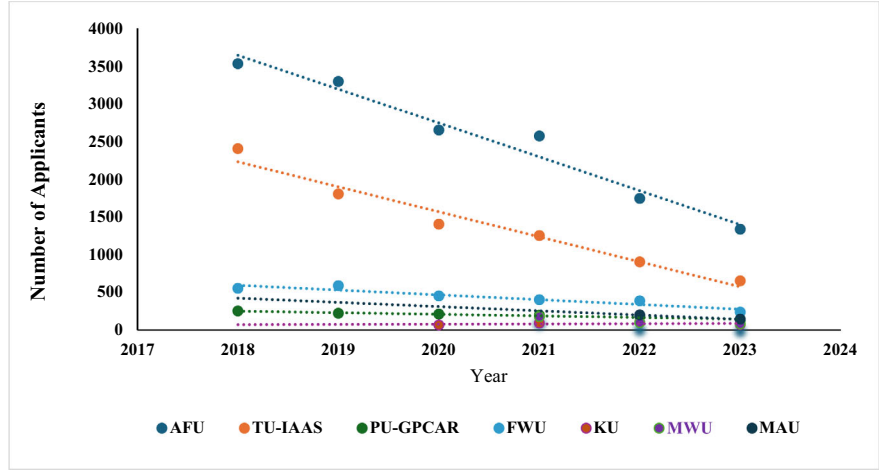


Fig. 3 Application of B. Sc. Agriculture aspirants in the last five years at different universities in Nepal. *Source* Research Survey, 2024

This decreasing trend in student enrollment in agricultural education institutes can be attributed to several factors. The first might be an irregular call for permanent jobs in the government sector, appending insecurity among youth to pursue agricultural studies. Additionally, the proliferation of agricultural colleges across the country has often been unregulated, leading to institutions that are poorly equipped and lacking adequate resources and resulting in a decline in the quality of education, further deterring students from enrolling in these programs. The government has not adequately filled the vacant positions at the Nepal Agriculture Research Council (NARC; where 52% of staff positions remain unfilled) and the Department of Agriculture (DoA; where 47% of staff positions remain unfilled; MoALD, 2024; NARC, 2024). Furthermore, graduates from agricultural colleges that are considered the role models for the development of commercial agriculture are often not retained in Nepal; instead, many choose to migrate to foreign countries in pursuit of better opportunities (Kattel & Sapkota, 2018). Our survey indicated that the reasons for the migration of agricultural graduates from Nepal include the pursuit of academic excellence (78%), access to scholarships (74%), and the quest for social security (52%), as shown in Fig. 4.

Interestingly, agricultural graduates in their home countries often prefer employment in sectors outside their field of study, such as in banks, public administration, or development organizations (Zakaria et. al., 2014). Graduates who previously focused primarily on agricultural subjects encounter nontechnical topics (e.g., general knowledge, ethics, communication skills, administrative aptitude) during the recruitment examination in the public service commission, resulting in increasing attraction toward public administration jobs. This was reflected in our survey, with

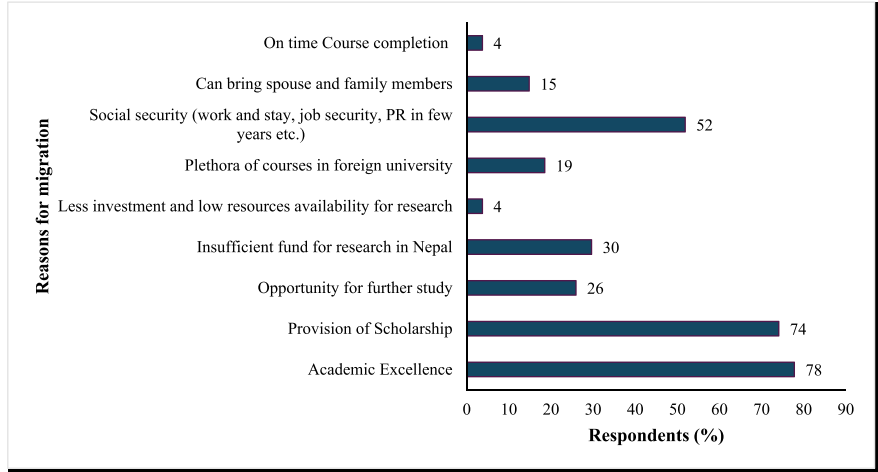


Fig. 4 Major reasons pointed to by agriculture graduates of Nepalese universities in choosing migration to foreign countries. *Source* Research Survey, 2024; migration reasons are adopted and modified from Kattel & Sapkota, 2018

most agriculture graduates—and more precisely, the top ranked graduates—prioritizing social research rather than biological research during their elective courses, internships and M. Sc. study. A shortage of the essential infrastructure, basic equipment, and resources required for effective laboratory and field study and limited funding and support in universities are factors for the dominance of social research in comparison to biological research.

5 Gap in Accreditation and Quality Assurance

Agriculture education requires a substantial investment in physical infrastructure, teaching materials and scientific equipment (Van Crowder et al., 1998). The significant migration of rural populations to urban areas has had a direct impact on investment in rural infrastructure, including educational institutions such as agriculture. Common issues include low infrastructural facility of classrooms, laboratories and field equipment among Nepalese universities because of budget cuts, along with reduced recruitment and staff development (Paudel et al, 2013; Pun, 2019). Unfortunately, new universities meant to transform agriculture education are facing the same problems and adhere to the similar curriculum and teaching approach of IAAS, TU (Ghimire, 2020). This highlights the need for a dedicated governing body for agriculture programs in Nepal apart from the UGC accreditation system. Despite of all these limitations, the number of constituent and affiliated colleges and student intake numbers in Nepal's universities have not been reduced. This indicates a lack of systematic study on the requirements of agriculture human resources in Nepal for the region in a given time (Gurung & Azad, 2013). Though UGC organizes different types of quality assurance and provides accreditation to universities, it does not represent department or specific constituent colleges or institutes. A survey conducted for students' level of satisfaction in technical education in Nepal by UGC showed the level was declining by 37% (UGC, 2018).

Nepal has established separate agencies to provide agriculture education, research, and extension services (Babu & Sah, 2019; Parajulee, 2017). NARC is responsible for conducting research, developing crop varieties, generating technologies, and offering solutions to specific agricultural challenges. The dissemination of agricultural technology to farmers is facilitated through a robust network comprising 51 Agriculture Knowledge Centers (AKCs), 16 Agriculture Development Offices (ADOs), 62 veterinary hospitals and livestock service centers along with 753 local governments. Since the adoption of the federal system in 2015, structural changes have occurred in agriculture offices, resulting in a three-tiered extension system. The challenges in linking research and extension services in Nepal have been exacerbated by the need to serve an additional 753 local governments. Due to inadequate human resources in organizations such as NARC, the Department of Agriculture and local governments, the quality of agriculture research and extension activities has declined significantly. In this context, the establishment of land-grant universities becomes a compelling solution. This survey showed that AFU in Nepal was designated as a land-grant

university in 2010, with a mandate encompassing research, teaching, and extension services. The land-grant model, which originated in the United States of America, integrates these three functions to enhance agriculture productivity, food security, and forestry development. Notably, the success of land-grant universities in the USA and the Netherlands has inspired similar initiatives in South Asia, including Nepal (Das et al., 2019). However, despite this vision, AFU faces challenges due to a poor plan to diversify internal income sources and insufficient investment from the government. Instead of achieving expected outcomes, Nepal has seen a proliferation of agriculture constituent and affiliated colleges under AFU (Fig. 2). This situation raises concerns about the quality of agriculture education in Nepal, especially in the absence of a dedicated council to monitor educational standards. An agriculture council can play a crucial role in maintaining basic standards of undergraduate and graduate agricultural education through the regular monitoring of the curriculum, physical and human resources of agriculture courses offered at universities and the licensing of agriculture graduates. In addition, the Agriculture Council can help to integrate the three foundational pillars of agricultural development: education, research and extension. Similar practices have been noted in medical education, engineering education and veterinary education in Nepal. Particularly, the Nepal Veterinary Council (NVC) plays a crucial role in regulating veterinary practice and ensuring the quality of veterinary education and services in Nepal. It operates under the Veterinary Council Act, 1999, and its responsibilities are focused on maintaining professional standards, promoting animal health, and safeguarding public health (www.vcn.gov.np). In India, the Indian Council of Agricultural Research (ICAR) serves as a prominent example of such an institution. ICAR is responsible for coordinating and managing agricultural research and education across the country. It also evaluates and ranks agricultural universities based on their overall performance, fostering accountability and excellence in the sector (www.icar.org.in).

6 Reforms in the Current Agricultural Curriculum

Curriculum development is often hierarchical, top-down, and content-oriented, with stakeholder consultation being more of a formality and controlled by experts (Taylor, 1998). Maredia (2011) identified major shortcomings in agricultural education curricula in developing countries, such as their irrelevance to the changing rural context, poor understanding of the labor market, and reliance on traditional lecture methods that are theoretical with little practical application. Additionally, these curricula are rigid and lack provisions for credit banking systems.

Given the substantial scientific progress in agriculture, environmental changes, increased participation of women in agriculture, urban migration, and youth outmigration, there is a pressing need to update agricultural curricula to address these evolving contexts. Moreover, there are challenges in enrollment and resource decline

while universities are not able to attract the best students. Agricultural education institutes need to enhance their curricula to provide students with the knowledge and skills necessary for private sector employment, especially when government job opportunities are declining (Pun, 2019). These institutes should focus on equipping students with entrepreneurship skills to better prepare them for the evolving job market (Van Crowder et al., 1998). As an example, the higher education agriculture curriculum of India was recommended for revision by the Fifth Dean's Committee Report and the National Education Policy 2020 to ensure flexible, robust, and globally relevant education for employability and entrepreneurship (Thammi-Raju et al., 2022). It was proposed that the curriculum should include recent advancements in agricultural technologies, integrating machine learning, artificial intelligence, virtual and augmented learning, and entertain flexible learning with the provision of academic credit banking—an open educational system that recognizes the diverse learning experience in- and outside the university and is more student-centered and project-based, with flipped classroom and inquiry-based courses. Similarly, the World Bank suggested shifting toward an interdisciplinary production-marketing focused curriculum rather than the current discipline-and department-focused conventional curriculum (Maguire & Atchoarena, 2003). In summary, changes in agriculture education curricula are needed to integrate courses that can guide students to be growers, organize cooperatives, create value-added products, and create a market information system (Maredia, 2011). The author further purposes to include “Outreach” programs so that small-holder farmers have easier access to university learning opportunities.

In Nepalese universities, there has been revision of the curriculum over five decades; however, it has been limited to minor updates in courses and failed to address the agenda raised by Maredia (2011). The course curriculum is still packed with a higher number of credit loads. To enhance agriculture education, we recommend a comprehensive curriculum within 120–128 credit hours, including practical classes. This type of curriculum has been adopted by universities abroad with well-developed agricultural science programs, and aligns with the country's agricultural industrialization (www.caes.uga.edu; <https://cfaes.osu.edu/>; www.wisc.edu). Agriculture education should surpass the rhetorical effect of getting a university degree for a government or nongovernment job. Undergraduates in agriculture should feel empowered to create employment and engage in agribusiness ventures. Similarly, integrating artificial intelligence, GIS and other modern tools in the agriculture curriculum can upgrade the national agriculture technologies needed to rebuild the national economy through agricultural transformation.

7 Agribusiness Incubation Centers at Universities for Technology Transfer

The successful delivery of agricultural science and technology to farmers is pivotal for transforming the agriculture sector, promoting commercialization, and enhancing efficiency (Saiz-Rubio & Rovira-Mas, 2020). In Nepal, agricultural research primarily occurs in government research stations and laboratories, with limited connections to universities. Most of the research conducted at universities as part of undergraduate and postgraduate programs often goes unrecognized in national research initiatives. Additionally, extension services face significant human and financial deficits, particularly after the devolution of the agriculture sector in federal systems. As with research, universities have limited contributions in extension and community outreach despite the enormous possibility of linkages among stakeholders in research, extension, education and grower (Chittoor & Mishra, 2012; Jaishi et al., 2022a, 2022b).

Universities have the potential to transfer technology and impart entrepreneurship education to commercialize the agriculture sector (Robinson & Sexton, 1994). Yaakub et al. (2011) stated that innovation at agriculture universities should be considered an important tool for economic growth, but it requires a comprehensive model of integrating agriculture research, extension and education institutes empowered with business incubation provision. A novel approach to encouraging agribusiness in India has assimilated research, education institution and extension, along with agri-incubation for fostering agribusiness and start-ups through the agribusiness incubation system (Saxena et al., 2020). Recently, UGC in Nepal has already prepared a guideline for establishing business incubation centers at universities and allotted funding for those universities interested in establishing incubation centers (UGC, 2023). However, the incubation center represents only an additional center within the university and lacks linkages with extension and research institutes.

Instead, we propose a modified model of agribusiness incubation at universities that consists of structural linkages with agriculture research and extension institutions (Fig. 5). The proposed agribusiness incubation center is a specialized facility designed to support and nurture entrepreneurial ventures in the agricultural sector. This center aims to transform innovative ideas and technologies into viable agribusinesses by providing entrepreneurs with the resources, expertise, and networks they need to succeed. The agribusiness incubation center serves as a bridge between research institutions, universities, and the marketplace, ensuring that agricultural innovations are effectively transferred and utilized in real-world applications. A key function of this center is to facilitate collaboration with research and development institutes, government financial support programs, donor agencies, and other stakeholders. By building strong partnerships with farmers, NGOs, business enterprises, and educational institutions, agribusiness incubation centers create an ecosystem that promotes knowledge sharing and technological advancement in agriculture. These centers can help entrepreneurs and start-ups to overcome common barriers and serve innovation-driven growth in agriculture (Nwakoby & Ihediwa, 2024). The proposed model of

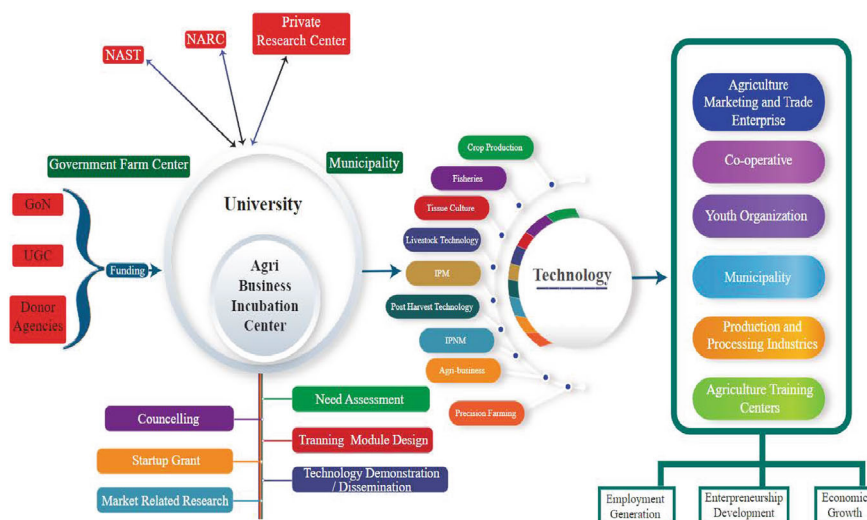


Fig. 5 A model of universities adopting the Agri-business incubation system to foster entrepreneurship through the innovation and enhancement of technology. *GoN*: Government of Nepal, *NAST*: Nepal Academy of Science and Technology, *NARC*: Nepal Agriculture Research Council, *UGC*: University Grant Commission, *IPM*: Integrated Pest Management, and *IPNM*: Integrated Plant Nutrient Management. *Source*: authors drawn

agribusiness incubation center supports implementing commercialization activities of the agriculture sector from the current subsistence farming system as directed by the National Agricultural Policy, 2004 and the National Educational Policy, 2019 of Nepal. Studies conducted by the World Bank have demonstrated the effectiveness of business incubation in fostering sustainable agricultural entrepreneurship, ultimately contributing to economic growth and food security in these regions (World Bank, 2017).

8 Conclusions

Universities play a crucial role in producing agriculture experts and professionals who assist farmers in adopting new technologies and addressing farming challenges. In Nepal, eight universities through 35 colleges produce 2164 undergraduates and 296 institutions under CTEVT contribute 11,840 skilled human resources to the agriculture sector. Despite their potential to commercialize the sector, many graduates either work in government or nongovernment jobs or migrate abroad for higher education or employment. Notably, innovations in agricultural technologies in the Nepalese market often come from returnees trained in foreign institutions. These scenarios have created concerns about the quality of the agricultural education provided by Nepalese universities. The growing demand for agriculture professionals has led

to an increase in colleges offering undergraduate and graduate studies across the country, though student interest in studying agriculture has declined in recent years.

Nepalese universities have yet to fully align their curricula with recent technological advancements and emerging trends in the agribusiness sector. Interestingly, graduates increasingly favor nonagriculture courses over biological sciences. This preference arises partly because the public service commission allocates a substantial portion of positions to social sciences, encouraging students to choose nontechnical fields. Unfortunately, quality assurance and accreditation institutions, including the University Grants Commission, acknowledge the decline in satisfactory technical students within Nepal, but concrete steps toward the improvement have not been observed. These facts point toward the need for reformation in the agriculture education system in Nepal. We recommend the following points to restructure the agriculture education system and move forward to entrepreneurship:

- **Agriculture Course Curriculum, Resources, and Entrepreneurship:**
 - The existing B. Sc. Agriculture program is suggested to change separately as B. Sc. Agriculture (Plant Science) and B. Sc. Agriculture (Animal Science and Fishery) programs. The curriculums of these programs should be concise and limited to 120–128 credit hours for 4 years with 80% course weightage of the respective domain.
 - Separate practical courses for both laboratory and field-based courses should be developed to ensure the hands-on skill of agriculture graduates. The weightage of practical-based courses should be included as a minimum 40% in the future curriculum.
 - The integration of Modern Tools such as AI concepts and applications into the curriculum can empower students to analyze data, optimize processes, and make informed decisions. Thus, courses related to machine learning, data analytics, Geographic Information Systems (GIS), precision agriculture, molecular biology and tissue culture should be added to the current curriculum.
 - Future curriculums should be integrated with business incubation centers to develop agriculture-based business start-ups rather than meeting the eligibility criteria for the public service commission of Nepal. Universities can work to establish a Seed Money Fund in support of government and donor agencies to provide fresh graduates through competition for start-up capital.
 - Basic standards for physical infrastructure, including laboratory and field, human resources, libraries, etc. should be fixed and regulated by the authorized body of government before establishing/launching the agricultural college.
- **National policy and cross-cutting issues:**
 - An Agriculture Council—an autonomous body that is required with rights to monitoring physical and human resources of agricultural colleges, the licensing of graduates and suggesting both federal and provincial universities for periodic updating of the curriculum.

- A separate Agricultural Education Policy needs to be developed within the framework of the National Education Policy, 2019 with focus on linking education to entrepreneurship and bridging the gap of agricultural teaching, research and extension services in Nepal. The proposed Agricultural Education Policy should provide direct roles and coordination areas between the Ministry of Education and Ministry of Agriculture and Livestock Development of Nepal.
- An Academic Credit Banking system should be implemented by universities as envisioned by the National Education Policy, 2019. Interested farmers or agro-entrepreneurs should get a facility of certification from the universities after accumulating the required credits for selected degree.
- An independent board of trustees could be a solution to avoiding political interference in the selection of leadership for the universities.
- Participation of disadvantaged groups and women, conservation of neglected crops, livestock, and indigenous knowledge in the context of climate change should be protected in the curriculum of the new agriculture education system.

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Part III

Commodities and Sector-Specific

Chapter 13

Commercialization and Transformation of Horticulture Through Integration of Improved Postharvest Management: A Roadmap for Nepal



Durga Mani Gautam, Kishor Chandra Dahal, Devendra Gauchan, and Jagadish Timsina

Abstract Nepal has endowed with diverse agro-climates that enable the production of tropical to temperate fruits, plantation crops, vegetables, spices, and medicinal herbs from Terai to high hills and mountains. Nepal is annually importing a huge quantity of fruits and vegetables to meet its increasing demand. The low production and consumption of fruits and vegetables is due to limited commercialization, especially in the hills and mountainous areas. This chapter aims to assess current constraints and challenges in commercialization of horticulture and suggests a potential road map for integration of improved post-harvest management with specific focus on packhouses and cold-chain technologies and facilities for horticultural crops. Current constraints to commercialization include low volume and scattered production, use of low yielding varieties, traditional production practices, high postharvest losses, lack of infrastructure and transportation facilities, poor linkage between industries and market, long gestation period of fruit crops, and high initial cost of establishment. Nevertheless, Nepal has great scope for their commercialization, particularly of citrus, apple, and offseason vegetables, which will help transform Nepalese horticulture industry. Packhouses with cold-chains facilities have potential as they can facilitate commercial production of fruits and vegetables, help establish efficient supply chain and linkages between producers and market, and can consolidate produce and supply to distant markets. Commercialized fruit and vegetable production coupled with the improved supply chain management enables the regular export of fresh produce abroad, especially to India and Bangladesh. To

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commercialize the horticulture sector, the government should establish a land use policy to consolidate small, fragmented areas into large commercial blocks with provision of packhouse facilities and establishment of processing industries so as to substitute import and promote export. We propose a roadmap to promote and commercialize the horticulture industries and facilitate markets and export through the establishment of packhouses, cold-chain facilities, and relevant industries and suggest necessary requirements and policy issues for agricultural transformation through the transformation of horticulture sector.

Keywords Agro-industry · Supply chain · Postharvest handling · Packhouse · Cold chain

1 Introduction

Nepal is situated in subtropical region ($26^{\circ}22'$ N to $30^{\circ}27'$ N latitude and $80^{\circ}4'$ E to $88^{\circ}12'$ E longitude) enriched with diverse agro-climates suitable to produce different crops. The lowland of southern terai is suitable to produce cereal food grains and legumes while the hills and mountains are more suitable to produce fruits and vegetables. Various offseason vegetables can be produced in the higher hills and marketed to the distant markets in Nepal and India. However, despite various efforts made by the government and nongovernment sectors in the last five decades, the current production and productivity of fruits and vegetables are quite low. As a result, the production of horticultural crops has not met the increasing demand (Pandey et al., 2022). Since the demand is higher than the production, Nepal imports substantial amounts of fruits and vegetables from overseas, especially from India, every year. The import of fruits has increased by 105% and vegetables by 76% during the last six years (2013/14–2019/20). During 2022/23, the value of imported fruits and vegetables was NPR 20.56 billion and NPR 31.87 (1 US\$ = 130 NPR), respectively (NFTS, 2023). On the other hand, a large quantity (20–30%) of fruits and vegetables produced and marketed in the country is lost during postharvest handling, storage and marketing (Bhattarai, 2018). These huge postharvest losses have not only reduced availability of fruits and vegetables for local consumption but also increased the loss of scarce foreign reserves used for import.

The low production of fruits and vegetables is due to their limited commercialization, especially in the hilly areas. Often reported major constraints to commercialization are low volume and scattered production, use of low yielding varieties and traditional production practices, high postharvest losses, lack of infrastructure and transportation facilities, poor linkage between industries and market, long gestation period of fruit crops, and high initial cost of establishment. Despite many constraints, several horticultural industries are being established, which have potential to export horticultural products to domestic and foreign markets. Nepal has great scope for commercialization and export of apple, walnut, apricot, peaches and pear in western mountains; coffee, citrus, and avocado throughout the mid hills; tea and cardamom

in the eastern hills; offseason vegetables in the mid- and high hills; kiwi and dragon fruit in the mid hills; and banana and mango in terai. Some key government policies such as Agriculture Perspective Plan (APP, 1995) Agriculture Development Strategy (2015–2035), National Agriculture Policy (2004) and Agribusiness Policy (2006) have emphasized promotion of high value crops (mainly horticultural crops) in different agroecological zones. Many farmers are, however, reluctant to grow fruits on a commercial scale due to high initial investment, poor technical knowhow, lack of research, and poor postharvest handling. Furthermore, marketing of fruits in small quantities is difficult and less profitable in the hills and mountains due to poor transportation networks and high cost of produce collection from the scattered and remote locations. Hence, some projects and programs have established collection centers in production pockets for assembling produce and marketing in bulk. In this context, appropriate and well-designed packhouses could help convert farm fresh products into market-ready packages.

Establishment of packhouses with cold-chains facilities provides an option to manage supply chain for distance markets. Properly constructed and well positioned packhouses can assemble the produce, perform different operations, and dispatch the fruits and vegetables to markets and processing plants (Acedo et al., 2016). Such packhouses can provide the opportunity for storing fruits and vegetables of small growers in the local areas as well, which will also help with commercialization. The commercialized vegetable production coupled with the improved supply chain management enables the regular export of fresh produce, especially to India and Bangladesh. At the same time, it is also essential to establish processing industries, for example, for the preparation of jam, jelly, marmalade, juice, candies, beverages and liquids which can substitute the import and potentially be exported. Hence, there is need by the government to establish a sound land use policy to consolidate small, fragmented areas and bring large areas under horticultural production.

A proper postharvest management plan is important to transform Nepalese agriculture into a commercial profit making agriculture. This chapter aims to amplify the horticultural industries for commercialization and export promotion through establishment and scaling of packhouses and improvement of postharvest management system. The major data sources and information for the chapter are from the review of published and unpublished research papers, official national statistics, and expert consultations. A roadmap has been prepared for promoting and commercializing the horticulture industry in the country through the establishment of packhouses and cold-chain facilities and export of high value horticultural products.

2 Constraints to Commercialization of Horticulture

There are several constraints and challenges to commercialization of horticulture in Nepal, which are briefly outlined below:

2.1 Small Land Holding and Scattered Land

In Nepal, lands are highly fragmented, and parcels are scattered in different places. The average land holding size is about 0.55 hectare per family (CBS, 2022). The decreasing size of the farm increases the difficulty for mechanization as well increases the cost of operations. For commercial production, large land area should be brought under cultivation. In general, bigger farm size lowers the cost of production per unit area. Hence, the government should formulate an appropriate land use policy to provide private land on long-term lease to promote the commercialization of horticulture crop production. Most of the fruit trees have 30–50 years of productive life and they have gestation period of 3–7 years. If larger area is under mechanized production, the bulk production also enables the establishment of packhouses, cold storages, handling, transportation, and consistent supply chain for long-distance marketing.

2.2 High Cost of Production, Poor Value Addition, and Inaccessibility to Market

High cost of production, low value addition, and weak marketing are major constraints to commercialization of horticultural crops. The cost of production is higher than purchasing food in the market due to the higher cost of inputs and labor wages. In addition, most of the youth and workforce, especially in the hills and mountains, have flown away in search of job, and mostly the aged people are residing in the villages. This has resulted in huge labor scarcity leading to land fallowing and constraining the adoption of commercial farming. It has been reported that about 40% of cultivated land in Karnali Province is fallow and a similar situation is prevalent in other provinces too. Furthermore, due to poor linkage of production with industry, there is a poor value addition of fresh product resulting in high postharvest losses. Marketing of fresh horticultural products is also constrained by poor market linkage, poor packaging, and lack of branding and marketing information. For instance, although in Kathmandu and other major cities the government has established fruit and agriculture wholesale markets, not all these markets are directly linked with the producers. Most of the time producers bring their produce to the market, look for traders, and negotiate the price, however, disparities are reported in dealing with individual farmer and traders linked suppliers.

2.3 Lack of Economic Scale of Production and Marketing

Commercial production of a particular crop should be concentrated to make a convenient supply of inputs and the produce. Postharvest handling and proper management

are much needed to supply fresh produce, especially to distant markets and industries on a regular basis. Packhouses and processing facilities and supply chains run in a cost-effective way with increasing volume of production. Large volumes can be achieved if specific crops are produced in specific areas as per their comparative advantage. For example, in India, Nasik is famous for onion, Nagpur for santra (oranges), and Simla and Kashmir for apple production. Premium quality produce can be targeted for export market to fetch high value, standard grade to nearby market, and low grade to the industries. Nepal has made a trade agreement with China in 2012 for the export of citrus to Tibet. Until date, Nepal could not export fruits to Tibet because of phytosanitary requirements. Insects and diseases are endemic in Nepal and therefore it is difficult to meet the requirements. An agreement signed in 2019 with some relaxation allows pest free product to export (Aryal et al., 2022). The product must be from designated production areas and packhouses controlling measures. Suggestions were made for cold treatment with precooling at 7 °C for 24 h and then to 3 °C for 16 days. In order to accomplish phytosanitary requirements for export, the establishment of a well-equipped packhouse is needed.

2.4 Poor Postharvest Management and Handling Practices

In traditional practices, farmers usually harvest the horticultural crops at a fully mature stage and handle them with least care. Moreover, all the harvested fruits (healthy and injured) are kept together and sold in the markets as such without proper sorting and grading. Thus, the postharvest loss of horticultural produce in Nepal is very high, often reaching up to 50% (ANSAB, 2016; Gautam et al., 2023). Harvesting at the appropriate stage of development/maturity and appropriate storage and handling are crucial for better-quality produce. In conventional methods fruits and vegetables are transported in conical bamboo baskets or sacks, which results in higher damage to the produce. In recent years, however, plastic crates are generally used for transportation of fruits and vegetables (especially tomatoes). During summer months, transportation of vegetables is more problematic as the high ambient temperature accelerates their physiological processes. Such acceleration in detached fruits or vegetables increases spoilage loss and shortens the shelf-life. Further, any kind of injury to harvested produce increases its respiration and ethylene production and degrades the produce at a faster rate. Pathogens invade through the wounds and cause diseases and rotting of produce. Inappropriate harvesting, handling, and transportation and storage can lead to inferior quality produce with high postharvest losses, limiting their potential for long-distance marketing.

2.5 *Inadequate Policy and Investment Support for Horticulture Sector*

The horticulture sector is less prioritized in implementation of government programs and priority, despite government policies that have emphasized commercialization and exploiting comparative advantage of high value horticultural crops. For instance, the Agriculture Development Strategy (2015–2035) has emphasized competitiveness and increased export of horticultural crops through enhanced agribusiness activities. Similarly, Nepal Trade Integration Strategy (NTIS) in 2010, 2016, and 2023 have identified some of the horticultural crops (large cardamom, ginger, tea etc.) having export potentials, but limited efforts are being made in boosting export of these crops. Since the government of Nepal has currently given higher emphasis on programs for immediate food security than nutrition security, fruits and vegetables that are essential for ensuring nutrition security and income generation are less prioritized in program implementation. Hence, horticultural crops have received less attention in R&D and resource allocation as compared to major cereals (rice, maize, wheat). In addition, the research, innovation and human resource capacity in perennial fruit trees and post-harvest management of fruits is very limited due to their long gestation period. There is also limited donor funding, research priority and private sector investment on fruit crops as they require longer time to achieve the results (Pandey et al. 2022).

3 *Packhouse Operations and Improved Postharvest Management*

Postharvest management deals with the planning and execution for handling of the produce in different stages from the producers to the consumers. Postharvest management refers to assembling of produce, packhouse operation, processing, storage, transportation, and marketing. Packhouse is the mid-point for linking both producers and markets that enables quality assurance, serves as a hub for coordination between producers and market, dictates production, and regulates the supply. General packhouse operations are pre-cooling, sorting, trimming, grading/sizing, coloring, disinfection, waxing, fumigation, and packaging (Acedo et al., 2016). These operations differ for different commodities (fruits, vegetables, tuber, bulb, etc.) based on the nature of perishability. There is no standard design for a packhouse. It is designed based on volume, activities and requirements for the market. A general flowchart with major components of packhouse is shown in Fig. 1, and a general set up for a typical packhouse operation is illustrated in Fig. 2.

Fruits and vegetable packhouses are mostly used to assemble and market the produce aiming to sale in supermarket. Large packhouses are operating in USA, Brazil, Israel, Australia, China, and many other countries. Citrus academy in association with citrus research international and citrus growers' association has provided guidelines for production and different packhouse operation practices for citrus

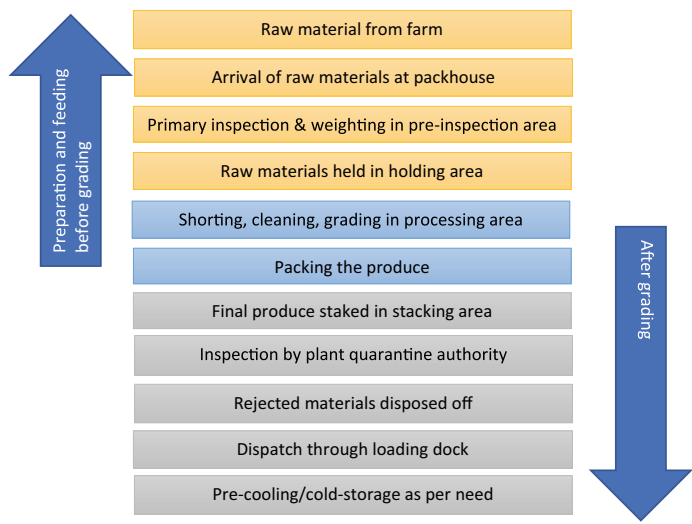


Fig. 1 A general flowchart of packhouse operations

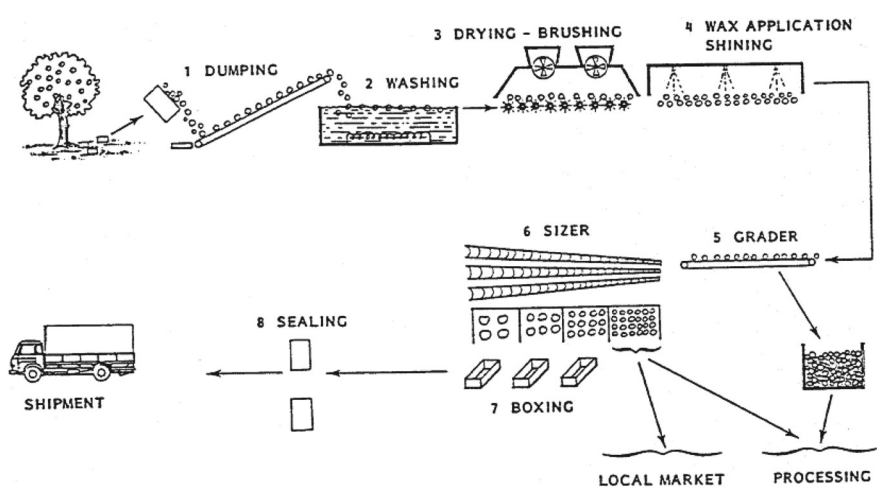


Fig. 2 A simple schematic illustration of general packhouse operations. Adapted from FAO, 1986

(Citrus Academy, 2022). The guidelines require that a packhouse must be clean and sanitary, the fruit must be of food safety standard, its processes must be monitored for quality, and all workers in the packhouse must maintain high level of personal hygiene and adhere to health and safety regulations. All relevant details should be recorded on arrival of citrus such as date, time, weight, citrus type, and cultivar, production unit, and orchard and grower(s). Depending upon the delivery market, inspection is necessary against moth and fruit fly infestation. After pre-sorting, fruits

are treated with fungicide in a bath or floodwater to cure young infection that can cause decay. After treatment fruits are passed through a drying tunnel. Dry fruits are waxed to prevent moisture loss through the rind, enhance their appearance, and sometimes fungicides are used for long-term protection. After waxing, fruits are again passed through the drying tunnel. Fruits are graded based on size and other quality parameters. In most packhouses, sorting is done manually. Same quality fruits are packed together in a cartoon or labeled one by one and wrapped if required for the destination market. Cartoons are labeled in accordance with market specifications and stacked on pallets. Finally, the Perishable Product Export Control Board (PPECB) inspects to make sure it complies with the minimum requirement for export to destination market.

In case of vegetables, some differences occur with the fruits. Most of the vegetables require washing, cleaning, trimming, sorting and grading, sanitization, drying, and packaging and labeling. Vegetables like capsicum, brinjal, tomato, carrot may need grading accessories in the packhouse to segregate in different sizes or grades. Acedo et al. (2016) and USAID (2021) have given guidelines for construction of a small vegetable packhouse for small producers in Nepal. Before establishing a packhouse, appropriate location and land, accessibility to road, reliable water and electricity, and the robust planning for the packhouse are needed (Citrus Academy, 2022). The packhouse should be located as close to the vegetable farms as possible to provide service to the greatest number of farmers and the land should be flat and sufficient to construct the packhouse building, storage facilities, and receiving and dispatch units. It is better to establish a greater number of small packhouses if production is scattered in large distance locations.

Since packhouses are directly linked with the markets and farmers they should be established in production pockets to minimize the involvement of middlemen. Effective marketing of fruits and vegetables is possible by constructing the packhouses in production pockets and to regulate their supply. Subedi et al. (2017) suggested corrugated paper cartoons for transport of apple from Jumla to Nepalgunj for effective transportation and with minimum postharvest loss. Others (Gautam et al., 2019; Gautam, 2020; and Gautam & Baral, 2024) also suggested an approach for packhouse establishment and cold-chain management for long-distance marketing of fruits and vegetables. A private packhouse established in the remote district Manang has found to be effective for the marketing of apple to the distant markets (<http://agromanang.com.np/>). Figure 3 presents packhouse and their linkage with farm and markets.

4 A Roadmap for Postharvest Management of Fruits and Vegetables

A visionary roadmap is required to integrate commercial fruits and vegetable production with postharvest management. To accomplish the proposed road map, it requires a concrete long-time plan and adequate investment. Government can include such

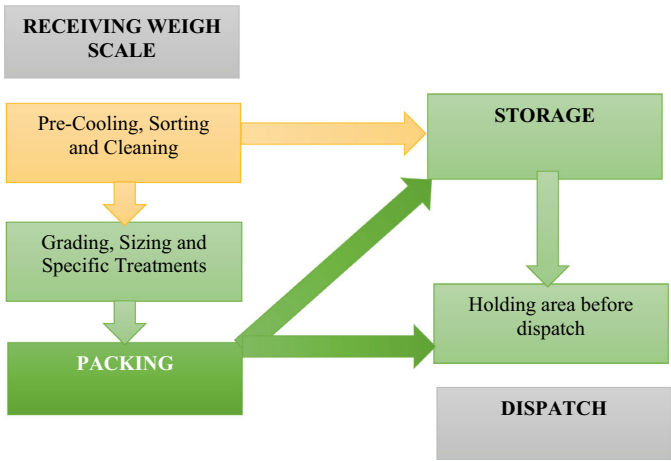
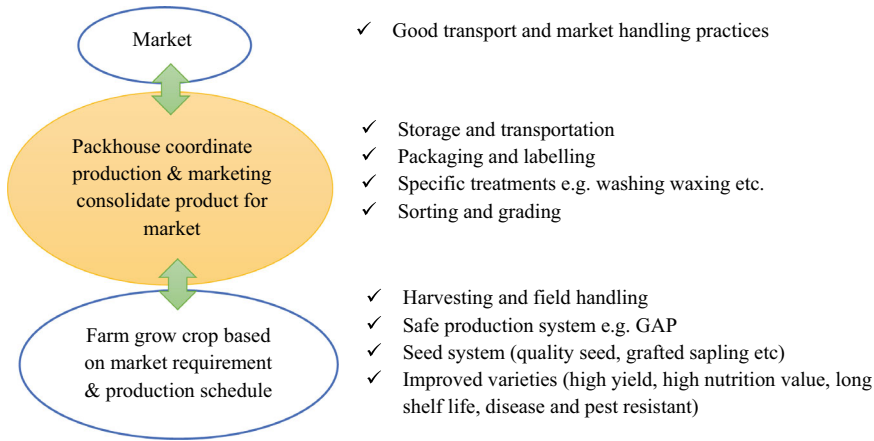


Fig. 3 a A packhouse and its linkage with farm and market, and **b** components of a model packhouse. Adapted from Acedo et al., (2016)

plan in its visionary document and amend periodically in five-year plans. The suggested strategic priorities for the roadmap include mainly two aspects: (i) strategic interventions for overall post-harvest management and (ii) specific actions related to packhouse technologies and facilities.

4.1 Strategic Priorities for Postharvest Management of Fruits and Vegetables.

The strategic priorities for commercialization of horticulture through integration of improved post-harvest management include research and innovation, policy and regulatory framework, investment in institutions and infrastructure, incentives to farmers and agro-industries, and trade facilitation. The suggested actions are briefly outlined below.

4.1.1 Identifying Pocket Areas and Prioritizing Specific Horticultural Crops

The government needs to conduct comprehensive agroecological mapping and zoning to identify suitability of specific horticultural crops in specific agroecological zones. This will require research and innovation to identify and prioritize suitable crops based on crop suitability analysis by linking suitable climate, soils and water resources employing new tools and techniques such as GIS and remote sensing. This can be achieved through implementing zoning regulations and incentivizing farmers and stakeholders to cultivate in designated pocket areas for different types of horticultural crops.

4.1.2 Developing and Executing Long-Term Land Use Policy

Nepal has already formulated Land Use Policy (2015) and Land Use Act (2019) for implementation of land use policy that categorize lands into 11 broad classes (e.g. agriculture, forestry, industry, settlement area, etc.). The current land use policy provides authority to local governments to classify lands into agricultural and non-agricultural purposes. Based on this policy, most of the local governments in peri-urban and urban areas are currently allocating the productive agricultural lands for non-agricultural purposes in view of receiving high benefits from the sale of lands for housing and industrial purposes. This requires formulation of strict regulations and adequate incentive mechanisms to reallocate the productive lands currently being used for non-agricultural purposes to agriculture with an emphasis for commercial horticulture.

4.1.3 Investment in Institutions and Infrastructure

Food safety issue is currently the biggest hurdle for commercialization of horticulture and for both domestic and export markets in Nepal. The government of Nepal needs to make increased investment in post-harvest management research, education and extension to develop and promote innovative technologies and solutions to improve

value chain efficiency, reduce cost of production, and minimize post-harvest losses and food waste. Increased investment is also needed for modern laboratory facilities for post-harvest research, testing facilities, and food safety requirement specifically focusing on pesticide residue and microbial presence and resistance analysis for both domestically produced and imported fruits and vegetables. The institutional capacity of country's sanitary and phytosanitary (SPS) agencies with modern laboratory and human resources is crucial for export of high value potential horticultural products.

4.1.4 Policy, Regulatory Support, and Incentives for Horticultural Business

Presently micro-small and medium enterprises (MSMEs) and entrepreneurs lack adequate policy support, regulation and incentives to make increased investment in horticulture business, value chain development, and postharvest management infrastructure and facilities. The government of Nepal, therefore, needs to make increased priority and investment in horticulture business, specifically focusing on postharvest management, by strengthening functional interagency coordination mechanism and improved policy and coordination among the three tiers of governments. Smallholder farmers and MSMEs need to be provided with adequate access to subsidized loans, agricultural insurance, and start-up funds and subsidies for investment in horticulture value chain and marketing. They need special tax holidays, reduced tariffs and subsidies on infrastructure and inputs for setting up packhouses in production pockets and introducing cold-chain management and linking packhouses with farmers and market. Incentives and policy support to private sectors operating agribusiness is essential with tax rebates, financial incentives, and market linkage for exports of horticultural products. The government of Nepal needs to develop a special standard and regulatory support to enforce establishment and promotion of packhouse operations, ensuring hygiene, quality, and safety of horticultural products.

4.1.5 Market Logistics and Trade Facilitation of Horticultural Products

Improved market logistics and trade mechanisms reduce postharvest losses, enhance market access, promote exports, and boost the overall competitiveness of Nepal's horticultural sector. Strengthening linkage of rural collection centers from the production pockets with energy efficient transport systems by connecting rural farmers with distant markets helps in marketing of horticultural products and reducing the postharvest losses. In addition, logistics and facilities related to improved supply chain efficiencies, rapid pesticide residue testing and efficient quarantine facilities at border points will improve Nepal's export performance and reduce import of unhealthy and dumped horticultural products. There is also a need of trade facilitation of Nepalese horticultural products in overseas market through diplomatic mission with focus on overseas trade fairs, trademark registration, and export market linkages (Gauchan et al., 2024). Special focus should be given to simplify and modernize customs

procedures and establish export hubs, and provide quality certification support for the export of Nepalese high value horticultural products.

4.2 Strategic Priorities for Packhouses Including Processing and Marketing Facilities

Packhouses, processing plants, and cold storage and cold-chain facilities should be established with a public–private partnership model. The government should establish the necessary road facilities and electricity in subsidized rates and provide loans and exemption of tax in initial years of establishment. For the commercial production of fruits and vegetables in remote areas for distant markets, a visionary roadmap as presented below suggests for the establishment of appropriate types of packhouses for different kinds of fruits and vegetables in different production pockets. In the first phase, three model packhouse are suggested, one each for apple, mandarin, and vegetables.

4.2.1 Temperate Fruits for Distant Markets

Karnali Province is suitable to produce apples and other temperate fruits. The province produced a total of 32,712 mt of apples from 3690 hectares of productive orchard while Jumla district of the province alone produced 13,958 mt in 2021 (MoALD, 2023). Total apple planting area has now been increased to 9591 hectares indicating that the production will likely triple after a few years. Establishment of a model packhouse for apple fruit and nuts is necessary in the Karnali Province targeting the distant markets. For this, Jumla is proposed due to its high production potential, availability of flat land, and its accessibility to highway. A packhouse management board should be formed from the producers group to provide guidelines for production of quality fruits as demanded in the market. It is not possible to process and export large quantity of apple within a short period of time. Hence, construction of a sizeable cold store (to accommodate up to 50,000 mt of fruits) nearby the packhouse is suggested to store apples before and after processing. Refrigerated vehicles for transport of fruits and some of a cold stores (to accommodate up to 15,000 mt of fruits) nearby Surkhet district are also needed to store fruits in case of road disturbances. A separate processing plant also needs to be established to utilize sub-standard and excess fruits to produce jam jelly, juice and liquors. Establishment costs for the packhouse and allied facilities are high; thus, the government should support fully or partially. In the long run, packhouses should run autonomously by the management board formed by the commercial producers.

4.2.2 Mandarin for Distance Market

The Gandaki Province has the highest acreage and production of mandarin. The leading district Syanja in the province produced 13,800 mt mandarin in 2022 (MoALD, 2023). Hence, a model packhouse for citrus is necessary in Syanja or nearby convenient areas. We propose for the construction of a packhouse along with a cold store (upto 20,000 mt capacity) and eight refrigerated trucks is suggested. Refrigerated carriers are needed for transportation of citrus to the distant markets or for export to Tibet, as Chinese government has already made agreement with Nepal government to import Nepalese oranges. To utilize excess production in season and sub-standard quality produce for fresh consumption, a processing industry should be established along with a packhouse to produce jam, jelly, and beverage.

4.2.3 Long Distant Markets

For distant marketing of vegetables, assembling, sorting, grading, pre-cooling and refrigerated transport are essential. In the absence of these it is not possible to transport vegetables to distant markets in good condition. Salyan, Pyuthan, Rolpa, Rukum, and nearby districts are the production pockets of cauliflower, cabbage, capsicum, beans, radish, carrot, tomato, onion, and many leafy vegetables. In recent years, efforts have been made to export vegetables to India from these districts. However, serious problems of high postharvest losses have been reported due to wilting, desiccation and diseases, emphasizing the need for a packhouse along with refrigerated vehicles. In general, a vegetable packhouse will be less sophisticated compared to a fruit packhouse. It is proposed to establish a larger vegetable packhouse in the central location Kapurkot and a few small packhouses in different locations so that the vegetables can be collected and transported by refrigerated vehicles to distant markets.

4.2.4 Peri-urban Areas or Urban Centers

The postharvest roadmap for vegetables grown in peri-urban or urban areas or for short distant markets should have a different modality. Existing vegetable collection centers should be provided with facilities for washing, trimming, sorting, grading, precooling, and packaging of vegetables. Individual farmers or farmers' cooperatives can manage their own packhouses for sorting, grading and packaging. Few of such vegetable packhouses and cold storages have already been established by various GOs and I/NGOs at Kavre, Nuwakot, and Makawanpur districts to facilitate vegetable marketing. However, in the present context, farmers are reluctant to use packhouses and cold storages for vegetables due to the cost required for additional activities and thus adding cost to the produce and lack of cold-chain transportation facilities. Commercial farmers prefer to perform different packhouse activities such as washing, sorting, and grading in their own farm. Though pre-cooling is effective to lower the

metabolic activities and prevent loss, sophisticated precooling is not suggested in peri-urban areas as it adds cost to the produce. Cooling can be done just by keeping in shade, harvesting during the cool hours, and washing with cold water wherever applicable. Thus, precooling may not be essential to the vegetables that are either harvested in the evening or early morning and transported immediately to the market during night or early morning. The emphasis should be given for the control of quality especially pesticide residue assessment, cleaning and grading, and labeling of the produce.

5 Financial and Human Resource Requirements for Constructing a Packhouse

Packhouse facility is assessed based on the crop, the volume of production and the targeted market. For fruits, labeling, grading and packing of individual fruit is important while for vegetables washing and labeling of packages are important. Similarly, fruits can be stored comparatively for a longer period than vegetables. Hence, the facilities within a packhouse will be different for fruits and vegetables. We propose below the estimated costs for three types of packhouses to process apple, mandarin, and vegetables for distance markets (Table 1).

A board of management (7–11 members) is suggested to operate each packhouse depending on the number of growers involved in the packhouse facility. Clear guidelines are needed for the management board and operational staff and the proper coordination of all staff and equipment is important in the packhouse for its synergistic efficiency. It is proposed to form a putative board of eleven members with nine members to be elected from the general assembly. The General Manager/Chief Executive Officer will act as a member secretary and another officer should be nominated from the concerned government authority (for example, for the fruits packhouse, a member from National Center for Fruit Development and for the vegetable packhouse, a member from the National Centre for Potato, Vegetable, and Spice Crops Development) can serve as a member.

The operating staff for running a packhouse are as follows: (1) General Manager or Chief Executive Officer; (2) Administrative Officer; (3) Account Officer; (4) Operating Engineer (Machine operator); (5) Quality Control Officer; (6) Production and Marketing Officer; (7) Seasonal staff such as Sorters, Graders, Packers, Palletizers, Lifters, etc. Though seasonal staff are required only when the packhouses are in operation, their recruitment is critical as people with such skills are scarce in Nepal. The numbers of sorters, graders and packers varies depending on the size of the packhouse and the quantity of production.

Table 1 Estimated cost for the three packhouse models (based on 2024 estimate)

S. N.	Model	Allied facilities	Refrigerated trucks	Estimated cost (NRs millions)	Remarks
1	Temperate crops particularly apple in Jumla: Packhouse operations (washing, sponging, waxing, electronic grading, drying and grading line machine)	Three cold stores: 20,000 mt and 15000 mt in Jumla; and 15,000 mt in Surkhet; One processing plant in Jumla	10–12	900	Includes the cost for land acquisition, office building, packhouse building, machineries, processing plant, quality control laboratory, packing material, bins, local vehicle etc
2	Mandarin particularly in Syanja: Packhouse operations (washing, sponging, waxing, drying and grading line machine)	Two cold stores: 10,000 mt each in production site; one processing plant in Syanja	8–10	500	
3	Vegetables: Packhouse operations for non-round type vegetables (shrink wrapping facility in conveyor belt with washing, cleaning, drying and labeling. Packhouse operations for round fruit vegetables (sorting, washing, drying and grading line machine)	One cold store: 25,000 mt in production sites	5	400	

6 Quality Assurance and Working Modality for a Packhouse

For the quality assurance in the packhouse, overall emphasis should be given to integrated disease and pest management, and quality production since a systematic implementation of quality assurance is the key to the success in the emerging market (Khatiwada et al., 2022). The Plant Quarantine and Pesticide Management Center, the Department of Agriculture (DOA), and the National Fruit Development Centre under the Ministry of Agriculture and Livestock Development (MoALD) should support area-wise disease and pest management plans, orchard inspection, package of practices verification, transport facilitation, and privilege marketing and export. There should be monitoring of pesticide residue in fruits and vegetables at the wholesale

market. Some of the quality assurance systems for assessing fresh fruits and vegetables quality are Global Good Agriculture Practice (GlobalGAP), safe quality food (SQF), Fresh Care, Codex elementaries code, and Good Hygiene Practice (GHP).

Fruits and vegetable packhouses established at Jumla, Syanja, and Sallyan districts can be operated either on producers' cooperative basis or with a company model. If they are operated on a cooperative basis, producers will have to form association and contribute for their ownership. The government should support by subsidizing the establishment cost. If they are to be operated on a company basis, each individual farmer will have to purchase the share of the company. Besides producer farmers, other persons may also purchase the share as that of other companies. The Management Board will decide the purchasing and selling price of the product. The packhouses will run themselves and generate profit for the cooperatives or shareholders. It is assumed that upon successful implementation of above mentioned packhouses, more numbers of packhouses will be established by private sector in different production pockets.

7 Postharvest Research and Execution Modality

After harvest, fruits and vegetables are deprived of regular anabolism process, thus, sensitive to the various factors that regulate metabolic processes. The postharvest handling and management related research are very specific to the growing season, crop, variety, accessibility to road and market, and transportation, along with preharvest factors. Continued research is needed as the technology on crop, variety, facilities, etc. have been changing over time. In Nepal, the Nepal Agricultural Research Council (NARC) is responsible for research, the departments of agriculture and livestock are for dissemination of technologies, and the agricultural universities and institutions are responsible to produce the human resources, though the later are also involved in research and extension. Programs and activities are stretching in unorganized way without any coordination. For effective and synergistic research in postharvest horticulture, there is a need of coordination among related institutions. To create linkage among NARC, agriculture universities/institutions and DOA, a National Agriculture Research, Education and Extension (NAREE) board is proposed. The board should be created with a clear term of reference for the effective utilization of resources, streamline the resources on national priority areas, and synergize the efforts for quality education, research, and extension services. The board should be responsible for the identification of national priority areas and should limit the resources within the frame of the Management Team.

8 Conclusions

Nepal has potential to increase production and commercialization of different kinds of horticultural produce on a commercial scale to supply to distant markets within the country as well as for export to other countries. The country has comparative advantages in the production and marketing of high value horticultural products. This will require identification, prioritization and promotion of production of niche-specific potential horticultural crops in specific agroclimatic zones by identifying production pockets and integrating with postharvest management facilities with specific focus on packhouse technologies and practices. However, the scattered and low production volume, high cost of production, and undeveloped marketing are the major bottlenecks to boost production volume and marketing. The production plan should focus on bulk handling and transport to long distant markets. There is a need of strategic interventions for overall postharvest management and specific actions related to packhouse technologies and solutions for the effective marketing of fruits and vegetables. In addition to packhouses and cold-chain facilities, investment in construction of cold storages, establishing relevant R&D institutions and industries for processing, and smooth roads for transport of horticulture produce is necessary. Similarly, the integration of postharvest management with focus on packhouse technologies and facilities will help in commercialization of horticulture. However, this will require strengthening post-harvest horticultural research and innovation, enabling policy and regulatory frameworks, investment in institutions and infrastructure, and adequate incentives and support to farmers and agro-industries for marketing and trade facilitation. The proposed roadmap for postharvest management with establishment of packhouses and cold-chain facilities can be a significant milestone for transforming the agriculture sector in Nepal.

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Chapter 14

Enhancing Nepal's Vegetable Subsector: Strategies for Import Substitution and Export Promotion



Ramhari Timalisina, Santosh Pathak, and Krishna Timsina

Abstract The vegetable subsector is one of the prioritized areas in the Government of Nepal's agricultural transformation initiatives. Despite increasing production during the past three decades and the government's high prioritization to enhance this subsector, the Nepali market largely relies on imports to fulfill national demand for vegetables. This chapter outlines strategies to reduce trade imbalances within Nepal's vegetable subsector. Key challenges facing this subsector, particularly focusing on the vegetable trade, are discussed and potential interventions identified. To tackle current challenges, recommendations are made that include optimizing costs, improving value chain efficiency, strengthening institutions related to smallholder farmers, redesigning subsidy schemes, increasing investment for contextualized innovations, developing linkage of production pockets with (inter)national markets, strengthening quarantine and (phyto)sanitary measures, enhancing trade negotiations, and promoting interagency collaboration.

Keywords Competitiveness · Policy · Self-sufficiency · Trade · Vegetables

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1 Introduction

Vegetables promote dietary diversity and are thus considered vital to achieving food and nutrition security (Schreinemachers et al., 2018). In agrarian economies, vegetable farming has the potential to reduce poverty, foster women's empowerment, and improve rural livelihoods due to the superior returns compared to staple crops (Balayar & Mazur, 2022). The vegetable subsector holds significant potential to improve agrarian Nepali livelihoods by overcoming poor dietary diversity, nutrition insecurity, and poverty through a higher rate of returns, the empowerment of women and marginalized farmers, and prospects for commercialization and gradual scaling up (Pamuk et al., 2021; Thapa, 2021). Currently, the vegetable subsector contributes 19.79% (13.44% excluding potato) to the agricultural GDP of Nepal (MoALD, 2023a, 2023b). Due to its significant share in the agrarian economy, the Government of Nepal has been increasingly prioritizing the vegetable subsector, both in its Agriculture Development Strategy (ADS) and in the Nepal Trade Integration Strategy (NTIS) to tackle rural poverty and address growing trade imbalance (MOALD, 2016; MOICS, 2023).

Diverse agro-climatic conditions in Nepal enable the production of a wide range of vegetables throughout the year.¹ Specifically, favorable agro-climatic conditions in the Nepali hills and mountain regions during the summer and rainy season offer the promising potential to supply off-season vegetables to both national and international markets, especially for neighboring Indian states such as Uttar Pradesh, West Bengal, and Bihar. Despite this potential and the vast untapped markets in neighboring states, Nepal imports vegetables worth around Rs. 17 billion annually (~Rs. 14 billion from India alone; DoC, 2024).² This is mostly attributed to the unorganized and small scale of vegetable production by farmers, along with an inefficient supply chain, high price volatility due to poor cold-storage and post-harvest management, export hurdles, and a large producer as a major trade partner (ADB, 2019; Pamuk et al., 2021; Thapa, 2021). The federal government has been investing substantial public funds through vegetable (super)zones, blocks, and pockets³ in >43 districts to build farmers' capacity and market infrastructure, enhance commercialization, and ultimately reduce trade imbalance. Similarly, provincial and local governments are also investing in programs focusing on the vegetable subsector. However, fresh vegetable acreage spreads just over 0.3 million hectares (~10% of total farmland) mostly on highly fragmented farmland with a substantial yield gap.

¹ Agro-climatic diversity in Nepal is shaped by four distinct seasons (i.e., spring, summer/monsoon, autumn, and winter) across three major ecological belts (i.e., mountain, hills, and Terai). With the hilly region covering ~68% of the country's total area and its four aspects (i.e., east, west, north, and south), this further creates microclimatic variation in the country.

² Rs. 132.25 = US\$ 1 (as of July 31, 2024).

³ Super zone and zone are the components of Prime Minister Agriculture Modernization Project (PMAMP), a 10-year project of the Government of Nepal. A super zone and zone constitute 1000 ha and 500 ha of cropland, respectively, in the project areas. Similarly, a block requires 100 ha cropland in Terai (70 ha in hills and 50 ha in mountains), while a pocket is formed of 10 ha cropland in Terai (7 ha in hills and 5 ha in mountains).

During the past three decades, the vegetable subsector in Nepal has shown remarkable production and productivity growth, contributing approximately one-fifth to the country's agricultural GDP. However, there is still substantial untapped potential in this subsector both at extensive (i.e., acreage) and intensive (i.e., productivity) margins. Most existing research and policy discussions on vegetables are conducted from horticultural (e.g., varietal performance, shelf life, nutrition content) or plant protection (e.g., insect pests or disease prevalence and control) points of view, with comparatively less emphasis on the macroeconomic dimension and discussions of implications for national agricultural policy. Against this backdrop, our study aims to explore the factors that could further propel Nepali vegetable subsector growth, shed insights on promising pathways for vegetable self-sufficiency and trade surplus, and discuss policy options to overcome vegetable subsector-related trade barriers.

Our contribution will be primarily twofold: first, we explore historical production and trade patterns of vegetables in Nepal, along with the challenges faced by the vegetable subsector. The existing literature attributes low productivity, poor postharvest management, middlemen-dominated supply chains, unpredictable market price fluctuations, climate change impacts, the untethered import of low-priced produce, and export hurdles as the major issues hindering the commercialization of vegetable production. We investigate alternatives to tackle these issues through key informant interviews⁴ with vegetable producers, market managers of primary wholesale markets, quarantine officers, agri-technicians, and traders, along with an analysis of national production and trade statistics. Second, we outline diverse policy options to address policy misalignments, uplift vegetable growers, overcome cross-border trade barriers, reduce trade imbalance, and ensure self-sufficiency in major vegetables consumed in Nepali markets, ultimately aiming to achieve a trade surplus. This topic is a pressing concern for a small country like Nepal, which is impacted by the flooding of highly subsidized vegetables from big players in international trade, particularly India.

Overall, our study will provide useful insights to policymakers about the roadmap of vegetable subsector transformation, specifically focusing on commercialization, production competitiveness, and envisaged trade surplus. The policy-relevant insights are expected to further both micro- and macro-level discussions about enhancing the vegetable subsector of the country.

⁴ Key informant interviews (KII) were conducted via telephone to cross-validate existing news, anecdotal evidence, and reports while also uncovering new insights regarding vegetables production and trade. KII primarily focused on informal vegetable exports, quarantine hurdles, vegetables marketing, and (phyto)sanitary measures.

2 Vegetable Production in Nepal

Vegetable farms in Nepal are spread over 488,095 hectares, covering ~15% of total agricultural land (~10% excluding potato) (MoALD, 2023a, 2023b). The major vegetables produced in Nepal include potato, cauliflower, cabbage, tomato, radish, broad leaf mustard, and onion. The significant share of potato (~5%) reflects the importance of this crop to Nepali farmers.

From 1990 to 2022, vegetable area and productivity both doubled and grew at a modest compound annual growth rate of ~2% (MoALD, 2023a). Current annual demand for vegetables is ~3.2 million mt and is expected to grow at the rate of 2.4% every year (Kumar et al., 2019). While vegetable production has increased at the rate of 4.21% annually, its seasonal distribution remains uneven. Lack of effective post-harvest management facilities to extend shelf life, along with export challenges, lead to seasonal gluts in some periods and shortage in others, distorting the domestic market. Even though the vegetable subsector is prioritized second only to cereals in the ADS, resulting in increased government spending, its growth trajectory has not significantly changed from its usual pace (Fig. 1). While doubling productivity is a significant achievement on its own, it remains below the global average (~20 mt/ha) benchmark. The Nepali vegetable subsector is indeed growing, but this growth is not sufficient to meet national demand and alleviate the increasing trade imbalance.

Currently, the productivity of vegetables in Nepal is approximately five times higher compared to cereal crops. The benefit–cost ratio of vegetable farming stands at 3:1, in contrast to 1.5:1 for cereals (Bhandari et al., 2015) and fits with the farming

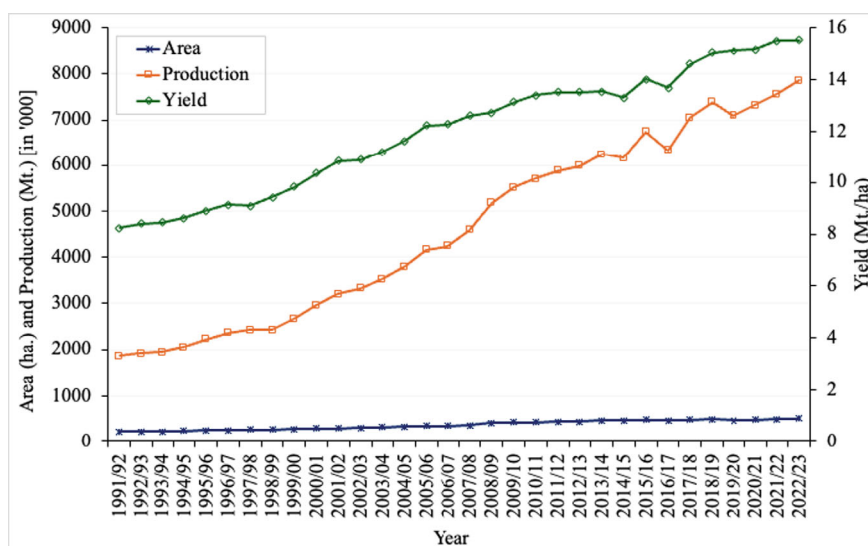


Fig. 1 Area, production, and yield of vegetables in Nepal during 1991/92 to 2022/23. Vegetables include both fresh produce and potato. Data source MoALD (2023a, 2023b)

system of smallholders and marginal farmers, offering prospects for scaling up and gradual commercialization. Thus, farmers could increase their revenue from farming by focusing on vegetable production due to its high value. This has implications for farming in Nepal, where farmland is highly fragmented and land pooling seems an arduous task due to weak governance. The yield of vegetables in Nepal appears higher when compared with cereals, but it still demonstrates a conservative yield far less than the target yield.⁵ For instance, potato productivity is only 17.2 mt/ha, the lowest in South Asia and ~18% lower than the world average (ADB, 2019; FAOSTAT, 2024). Likewise, tomato has the highest average yield (~18 mt/ha) in Nepal due to protected cultivation, which is just about a half of the global average yield.⁶ These figures show that the gap between current yield and achievable yield—let alone yield potential—is still high, and that there is still significant potential to narrow the yield gap.

The Terai region leads in vegetable production with ~55% share of the total vegetable area, followed by the mid-hills (~40%) and high hills (~5%) (Pamuk et al., 2021). There is regional variation within the country in vegetable production timing, primarily due to its diverse agro-ecological zones. The Terai region mainly produces vegetables from November to May, which includes the winter and spring seasons. However, from May to November, high temperatures coupled with land inundation from floods restrict vegetable (especially cole crops and tomato) production in the Terai. Therefore, the market is dominated by produce supplies from the mid-hills and high hills during the summer and rainy seasons. During these off-seasons, vegetable prices are generally higher than in winter and spring. The favorable agro-climate in the Nepali hills and mountains during the summer and rainy seasons offers good potential to market off-season produce not only to the Terai region, but also to neighboring states in India—Bihar, Uttar Pradesh, and West Bengal—that experience similar climatic conditions during this time. The high population density and proximity of these markets present significant opportunities for Nepali vegetables, but these markets largely remained untapped because most fresh vegetables (with the exceptions of cole crops and radish) are not yet included in India's Plant Quarantine Order.

3 Vegetable Trade Trends

Nepal imported vegetables worth ~Rs. 17.8 billion with a comparatively minimal export of ~Rs. 248 million in 2023. The import–export ratio of vegetables has been ~70 during the past five years, indicating substantial trade imbalance and reliance on imports. Figure 2 clearly portrays the disproportionate growth of fresh vegetable

⁵ Target yield represents achievable yields by a good grower, not the maximum potential yield.

⁶ The Prime Minister Agriculture Modernization Project (PMAMP), a nationally prioritized project covering about 6% of national area under vegetable reports >20% higher yield for vegetables in the project area than the national average yield.

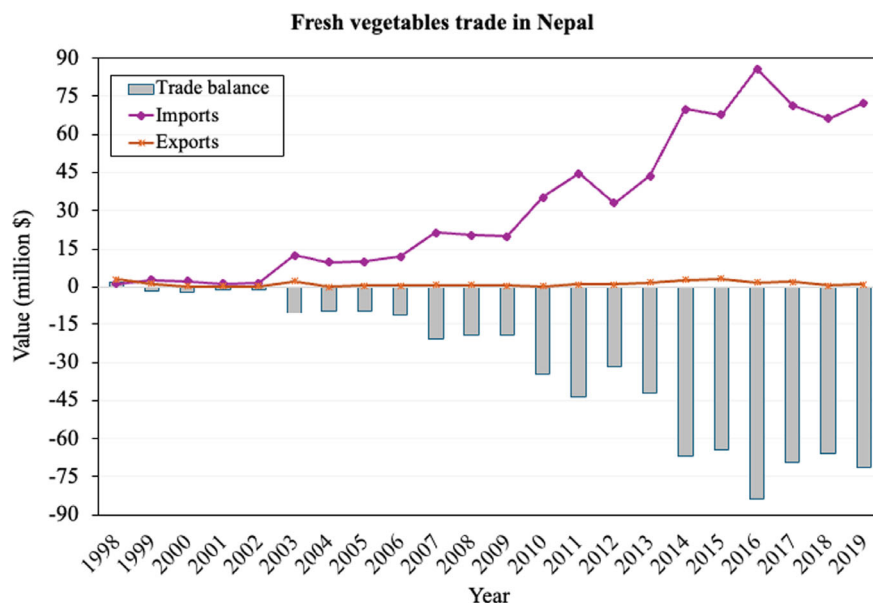


Fig. 2 Vegetable import and export trends in Nepal. Data source: BACI (2023)⁸

imports compared to the nominal and steady rate of exports. Currently, vegetable imports account for ~10% of agri-food commodity imports (DoC, 2024).⁷ A closer view of the agricultural trade data reveals that more than half of vegetable imports come from four items: potato, onion, garlic, and tomato. The source country for almost all of the vegetable imports is India, with the exception of garlic, most of which is imported from China. The higher imports of these vegetables are reflective of consumption trends, the highly seasonal nature of production, and market demand in Nepal. Thus, discussion on reducing trade imbalance within the vegetable subsector could be made more meaningful by centering on these major vegetables.

On the export side, cabbage (~Rs. 145 million) remains the major exported vegetables to India from eastern Nepal from June to September. Other exported vegetables include radishes, mushrooms, cucurbits (e.g., pumpkin, squash, and gourds), and asparagus. Some informal exports of tomatoes are reported during the summer and rainy seasons, as the formal export of tomatoes is restricted due to it not being listed in India's Plant Quarantine Order. To export vegetables to India through formal channels, it is essential for them to be included in the Plant Quarantine Order and accompanied by phytosanitary certificates confirming that they are free from quarantine pests. In the absence of such listings, many Nepali vegetables have been struggling to penetrate potential Indian markets. Until recently, India remained the

⁷ Agri-food commodities are represented by Chaps. 1–24 in the trade data.

⁸ BACI Database. https://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele.asp.

primary export destination for vegetables produced in Nepal, though Gulf countries such as Qatar and UAE are emerging as new export destinations from Nepali vegetables fueled by low tariff rates and rising demand. In 2022/23 alone, capsicum and asparagus worth ~Rs. 19 million were exported to Gulf countries, opening new market opportunities for Nepali produce.

4 Strategies to Minimize Trade Imbalance

As presented in the previous section, both imports and exports of vegetables are dominated by a select few vegetables. Due to the concentration of trade in very few vegetable commodities, targeted intervention efforts could be relatively easier for the Government of Nepal, and we thus center our discussion on major important vegetables from a trade point of view. This is necessary because reducing trade imbalance can only be achieved if we study these vegetables in isolation, rather than collectively. Major vegetables that could be targeted for import substitution are potato, onion, garlic, main season tomato, pumpkin, bitter gourd, okra, and green legumes. Similarly, export promotion efforts could be targeted toward crucifers (e.g., cabbage and cauliflower), rainy/summer season tomato, mushroom, capsicum (bell pepper), and asparagus. Among these, three vegetables, potato, onion, and tomato, warrant special discussion due to their high consumption levels and greater dependence on imports to meet national demand (Table 1).

Like rice among cereals, potatoes alone contribute over 6% to Nepal's agricultural GDP (MoALD, 2023a, 2023b). Although potato constitutes the lion's share of agricultural GDP, productivity (~17 mt/ha) is low—in fact, it is the lowest in South Asia and ~18% below the global average (ADB, 2019; FAOSTAT, 2024). Our back of the envelope calculation shows that increasing potato yield by just 2 mt/ha, or a ~12% increment from the current yield, would sufficiently substitute the existing import of ~310,000 mt. The dominance of the informal seed system and the poor availability and accessibility of good quality tubers are major problems facing potato

Table 1 Major vegetables in terms of production and trade in Nepal (2022/23)

S. No.	Top 5 vegetables		
	Production	Imports	Exports
1	Potato	Potato (Rs. 7,933 MM)	Cabbage (Rs. 145 MM)
2	Cauliflower	Onion (Rs. 6,868 MM)	Dried/chilled vegetables (Rs. 31 MM)
3	Cabbage	Garlic (Rs. 1,246 MM)	Mushroom (Rs. 19 MM)
4	Tomato	Tomato (Rs. 611 MM)	Tomatoes (Rs. 15 MM)
5	Radish	Frozen vegetables (Rs. 525 MM)	Others (Rs. 37 MM)

Note MM denotes millions

Data source DoC (2024) and MoALD (2023a, 2023b)

farming in Nepal (Gairhe et al., 2023). Improving the affordability and accessibility of high-yielding seeds (or tubers), mechanizing planting and harvesting, investing in irrigation facilities, and ensuring the availability and proper use of chemical fertilizers and plant protection products can significantly boost yields. To ensure year-round availability of potatoes and reduce post-harvest loss, it is crucial to assess existing cold storage facilities, develop the necessary infrastructure, and establish connections to major production and market centers with appropriate government support. Equally crucial are policy interventions aimed at strengthening quarantine measures to prevent Indian potatoes from easily penetrating domestic markets.

In the case of onion, ~180,000 mt. is imported annually; in fact, ~99% of the onions marketed through major wholesale markets are imported, mainly from India, though this importing occurs from China when there is an export ban in place from India. The domestic production of onions (~166,000 mt) is highly scattered and used for direct household consumption, and thus does not go beyond local market. Despite favorable climatic conditions, the low competitive capacity of domestically produced onions compared to imported ones was informally recognized by the “Onion Mission Program.” Initially launched with an import substitution agenda, this program eventually deviated from its goals and was ultimately aborted, acknowledging high production costs, lack of quality cultivars and seeds, poor storage facilities, and ineffective implementation modalities (Kaini, 2020). Steeply rising demand and India’s volatile policy regarding onions (which have often led to scarcity in the domestic market) calls for rethinking about the scaling up of onion production in the country. Currently, quality onion seeds are scarce, and their availability remains a pressing concern as India restricts seed exports. The path to self-sufficiency could be traced through farmers’ capacity building in strategic partnership with foreign companies for quality seeds, the development of farmer-preferred varieties, the promotion of three-season onion production technology across the country, the development of cold storage facilities, and enhancing post-harvest management technologies to smooth supply during the scarce season. This is important because it could help overcome the current crisis of quality seed and poor postharvest management capacity. The government can create a facilitatory environment for collaboration with foreign companies, allowing such partnerships for a certain period until the Nepali capacity for seed production and post-harvest management is sufficiently enhanced. Achieving strategic fit between downstream and upstream segments of the onion supply chain is equally important (Timalisina et al., 2016) to achieve the goal of achieving self-sufficiency in onion production.

Tomatoes are another important vegetable in Nepal, with current production at ~423,000 mt (MoALD, 2023a, 2023b). They hold promising export potential due to high production volumes and profit margins, driven by protected structure cultivation and value addition by the unique taste of Nepali varieties. However, formal exports are restricted, as tomatoes are not included in India’s Plant Quarantine Order, with exceptions such as that in the rainy season of 2023, when restrictions were temporarily lifted due to the shortage of tomatoes in the Indian market. Although summer season tomatoes are informally exported, lobbying with India for formal trade could greatly benefit tomato growers while contributing to minimizing trade imbalance.

In the following subsections, we briefly discuss strategies to promote vegetable production, minimize dependence on imports, and ultimately achieve a trade surplus.

(i) **Optimize Input Use and Reduce Costs:** The reduced competitiveness of Nepali produce in the market is largely due to high production costs resulting from the inefficient use of inputs. Thus, reducing costs, promoting local value addition, and improving efficiency are crucial to positioning the vegetable subsector competitively in (inter)national markets. In a production system that is mostly conventional, even a simple intervention is likely to reduce costs significantly. For instance, labor costs typically account for ~50% of production expenditures and can be reduced through simple mechanizations in tillage, planting, and harvesting. Educating farmers to use innovative weed control (e.g., plastic mulching and herbicide application) and irrigation (e.g., drip irrigation and fertigation) options could also yield promising results. However, it is important to ensure that the recommended tools and techniques are well-suited to the scale of farmers' operations to avoid economic losses.

Regarding seeds, Nepal produces a minimal amount of vegetable seeds (mostly open-pollinated varieties) relative to demand. Thus, farmers rely on imported hybrid seeds, which is a serious issue for strengthening the vegetable subsector in Nepal (Timsina, 2024). Imported seeds are not only costly, but are not fully suited to Nepal's agro-climatic conditions, and most seeds are informally imported without being registered in the national system. Formal registration in the national system entails at least two years of research trials at the Nepal Agricultural Research Council (NARC) to assess suitability and performance in specific domains.⁹ Due to weak enforcement of the seed quality control mechanism and wide profit margins on the side of distributors, unregistered and technically unsuitable varieties have hindered farmers' ability to harness a realizable yield (Poudel et al., 2020). Thus, programs should be launched targeting vegetable seed production that would not only reduce input costs, but also contribute to increased revenue through higher yield. While some vegetable seed projects are already operational with implications for food and nutritional security and the economic prosperity of rural areas (CEAPRED, 2014), further integration of formal and farmer-managed seed systems, along with improving community-based seed production (CBSP), could further enhance both national and local seed supplies. Currently, most vegetable research farms/centers are divided between NARC and the Department of Agriculture (DoA); however, farms under DoA located in Khumaltar, Sarlahi, Marpha, Rukum, and Dadeldhura are not given a research mandate. Reconsidering mandates for these farms and providing an enabling environment for private seed companies could have important implications for the availability of quality vegetable seeds.

Besides seeds, fertilizers and manures are another crucial input for vegetable production. In Nepal, the chemical fertilizer supply, which is mostly subsidized, is handled by the government, with limited involvement from the private sector. Due to inefficiencies in the fertilizer supply chain, meeting the farmers' demand for

⁹ The formal seed system features a vertically organized production and distribution of tested and released/registered varieties by public and private organizations under quality control mechanisms set by the Seed Quality Control Center (SQCC).

fertilizers in peak growing seasons remains a challenge, with availability being a more pressing issue than price. Ensuring the availability of fertilizers in response to farmers' demands and promoting their judicious use holds the potential to enhance productivity and production efficiency. The enrichment of locally produced manures, primarily sourced from livestock, crops, and forest byproducts, plays a pivotal role not only in boosting production but also in maintaining soil health and promoting sustainable agricultural practices. Extension programs on improved composting, nutrient-preserving techniques, and bio-fertilizer usage are remarkable for both increasing yield and promoting soil/plant health. Low-cost programs such as the integrated pest management (IPM) approach not only reduce costs by promoting the use of locally available botanicals and biological pests, but also by promoting food safety and sustainability. Such practices also add value to the produce in the market as people are increasingly made aware of safety and sustainability issues. The establishment of dedicated agriculture sections in each (rural) municipality creates a significant opportunity to expand outreach to farmers and bridge the technical knowledge gap. Utilizing effective communication channels (e.g., social media), engaging progressive farmers, and conducting in-person training or demonstrations on the proper usage of (bio)chemical fertilizers could be beneficial.

Irrigation stands as another critical input in vegetable farming, given that only 39% of agricultural land currently has year-round irrigation facilities (NSO, 2023). Dependency on seasonal rainfall and the lack of modern irrigation technology is a problem for vegetable farmers (Pamuk et al., 2021). The availability of irrigation facilities for smallholder farmers is even more limited, presenting a significant challenge to the productivity and success of small-scale vegetable cultivation (Rai et al., 2019). Despite substantial government investment in the development of large-scale irrigation facilities and subsidies for small-scale irrigation schemes through agriculture development programs, the challenge of ensuring year-round availability of irrigation water persists. Drip irrigation, known for producing more crops per drop and improving productivity, can be promoted to increase irrigation availability at an affordable scale. Along with drip irrigation, developing a user-friendly fertigation protocol based on readily available fertilizers and its extension to farmers through emerging information and communication tools can significantly enhance productivity and reduce production costs. Adapting such user-friendly water conservation technology to the local context and specific commodities requires effort from the Soil Science Division and the Agricultural Machinery Division of the Nepal Agricultural Research Council.

(ii) **Capitalize Achievable Yield by Reducing Yield Gap:** The stark difference between current yields and the realistically achievable yield is widely known and acknowledged in the vegetable subsector. Achievable yields could be harnessed to narrow the yield differential by exploiting gene–environment–management ($G \times E \times M$) interactions (Cooper et al., 2021). Concerted breeding efforts through regional and national collaboration at varying levels are of the utmost importance. The vast amount of germplasm available at the National Agriculture Genetic Resources Center (also known as Genebank) could provide valuable traits to enhancing vegetable lines. Use of local genetic resources in breeding programs also promotes the development

and supply of improved locally adapted varieties in a sustainable way (Timsina et al., 2024). For example, in potato production, there is a scope of increasing yield in Nepal up to 32% by simply adopting improved varieties, recommended seeding rates, and irrigation (Adhikari et al., 2023). To realize this potential, it is crucial to invest in the research and development of prebasic seeds and create reliable distribution channels and effective extension that fosters their innovation, availability, and adoption to reduce the average ages of the potato varieties currently used by farmers (Timsina et al., 2019).

Using frontier technology such as CRISPR represents another possibility to enhance vegetable varieties, which is possible only through mutual collaboration with Nepali professionals working in international educational and research institutions within this field. However, given resource limitations and barriers to adoption, frontier technology is less likely to generate immediate results in our settings. Given such circumstances, the short-term strategy of importing the best available seeds and associated technology could push yields upwards. While farmers prefer hybrid vegetable varieties for their superior yields, the country lacks a robust research infrastructure and dedicated teams focusing on hybrid development. To date, the public sector in Nepal has developed only three hybrid varieties of vegetables, specifically tomatoes, well below the National Seed Vision's target of 20 hybrids (Timsina et al., 2023a).¹⁰ Developing additional hybrids is consequential to vegetable productivity and requires more attention from national research institutions. The role of private seed companies in developing hybrids should not be undermined, and it is essential to create an enabling environment for their growth.

(iii) **Improve Value Chain Efficiency:** The Nepali vegetable value chain is characterized by seasonality and fragmentation, involving numerous unorganized actors. This situation restricts access to credit, input, and information, leading to poor relationships, high transaction costs, significant postharvest losses, and a weak value chain. As a result, farmers receive only 40–50% of the consumer price (ADB, 2019; Pamuk et al., 2021). Market-led infrastructure in Nepal is inadequate, and the price-setting mechanisms lack transparency, mainly due to the oligopolistic practices of large-scale traders. These traders often prefer selling Indian vegetables, as they benefit from credit sales and lower prices, making domestic vegetable trading less appealing.

Enhancing the efficiency of the value chain involves addressing the aforementioned issues through the tailored development of major markets. This includes equipping markets with essential postharvest management facilities such as cold storage, grading, and processing to reduce the existing postharvest losses of ~20–35% for vegetables (Khatiwada, 2020). These losses, whether in quality or quantity, lead to decreased values and volumes of produce. Thus, addressing postharvest losses not only reduces waste, but also increases the availability of produce, thereby contributing

¹⁰ The National Seed Vision of Nepal aims to develop 20 hybrid varieties of vegetables from the public sector and 10 from the private sector. However, to date, only three tomato hybrids—Srijana, Khumal Tomato Hybrid-2, and Khumal Tomato Hybrid-3—have been released from the public sector, with none yet developed by the private sector.

to food and nutritional security. Given that temperature is the most important factor in maintaining postharvest quality, investing in and raising awareness about temperature control practices (such as precooling, forced air cooling, hydro cooling for radish, and ice cooling for cabbage, radish, and broccoli) could yield substantial benefits. In addition, educating stakeholders about the physiological processes that affect postharvest quality along with the impacts of manipulating temperature, relative humidity, and gas concentrations on produce quality and economic returns is crucial. At the outset, NARC and the agricultural university system should lead the effort to educate farmers about the importance of postharvest management issues and their solutions in collaboration with DoA and local agricultural offices.

Furthermore, it is equally important to connect the major markets with production centers using necessary infrastructure, including cold chains and collection centers. Such facilities increase storability, curb seasonality, reduce price volatility, and ensure the extended availability of vegetables, which for fresh produce is currently limited to around 2 weeks between production and consumption. Since delaying cooling after harvest by just one hour can reduce shelf life by one full day (Cantwell, 1997), the provisioning of refrigerated transport vans (or agricultural ambulances) could have a remarkable impact on the value chain. This could be managed jointly by local (rural) municipalities and agri-cooperatives, with partial financing by the provincial or federal government. Financing or a tax break could be based on the value of production marketed through the agri-cooperatives, ensuring the efficient and effective allocation of scarce resources.

Recently, the Government of Nepal and its development partners have placed considerable emphasis on promoting value chains for vegetables. Vegetable value chains could be further strengthened through the promotion, incentivization and legalization of contract farming and cooperative marketing to connect local production areas with high-value domestic and foreign markets. Moreover, enhancing farmers' capacity in postharvest management tailored to high-value markets is essential to tap into available opportunities. Such measures provide assurance to the market regarding produce availability, incentivize traders to innovate in market identification and marketing strategies, and establish a reliable marketing channel. Such an environment is currently lacking in Nepal, hindering the sustained and incremental development of the value chain. To address this issue, a strong legal framework is needed to deter contract breaches, along with targeted promotion programs focused on key production pockets, commodities, and high-value markets to generate momentum. In addition, developing a robust market intelligence system that tracks commodity-specific supply and demand volumes as well as price dynamics and making this information easily accessible to farmers and traders is also crucial.

(iv) **Organize Smallholder Farmers:** Around 80% vegetable farmers in Nepal are smallholders cultivating <0.5 ha of land. The small scale and fragmented nature of production, coupled with weak supply chain linkages, result in inefficiencies in both production and marketing in many promising vegetable-growing regions. This makes it challenging for farmers to adopt modern technology and attain economies of scale (NSO, 2023; Pamuk et al., 2021). Despite these challenges, small farms are resilient to large shocks such as the COVID-19 pandemic, and their role in

achieving self-sufficiency should not be undermined. The dominance of smallholder farmers in vegetable farming and the challenge of consolidating land due to individual ownership and potential property rights issues necessitates the proactive organization of these farmers. Even though land pooling could not be achieved as envisaged by ADS, crop (or production) pooling through cooperatives or farmers' groups could be promising in Nepal to channelize produce more efficiently. Such pooling fosters synergy in production, marketing, quality input supply, and the delivery of technical services, boosting the vegetable subsector's commercialization and competitiveness.

Small farmers cooperatives, along with Prime Minister Agriculture Modernization Project (PMAMP) units such as pockets, blocks, and (super)zones, have been remarkable in organizing smallholder farmers. However, PMAMP is expected to be phased out in 2026, with implications for sustainable and self-reliant agriculture. Retaining and perpetuating the program's institutional arrangements—including the management committee, despite the program's exit under a local government—could boost resilience to external shocks in production and marketing. Such institutional arrangements could provide focal points for needed interventions in the future.

Organizing smallholder farmers, who are often engrossed with poverty and have limited access to information and support services, requires sustained efforts to institutionalize their organizations and enhance their capacity. The approaches to organizing smallholder farmers may differ based on the context, the type of commodity they produce, and the target market for their produce. Timsina et al. (2023b) suggested strengthening the role of commodity-specific producer associations in Nepal for technology transfer and market management, as is done in Kenya, Israel, India, the Philippines, South Korea, Indonesia, and China. ADS also proposed a commodity-specific value chain association to promote commercialization of the agricultural sector. Thus, each vegetable development program should include a dedicated wing for providing business development services to institutionalize farmers' organizations to link them with the national value chain. Such provision would ensure consistent production, access to information, inputs, technology and market, along with resilience to external shocks in production and marketing.

(v) **Facilitate Trade and Remove (Unfair) Trade Barriers:** Agricultural trade between Nepal and its primary trade partner, India, is governed by the Reciprocal Trade Agreement (RTA). However, nontariff barriers from India in the form of quality standards, regulatory requirements such as the Plant Quarantine Order, and dynamic import policies have impeded market entry and trade for exporters. On the other hand, the national vegetable market is often disrupted by the influx of inexpensive vegetables from India. To mitigate market disruptions arising from the unrestricted entry and dumping of low-cost vegetables, seasonal tariffs could be considered during peak production periods to protect domestic farmers. Specifically, including vegetables in the sensitive list would help prevent duty-free unrestricted access to Indian products, thus safeguarding the domestic market. To counter the import of low-quality products, it is imperative to strengthen our quarantine measures, focusing on pesticide residue analysis and pest risk assessment. However, for long-term benefits, trade diplomacy aimed at reducing non-trade barriers and promoting the deeper integration of agricultural markets is crucial for fostering a more seamless trading environment.

Unlocking the full potential of the vegetable subsector requires establishing focused production programs targeting the export market and strategically leveraging available export opportunities. This involves identifying potential markets and commodities, ensuring compliance with the importing country's quarantine requirements, and establishing strong linkages between traders in the importing country and domestic producers and traders. Additionally, it also necessitates the development of essential infrastructure, such as cold chain maintenance facilities, at key customs points. Currently, critical locations such as Tribhuvan International Airport—a major export gateway to the Middle East—lack these facilities. Enhancing the capacity of local traders by offering them opportunities to study and observe potential export markets is also crucial for promoting exports.

(vi) **Improve Food (Produce) Safety and Quarantine:** Current and past programs targeting the vegetable subsector in Nepal have mostly centered on boosting yield, with limited emphasis on produce quality. In the face of evolving food safety standards, it is essential to adopt a strategic approach to navigate the opportunities and challenges arising from high-value agricultural and food markets. This entails anticipating the actions of trading partners and taking proactive measures (e.g., exit, loyalty, and voice) in response (Henson & Jaffee, 2006).¹¹ Nepal clearly lacks a strategy to address this need; moreover, producers and traders exhibit a considerable lack of awareness regarding quarantine, (phyto)sanitary, and food safety issues. Additionally, the government infrastructure responsible for regulating and enforcing food safety and (phyto)sanitary measures is often perceived as unreliable (World Bank, 2015). Nepal's food safety standards receive minimal recognition in India, let alone in other developed markets (Thapa, 2021).

Establishing reliable and trusted markets and communication channels with consumers to ensure food safety is a daunting challenge (Pamuk et al., 2021). To overcome this issue, Nepal must upgrade and enforce (phyto)sanitary and food safety standards to meet international requirements, or at the very least, align with the standards of its target export markets. This would involve enhancing the capacity of (phyto)sanitary laboratories to ensure that phytosanitary and food safety certificates are trustworthy to importing countries. The national plant protection organization should prioritize regular surveys/surveillance and pest risk analysis of the identified exportable commodity. For instance, radish should be free from *Erysiphe cruciferanum* (powdery mildew of crucifers), *Pseudomonas viridiflava* (bacterial leaf blight of tomato), and other plant debris to be listed in India's Plant Quarantine Order. Similarly, *Brassica* species (such as mustard, rape/canola, cabbage, cauliflower) should be free from *P. viridiflava* (bacterial leaf blight of tomato) and other plant debris. Assessing the quarantine pests in the target market and their proactive management occurs only when there are dedicated teams for survey/surveillance and pest risk analysis of the identified export commodity. In addition, with the introduction of

¹¹ The exit strategy involves anticipating standards, leaving a particular market or market segment, and making necessary commercial shifts. The loyalty strategy focuses on anticipating standards and complying with them proactively. The voice strategy centers on participating in standard creation and negotiating terms before the standards are enforced (Henson & Jaffee, 2006).

NepalGAP¹² standards, Nepali farmers should adopt Good Agricultural practices (GAP) to meet quality standards in export markets, ensuring their products are suitable for export. All of this can be achieved through increased investment in strong quarantine and support services, educating farmers about the safe production protocol required by (inter)national markets, and establishing cold chain connections from production areas to destination markets.

(vii) **Revamp Subsidy Policy:** Different tiers of government offer a wide range of subsidy schemes to motivate existing farmers and provide incentives for new ones. Farmers receive subsidies for production inputs (e.g., chemical fertilizers, seeds, and irrigation), farm equipment, and agricultural infrastructure in the form of direct input supply, concessional loans, discounted insurance premiums, or cash incentives. However, subsidy coverage is quite limited, with only 7% of farming households benefiting from it (NSO, 2023). Subsidy programs, mostly at the provincial and local levels, have often overlapped, and the persistence of operations beyond the subsidy period has received very limited attention. In the absence of a centralized control system, current subsidy schemes are also likely nonadditional; i.e., many recipients could have performed equally well even without the subsidy. For instance, approximately 35% of subsidy recipients are relatively large-scale farmers with holdings >0.5 hectares (NSO, 2023). In our highly resource-constrained setting, point-based centralized subsidy allocation based on the number of years in operation, the type of vegetables grown, the scale of operation, the potential value of the produce, growing method and other factors could be considered. Similarly, different approaches to delivering subsidies should be piloted before implementing them on a broader scale. While current subsidies are centered on production, the vegetable subsector is less likely to flourish if marketing and postharvest infrastructures are not scaled at the pace of production. Thus, subsidies should be channeled across the entire value chain and accompanied by periodic impact evaluations at a disaggregated level to assess the effectiveness of various subsidy schemes.

(viii) **Promote Innovation Through Applied Research and Extension:** There is potential for a cost reduction of 75% in Nepali vegetable farms through technology adoption and the optimal allocation of resources (Shrestha et al., 2016). The current resource allocations for innovative production systems and management technologies are inadequate, particularly in areas such as food safety, climate change, nutrition, conservation, biotechnology, and mechanization (Timsina et al., 2024). Since most modern technologies are not suitable for Nepal's small farm sizes, each provincial government should prioritize investing in innovative technologies tailored to our land and farming practices. Optimal resource allocation is best achieved by educating farmers about recent innovations by expanding coverage of the agriculture section within (rural) municipalities and district-based agricultural offices. Currently, agricultural colleges under national and regional universities have been established across the country, providing another opportunity to disseminate knowledge about

¹² NepalGAP is a voluntary standard introduced by the Government of Nepal to address food safety, sustainability, and trade issues. It has five modules: food safety, environment management, product quality, worker health, safety and standard, and general requirements.

best practices in vegetable production. The outreach sites of NARC hold significant potential and could be further equipped to foster interagency collaboration, accelerate the adoption of innovations, and ensure broader access to new technologies, practices, and promising research outcomes. Moreover, expanding the research footprint from nutrient and pest management and varietal adaptation studies to address broader challenges facing farmers and farms (e.g., input usage, postharvest practices, marketing) could greatly help advance the vegetable subsector. This is necessary because production and postharvest techniques could vary widely based on agro-climate, agricultural practices, and crop varieties. Concerted research efforts to converge our productivity levels toward the world average could be promising on a long-term basis.

(ix) **Ensure Interagency Collaboration:** In addition to the vegetable subsector, the entire agricultural sector is intrinsically linked to soil, water, and land resources. However, the Department of Soil Conservation currently operates under the Ministry of Forests and Environment, while irrigation infrastructure development falls under the Ministry of Energy, Water Resources and Irrigation. Similarly, land management is separately dealt with by the Ministry of Land Management, Cooperatives and Poverty Alleviation. The existence of these interrelated ministries as separate entities and the lack of sound collaboration between them has left longstanding issues in soil conservation, land management, irrigation provision, and agricultural development unresolved. Due to this lack of adequate collaboration, the Government of Nepal's investments in developing infrastructure aimed at agricultural sector transformation have not achieved expected returns. Further, the inefficient use of limited public funds, stemming from fragmented authorities and their lack of consistent collaboration, has rendered the goals of agricultural mechanization, commercialization, and transformation likely unattainable in the near future. Thus, the Nepali agricultural sector would benefit from the consolidation of all three ministries mentioned above. At a minimum, these line ministries should work in unison, fostering intra-agency collaboration under the leadership of the Ministry of Agriculture and Livestock Development.

5 Conclusions

The vegetable subsector remains one of the major pillars of Nepali agriculture. As this subsector is gradually transforming from subsistence-based production to commercialized production, several challenges are preventing the nation from realizing its potential. These challenges—which include extremely volatile prices, trade barriers, and others—have hindered farmers from reaping the benefits of transformation. Achieving the triple goals of rural livelihood enhancement, food and nutrition security, and trade balance may seem like a somewhat distant goal, but with the concerted efforts of stakeholders and knowledge share, it is achievable. We suggest that policymakers tailor agricultural policy and design action plans focusing on major vegetables such as potato, tomato, onion, and garlic. Interventions focused

on the provisioning of inputs and local innovations hold the greatest potential to make the vegetable subsector competitive, and trade negotiations are imperative to facilitating the cross-border movement of produce. Redesigning agricultural subsidy policy could address the input needs of smaller holders and the scalability of large operations. The sustained commitment of all three tiers of government, in partnership with leading educational and research institutions through a nexus approach, would be pivotal in reshaping the course of the vegetable subsector. Future research on vegetables could center on the empirical assessment of technical (in)efficiency, market competitiveness, the impact of subsidies, and trade flows at a disaggregated level to support evidence-based decision-making and strengthen the overall vegetable subsector in Nepal.

6 Policy Recommendations

Strategies that could enhance yield, promote self-sufficiency, and reduce dependence on imports for agricultural products such as vegetables consistently lie at the forefront of agricultural policy discussions. As policy provisions are fundamental to driving agricultural transformation, we offer some recommendations below to specifically strengthen the vegetable subsector in Nepal:

- The vegetable subsector transformation envisioned by the Government of Nepal could potentially be materialized by increasing investment in research and innovations for producing hybrid seeds and geographically suitable production technologies at the outset. Governments and developmental partners should promote cost-reducing and productivity-enhancing technologies such as low-cost greenhouses (or plastic houses), mechanized planting and harvesting, plastic mulching, chemical weed control, drip irrigation, fertigation, and high-quality seeds that fit within the farming systems of smallholder farmers and the specific needs of selected vegetables. As seed quality is consequential to final production, ensuring the availability of quality seeds of the desirable potato, onion, and garlic varieties in all production centers should be the top priority of agricultural extension centers. The focus should also be on properly utilizing existing cold storage facilities by linking them to major production centers.
- Designing targeted programs through coordinated research, education, and extension could have lasting impact on narrowing the existing yield gap. Compared to other vegetables, onion has the lowest self-sufficiency ratio (~62%); thus, re-initiating a special program to increase onion production is of the utmost importance. For tomatoes, off-season production in low-cost plastic houses should be further promoted in an organized way. In addition, existing hurdles to exporting tomatoes to India requires immediate attention. To facilitate smooth cross-border movement of tomatoes by having them listed in India's Plant Quarantine Order, it is crucial to engage in trade diplomacy and lobbying by the National Plant Protection

Organization and high-level government officials. At the same time, the Nepal–India trade treaty must be revisited, specifically focusing on the unrestricted entry of Indian vegetables into the Nepali market.

- On the side of value chains, the government could promote the efficiency of chain actors through the customized development of major markets based on local needs. This is possible by equipping local centers with on-demand postharvest management facilities and linking them with major production centers. Horizontal coordination among vegetable producers should also be strengthened to ensure the regular supply of vegetables in the market. Further incentivizing contract farming and cooperative marketing is also needed to link local production areas to high-value domestic and foreign markets. Tapping the potential of foreign market also requires additional investments in trade infrastructure (e.g., transportation networks, logistics and storage, customs and border facilities, reliable financial and communications systems, legal/regulatory frameworks) and trade facilitatory measures (e.g., integrated border management, harmonized (phyto)sanitary standards, traders' capacity building). Strengthening the roles of commodity-specific producers' associations is also necessary to effectively link producers and markets. As plastic houses are increasingly adopted on vegetable farms, validating and recommending such technologies, specifically regionally, is essential to reap good harvests. Educating farmers to target India's lean season is equally crucial for them to secure higher prices.
- To meet international market requirements, the regular study of food safety and quarantine requirements of the target market should be institutionalized. In addition, existing (phyto)sanitary facilities, quarantine measures, and safe production practices need to be further strengthened to ensure compliance with market standards. Similarly, vegetable subsector development programs should include dedicated business development services to identify, pilot, and institutionalize smallholder farmer organizations tailored to local contexts and needs.
- To avoid the overlapping of programs, the functions and responsibilities of each tier must be clearly demarcated. A feasible roadmap for the vegetable subsector could be policy decisions by the central government, quality supervision and facilitation by the provinces, and production protocol and technical service delivery by local governments with adequate provisioning of budgets and human resources. The government should also provide an enabling environment for private players in vegetable-related research and development.

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Chapter 15

Prospect of Rubber (*Hevea brasiliensis*) Commercialization in Nepal



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Abstract *Hevea brasiliensis* is a high-value para or Brazilian rubber tree species with both ecological and economic benefits. The rubber plantation enterprise contributes to the sustainable development of rural communities and small-holder farmers while aiding in conservation of the environment. More than 50,000 types of economic products can be made from this rubber species. In addition, 400 rubber products are known to have pharmaceutical uses. In today's competitive economies, the value of natural rubber is maximized through the production of automobile tyres, toys, and many other specialty items for value addition. From the standpoint of natural resource conservation, rubber plants reduce soil erosion, enhance soil fertility, and add carbon to the soil. Secondary activities can also be derived from rubber trees, such as the production of honey and rubber seed oil. This chapter highlights the gaps and future strategies for the commercialization of this species in Nepal, where the eastern region of the country has suitable climatic and soil parameters for the commercialization of the rubber tree. Nepal imports approximately 13 billion rupees (USD \$104 million) worth of rubber annually, signifying the high potential for the rubber production industry in the country. Current rubber farmers in Nepal face production challenges, including mechanization, skilled human resources, a reliable market, seedlings, input materials, agriculture credit, crop insurance, and improved production technology. We emphasize the need for examining the habitat suitability of *H. brasiliensis*, optimum cultivation practices, a reliable estimate of input costs, and productivity to ensure that these parameters are considered while formulating a robust policy for rubber commercialization. Additionally, a strong outreach and educational program is needed to increase awareness in small-scale farmer communities for the successful commercialization of the rubber enterprise in Nepal.

Keywords *Hevea brasiliensis* · Commercialization · Carbon trading · Sustainable development · Rubber industry

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1 Introduction

Rubber is one of the most high-value agro-industrial crops in the world. The *Hevea*, also called the Brazilian tree, is endemic to the Amazon River basin, and *Hevea* rubber belongs to the family Euphorbiaceae. The rubber tree can synthesize natural rubber and has > 2000 plant species, of which ~ 300 genera belonging to seven families viz., Euphorbiaceae, Apocynaceae, Asclepiadaceae, Asteraceae, Moraceae, Papaveraceae, and Sapotaceae are considered economic species of natural rubber (Venkatachalam et al., 2013). To date, 79 families, 300 genera, and 2500 species of latex-producing plants have been known. The rubber tree grows and performs satisfactorily across diverse climatic conditions and soil profiles throughout the world. Natural rubber species are fast-growing industrial crops that have high economic impacts. Thus, *Hevea brasiliensis*, also known as the para rubber tree, has white, milky latex, which is the source of natural rubber. This species can retain a significant amount of carbon in the tree; one metric ton of CO₂ is retained in its 30-year economic life cycle under average management conditions (Roy et al., 2014). Thus, commercialization of the rubber tree as a renewable source of energy has benefits both economically and ecologically through permanent and steady income for farmers and environmental conservation. In addition, it aids in increasing soil fertility and supplies ~ 23 mt/ha of carbon to the soil (i.e., the equivalent of 84 MT of CO₂) during its economic life period via annual leaf senescence. Tea intercropping with rubber trees also adds a large amount of organic matter to the soil (Rodrigo et al., 2014).

While observing the global economics of rubber plantations, the worldwide export trade of rubber and rubber products, including natural and synthetic rubber, was \$227 billion in 2022, among which 88% were from the Asian continent (FAOSTAT, 2022). Southeast Asia is also the dominant region of natural rubber production. Out of 14.84 million tons of global natural rubber production, 90.3% was produced in Asia alone in 2020 (FAOSTAT, 2022). The top six largest rubber-producing countries in the world are Thailand (4.9 mt), Indonesia (3.6 mt), Vietnam (1.2 mt), India (0.9 mt), China (0.8 mt), Malaysia (0.7 mt), while Sri Lanka, Ivory Coast, the Philippines, and Cameroon are also significant natural rubber producing countries, with a combined production of 0.3 mt. In the case of Nepal, four districts of Koshi Province, namely Ilam, Jhapa, Morang, and Sunsari, form the technically suitable region for producing high-quality rubber (Pandey et al., 2020). Phytochemicals produced by rubber trees contain a considerable quantity of protein and oil (24.5 and 6.1%, respectively), while the rubber latex contains 4.2% polyphenol with 2% hydrocarbon. Rubber has a comparatively higher gross calorific value of 28.7 MJ kg⁻¹, with the oil fraction having 32.8 MJ kg⁻¹. More than 400 types of products related to the medical industry can be produced from *H. brasiliensis* (FRTC, 2021). Rubber plantations have expanded rapidly over the last half century from 4.6 million ha of global area harvested in 1969 to 12.8 million ha harvested in 2020 (FAOSTAT, 2022).

The rubber industry possesses a high degree of potential of expansion in Nepal. In 2019–2020, Nepal imported ~ \$500 million worth of rubber (Poudel et al., 2020).

Rubber plantations have been providing consistent and regular income to farmers, averaging \$3000–\$4000 per ha per year, which also generates stable rural employment for 25,000 people. Although the availability of technical knowledge, price fluctuation, and the high cost of input determine the level of adoption of the rubber plantation enterprise, farmers with a high adoption level could potentially generate a yearly income of \$4600 per ha and a latex productivity of 3.04 mt/ha, while farmers with lower adoption levels could fetch a yearly income of \$1600 per ha and latex productivity of 1.23 mt/ha (Khanal et al., 2021). Rubber plants require a low investment of \$3000 per ha (1–7 years) and provide a long period of productivity (~ 25 years), plus a high volume of tropical rubber wood @8800 cubic feet after 32 years (MOAD, 2013). Rubber plantations also have the potential of utilizing economic intercrops such as tea, cardamom, ginger, and others that provide additional economic benefits for farmers as well as contribute to improved soil health and environmental conservation. Plantation labor cost in Nepal is also cheaper than in other Asian countries, which signifies the potential emerging business sector in the country. Additionally, commercialization of rubber could be a novel technology adhering to carbon trading. Rapidly increasing vehicular densities in Nepal (4.2 million registered vehicles as of June 2024) also demand the equivalent amount of rubber for tire. Hence, rubber commercialization can be a viable business while tapping vast economic potential through smart agriculture in Nepal.

Natural rubber is a promising multiple value species; however, it is still an underutilized commodity in Nepal. The tropical climatic conditions in the eastern Terai region of Nepal are highly suitable for rubber plantation; however, the commercialization of rubber production in Nepal is hindered due to the lack of a comprehensive agriculture policy and government prioritization (FRTC, 2021). The limitation of petroleum products will likely result in the reduction of synthetic rubber supply and, if natural rubber production is not enhanced, there may be a conspicuous gap between demand and supply of rubber and rubber products globally. Therefore, the scope of natural rubber production and expansion in Nepal is immense. A comprehensive rubber policy will create significant potential for Nepal to enhance its rubber enterprise, decrease natural rubber import, and likely increase its export of various rubber products.

2 Approach and Methodology

A thorough review of rubber production, promotion, and international trade literature formed the basis for this chapter. In addition, the authors' experience in rubber research, outreach, and promotion together with rubber field visits and interviews with rubber farmers in Jhapa helped formulate the national rubber promotion roadmap. The senior author is a pioneer rubber researcher who worked in the Gorakhkali Rubber Industry for more than 15 years and serves as International Rubber Expert, Executive Director of Institute of Rubber Research Nepal-USA, Member Secretary of the NRNA Agriculture Promotion Committee, and Member

Secretary of the Rubber Development Board. The co-author serves as the President of the Institute of Rubber Research Nepal-USA and possesses rubber field research in Nepal's rubber zone.

3 Background and Current Status

Rubber seeds were first introduced in Nepal in 1970, but the initial effort failed to establish the rubber plant stand. Fifteen years after this initial attempt, the first rubber nursery was established in Nepal, with 5000 rubber budded stumps in 1985. In 1985, Gorakhkali Rubber Industry Limited (GRIL) was also established to oversee and promote the rubber enterprise in Nepal, with a 5 ha rubber plantation as a pilot project. Seven years after the establishment of GRIL, Nepal had its own home-produced automobile tyre with the slogan "*Aayo Gorakhkali Tyre*" ("*Gorkhali tyre has arrived*," indicating pride in the domestic production of tyres) that essentially monopolized the country's tyre market and exported premium tyres to Sri Lanka and Thailand. In 1994, the Rubber Development Board-Nepal was established to promote and expand the country's rubber industry. The production of high-grade rubber set the stage for rubber enterprise expansion in Nepal; nevertheless, nearly three decades since the country's first commercial establishment of natural rubber, the rubber enterprise in Nepal has not gained satisfactory expansion nor received any government priority for expansion. Currently, Nepal's rubber industry is restricted to 553 ha of rubber plantation in Jhapa, Morang, Sunsari, and the lower part of Ilam districts, with 880 tons of latex yield (1.86 kg per tree) per annum (FRTC, 2021) and no rubber processing industry in the country until the establishment of the first tyre manufacturing facility, Green Tyre Pvt. Ltd., in Kathari, Morang in 2015 and the Kankai Rubber Industry in Jhapa in 2021. The country's only rubber processing industry, GRIL, closed its doors in August 2012. The Government of Nepal included a rubber production program on nearly all of its 5-year national development plans in the last 30 years, but until recently there has been no seriousness on the part of the government to execute its own stated goal of rubber enterprise expansion in the country. In 2014, the Crop Development Directorate of the Ministry of Agriculture and Livestock Development (MoALD) started subsidies for rubber cooperatives as an incentive for farmers to remain in and to encourage the expansion of rubber production. In FY2018-2019, the Government of Nepal set up a Rubber Zone in Jhapa district to highlight the scope and prominence of rubber production in this region, which was followed by a conditional grant to 17 municipalities in Jhapa, Ilam, Morang, Sunsari, and Udayapur districts by MoALD in FY2022-2023, indicating a positive trajectory for Nepal's rubber industry.

H. brasiliensis is a tropical and subtropical tree species that can grow well up to 500 m above sea level. A well-distributed annual rainfall of 2000 mm or higher is suitable for the plant's optimum growth. The species grows best on well-drained loamy and sandy, loamy soil with a pH between 4.5 and 6.5. These types of climatic and soil parameters are found in Nepal's eastern Terai districts and the area below

Ilam district, as well as in the central mid-hills of Nepal up to 450 masl (FRTC, 2021).

Most of the varieties of rubber trees used in Nepal are imported from India, such as RRIM 600, RRIII 105, and GTI. The propagated material mostly used for shipping in transport is budded stump, and these are mostly imported from India. These stumps are grown in the nursery for one year and then transplanted. The tree-to-tree spacing currently practiced in Nepal is usually 12–16 feet, but this depends on soil fertility, types of intercropping, rubber cultivar, and the irrigation facility. Rubber growth and production are best when optimum fertilizer, ample irrigation, weed management, and pest management are used. Generally, in the first year, 40 kg of compost, urea 50 g, DAP 50 g, and Potash 10 g are used, and the rates are gradually increased in succeeding years (MoAD, 2013).

Many rubber stakeholders are involved in current rubber production activities. A productive and synergistic network among 90 individual farmers, 6 community forest user groups [Kalika Community Forest (Mechinagar), Adarsha Namuna (Buddhashanti), Jamunbari (Jamunkhadi), Telpaani (Bahundangi), and Hariyali (Urlabari)], 2 leasehold lands, 15 private firms, and 4 cooperatives is credited for the current rubber enterprise (FRTC, 2021). In addition, the Nepal Tea Development Corporation, Kankai Rubber Industries, the Division Forest Office and *Krishi Gyan Kendra* (local level agriculture extension office) in Jhapa, Morang, Suasari, and Ilam districts contribute to rubber production and promotion efforts through multi-cropping systems, farm forestry, and technical training and outreach. More than 61% of rubber farmers are small-holders with less than one ha, where both paddy fields and marginalized land are used for rubber plantation. Approximately 5% (~ 25 ha.) of rubber plantations are under a multi-cropping system (primarily tea intercropped with rubber) while other areas are largely rubber monocrop.

4 Potential of Commercialization

H. brasiliensis is the primary source of natural rubber with multiple uses. Approximately 400 types of surgical equipment and 50,000 types of other products are manufactured from synthetic and natural rubber (Pandey et al., 2020). The post-latex production life of rubber trees also provides high-quality timber, planks, logs, and firewood. In addition, rubber trees provide an excellent foraging environment for apiculture operation and producing high-quality honey. Rubber trees are also one of the most efficient carbon-capturing trees (Roy et al., 2014), as they possess deep, complex root systems that are ideal for storing carbon in the soil. Consequently, in a 30-year period, a rubber tree sequesters one metric ton of carbon per year, which equals 30 metric tons in 30 years. Their root structures also helps to stabilize the soil, increase moisture levels, retain nutrients, and improve soil fertility. Developing countries lying in tropical areas can have an advantage in carbon trading through sequestrations to rich countries that have a high amount of carbon emissions. Rubber plantations are an important instrument in preventing deforestation and soil erosion, a

critical agricultural and natural resource management issue in tropical countries. The major problem of forest encroachment in Nepal can be reduced by commercializing the rubber tree and supplying timber at low costs.

Natural rubber is a raw material for the tyre industry. With the advancement of automobile technology, the need for natural rubber is an increasing trend in Nepal, and no alternative to the natural rubber industry exists to address increasing automobile use and tyre demand growth in Nepal. The commercialization of *Hevea* is the only way to fulfill the growing demand for rubber in the country (Diaby et al., 2011, 2013). Also, with relatively low production costs (Poudel et al., 2020) and faster plant growth, the rubber enterprise is expected to benefit the country's overall economy, as rubber imports will decline significantly within 7 years of the commencement of commercial rubber production.

While latex production is the primary purpose of a rubber industry, income from secondary activities include honey (150 kg/ha; 1500 mt/25 years), rubber seed oil and cake (150 kg/ha), and tropical rubberwood (250 cubic feet/ha; 2 million cu. ft after completed one cycle; Prabhakaran Nair, 2010). In addition, rubber plantations have the potential to generate self-employment (25,000 persons directly and indirectly) and sustainable livelihood for youth and marginalized people (MoAD, 2013). Rubber plantations also have several environmental benefits, including improved soil chemical, physical, and biological properties, reduced agricultural inputs and agrochemicals in the ecosystem, soil and water conservation via reduced soil erosion and flash flooding, and improved air quality via carbon sequestration (Panda & Sarkar, 2020). While rubber plants grow with almost all the attributes of a forest species, rubber plantations could also be incorporated in eco-tourism promotion. Various studies have demonstrated that Nepal possesses significant potential to meet domestic demand as well as export rubber goods (FRTC, 2021; Poudel et al., 2020; PMAMP, 2019, 2021).

5 Current Status, Gaps, and Scope of Commercialization of *Hevea* in Nepal

Although rubber plantation is limited to only small farmers in eastern Nepal, the country has a high scope to pursue a large-scale production operation and transform itself into a rubber exporter country. Despite this potential, rubber cultivation is currently confined to a 553-ha area mostly in the lower Terai region of eastern Nepal (Poudel et al., 2020). Rubber-producing farmers are supported with subsidies and incentives; however, farmers are facing a lack of market information, management, education, and technical training regarding rubber plantation and primary processing. Youths are compelled to migrate overseas to seek foreign employment due to political instability, government indifference in developmental activities, and lack of incentives in start-up agri-business and agricultural innovations. The major economic advantages of the commercialization of the rubber tree in Nepal will be to increase

employment and raise the economic and social status of the country by engaging smallholder farmers in production, processing, and other value addition activities of rubber products. Political, social, and economic barriers are the major hindrances for rubber industry growth and expansion.

The world rubber export trade is a \$18 billion economic activity that traded ~ 28 million metric tons of rubber in 2022, significantly influencing the scope of the natural rubber industry. Nepal imported 227, 384, and 550 mt of natural rubber in 2020, 2021, and 2022, respectively, indicating an increasing trend in natural rubber import in Nepal (FAOSTAT, 2022). The country is spending a considerable amount of money on the import of natural rubber because the current area under cultivation of rubber is negligible compared to what is needed based on demand. This signifies the higher scope of rubber commercialization in Nepal. Government institutions, national and international nongovernment organizations, and private industries are involved in the rubber plantation effort in Jhapa, Morang, and Ilam. By realizing the economic benefit of rubber plantation, the Nepal Tea Development Corporation is replacing several of their old tea estates with rubber plantations. There is no managed and/or formal database of rubber enterprise-related information in Nepal, making information sharing difficult in promoting rubber plantation and commercialization among Nepalese farmers (MoAD, 2013). In Nepal, although rubber plantation started in 1947, it never transformed into a commercial enterprise, owing to government indifference, while the delay in commercialization of the rubber industry in Nepal is a major economic and environmental loss for the country.

The cost of rubber production could be relatively low because of the excellent availability of land, infrastructure facilities, the reasonable cost of labor, and other concomitant benefits. The Ministry of Agriculture and Livestock Development (MoALD), Rubber Board Nepal, and International Rubber Research Nepal are available for advisory roles in research, training and extension services at all stages, including offering suitable credit, site selection, nursery establishment, beekeeping, crop processing, grading, packaging, market access, rubber goods manufacturing technology, and other services. Various elements are necessary for the success of small- and large-holder rubber plantations in the country. Small-holder rubber farmers demonstrate more flexibility in operation and develop more competitive and industrial enterprises, and supporting the organization of planters and producers through cooperatives and their involvement in the initial process is a necessary first step in rubber commercialization in Nepal (MoAD, 2013, 2019).

Latex from the rubber plant has various uses in the tyre, toy, shoe, and surgical good production industries. Therefore, a successful rubber production industry serves as a value chain to provide value to stakeholders at every level of the industrial chain. Moreover, the production of ammonia and other chemicals adds another dimension to the rubber value chain industry, as ammonia is needed for latex processing. The Government of Nepal should emphasize the establishment of rubber production industries, surgical goods production industries and other industries that consume latex. Nepal has developed a nationally determined contribution (NDC) plan (2020) and its implementation plan for actions and National Adaptation Plan (NAPA) as well as a local-level climate change adaptation plan (LAPA) to address the climate

change impacts on agriculture and allied enterprises. Because the rubber tree has been demonstrated to possess a significant potential for carbon sequestration, rubber plantations could be one of the most effective strategies for climate change mitigation in the country. The *H. brassilens* tree grows profusely without much agronomic management and survives well under extreme environmental conditions such as high temperatures and limited water supply (Augustus & Seiler, 2011). It is propagated through stem cutting but requires primary care to establish plantation. The gestation period to attain maturity is still 6–7 years even if root trainer plants are planted; therefore, assessments of plant growth characteristics, especially on growth rates in different climatic conditions, habitat suitability, clustering the land as per habitat, and soil conditions are important considerations in advancing rubber production in Nepal.

Climatic suitability, demand for raw rubber for local markets, employment prospects, and economic opportunities all clearly support the need for an expanded rubber industry with sustainable commercial production. Nevertheless, potential rubber farmers are reluctant to expand the current production enterprise due to the lack of government programs to support natural rubber industry expansion, insufficient technical know-how, skills, and human resources on the commercial promotion of natural rubber, lack of information dissemination on market and price, deficiencies in training and skilled manpower, a high incidence of insect pests and diseases, increased production risks exacerbated by climate change, and a lack of networking among current rubber farmers (FRTC, 2021; Pandey et al., 2020; Poudel et al., 2020). As a result, current rubber farmers in Nepal, especially small-holders, are deprived of access to income-generating and economic opportunities.

Hevea brassilensis species has an enormous potential for commercialization of the rubber industry in Nepal (Venkatachalam et al., 2013); however, morphology, cultivation practices, the status of commercialization and the potentiality of natural rubber in Nepal must be thoroughly examined, its future direction clearly outlined, and government commitment and support rendered in advancing Nepal's ineffective rubber industry to a more prosperous commercial rubber enterprise.

6 Policy Recommendations and Rubber Promotion National Roadmap

Here we propose policy recommendations and guidelines to facilitate the expansion of rubber production area and develop a commercial rubber enterprise in Nepal. These guidelines are expected to serve as a rubber promotion national roadmap.

1. As stated previously, rubber growing in Nepal never transformed into a commercial enterprise, which might be a major economic and environmental loss for the country. Therefore, first and foremost, the government must treat the rubber enterprise as its national priority program in its national development plan. A robust national rubber policy, associated budget, and government commitment

are essential prerequisites for a successful and visionary commercial rubber enterprise in Nepal.

2. In addition to existing rubber growing areas, other potential suitable areas in the country must also be explored for rubber production, especially where land is more vulnerable to soil erosion and irrigation is limited for row crop production.
3. A productive collaboration must be forged with other industrial crop enterprises such as banana, pineapple, pepper, medicinal and aromatic plants, tea, and apiculture to take advantage of integrated cropping systems and leverage resources.
4. Cultivars, technological advancements, and technical services must be enhanced to reduce dry rubber yield variability (1300–1800 kg/ha/year) and uncertainty and optimize yield at 2000 kg/ha/year. A strong integrated rubber and farm forestry extension program must be developed to ensure that grower training, technical service delivery, and the dissemination of research findings are timely and impactful.
5. Rubber farmers and rubber industry stakeholders must have access to low interest credit, insurance, technology, and robust markets.
6. The government's efforts should be toward strengthening farmer-responsive research, training, and extension services, including internships for undergraduate students, training for junior technicians and agriculture officers, and higher education opportunities for students in rubber science and technology.
7. A rubber development plan should be developed to involve farmers, women, and youth in research design and implementation, promote participatory research and citizen science, and create farmer-led innovation networks. Rural youth and female empowerment must be an integral part of the national rubber policy.
8. There have been ample feasibility assessments across the eastern Terai region for natural rubber expansion. The current study by Forest Research and Training Centre in 2021 suggested a potential area of around 180,000 ha for rubber plantation across the country. However, expansion from the current 553 ha to the proposed 180,000 ha may likely be adjusted for near-term success. Therefore, a 10-year rubber production expansion program is proposed (Tables 1 and 2) where most of the production expansion should take place in the eastern Terai districts, with some expansion in new districts. The 10-year horizon of the expansion program is split into two 5-year phases with 19,000 ha of rubber plantation that includes both public and private lands. The first 5 years will invest the most effort in the expansion of the production area by about 9000 ha. The latex yield will begin to commence from about six years of the first planting, so the second phase will include both production expansion and latex yield management. Based on several previous studies, we propose 9000 ha expanded in the first five years and 10,000 ha in the following five years. Previous reports have also recommended that an approximately 20,000 ha rubber industry is both attainable and sustainable for a vibrant rubber industry in Nepal.

Table 1 Proposed area (hectares per district or region) of rubber production expansion during the first five years of the national rubber promotion plan

District	Year 1	Year 2	Year 3	Year 4	Year 5	Total
¹ Jhapa	580	1060	1060	1060	1060	4820
¹ Morang	200	300	300	300	300	1400
¹ Sunsari	100	300	300	300	300	1300
¹ Illam	100	300	300	300	300	1300
² Makwanpur	10	20	20	20	20	90
² Chitwan	4	10	10	10	10	44
² Gorkha/Lamjung/Tanahun	6	10	10	10	10	46
Total	1000	2000	2000	2000	2000	9000

¹Currently rubber grown districts with expanded areas of production; ²New districts with rubber production potential

Table 2 Target area (hectares per district or region) of rubber production expansion during the second five years of the national rubber promotion plan

District	Year 1	Year 2	Year 3	Year 4	Year 5	Total
¹ Jhapa	800	800	800	800	800	4000
¹ Morang	450	450	450	450	450	2250
¹ Sunsari	450	450	450	450	450	2250
¹ Illam	200	200	200	200	200	1000
² Makwanpur	25	25	25	25	25	125
² Chitwan	25	25	25	25	25	125
² Gorkha/Lamjung/Tanahun	50	50	50	50	50	250
Total	2000	2000	2000	2000	2000	10,000

¹Currently rubber grown districts with expanded areas of production; ²New districts with rubber production potential

9. A strong public–private partnership with approximately 50/50 contribution of marginalized public lands and private lands from interested farmers can constitute the total target areas for new rubber plantation. Such public–private partnerships will also ensure the establishment of new rubber processing industries and other allied manufacturing industries.
10. The establishment of modern rubber processing plants in the fifth year (latex production begins 5–6 years after rubber plantation) will ensure increased efficiency of raw latex storage, transportation, and processing. Several rubber-based agro-industries can be established in 6–7 years via private, public, and public–private ownership for efficient utilization and consumption of domestic rubber production while supplementing the raw rubber demand to operate these industries at full capacity through import.

11. GRIL can be revamped and empowered with necessary technical expertise, financial resources, and accountability for profitable operation.
12. The National Rubber Promotion Board (NRPB) can be established and empowered with a mandate for rubber research, education, and outreach. The NRPB must coordinate its research, teaching, and outreach activities with agriculture institutions (AFU, HICAST, IAAS, and others), NARC, and the Ministry of Agriculture and Livestock Development, Ministry of Forests and Environment, Ministry of Energy, Water Resources and Irrigation, other relevant ministries with natural resource management portfolios, and international rubber institutions (e.g., Institute of Rubber Research Nepal, International Rubber Research and Development Board, and others). A strong coordination between NRPB and local governments such as municipalities must be ensured.
13. A strong financial commitment, robust industrial crop/rubber policy, and short-, medium-, and long-term goals and benchmarks must be clearly outlined and executed by all parties involved (see #11 above), followed by regular monitoring, assessment (program activities and impact), and readjustment of the program.
14. Outcome indicators of this program (10-year horizon) are expected to include (a) direct employment throughout the year for at least 4000 farmers and additional employment generation via an extensive natural rubber enterprise network, (b) establishment of 20–25 rubber-based commercial nurseries fully operated for commercial production and supply of improved varieties of rubber saplings, (c) about 190,000 ha of land planted with high-yielding varieties of rubber plants, (d) four high-yielding and proven cultivars (e.g., RRIM600, RRII105, RRII208, and Hinan1) used in this natural rubber expansion program while importing new germplasms from India, Malaysia, and China for rubber genetic stability, (e) establishment of an extensive natural rubber research program, including germplasm evaluation, agronomic and crop pest management, economics, and market exploration, (f) meeting 100% of the natural rubber demand through domestic production and establishment of a sustainable commercial production system that will be the two primary benchmarks for this program's success, and (g) a goal of poverty alleviation, manpower development, providing environmental stewardship, and natural resource conservation.

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Chapter 16

Transformative Pathways to Tackle Soil and Water Management Issues in Nepalese Agriculture



Roshan Babu Ojha, Bhaba Prasad Tripathi, Roshan Man Bajracharya, Dinesh Panday, and Jagadish Timsina

Abstract Nepal's agriculture faces emerging soil and water issues and challenges in agricultural production, necessitating urgent attention. These challenges include soil compaction, pollution (including microplastics), cropland abandonment, and the depletion of spring and groundwater resources. Additionally, persistent issues such as soil nutrient and carbon depletion, acidity, erosion, and imbalanced fertilizer and improper water management continue to impact agricultural productivity. The presence of rugged terrains, diverse geography, and the compounding effects of population growth and climate change exacerbate these challenges. Transformative strategies and interventions are imperative to effectively manage soil- and water-related issues and challenges to increase crop, soil, and water productivity amidst climate change and population growth. Existing institutions, including research, extension, and education bodies under various ministries, can play a pivotal role in addressing soil and water issues. However, their roles, responsibilities, and resource allocation are not effective in tackling the present and emerging issues related to soil and water management and in making the country self-sufficient in agriculture production. The recent federalization of Nepal's government structure has further empowered local governments to engage in local-level soil and water management.

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However, it is essential to acknowledge that institutions focused on researching and disseminating soil and water-related technologies have faced setbacks. Current legislation and policies related to soil and water management fall short in adequately addressing emerging issues. In this chapter, we explore how Nepal can navigate existing and emerging soil and water management-related issues and challenges within the context of geographic diversity, climate change, and population pressures. We propose transformative pathways related to improved institutional quality (e.g., human resources development and improved governance) and policy reforms that align with the present legislative and federal frameworks. By adopting innovative approaches and fostering collaboration across sectors, Nepal can safeguard its soil and water resources, increase agricultural production, achieve food security for growing populations, and realize sustainable and transformative agricultural development.

Keywords Institutional framework · Transformative changes · Soil issues · Soil policy

1 Introduction

Managing soil and water properly and effectively in Nepal is crucial because of the country's challenging landscape, with mountains and fragile ecosystems, and the pressure of a changing climate and growing population (Krupnik et al., 2021). Soil erosion, especially in the Hilly areas, poses a significant problem, causing land degradation and reducing agricultural productivity (Acharya & Kafle, 2009). Water management is challenging due to erratic rainfall, rugged terrain, insufficient irrigation infrastructure, and depleting water resources. This chapter proposes strategies, policy reforms, and institutional improvements to tackle these soil and water challenges, aiming to achieve sustainable agriculture and food security amid climate change and population growth. By dividing into topical sections, it covers emerging issues in soil and water management, evaluates how national policies address these challenges, reviews the current institutional framework, and outlines a transformative roadmap for better management. The study is based on a comprehensive review of academic articles, government reports, and expert consultations, and presents the authors' perspectives.

2 Emerging Issues in Agricultural Soils and Water Management

Agricultural land use in Nepal is closely related to the United Nations Sustainable Development Goal, which deals with food security. In the “Voluntary Guidelines for Sustainable Soil Management,” the Food and Agriculture Organization of the United Nations highlighted a list of ten principal soil threats (Baritz et al., 2018), which include soil erosion, depletion of soil organic matter, nutrient imbalances and disrupted biogeochemical cycles, salinization and alkalinization of soils, contamination, acidification, loss of soil biodiversity, sealing, compaction, and reduction in soil moisture content. Notably, apart from soil salinization, all other threats are evident across various landscapes in Nepal as depicted in Fig. 1 (Ojha et al., 2021). Moreover, the country is encountering nascent soil-related challenges such as the abandonment of agricultural lands (Chaudhary et al., 2020; Ojha et al., 2023), soil compaction followed by reduced rooting depths (Sitaula et al., 2004), attributable to soil erosion and weak geology (Baumler & Zech, 1994; West et al., 2015), contamination from microplastics (Napper et al., 2020), shifts in soil biodiversity, pollution from chemical fertilizers, heavy metals, and pesticides (Pokhrel et al., 2018), the occurrence of frequent dry spells, and groundwater level depletion (Nepal et al., 2021). The ecological belts, Tarai and Hills, should have sustainable agricultural production systems to meet the increasing food demand. However, land fragmentation is high in rapidly urbanizing Tarai, whereas, increasing fallow land and landlord absentees are widely prevalent in the hills.

The agriculture sector is also the primary water consumer with around 95.9% of the total consumption, while only 3.8% is used up by the industrial sector. Irrigation systems increase resilience to drought and climate change, as well as help in reducing poverty and enhancing the adaptation capacity of farming communities to climate change.

3 Soil and Water Management Issues Addressed in National Policies and Legislation

Several policies, acts, and rules are promulgated at different tiers of government to manage and regulate agricultural soils and water. The multi-faceted issues in soil and water require a large stakeholder collaboration and coordination. In the present federal structure, soil and water conservation plans and programs at a local level are tied in with federal policies and legislation. The federal institutional framework to deal with soil and water management-related issues is governed by multi-sectoral ministries of Nepal (Tables 1 and 2) and less coordination between them causing difficulty in implementing the policies. In a broader sense, most of the soil and water management-related issues are covered by current legislation. However, emerging issues like soil contamination and biodiversity loss are still to be addressed.

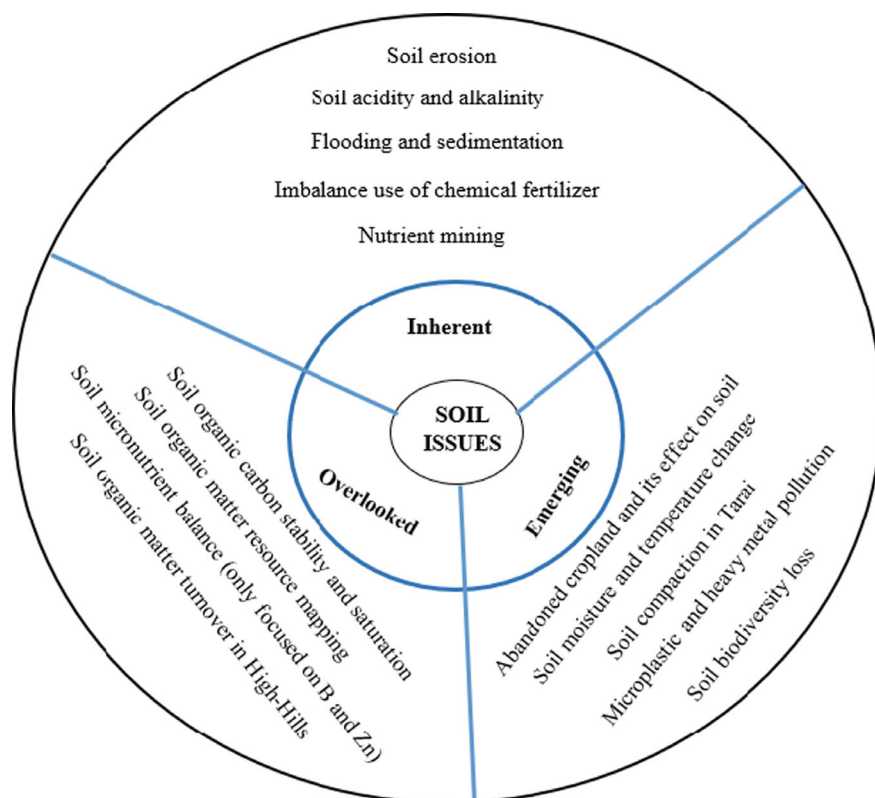


Fig. 1 Soil-related threats in agricultural soils of Nepal. Modified from Ojha and Panday (2021)

The Constitution of Nepal (2015) has directed the government to protect and promote the rights and interests of rural farming communities, utilize the Land Use Policy, and preserve the right to a clean and healthy environment. Land plotting business is flourishing more in-and-around the Kathmandu valley, various districts/provincial headquarters, and different parts of the Tarai region. Moreover, the Local Government has been constructing roads, particularly in the hills and mountains, in a haphazard manner without any clear land-slope stabilization plan. To address the inefficient land use and low crop productivity issues, the Government of Nepal has endorsed the Land Use Act in 2019. However, its proper implementation at the field level is not effective. Therefore, urgent steps are needed to reverse the trend in land degradation for maintaining land productivity through sustainable land management approaches (Bajracharya, 2022). The Land Use Act also provides power to local government to make and use of land use plans for the local unit. This allows for implementing scientific and sustainable land management practices addressing local needs.

Table 1 Summary of the agriculture-related policies addressing soil and soil water issues at federal level in Nepal

S. No.	Policy	Implementing institution	Soil-/water-related provision
1	Soil and Watershed Conservation Act, 1982	Ministry of Forest and Environment (MoFE)	Soil fertility conservation is a part of soil conservation and addresses issue of sustainable use of soil resources
2	Agriculture Perspective Plan 1995–2015	Ministry of Agriculture and Livestock Development (MoALD)	Encourages the use of chemical fertilizers and pesticides
3	Fertilizer Control Order, 1999	MoALD	Specifies the criteria of chemical fertilizer standard for Nepalese soil
4	National Fertilizer Policy, 2002	MoALD	Emphasizes the use of chemical fertilizer with adoption of integrated plant nutrient management system
5	National Agricultural Policy, 2004	MoALD	Focuses on the use of organic fertilizers and organic farming, and endorses harms of agrochemicals on soil
6	Agribusiness promotion policy, 2006	MoALD; Ministry of Industry, Commerce, and Supplies	Envisions special production zones including organic/pesticide-free production zone
7	Agro Biodiversity Policy, 2007 (First Amendment, 2014)	MoALD; MoFE	Identifies soil biota as a part of agro-biodiversity and promotes organic based integrated farming
8	The constitution of Nepal, 2015	Government of Nepal	Provision of land reforms, food sovereignty right, and liveable clean environment. Policies of state reflect on the sustainable use of land resources
9	Agriculture Development Strategy, 2015–2035	MoALD	Soil organic matter (SOM) is considered as an important indicator of sustainability, aiming to increase SOM by 4% by 2025
10	Land Use Policy, 2015	Ministry of Land Management, Cooperatives and Poverty Alleviation (MoLMCPA)	Ensures the use of land based on land use zones and land use plans
11	Food Right and Food Sovereignty Act, 2018	MoALD	Enacts fallow land utilization and sustainable fertility management, and discourages land fragmentation
12	National Food Safety Policy, 2019	MoALD	Aligns the organic agriculture product quality standards with international standards

(continued)

Table 1 (continued)

S. No.	Policy	Implementing institution	Soil-/water-related provision
13	National Agroforestry Policy, 2019	MoFE	Encourages for the utilization of marginal, vacant, and barren land to develop agroforestry model
14	Land Use Act, 2019	MoLMCPA	Provision of land consolidation and provides power to provincial and local government for land management
15	National Climate Change Policy, 2019	MoFE	Emphasizes organic farming system, crop diversification, agroforestry considered as adaptive options
16	15 th Five Year Plan, 2019/20–2023/24	National Planning Commission	Sustainable soil management program implemented through organic farm establishment and certification program. Aims to increase soil organic matter by 2.4% by the end of 2024
17	Hydro-power Development Policy, 2001	Department of Electricity Development, MoEWRI	Rural electrification for development of rural economy and agriculture
18	Irrigation Policy 2013	Department of Irrigation, MoEWRI	Identifies available water resources for irrigation to increase agricultural productivity
19	Environment Protection Act, 2019	Department of Environment, MoFE	Emphasizes on preventing degradation and pollution of the environment; minimizes impacts due to development activities; addresses GHG emissions and climate change adaptation and mitigation; Minimizes pollution of land and water from agricultural chemicals; prevents soil erosion and land degradation
20	Water Resources Rules, 1993; Water Resources Act, 1992	Ministry of Energy, Water Resources and Irrigation (MoEWRI)	Conservation and development of water resources for power generation, irrigation and agricultural production; increases available water for irrigation and enhancing farm productivity
21	Irrigation Master Plan, 2019–2029	MoEWRI	Increasing food security and reducing poverty through a significant increase in irrigation area coverage
22	National Water Resource Policy, 2020	MoEWRI	Efficient use of water resources for the economic upliftment of water-related sectors including agriculture

Adapted and modified from Paneru et al. (2023)

Table 2 Existing policy instruments and regulations, and their provisions for soil contamination assessment in Nepal

S. No.	Legal instruments	Implementing institution	Provisions for soil contamination
1	Industrial Policy, 2010	Ministry of Industry, Commerce, and Supplies	Broad aspects of pollution covered
1.1	Industrial Enterprise Act, 2020		Submission of a report on environmental safety while establishing an industry
1.2	Industrial Business Act, 2020		
1.3	Mines and Minerals Rules, 2000		
1.4	Private Firm Registration Rules, 2020		
2	National Environment Policy, 2020	MoFE	Provides a clear direction to control pollution generated by industrial waste
2.1	Environment Protection Act, 2020		Provision of submitting pollution-controlling certificate
2.2	Environment Protection Regulation, 2021		States that any individual, organization, or industry is not allowed to throw waste that impacts environment and public health Initial environmental evaluation test and environmental impact assessment report should be submitted
2.3	Hospital Waste Criteria and Sampling Method, 2019		Provides upper limits to few heavy metals (Hg, Cd, Pb)
2.4	Kathmandu Valley Air Pollution Control Guidelines, 2019		Brick factories and boiler-fitted industries are indicated as sources of air pollution Provision to set the critical limit of calorific value every two years for sulfur content, and ash content for material to be used in brick
2.5	Water Quality Standards, 1997		Provides standard for industrial effluents
3	National Agricultural Policy, 2004	MoALD	Aims to reduce soil pollution caused by agro-chemical input
3.1	Agricultural Development Strategy (2015–2035)		Indicates soil biodiversity, carbon, and productivity as a proxy of safe soil Focuses on integrated approach to fertilizer, pest, and disease management
3.2	Organic and Biofertilizer Regulation Directives, 2011		Provides critical limits of heavy metals for organic fertilizers

(continued)

Table 2 (continued)

S. No.	Legal instruments	Implementing institution	Provisions for soil contamination
4	National Transport Policy, 2001	Ministry of Physical Infrastructure and Transport	Envisioned proper management of petroleum products and emission control from gasoline transports
4.1	Motor Vehicles and Transport Management Act, 1992		Provision of emission control mechanisms from public and private vehicles
4.2	Motor Vehicles and Transport Management Rules, 1998		Certificate of pollution (emission) control from gasoline vehicles should be submitted during registration
4.3	Eco-friendly Motor Vehicles and Transport Policy, 2014		Promotion of alternate energy vehicles to substitute gasoline vehicles and reduction in petroleum emissions

Adapted from Sapkota et al., (2022)

Considering the promulgation of the Constitution of Nepal (2015), most of the policy instruments enacted before the constitution require a thorough review to address the current federal structure needs. For example, Motor Vehicles and Transport Management Act, 1992; National Agricultural Policy, 2004; Mines and Minerals Rules, 2000, etc., should be revised. Numerous existing policies are instrumental in addressing national soil issues, however, there are still some weaknesses that remain to be addressed. Addressing those in the current policies offers vast opportunities considering the future risks (Table 3).

4 Current Institutional Framework for Soil and Water Management

Multiple institutes are implementing the policies, acts, rules, and regulations mentioned above. Different institutes have a separate mandate for research, education, and extension likewise other sectors of agriculture. Four major institutions are working specifically in the areas of soil and water management such as the National Soil Science Research Centre (NSSRC), Central Agricultural Laboratory (CAL), Department of Soil Conservation and Watershed Management (DoSCWM), and Department of Irrigation (DoI). Their working mandates and scope are presented in the following paragraphs.

The NSSRC of Nepal Agricultural Research Council (NARC) is mandated for identifying soil-related problems and developing technologies related to soil management. The NSSRC has in partnership with CIMMYT the “Feed the Future Nepal Seed

Table 3 Analysis of existing policies that can address major soil issues

Thematic soil issues	Strengths of existing policies	Weakness of existing policies	Opportunities	Risks
Land degradation, Unscientific land management	• Constitution of Nepal (2015) mandates protection and promotion of rural farming communities' rights and interests	• Ineffective implementation of the Land Use Act (2019) at the local level	• Local governments empowered to create and implement land use plans	• Flourishing land plotting business leading to inefficient land use • Right of land as a private property
	• Land Use Policy and Land Use Act (2019) provide a framework for sustainable land management	• Existing provisions on land use policy are not enough for soil conservation and management of agricultural lands for producing more food to feed growing population	• Potential for scientific and sustainable land management practices	• Land degradation due to poor land management practices
Soil nutrient imbalance, soil contamination, and soil biodiversity loss	• More than 22 policies related to soil, land, fertilizer, and water management	• Some of the policies were developed before the federalization of the country so they are less relevance to the federal governance structure	• Multi-stakeholder involvement developing and implementing the coordinated plans, programs, and actions within different tiers of government	• Climate change impacts on soil and water resources
Soil water management	• National Water Resource Policy (2020) aims for sustainable water resource management • Irrigation Master Plan (2019) aims to irrigate nearly all agricultural land by 2050	• Legal framework for water resources management is outdated (Water Resource Act of 1992)	• Multipurpose development of water resources for economic prosperity and social transformation	• Continued land degradation affecting agricultural productivity

and Fertilizer Project” developed a Digital Soil Map (DSM) for Nepal, which gives location-specific information for making localized management decisions such as identifying soil problems and applying correct types and rates of fertilizers. Such a tool is becoming popular among farmers, development workers, and policymakers to understand the fertility status of a particular area and manage their soils accordingly. Additionally, NSSRC has initiated the establishment of a geological park and soil museum within its premises that aims to create awareness and provide supplementary soil information system.

The CAL in the DoA of the MoALD is responsible for extending soil technologies and providing soil analyses services to the farmers. In the seven provincial governments, there is a provision for developing provincial soil laboratories. Only a few local governments have established soil laboratories for qualitative assessment, which requires sustained and trained manpower.

The DoSCWM and DoI of the MoFE is mandated to carry out all the soil and water conservation activities while the DoI of the Ministry of Power, Water Resources, and Irrigation is responsible for water management.

After the federalization of the country, previous institutes were either merged or expanded, however, their weak coordination remains a continuing issue. Because of human and financial constraints in the NARC, DoA, DoI, and DoSCWM, research and extension (federal, provincial, and local) related to soil and water management issues are inadequate. Weak linkage between soil research and extension along with a lack of relevant messages to be delivered to the local land users are the most pervasive factors for the ineffectiveness of the extension system in Nepal. The present institutional structure and mandates have key limitations, such as lack of capacity, poor institutional governance, and issues around understanding, as well as responding to climate change. Due to implementation gaps in policies, poor and marginalized households are more exposed to climate risk and vulnerability. The poor and marginalized households and communities are also deprived of services due to constraining provisions within policies and practices. While there are many policies, plans, and strategies for soil and water management in Nepal, their implementation is woefully inadequate.

5 Transformative Roadmap for Agricultural Soils and Water Management

Current policy instruments and institutions are not fully able to deliver solutions to manage existing soil- and water-related issues and challenges in the agriculture sector. The emerging issues of soil contamination, soil biodiversity loss, and water resource depletion require more coordinated effort, state-of-art-technologies, and new policies. Here, we present a roadmap to transform the current framework to address the existing and emerging soil- and water-related issues and challenges.

5.1 *Legislative and Policy Reforms*

There is no single legislation act and/ or policy formulated to combat land degradation in Nepal though there are numerous sectoral policies and periodic plans that have listed soil and land management as a high priority. Based on current and emerging soil threats, the technical manpower in NSSRC, MoALD, and DoSCWM needs to prepare periodic plans research themes that are more realistic, emphasizing capacity enhancement, active participation of local people, and infrastructure strengthening. Local people will adopt the soil management practices only when they get economic benefits from the farmers' friendly technologies. Participatory action research by involving local people and adopting integrated soil management practices is necessary for maintaining healthy soil and improving crop productivity.

In the hills and mountainous regions, lands are usually steep and sloping and hence, are prone to soil erosion and landslides, causing the washing away of manure and fertilizers after heavy rain. The NSSRC and the DoSCWM should give more emphasis to soil research on rainfed unirrigated lands. Priority of soil research should be restoration of productivity of degraded lands by cultivating legumes, practicing crop rotations and multiple cropping; increasing the productivity of poor quality land resources by planting in bunds and hedge rows; and increasing in the productivity of good quality land by practicing better water management and adopting regenerative agriculture (Bajracharya, 2021; RI/TCU, 2017). Other restorative and sustainable land use practices include agroforestry (Bishaw et al., 2022; Pachauri, 2012), particularly in the hills and mountain regions (Bajracharya et al., 2015; Leakey, 2012), amendment of soil with biochar and farmyard manure (Dahal et al., 2018; Gautam et al., 2017), diversified and mixed cropping for climate resilience/adaptation, and water harvesting and micro- or drip irrigation (Bajracharya et al., 2014, 2024). Biochar addition to agricultural soils have been shown to improve nutrient and water retention while enhancing crop performance (Akhtar et al., 2014; Pandit et al., 2016; Pudasaini et al., 2012). When used in conjunction with agroforestry systems in hill farming, these practices can also achieve climate adaptation as well as climate change mitigation through soil carbon sequestration (Bishaw et al., 2022; Sohi, 2012; Stavi & Lal, 2013).

The provincial governments are yet to fully enact their legislation related to water and conform to the spirit of federalism. The federal levels need to set standards, umbrella policies, and acts to streamline provincial and local actions. Numerous policies exist, but the actual tools to implement them are missing. There are issues with both the availability of information and the extent of utilization of available resources. Hence, there is an urgent need to translate policies into actions.

The Digital Soil Map (DSM) of Nepal, prepared by NSSRC-NARC, could be refined and made at a higher resolution to improve the site-specific management measures taken by local farmers and land users (Panday et al., 2018). The DSM should be updated timely by adding more soil data gathered from different sites and places so that more realistic information at higher resolution will be made available to land users. The current use case of the DSM by farmers/land managers is very less

due to coarse resolution as some of the soil properties are not well predicted at farm levels. There are other approaches to make the wider applicability of DSM by integrating dynamic models to predict various soil properties. In addition, the fertilizer recommendation can be made through DSM with timely updates. Such an integrated tool is required for the water management sector. The possibility of integrating artificial intelligence with sensor-based precision farming should be introduced for which a separate digital agriculture policy is required.

5.2 Institutional Reforms and Governance Forms

Institutions need to be strengthened for the planning, implementation, and monitoring of the projects along with attracting capital in the water sector. Specific strategies to address adaptation and resilience in this sector are required. Increasing water harvesting, inter-basin transfers, water use efficiency, water reuse/recycling, and ground water use wisely is necessary for the sustainable development of the water resource sector. Essential institutional capacities for analyses, negotiations, and dialogues required for international or bilateral cooperation also need to be developed.

All the internationally funded research and development projects on soil and water conservation are included in the MoFE, which are reluctant to share the budget and programs with NARC and DoA. This results in very weak collaboration and coordination among different soil and water management agencies. Therefore, close coordination and cooperation among related ministries and departments is needed.

The government should make a strong decision to merge the DoSWC with the DoA. The research component of soil and water conservation should be in the mandate of NSSRC because soil and water management problems are more severe in agricultural lands than in forest lands.

Different policies, plans, and strategies related to soil and water management should be implemented effectively and in a timely manner by the concerned institutions and the related departments and ministries, so that people will benefit well. Implementation of policies should be done in partnership with local NGOs and community based organizations to improve the adoption and effectiveness of soil conservation measures.

5.3 Human Resource Requirements

There is limited technical manpower in all the government institutions to carry out research and extend new technologies to the doorsteps of the farmers at central, provincial, and local levels. Therefore, additional technical manpower in all three tiers (central, provincial, and local) of the government should be arranged. Moreover, the soil analysis laboratories should be equipped with modern and state-of-the-art

equipment, and at the same time appointment of trained technical manpower should be ensured to run the laboratories smoothly. The government should arrange special allowance for the technical persons involved to run the soil laboratories regularly because there are health hazards and risks to working in the laboratories.

5.4 Financial Requirements

The budget allocated by the government for soil research and development in NARC, and DoSWC is minimal, and hence, there is a need to allocate a sufficient budget in the future. Moreover, the coordination and collaboration between these institutions as well as agricultural universities need to be strengthened. Some research and development projects related to soil and water conservation in the hills and mountains are long-term and need to ensure long-term commitment of the budget in advance. A joint mega-project on soil and water management between DoA, DoI, DoSWCM, NARC, local governments, and universities is required that integrate the major soil and water issues in different ecological belts (Table 4).

6 Way Forward and Conclusions

Soil and water-related issues are continually evolving and remain critically pertinent to Nepalese agriculture. The surge in semi-commercialization, particularly within the fruit and vegetable sectors, has further exacerbated these emerging challenges. While current policy instruments address major soil- and water-related issues, there is an urgent need for developing new policies and reforming the existing policies and institutional structures for the comprehensive transformation of the soil and water sectors as well as for the overall agricultural transformation. The focus of this transformation through improved current policies and new policies should be on addressing persistent and emerging soil and water issues and challenges such as soil erosion and acidification. Currently, policies and institutional frameworks primarily emphasize production, fertility, and water availability. However, expanding this focus to include environmental effects and impacts is imperative. A rapid shift toward establishing advanced laboratory facilities, developing meritocratic governance, and fostering a robust, coordinated team is essential. This transformation involves more than five major government agencies, necessitating a guarantee of financial and human resource provisioning based on specific needs and skills. Therefore, a coordinated approach is required, integrating all tiers of government, soil and water research, and the education sector to effectively transform the agricultural soil and water sectors in Nepal. Addressing these issues comprehensively will not only enhance agricultural productivity but also ensure environmental sustainability and farm resilience.

Table 4 Roadmap and time frame (short term—1 to 5 years; long term—5 to 10 years) to transform the areas of agricultural soils and water management

Soil issues	Implementing institutions	Institutional/governance/policy reforms	Human resource requirements	Time frame
Soil erosion	DoWSCM	Recruitment of soil scientists should be mandatory for DoWSCM or it should be integrated with MoALD	Master's graduate in soil science	Within 1–5 years
	NSSRC, NARC	Soil conservation research unit should be established under NSSRC-NARC	2 soil scientists with a minimum of master's degree in soil science	1–5 years
Soil acidification	CAL, DOA; NSSRC-NARC; Provincial laboratories; local governments	A dedicated package of programs of soil acidity amelioration is required at a provincial government and soil lab in coordination with local governments rather than only focusing on the distribution of agricultural lime. CAL, DoA and NSSRC-NARC should facilitate the technical and lab support	I.Sc. Ag. and B.Sc. Ag. at Provincial and local levels; M.Sc. Ag. (Soils) at NSSRC	Within 1–5 years
	Provincial and local governments	Cropping system improvement programs such as crop rotation, reserve acidity replacement, and balanced fertilization should be planned and executed	I.Sc. Ag. and B.Sc. Ag. graduates recruitment at each local government	Within 5–10 years
Soil contamination and soil biodiversity	DoA, MoALD; DoI, MoEWRI; DoE, MoFE; NSSRC, NARC	Soil contamination policy and soil biodiversity policy are required; a state-of-the-art lab facility should be established at CAL and NSSRC-NARC for soil contamination study and metagenomics analysis	M.Sc. Ag. (Soils), lab technician training and capacity building	Within 5–10 years

(continued)

Table 4 (continued)

Soil issues	Implementing institutions	Institutional/governance/policy reforms	Human resource requirements	Time frame
Soil water management	DoI, MoEWRI; DoA, MoALD; NAERC, NARC	Irrigation research unit should be established under the National Agri-engineering Research Centre, NARC. A high-level joint team/committee between MoEWRI, MoALD, and NARC should be provisioned in the Irrigation Policy and National Agricultural Policy	B.Sc. Ag. and M.Sc. Ag. graduates	Within 1–5 years
Soil fertility management	DoA and NSSRC	Strengthening of Soil survey, Soil Physics, Soil Microbiology and Plant Nutrition Units of NSSRC in terms of technical workforce and budget	Special attention for Masters' graduates and short-term training in specific areas	Within 1–5 years
	DoA, provincial, and local governments	A mega-project of sustainable soil management on mid Hills and Tarai should be designed and implemented for multiple years. A separate project implementation unit is required	Ph.D. (7) or Masters (7), B.Sc. Ag. (14) and I.Sc. Ag. (21) graduates at all provinces	Within 5–10 years
Soil education	Departments of Soil Science of Agriculture and Forestry University (AFU) and Institute of Agriculture and Animal Sciences (IAAS) of Tribhuvan University (T.U.)	Establishment of Soil Survey, Soil Physics, Soil Microbiology, and Plant Nutrition Units under the Soil Science department in AFU, IAAS, and other universities where master's degree in Soil Science is offered	Special attention for the Masters' degree program Short-term training and Masters' degree to faculties and soil-based problem research thesis and dissertation continue	Within 5–10 years

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Chapter 17

Transforming Agriculture Sector Through Sustainable Improvement of Soil Fertility and Fertilizer Sub-sector in Nepal



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Abstract Improving soil fertility is essential for increasing crop productivity and meeting the food demand of Nepal's growing population. This chapter presents the challenges in soil fertility and fertilizer sector and suggests potential strategies, including role and responsibilities of respective stakeholders to improve soil fertility and fertilizer management practices. Nepalese agriculture faces multiple challenges in improving soil fertility. Farmers' nutrient management practices are based on outdated and blanket fertilizer recommendations. Farmers often lack access to extension services, and most are unaware of even the guidelines for application of outdated fertilizer recommendations. The chronic fertilizer shortage, worsened by inefficient procurement and distribution systems, and climate change impacts, further exacerbates these issues. Addressing these challenges requires integrated interventions across policy, institutional, human resources, and research and extension services, to adapt to evolving agricultural and climatic dynamics. The Government of Nepal should first ensure timely access to quality fertilizers. Research should focus on crop- and site-specific integrated soil fertility management practices (ISFM) that combine organic and inorganic inputs, following the 4Rs (right source, right rate, right time, and right placement) of nutrient stewardship to improve fertilizer use efficiency and net farm returns. This chapter proposes a roadmap focusing on five key areas: (i) research activities on developing effective and efficient fertilizer management practices that are crop- and site-specific involving public and private partners, (ii)

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extension services for evaluating and commercializing efficient fertilizer application technologies, (iii) scaling ISFM practices through dealers, retailers, cooperatives, and development partners, supported by extension agents, and providing farmers access to soil testing facilities at local level, (iv) revising policy to improve fertilizer supply and promote balanced fertilization strategies, and (v) improving soil health and fertilizer use efficiency strategies for reducing reliance on inorganic fertilizers by promoting the use of organic inputs, where applicable. These reforms on soil fertility and fertilizer sub-sector aim to revitalize Nepal's stagnant agricultural sector, thereby increasing productivity and sustainability.

Keywords Fertilizer policy · Food security · Inorganic fertilizers · Organic inputs · Soil fertility

1 Introduction

Nepal, with about 66% of its people engaged in farming, imports a large volume of food every year because of low crop productivity and production mainly due to declining soil fertility, less use of fertilizers and insufficient irrigation, and unavailability of improved seed, among the others (Krupnik et al., 2021). In the soil fertility and fertilizer sub-sector, the country faces multiple challenges including lack of improved fertilizer management practices such as high use of blanket and outdated application rates and timings, low use of high yielding and hybrid varieties, declining application rate of organic inputs, and deteriorating soil health conditions. Fertilizer management varies by geographic region; it is mainly organic-based, with chemical fertilizer as a supplement across the hills and mountains, while it is inorganic-based, with organic inputs as a supplement across the terai region. However, it is often reported that the quality of organic inputs is often poor (Tripathi et al., 2022). Moreover, farmers have poor access to extension services and are not aware of even the old and blanket recommendations.

In addition, chemical fertilizers shortage, particularly during the peak crop-growing season is a chronic problem (Prasain, 2021). The shortage is associated with a low subsidy budget, and inefficient procurement and distribution systems. This shortage, together with lack of farmer's awareness on improved fertilizer management practices, has resulted in less fertilizer use by farmers compared to neighboring countries. Moreover, farmers' practice for fertilizer use is imbalanced due to poor awareness on judicious and balanced use of inorganic fertilizers and higher level of subsidy to nitrogen (urea) compared to other fertilizers including potassium (muriate of potash) and no subsidy to secondary and micronutrient fertilizers (MoF, 2020).

Therefore, Nepal urgently needs some interventions for improving soil fertility and fertilizer supply system and to raise farmers' awareness on right and judicious use of fertilizers. This chapter reviews major issues and challenges in soil fertility and fertilizer sub-sector including farmers' management practices, supply system, and policy recommendations. Furthermore, it suggests strategies to improve overall

soil fertility and fertilizer sub-sector like updating soil fertility management practices, policy changes including subsidy restructuring, site-specific fertilizer recommendations, transitioning toward balanced fertilization, and improving fertilizer use efficiency. Drawing on existing literature, the authors' experience, and insights from public and private sector stakeholders, the chapter provides a comprehensive overview of status, challenges, and strategies for advancing soil fertility and fertilizer management in Nepal.

2 Challenges in Soil Fertility and Fertilizer Sub-sector

2.1 Fertilizer Shortage and Poor Distribution System

The total fertilizer demand estimated by the Ministry of Agriculture and Livestock Development (MoALD), based on a rough estimate from across 77 districts in Nepal, is around 700,000 metric tons (mt)/year. The more comprehensive estimate based on survey of more than 800 fertilizer retailers shows that the active fertilizer demand is 603,500 mt/year (Gautam et al., 2022). However, government fertilizer supply is only about 300,000–400,000 mt (i.e., 50–66% of the total demand) depending on the price at the international market. Notably, the government is spending about 30% of the agriculture budget on the fertilizer subsidy and may not be able to further increase this allocation (MOF, 2020). The current supply prioritizes crisis avoidance over meeting crop demand. Timely unavailability of fertilizers, particularly during rice transplanting and top dressing, is a chronic problem. Some portion of the unmet demand is supplied through gray market through porous Indian border. These shortages overshadow the importance of other agro-inputs and management practices.

The government has strong control over importation and distribution of subsidized fertilizers, which is not effective and efficient. Under government regulation and directives, Agriculture Inputs Company Limited (AICL) and Salt Trading Corporation Limited (STCL) are responsible for importation and distribution of subsidized fertilizers. The volume of fertilizer importation is determined based on the allocated budget and price of fertilizers in the global market rather than actual demand. Subsidy payment is overly bureaucratic. Of the total subsidy budget, 70% goes to AICL and 30% to STCL. These companies import fertilizers through a global tender in which any party (national or international) can bid on the contract. In general, AICL and STCL import fertilizer in three installments for rice, wheat, and maize. However, there is no fixed schedule to begin the procurement process. The delay in procurement creates a shortage of fertilizer at peak demand time.

Distribution of fertilizers to farmers is mainly through cooperatives, with very limited involvement of private sector, who are more accessible to farmers (Thapa et al., 2023). Farmer cooperatives (only those registered for fertilizer distribution) procure fertilizers from AICL/STCL depots and retail these to farmers (mostly to their

members). Until 2020, the policy of fertilizer distribution through farmer cooperatives restricted entry to business, limiting growth of the private sector and farmers' access to fertilizer. Later the government issued Fertilizer Distribution Directive (FDD) to improve distribution system, which has given local level a sole responsibility to select fertilizer retailers. The directive has opened the opportunity to include private sector (upon recommendation by a local level) in the distribution, but only in the areas where cooperatives are not active (MOALD, 2020). Although the government fixes the wholesale price at port level, the retail price is set by the respective cooperatives and is usually 3–10% higher than the wholesale price to cover expenses, including transportation, office rent, and storage. Thus, the retail price varies by cooperative based on their operational costs (logistics, staff, warehouse, etc.).

Although private sectors are allowed to import fertilizers, they are not able to compete with the subsidized fertilizers or with the gray markets. Thus, their role for import is limited and distributes only full-priced fertilizers (not included in subsidy program). The informal market plays an important role in meeting the demand gap. As per subsidy policy, only smallholder farmers (with land holdings up to 0.75 ha in the hills and mountains and up to 4 ha in the terai) are entitled to subsidized fertilizers for cereal crop cultivation. However, due to poor regulatory control, all farmers, including those growing cash crops, are also receiving subsidized fertilizers. Due to this, large farmers are benefiting, and small farmers are not able to receive benefits as targeted. Similarly, quality control and monitoring of fertilizer distribution are mandated across the value chain; however, enforcement is lax. Moreover, according to informal AICL estimates, urea leakage to non-agricultural uses is estimated at around 10%. Despite regulations prohibiting private sector actors from selling subsidized fertilizers, many still source fertilizers from the cooperatives. This leakage increases the retail price for farmers.

In addition to the above challenges, current distribution is influenced by politics; cooperatives that have good political ties may receive more fertilizers. Political influences on regional branches of AICL and STCL come from both Members of Parliament (MPs) and local government leaders. On one hand, since chemical fertilizers are costly for smallholder farmers, they use free organic input whatever is available in their farms and use lower amount of purchased fertilizers; on the other hand, transport to make fertilizer available when needed is a problem. The government provided a transport subsidy until a few years back, but this is currently discontinued. Therefore, the GoN should also pay attention to making fertilizer available in remote districts.

As mentioned earlier, more than 50% of fertilizer demand is being fulfilled by the informal market, but the quality of those fertilizers is questionable. Although the government monitors fertilizer quality for formal import, this is not effective for fertilizers from the informal market. Moreover, it lacks price monitoring for non-subsidized fertilizers. These issues highlight the challenges of fertilizer use across different levels (import, distribution, and use) in Nepal (Fig. 1). These issues are related to both policy and service levels.

Import	Distribution	Application and use
Policy issues		
➤ Delay in tendering and procurement process ➤ Delay in shipment (fertilizer is not listed as priority commodity) ➤ No subsidy on secondary and micronutrients, and customized balanced fertilizers	➤ Inefficient distribution—mostly through cooperatives, limited involvement of private sector ➤ Retail price not fixed by GoN ➤ Informal flow of unregulated fertilizers, sell by agri-input retailers	➤ Fertilizer shortage in peak crop growing seasons ➤ Poor extension services ➤ Fertilizer recommendations are blanket and outdated
Services issues		
➤ Procurement and transport are sole responsibility of GoN ➤ Private sector not allowed to import who could expediate the process	➤ Involvement of government parastatal firms and cooperates, private sector not prioritized ➤ Limited distribution points ➤ Lack of farmers' identity card	➤ Farmers' poor awareness on use of fertilizers ➤ Agri-input sellers lack knowledge on updated and improved crop management practices

Fig. 1 Policy and service issues during import, distribution, and field application of fertilizers in Nepal. *Source* Authors' developed

2.2 Low Application Rates and Imbalanced Fertilizers Use

The use of average fertilizer rate is in increasing trend, and at 97.8 kg/ha in 2021, which is low compared to its neighboring countries (https://www.theglobaleconomy.com/Nepal/fertilizer_use/; accessed on Sep 5, 2024). Fertilizer shortage during peak demand time, poor farmer awareness on the use of fertilizers, higher use of organic inputs (especially for vegetable cultivation), too little irrigation, and use of varieties unresponsive to fertilizers are some major reasons for the low fertilizer use. In addition to less use, farmer's fertilizer use is imbalanced and skewed toward urea. Higher use of urea is associated with the heavy subsidy which makes it the cheapest fertilizer in the country. Farmers' urea use is more than 55% compared to about 40% of DAP and less than 5% of MOP. Farmers do not pay much attention to using other fertilizers including potassium, secondary (S, Ca, Mg), and micronutrients (Zn, B) resulting in deteriorating soil fertility and low crop productivity. There is no price regulation for secondary and micronutrient fertilizers; they are imported and retailed by private sectors.

Although the government has registered some blended fertilizers, including crop-specific blends for rice, wheat, and maize in late 2019 (DOP, 2019), the subsidy program does not include any customized blended fertilizers except for DAP. Few blended fertilizers, such as NPK 20:20:10 and NPK 20:20:0, are produced in the country and used at a limited scale. Similarly, some blended fertilizers produced in

India are imported informally by the private sector and are sold to farmers often with the name DAP.

2.3 Inefficient Fertilization Management Practices

Farmers lack awareness of improved fertilizer management practices, such as the 4Rs (right source, right rate, right time, and right place) of nutrient stewardship that improve use efficiency. In addition, farmers have no choices for selecting the right sources of fertilizer as GoN provides only three fertilizers under subsidy scheme, with challenges in availability affecting proper rate and time. For urea, the traditional application practices combine both basal and topdressing through the surface broadcast method, leading to a huge loss of nitrogen to the environment, which reduces fertilizer use efficiency (Baral et al., 2020; Gaihre et al., 2015). Phosphate and potassium fertilizers are also inefficiently applied as basal doses, mostly following the broadcasting method.

Although fertilizer deep placement (FDP) technology offers substantial savings for farmers in terms of fertilizer cost and increases yields (Baral et al., 2020; Pandit et al., 2022a, 2022b), its wider use at farm level (availability) is constrained by (i) a lack of sustained policy focus, (ii) challenges in the retail system that prevents timely access to raw materials (urea, whether to allow producers to use subsidized urea or not) for manufacturers, and (iii) a lack of awareness building for farmers. Similarly, the government is not promoting any smart fertilization practices such as sensor-based real-time fertilization, use of slow or control release fertilizers (Baral et al., 2021; Pandit et al., 2022b), or based on predictive modeling or fertilizer decision support systems tools such as nutrient expert (Timsina et al., 2021).

Extension messages have largely neglected this area. There is a lack of studies on nutrient balance in soils (an account of soil supply, crop removal, amount of nutrients supplied by fertilizers, and losses to the environment). Most studies conducted by the Nepal Agricultural Research Council (NARC) and other research institutes have focused on yield responses rather than optimizing fertilizer rates to increase use efficiency (Krupnik et al., 2021; Tripathi et al., 2022).

2.4 Low Use of Organic Inputs and Declining Soil Fertility

Soil fertility is declining, with various reports confirming the depletion of organic carbon (C), and macro and micronutrients from soils. These problems exist to a greater degree in the terai region, which is considered the food basket of the country, compared to the hills and mountains. A recently developed digital soil map shows that organic matter, total nitrogen, and available phosphorus and potassium are lower in terai compared to the hills (<https://soil.narc.gov.np/soil/soilmap/>). Poor soil fertility status and nutrient mining are associated with lower use of organic inputs, intensive

cropping patterns, and low and imbalanced use of fertilizers. Despite the mining of nutrients from the soils, GON fertilizer recommendations did not include secondary and micronutrients for a long time. Although GON advocates integrated use of organic inputs and inorganic fertilizers, the extension program to increase farmers awareness on the importance of balanced fertilization is poor. Moreover, the application rate of organic inputs including manures has been decreasing over the last few years due to labor unavailability resulting from migration of local youth in cities and abroad.

2.5 Inadequate Research in Developing Site-Specific Fertilizer Recommendations and Customized Fertilizers

Fertilizer recommendations for most crops remain blanket approach-based, assuming the whole country as a domain despite the diversity in soils, other biophysical conditions, and agronomic management practices (including crop varieties), which do not cover the spatial variabilities in soil properties and agro-climate (Krupnik et al., 2021). These recommendations have not been updated for the last 40 years, even as soil fertility declines, and use of improved and hybrid crop varieties increases. Moreover, those fertilizer recommendations were developed based on the fertilizer trials conducted across research stations, not across farmers' fields. Fertilizer recommendations should be regularly updated, as the crop yield response to fertilizers depends on factors like cropping systems, soil type, inherent soil fertility, grain-to-fertilizer price ratio, and environmental conditions (Ojha et al., 2021). Moreover, research studies are constrained by lack of trained workforce in the research institutes including the NARC due to increasing brain drain (Kattel & Sapkota, 2018).

While it is recognized that fertilizer application should be site-specific and based on soil test results, there is no consolidated information on the use of a soil health card integrated into the extension program or available from any of the relevant public sector agencies. In addition, facilities on farmers' soil testing and their interpretation on right use of fertilizers are lacking. Most farmers are not aware of the fertility status of their own land.

2.6 Poor Agricultural Extension Services

As per the existing research and extension systems, the NARC develops fertilizer recommendations for crops and the Department of Agriculture (DOA) is responsible for disseminating these recommendations along with improved crop management practices to farmers. However, the extension system has become poor and unstable with the new federal structure (three tiers of government—federal, provincial, and local levels). The local level is responsible for the extension program; however, it

lacks sufficient technical manpower. According to the MoALD, only 18% of farmers have access to full agricultural extension services (ADS, 2015), but when it comes to access to knowledge of improved fertilizer management practices it is much lower than this. Most farmers and agro-input retailers are not aware of the rates and types of fertilizers required for a particular crop. Farmers purchase and use fertilizers based on their own experience rather than scientific guidance or recommendation.

3 Research and Extension Priorities and Policy Recommendations to Improve Fertilizer Supply System and Soil Fertility

The challenges faced by various stakeholders in the fertilizer sector regarding the fertilizer supply system and soil health are interconnected. Addressing these issues necessitates a thorough review of policy, research, and extension systems. It is necessary to assess the fertilizer policies that directly impact the fertilizer market, and design strategies to enhance market performance for fertilizer and open a window of opportunity to achieve broad-based fertilizer sector policy reform. The broad five areas need immediate attention to improve soil fertility and fertilizer management: (i) strengthening the fertilizer supply chain and markets, (ii) developing crop and site-specific fertilizer recommendation within the umbrella of integrated soil fertility management (ISFM), (iii) promoting balanced fertilization, (iv) commercializing efficient fertilizer application technologies, and (v) scaling of improved and innovative fertilizer management practices and ISFM. The potential strategies to address these broader areas are explained below.

3.1 Provide Policy Support to Improve Fertilizer Supply System

There is a substantial opportunity to improve the performance of the fertilizer sector and soil fertility by addressing the underlying constraints through public–private partnership (PPP) approach. Most issues are interrelated and interdependent, and achieving long-term value chain growth is necessary. The main challenge is to maintain steady growth in crop yields in the face of diminishing marginal returns to agricultural inputs. Farmers can improve their net returns from agriculture with lower input cost and enhanced input use efficiency.

As discussed above, the government may not be in a position to allocate more funding for the fertilizer subsidy to meet the active demand. The government must revisit its policy on the import and distribution systems to make fertilizer widely available to farmers. It is necessary to assess the current supply system and its associated inefficiencies in the distribution system, divert use of fertilizers from non-agricultural

to agricultural purposes, and select fertilizer retailers and allocate fertilizers to them in proportion to cropped area or total effective demand. The following are some policy recommendations:

- (a) *Restructuring Subsidy Scheme*: Given the annual rise in international fertilizer prices, it is neither feasible nor practical and sustainable for the government to continue to allocate more and more budget to subsidize fertilizer. Consequently, it is not possible to import 100% of the demanded fertilizer with the current level of subsidy. Restructuring subsidy could be a more viable approach. There is potential to reduce subsidy and free up some resources to increase the supply. A study on farmers' willingness to pay for fertilizer showed that farmers are ready to pay 30–40% higher price compared to the current retail price if they are assured of the timely supply (Thapa et al., 2024). This study suggested that if GON had adjusted subsidy, it could have saved NPR 1611 million for urea, NPR 653 million for DAP, and NPR 71 million for MOP in 2020. Such savings could have supported additional imports of 82,121 mt of urea, 67,914 mt of DAP, and 15,316 mt of MOP. This additional amount could have reduced fertilizer shortage, and farmers might have obtained fertilizer on time and required quantity (Thapa et al., 2024). This approach is well justified as Nepal should keep fertilizer prices relatively higher than in neighboring countries to avoid cross border trade.
- (b) *Simplifying Procurement Process*: The current import process is very lengthy and bureaucratic, taking at least four months, but often longer. Government data shows that once the decision to procure fertilizers is made, it takes at least 224 days for them to arrive in Nepal (Prasain, 2021). Import is done only by AICL and STCL—following open global tender. One of the alternative options for the timely supply of fertilizer could be a G2G agreement, at least for a certain percentage (50%) of the demand to supply at peak crop-growing seasons and fix the timeline to start import process so that fertilizers arrive before the start of the season. The government should give a priority to G2G with neighboring countries including India and China. For urea, an agreement with China and India would be a better option while for DAP, a potential supplier could be Office Chérifien des Phosphates (OCP), Morocco. The OCP has a long experience in supplying fertilizer in the region (Rahhou, 2023). The GoN could also explore the possibility of entering into some sort of agreement to ease the supply of fertilizer, including blended fertilizers, in the country.
- (c) *Increasing Private Sector Involvement in the Fertilizer Value Chain*: Involving the private sector in import and distribution can boost market competition and ensure timely supply by simplifying import protocols and shortening the process. A recent study showed that private sector's distribution is efficient and effective compared to that of cooperatives (Thapa et al., 2023). Opening the fertilizer market to any private sector firm may improve farmer access and create opportunities for improved efficiency. It will allow fertilizer dealers to operate within the policy guidelines and facilitate private sector investment based on market demand.

The issue of fertilizer shortage during peak demand (rice transplanting time) is mainly due to delay in the procurement (importation) process. In addition, the private sector has an established network of retailers (e.g., agro-vet) across districts and farmers could obtain fertilizers easily while purchasing other agro-inputs. The retail price would also be reduced due to competition, and there will be no additional logistic cost compared to cooperatives. The private sector could provide better technical information (e.g., the 4Rs of nutrient stewardship approach) while selling fertilizers, as they already do while selling seeds and pesticides.

In a broader context, the fertilizer marketing system in Nepal “functions” due to a heavy commitment by (and cost to) the GoN in administering the market. In addition to the policies that require reform measures, significant policy-related constraints impact the importer and distributor/wholesaler levels. The current subsidy policy is not in favor of the private sector importing subsidized fertilizers. The supply system could be improved by adopting a nutrient-based subsidy scheme rather than the current product-based (urea, DAP, and MOP) subsidy. This would provide a level playing field for the private sector and will encourage them to be involved in fertilizer import and distribution. The private parties may import and distribute any kind of fertilizers registered with MoALD including crop and site-specific blended fertilizers which can be extremely helpful to ensure balanced fertilization and increase crop productivity. However, GON should have a regular monitoring program to assure supply of quality fertilizers given the high chances of cross border trade of poor-quality fertilizers.

- (d) *Maintaining Buffer Stock to Ensure Availability at Critical Crop Growth Stages:* Another alternative to manage the crisis is maintaining buffer stock (at least 20–30% of the total fertilizers), which can be used while there is a delay in importing. Delays in imports are also attributed to frequent disruptions in transporting fertilizer from Indian port to Nepal. These disruptions have been caused by logistic issues, past trade blockades by India (such as the recent one in 2015), COVID-19 pandemics in 2020–2021, and various political and social unrest in the country over the years. It is advisable for the GoN to discuss with the Government of India to review bilateral agreement and consider designating fertilizer as a priority commodity, allowing for fast-track importation from Indian seaports to Nepal.
- (e) *Establishing a Fertilizer Plant for Domestic Production:* Establishing a fertilizer plant could be a long-term solution to supply fertilizer in time and quantity. This also saves a huge amount of budget spent on importing fertilizers and creating in-country job opportunities. Recently, the GoN has proposed to establish a urea plant with an annual production capacity of 700,000 mt as recent as 2021 (IBN, 2021). As the total demand of fertilizer is 700,000 mt, urea produced by this factory would be more than the demand (demand of urea is about 400,000 mt), and there could be a problem to sale surplus urea to global market. The government may replace this conventional approach with a new approach of production through green ammonia (NH_3), which requires less

investment than the conventional one. Recently, Kenya has signed a contract to establish NH_3 plant using hydroelectricity to get hydrogen from water electrolysis (<https://nation.africa/kenya/news/kenya-signs-deal-to-manufacture-affordable-fertiliser-by-2025-4011508>, accessed on November 10, 2022), replacing the need of natural gas as a raw material.

- (f) *Promoting Customized Blended Fertilizers*: The government may address farmers' imbalanced fertilization through promotion of customized blended fertilizers to meet the crop- and site-specific nutrient demand. This could be done by removing subsidies on DAP and MOP and providing subsidy for customized blends. Private sector may play a major role for domestic production by changing subsidy policy to include private sector and transition from straight fertilizers to blended fertilizers.

3.2 Adopt and Promote Integrated Soil Fertility Management Approach

Soil organic C shows a declining trend due to lower use of organic inputs in soils (increased cropping intensity, crop residue removal from the field, reduced livestock population, etc.). The shortage of inorganic fertilizers and farmers' poor awareness of judicious use of fertilizers pose challenge to improve soil fertility and health. To address these complex issues and consider the nature of Nepalese farming, an effective strategy to improve soil fertility, fertilizer use efficiency, and crop productivity could be the adoption of the ISFM approach.

The ISFM integrates organic inputs based on local availability, supplemented with inorganic fertilizers, to meet crop nutrient demand, and use of improved seeds to achieve maximum farm benefits (i.e., crop yields and income). This approach improves soil fertility based on local soil conditions and ensures the sustainable improvement of soil fertility (Timsina, 2018). The ISFM concept is like a three-legged pot—fertilizer, organic inputs, improved germplasm—where the system's effectiveness relies on strength of each component (Vanlauwe et al., 2010). The form of each component and the quantity required will depend on the local condition and may differ from one locality to another. For example, the type and quantity of fertilizer required depends on the soil fertility status, crop variety grown, and management practices. The types of organic inputs such as crop residue, manure, compost, or a combination of materials depend on the materials that are locally available (or produced within the community level so that transport cost could be minimum). Similarly, the improved germplasm will depend on the high yielding crop varieties developed and recommended for a particular agro-ecological region.

Potential sources of organic inputs include farmyard manure (FYM), crop residues, farm waste, green manures, compost, and many others (Timsina, 2018). Adopting ISFM improves fertilizer use efficiency, soil's physico-chemical, biological and hydrological properties, and profitability of farming systems. In hills and mountains, farmers practice ISFM by integrating FYM/compost, inorganic fertilizers,

agricultural lime, crop residues/farm waste recycling, inclusion of green manuring and grain legumes and catch crops in rotations, and agro-forestry. These practices improve soil organic matter (SOM), protect soil biodiversity, and boost crop yields and income.

Moreover, adoption of ISFM could be helpful to promote the use of organic inputs as envisioned by the Agriculture Development Strategy (ADS), the government's long-term (20 year, 2015–2035) agriculture plan. The ADS has targeted at increasing the SOM to 4% from the current 1.9% and highlighted the importance of balanced fertilization through ISFM. However, meeting this target is a challenging job considering the government's current plans and implementation efforts.

3.3 Develop Site-Specific Fertilizer Recommendations Based on Soil Test and Crop Nutrient Demand

Nepal has widely variable soils (shown by digital soil mapping; <https://soil.narc.gov.np/soil/soilmap/>), geography, agro-climates, farmers' crop management practices, etc., resulting in variable soil nutrient supply and crop yields. Therefore, the existing blanket and outdated fertilizer recommendations must be transitioned toward a domain or site-specific recommendations by adopting a 'Soil SMART' approach for getting higher yields and improving soil fertility (Fig. 2; IFDC, 2017). A domain refers to areas with similar biophysical (such as soils, climate, and season) and socioeconomic conditions. Fertilizer recommendations should be specific to a particular location/site and with consideration of seasonal crop nutrient requirements (based on target yields) and indigenous nutrient supplies (determined by soil type and agro-climatic conditions). This approach enhances both crop yields and nutrient use efficiency.

The amount of fertilizer recommended depends on the target yield and nutrient supply from soils. There are three fundamental steps to formulating site-specific fertilizer recommendations: (i) selection of yield goal (maximum yield based on the

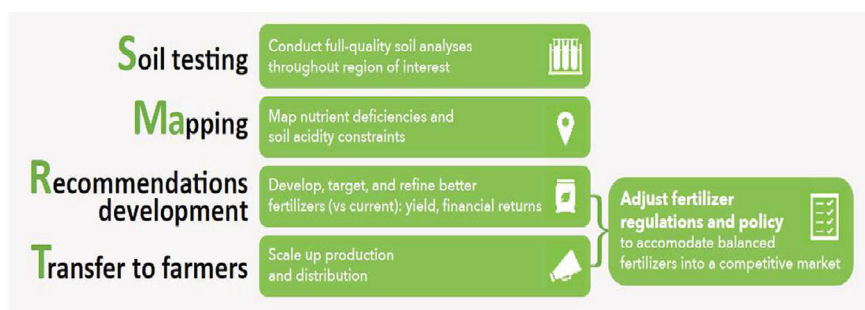


Fig. 2 Steps in formulating domain-specific fertilizer recommendations. *Source* IFDC (2017)

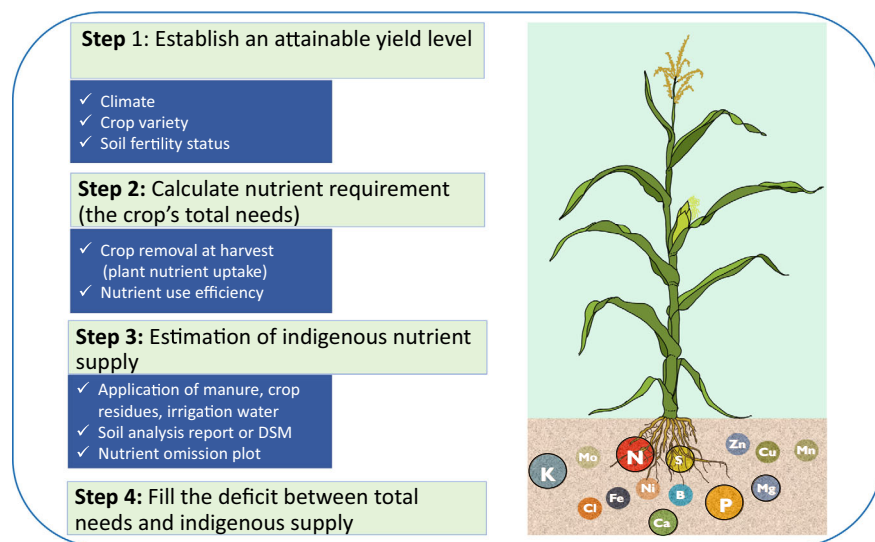


Fig. 3 Schematic diagram showing fundamental steps in formulating site-specific fertilizer recommendation. *Source* Author's developed

soil and management practices), (ii) estimation of crop nutrient requirement (total nutrients removed by crop from soil at harvest), and (iii) estimation of indigenous nutrient supplies (Witt et. al., 2009). Once these factors are determined, the nutrients deficit can be calculated, allowing for precise amount of fertilizer needed to meet the crop's total requirements (Fig. 3).

Recently, NARC launched site-specific recommendations for major cereal crops—rice, wheat, and maize (Agriculture & Livestock Diary, 2024; Kafle, 2022). This approach should continue to other crops as well. However, the conventional method of formulating fertilizer recommendations is very costly requiring a large set of data to be obtained by conducting field trials across different soil types, agroecologies, and management conditions. The best alternative is to conduct a few trials in a specific domain, formulate recommendations based on trial data, validate a model with observed data, and extrapolate a recommendation using the validated model (Timsina et al., 2021).

For the effective adoption of site-specific fertilizer recommendations, GON should provide facilities of soil testing at each local level so that farmers know soil fertility status of their field and guide them about right use of fertilizers. While it may not be possible to have a laboratory at each local level, farmers should be guided on the use of fertilizers based on previous soil analysis reports (but should have been conducted within the last five years). A recently developed digital soil map could serve as a valuable resource to provide an overview of the soil status, though it needs to be updated and upgraded to predict soil information for a specific farm condition. This could be helpful especially in the areas where farmers lack access to soil testing

facilities. Once farmers know the soil fertility status of their field, extension workers should translate technical guidance of fertilizer recommendations.

In 2014, the GoN introduced soil-testing mobile vans, which continue to operate, allowing farmers to have their soil samples tested for nutrient contents (deficiency or sufficiency) and receive fertilizer recommendations directly at their doorsteps. This program facilitates close collaboration between scientists and farmers, allowing them to share valuable information. It is aimed at improving soil health and sustainability and serves as a successful model for nationwide technology transfer (Pandey et al., 2018).

3.4 Introduce Customized Blended Fertilizers for Balanced Plant Nutrition

In Nepalese context, it would be difficult to ensure the balanced fertilization with a proper ratio of straight fertilizers. This would be costly and would take a long time to increase farmers' awareness of the proper ratio of nutrients required for plants through the conventional extension approach. The best alternative to ensuring balanced fertilization is to promote the use of customized blended fertilizers, which can be used as basal fertilizer, replacing DAP but adding other deficient nutrients. This enables farmers to have the correct ratio and quantity of plant nutrients, including deficient micronutrients, based on the needs of specific sites and crops. It will provide exactly what their crops require.

It is recommended that the GoN develop a holistic policy on production and use of blended fertilizers including quality control mechanisms (e.g., for consistency in nutrient content of various grades, uniformity in physical characteristics), modality of subsidy, etc. As discussed above, the subsidy on DAP and MOP should gradually be removed and be given to customized blended fertilizers.

Given the diversity in soils and agroecology zones, different formulations of blends are needed. This will require testing of blends for different crops and soil types. Therefore, initially, a broad type of blend, which can be used for all cereal crops, would be good to raise farmers' awareness on the use of blended fertilizers. The government should facilitate testing and evaluation of different blended fertilizers for yield and economic benefits. Selection of blend formulations (or nutrient grades) depends on crop requirements and nutrient deficiency in soils. The GON has registered three formulations: 20–20–20 NPK + 1% Zn for rice, 10–20–20 NPK + 0.3% B for maize, and 10–20–10 NPK + 0.2% B for wheat (DOP, 2019). While these formulations are likely to be more effective than DAP in delivering balanced nutrition, they have not been tested and validated in the field. Thus, their benefits and likelihood of acceptance by farmers are unknown. Moreover, these formulations do not include secondary nutrients, while several studies have shown a good crop response to sulfur (Pandit et al., 2022b).

3.5 *Improve Fertilizer Use Efficiency*

Research on fertilizer use efficiency is scarce, and the existing extension system in Nepal has not addressed significant measures to increase fertilizer use efficiency. There are different strategies available to increase fertilizer use efficiency, and they are commonly known as the 4Rs of nutrient stewardship approach. One of the effective approaches to improve nitrogen use efficiency is urea deep placement (UDP) or sub-surface application of fertilizer (applying fertilizer in plant's root zone either in a band or in a row), which is commonly called fertilizer deep placement (FDP)¹ technology. Urea briquettes (physically compressed form of urea, sized 1–3 g) are placed 5–7 cm below the soil surface. For rice, they are applied at the center of four plants at a depth of 7–10 cm within seven days after transplanting, which is labor-intensive. A mechanized option would be necessary to increase its fertilizer use efficiency and adoption rate. In general, deep placement can improve crop yields by 20–25% and save up to 50% of fertilizer compared to conventional broadcast application (Gaihre et al., 2015; Pandit et al., 2022a). Technology improves nutrient recovery by increasing plant uptake and reduces nitrogen losses that contribute to environmental pollution, including greenhouse gas emissions. Recently, it was tested in Nepal for rice (Baral et al., 2020), maize (Pandit et al., 2022a), and vegetables (Pandit et al., 2022b, 2022c) across various districts and has shown yield and economic benefits over farmers' practice. Urea deep placement increased rice yield by 15–20% and tomato and cauliflower yields by 12–16%. A similar yield was obtained in maize with 35% less N compared to the government-recommended rate. It has consistently increased the gross margin of each tested crop. Higher gross margins were achieved in vegetables compared to rice and maize. The MoALD should promote the use of this technology through local production of urea briquettes and their precise placement in soils by machines.

In Nepal, UDP, particularly for vegetable crops and high yielding maize, could offer a clear “win–win” situation for the GON, farmers, and private entrepreneurs. For farmers, it increases crop yields and incomes. For private entrepreneurs, it provides profitable business opportunity with only a small investment, as it can be produced locally across the country. For GoN, subsidies could be reduced due to decreased fertilizer use, and food security could be increased. It also reduces losses of fertilizer into the environment by retaining more fertilizer to soil and increasing plant uptake.

¹ Sub-surface placement of fertilizers or placement of fertilizers 5–10 cm below soil surface in the plant's root zone is called FDP. When only urea is deep placed, it is called urea deep placement (UDP). For ease of application, urea can be compacted into a larger granule (1–3 g), commonly called a urea briquette (or fertilizer briquette if more fertilizers are compacted). This technology was developed by IFDC. UDP was originally developed for irrigated rice cultivation; however, it is also being used effectively in other upland crops, including maize and vegetables.

3.6 *Develop Smart Extension Strategies for Out-Scaling Improved Fertilizer Management Practices*

It has been widely realized that a conventional extension approach (using training, demonstrations across farmers' fields, etc.) is costly as it requires huge human and financial resources and not effective for scaling agriculture practices across wider areas. Hence, there is a need to develop innovative extension strategies to reach many farmers. The new extension approach should focus on providing the extension services through intermediary service providers including agro dealers/retailers, cooperatives, and field-level extension workers (government and non-government), seed companies, and development partners, etc., so that they can provide right inputs with right technical information to farmers. Although most Nepalese farmers are still behind using smart phone or Internet to access different apps, the digital approach such as the use of crop modeling or fertilizer decision support systems tools, e.g., Nutrient Expert (Timsina et al., 2021), should be introduced first to field-level researchers and extension workers and progressive farmers, and then replicate progressively to a wide range of farmers. A mobile-based application for disseminating information, especially to farmers in the hilly areas, to increase productivity and economic growth of the country would be an economic approach. This will also ensure the continuity of field activities during a crisis, such as the COVID-19 pandemic.

4 A Road Map for Transforming Agriculture Sector Through Improvement of Soil Fertility and Fertilizer Sector in Nepal

While there are several constraints and challenges in the fertilizer and soil fertility sector, opportunities exist to strengthen the supply system, increase farmers' access to fertilizer, and improve management practices to achieve food security and soil health goals. This requires new interventions in agriculture policy, capacity building of research institutes, collaborations with stakeholders, and the development of innovative and effective extension strategies as discussed above (Sect. 3). Below is a roadmap outlining specific roles and responsibilities for stakeholders:

(a) *Developing and Providing Policy Support*

Short to Medium Term (1–5 Years)

- Government revisit the existing fertilizer policy and assure farmers' access to fertilizers in time and quantity.
- Reduce the current subsidy level by 20–30% and increase volume of import to meet fertilizer demand.

- Shift import modality from current open tendering to G2G agreement, maintain buffer stock for at least 30% of the demand, and develop a timeline for import targeting planting time of rice, wheat, and maize.
- Revisit the fertilizer distribution directive to involve the private sector and ensure inclusive distribution.
- Promote balanced use of fertilizers by importing or producing crop-specific blends and enhanced efficiency fertilizers like urea briquettes, particularly for vegetable crops.
- Promote the use of UDP and FDP and their application by scale-appropriate machines.

Medium to Long Term (5–10 Years)

- Establish a domestic urea plant to reduce import dependence.
- Transition from blanket fertilizer approach to production-based approach so that only targeted farmers get the benefits.

(b) Strengthening Capacity of Research Institutes and Universities

Short to Medium Term (1–5 Years)

- Strengthen the capacity of the research institutes by retaining trained workforce, and hire new scientists and researchers in NARC.
- NARC to coordinate with other agricultural research institutes and universities to standardize research protocols and conduct on-farm and on-station fertilizer trials across different agroecologies.
- Develop site-specific fertilizer recommendations, including deficient secondary and micronutrients based on soil test and crop nutrient demand.
- Continue research at NARC and other agricultural institutes and universities to identify appropriate ISFM practices that fit local context, update and upgrade digital soil maps, and increase farmers' access on soil analysis.
- NARC and other research institutes and universities to evaluate already registered customized blends for rice, wheat, and maize, continue research to identify appropriate customized blended fertilizer for other crops and sites, and identify efficient fertilizer and application practices to improve use efficiency.

(c) Improving Government and Private Sector Agricultural Extension Systems

Short-Term (1–5 Years)

- DoA to develop innovative and smart extension strategies, involve input and other service providers for effective extension, and promote extension systems by transitioning conventional extension toward the use of digital tools (e.g., mobile app, SMS).
- Commercialize enhanced efficiency fertilizers (e.g., urea briquette, slow or control release fertilizers) including blended fertilizers customized for crops and sites.

Medium to Long-Term (5–10 Years)

- MoALD and DoA to work with local governments to improve their technical capacities and delivery skills, and provide support to develop extension materials for local context considering local language, culture, etc.

(D) Alternatives to Chemical Fertilizers

- The GoN should develop holistic strategies on alternate use of fertilizers promotion of organic inputs, niche specific organic farming, and ISFM with the goal of reducing the use of inorganic fertilizers.

5 Conclusions

Crop production and productivity in Nepal are hindered by farmers' limited access to fertilizers, outdated fertilizer recommendation, and lack of their awareness about improved fertilizer application practices. Our perspective backed up by the scientific review highlights that fertilizer shortage is due to inadequate government subsidy and inefficient import and distribution systems. Improvements can be achieved through policy reforms, such as restructuring fertilizer subsidy system, which currently favors urea, improving import and distribution systems, maintaining buffer stock, and establishing domestic fertilizer production facilities.

Additionally, promoting alternative management practices, such as using locally available organic inputs and crop rotation within the framework of ISFM, can help reduce reliance on inorganic fertilizers. Similarly, strengthening research and extension capacity could address technological gap in fertilizer and soil health sector by developing crop- and site-specific fertilizer recommendations, identifying customized blended and enhanced efficiency fertilizers, and improving application practices. Furthermore, enhanced coordination among three tiers of government and increased public–private partnership can boost extension capacities and deliver these solutions to Nepalese farmers effectively.

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Chapter 18

Future Potential of Alternative Feed Sources for Livestock in Nepal



Prabhat Khanal, Akash Gupta, and Bhola Gautam

Abstract The identification of alternative nutrient sources is a critical issue in livestock production. Historically, Nepal has been dominated by subsistence agriculture practices with low livestock productivity. One of the key reasons behind this is ignoring the importance of animal nutrition in livestock production. Feed costs alone constitute up to 70% of total production costs, and the self-sufficiency of livestock in Nepal is low, including the poultry sector which imports a significant quantity of raw materials for feed production. In this chapter, we highlight that animal nutrition and feeding should receive a central focus to improve the self-sufficiency of livestock production in Nepal through novel feed resources. We suggest major policy changes to improve the domestic supply of feed sources for livestock. In the short term, underutilized aquatic plants and algae should be prioritized as alternative nutrient sources. In the medium term, insects can be scaled up as alternative protein sources for monogastric animals, including fish. Finally, long-term policies should consider biotechnology advancements in producing single-cell proteins from low-grade biore-sources. On the governance level, the central and provincial governments could play a major role in implementing such policies in coordination with local municipalities. A new act, Feed Safety and Quality (FSQ), with a decentralized legal framework, should be put in place to implement these policies and plans. It should shape the new feed regulations of Nepal, including specific sampling methods, analysis techniques, safety measures, and the environmental impacts of both existing and novel or alternative feed ingredients for animal production.

Keywords Freshwater algae and plants · Insects · Novel feed resources · Sustainability

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1 Introduction

Livestock farming is one of the major economic activities within Nepalese agriculture, especially in the hills and high hills of Nepal. Livestock is a core component of traditional crop-livestock integrated farming and has cultural and economic importance. The livestock sector exclusively contributes ~ 13% to Nepal's total gross domestic product (GDP) and ~ 27% to agriculture GDP (MoF, 2024). Cattle, buffaloes, sheep, goats, pigs, and poultry, mainly chickens, are the major livestock species in Nepal (MoALD, 2023b) as shown in Fig. 1a. Although the number of animals in Nepal is high, total livestock production is low (Fig. 1b) due to poor livestock productivity. Animal productivity is affected by multiple factors, including livestock species, breed, animal health, housing environment, available technology, and skilled manpower (Lamy et al., 2012), but providing an optimal nutritional environment is a central element of successful livestock production.

2 Feed: A Central Component of Livestock Production

Feed is a central component of livestock production, as feed costs contribute up to 70% of total production costs (NAFLQML, 2024). In Nepal, ~ 35% of total livestock productivity is directly hampered by poor livestock feeding (Garg & Upreti, 2019). Scientific animal nutrition and feeding practices have not been implemented in Nepal; instead, farmers rely on locally available resources such as crop residues, crop grains, crop grain byproducts, green forage, and fodder tree leaves to fulfill the nutritional demands of livestock (Upreti & Shrestha, 2006). Thus, traditional animal feeding approaches based on low-grade locally available feed resources and byproducts largely contribute to the less productive livestock sector in Nepal.

Appropriate animal feed strategies are needed in Nepal to properly manage existing feed resources while identifying novel and alternative feed ingredients. The mismanagement of existing feed resources is alarming, as about 37% of forage and rangelands in hills and mountains are at risk due to their overexploitation (NAFLQML, 2024), suggesting that appropriate conservation and utilization of existing biomasses is needed while searching for novel alternatives. Such a scenario is associated with a lack of knowledge of animal nutrition among farmers, the unavailability of superior feed ingredients, and the low economic status and investment capacity of livestock growers. Nepal has a feed deficit of 33% dry matter (DM) and 50% total digestible nutrient requirements (TDN) (NAFLQML, 2024); thus, 118 feed industries in Nepal import a substantial portion of feed ingredients for daily feed production of about 2600 tons. For example, > 80% of maize and soybean and 100% of feed additives and feed supplements used by Nepalese feed industries are imported, leading to a considerable trade deficit and poor self-sufficiency for the domestic feed supply (NAFLQML, 2024). The 2020/21 fiscal year saw a trade

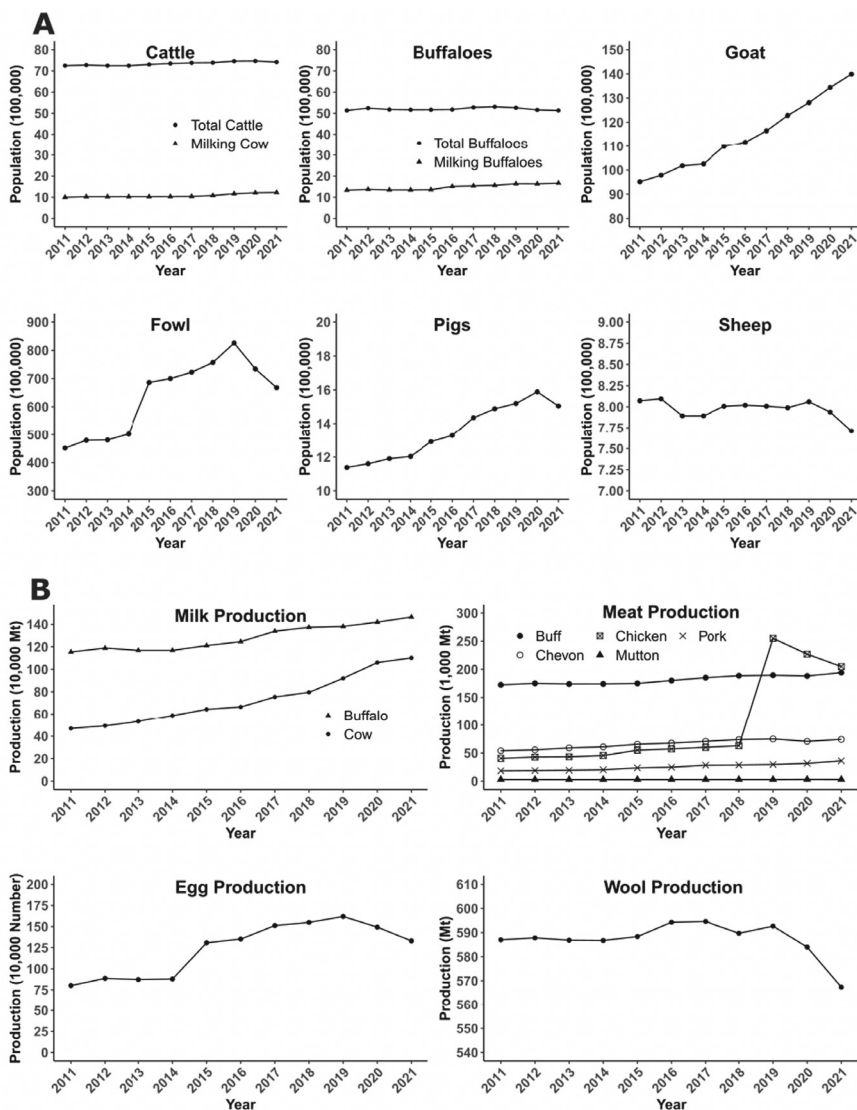


Fig. 1 **a** trend showing the population of major production in animals and **b** A trend of livestock production in Nepal. *Source* Ministry of Agriculture and Livestock Development, Nepal, 2023

deficit of NRs (Nepali Rupees) 13.25 billion while, until the third quarter of fiscal year 2021/22, this number was NRs 15.16 billion (MoF, 2024).

This chapter aims to elucidate the underlying causes of the enormous trade deficit in the Nepalese animal feed sector while scrutinizing the prominent scenario of procurement vs. availability of feed raw materials. Additionally, we confer ways

to improve the self-sufficiency of the domestic feed supply in Nepal, with a focus on identifying and utilizing novel and alternative feed components and changes in associated feed policies and governance mechanisms. After all, the availability of and access to nutritious feed resources year-round is critical to improving animal production in Nepal.

3 Procurement and Availability of Raw Materials for Animal Feed Production

Although feed requirements vary depending on the livestock species, all farm animals require a balanced supply of energy and nutrients for optimal growth and production. In Nepal, common feed resources for ruminant animals are agriculture byproducts, forages, and fodders. Most ruminants are reared on low input systems and hence are often provided limited or no concentrate feed and instead sustained on grazing (Thapa et al., 2016). Plant discards and byproducts such as maize cobs, rice straws, millet straws, sugarcane tops, sugarcane processing byproducts, fodder leaves, crop residue, vegetable leaves, fruit peels, and eggshells make up the majority of ruminant feeds (Osti, 2020; Singh & Singh, 2019a, b), and achieving superior animal performance requires using nutritionally balanced feed based on quality ingredients (Makkar, 2016). Feeding animals according to their body requirements, production objectives, animal species, age, and sex is equally important (Owens et al., 1993). These parameters seem to be rarely taken care of while feeding animals in Nepal, especially for ruminants. The primary reasons behind this might be a lack of technical knowledge among farmers on animal husbandry and the poor availability of quality feeding resources.

Meanwhile, the majority of commercial poultry and swine production farms rely on formulated concentrate feed, although a considerable part of these animals also rely on scavenging and feeding on household wastes (Singh & Singh, 2019a, b). Thus, demand for concentrate feed made from a variety of nutrient-rich ingredients for these animals is high, and feed industries play a central role in supplying various concentrate feeds for monogastric animals in the country. Currently, the Nepal feed industry is valued at 300 million USD (Prasain, 2022) and has adopted high-feed manufacturing technologies to produce feeds of diverse physical qualities and nutritional compositions (Singh, 2018). Annually, industrial production of animal feed reaches 900 thousand tons, with poultry feed comprising 90% of total production; however, most of these industries fail to run at full capacity due to a shortage of feed ingredients (Singh, 2018). Although the country has 46 large-scale pellet feed mills with a combined capacity of 5000 tons per day, they operate at only about 60% capacity, producing approximately 3000 tons per day (Singh, 2018). Low production volume and inferior quality, e.g., high moisture content (> 14%), small seed size, broken seeds, and fungal infection, of domestic maize are the major factors behind the high import of maize for feed production in Nepal (Timsina et al., 2016).

Currently, feed industries in Nepal import nearly 75% of yellow maize and 99% of the soybean cake required for their feed production, which contributes to increased feed prices and, ultimately, higher production costs for livestock farmers (Garg & Upreti, 2019). The import of these raw materials may further rise in the future, as it has been projected that demand for ruminants and pig feed should increase by 6% annually while fish and poultry feed should increase by 9% annually (Singh & Singh, 2019a, b).

In Nepal, efforts to increase the domestic supply of raw materials for feed are far from achieving self-sufficiency. Moreover, as agricultural land is scarce, the use of agricultural fields to produce feed ingredients can put pressure on food production and the food security of the country. Hence, we need to identify smart animal feeding strategies in Nepal that have the potential to minimize coemption for human food and animal feed sources (Khanal et al., 2022). We propose that such alternative feeding strategies should be based on novel and alternative feed sources that are less competitive to human foods, are locally available, and contribute to establishing a sustainable yet productive livestock sector in Nepal. These novel and sustainable feed resources can improve the status of the domestic supply of raw materials for feed industries in Nepal.

4 Potential Novel and Alternative Feed Resources

Various aquatic and land-based alternative animal resources have been proposed to play a critical role in sustainable livestock production (Khanal, 2024). In this context, this chapter highlights three potential alternative feed resources to improve the domestic supply of raw materials for commercial feed production for livestock in Nepal. In the short term, abundantly available but currently underutilized aquatic plants and algae could serve as alternate bioresources for livestock feeding. Recently, insects have gained significant attention as a nutrient source for livestock, particularly monogastric animals, as they have high protein and fat contents, can recycle various bioresources and low-grade byproducts (Adhikari et al., 2021; Khanal et al., 2023), and could be a key player of circular production and bioeconomy in the future (Purkayastha & Khanal, 2024). Finally, the use of biotechnological advancements in the long run could be useful in producing single-cell proteins from low-grade wastes and biomasses (Zhang et al., 2024).

4.1 *Aquatic Plants*

Nepal is rich in water resources as about 5% of its land (74,500 ha) is freshwater with diverse water coverage, including lakes, rivers, streams, ponds, and reservoirs distributed through different topographical regions (Sharma, 2008). This freshwater system supports the growth of diverse aquatic plants and algae, as 39 species of

aquatic plants and 105 phytoplankton species have been reported from the Setikhola watershed of central Nepal (Upadhyay et al. (2022)). Altogether, 711 different species of aquatic plants have been reported throughout Nepal (Ghimire et al., 2020b), where water fern, hydrilla, water lily, water hyacinth, water spinach, duckweed, and lotus are some of the abundant aquatic resources (Joshi & Joshi, 2005; Niroula & Singh, 2011; WWF Nepal, 2006). Due to their rapid growth, these freshwater plant species are sometimes considered weeds, primarily because their potential utilization has not been fully realized (Adelakun et al., 2016; Zakaria et al., 2023). However, these aquatic plants are rich in various nutrients and ideal candidates for inclusion in animal diets (Table 1). For instance, the suitability of certain aquatic plants, such as duckweed, has been proven for inclusion in the diets of cattle Shah et al., 2010a, b), sheep (Gule et al., 2023), broilers (Mwale et al., 2013), and laying hens (Aker et al., 2011). Furthermore, aquatic plant resources are rich in bioactive compounds, potentially improving animal health when included in diets (Shah et al., 2022a, b). High-quality aquatic plants such as *Justicia americana*, *Alternanthera philoxeroides*, and *Pontederia cordata* have shoot standing crops of 4–8 tonnes/ha (Little, E.C.S. 1979). Similarly, large floating plants, such as *Eichhornia crassipes*, have values of dry matter above 10 tonnes/ha, while other floating plants usually have standing crops below 5 tonnes/ha. The yield of submerged and floating-leaved plants can normally range from 1 to 5 tonnes/ha standing crop shoots. Thus, aquatic plants with high growth rates allow for multiple wild-harvesting or commercial cultivation to supply substantial biomass for direct feeding or feed production. Given that acreage and distribution of aquatic bioresources are assessed through Nepal, a substantial proportion of feed demand through aquatic plants could be supplied.

4.2 Insects

Insects feed upon various organic biomasses and byproducts and are a rich source of nutrients (Adhikari et al., 2021). Black soldier flies (BSF), crickets, houseflies, silkworms, and grasshoppers are recommended as suitable sources of feed ingredients for animals, and some of them are commercially produced in some parts of the world (Oonincx et al., 2015; Van Huis, 2013). Previous studies reveal that BSF larvae-based animal diets result in positive effects on nutrient digestibility and productivity in laying hens (Chu et al., 2020), broilers (Hartinger et al., 2021), fishes (Hua, 2021) and pigs (Biasato et al., 2019; Håkenåsen et al., 2021). Black soldier flies, house flies, and crickets can be successfully reared in locally available organic biowastes, such as municipal waste, agro-industrial byproducts, kitchen or restaurant leftovers, and livestock manures that can supply high-quality insect meals for feed industries (Table 2). In Nepal, more than 150,000 metric tonnes of municipal waste is produced annually, of which 62% is organic, providing a significant resource for insect rearing (Pathak et al., 2020). Recent developments, including the establishment of a BSF laboratory in Chitwan, Nepal, have demonstrated the successful colony rearing and larvae production in Nepalese biowastes, highlighting the suitability of

Table 1 Common aquatic plants of Nepal are distributed across various locations and seasons and their nutritional value

Common aquatic plants	Species found across Nepal ¹	Distribution across Nepal ¹	Season of abundance ²	Nutritional content of aquatic plants reported across the literature (% dry matter)					References
				Crude protein	Crude fat	Crude ash	Crude fiber		
Water fern	<i>Azolla filiculoides</i>	WCE Nepal; 100–150 m	–	14.2–20.6	1.8–2.8	15.6–18.8	19.4–22.3	Shaltout et al. (2013)	
	<i>Azolla pinnata</i>	WCE Nepal; 100–1600 m	Pre to post-monsoon/ winter						
Hydrilla	<i>Hydrilla verticillata</i>	WCE Nepal; 100–1500 m	Pre to post-monsoon/ summer, winter and spring	17.10	2.79	19.45	13.34	Shah et al. (2010a, b)	
Water lily	<i>Nymphaea alba</i>	C Nepal; 200–800 m	–	17.23–21.87	3.50–16.47	11.6–13.60	9.00–21.00	Adelakun et al. (2016), Shah et al. (2010a, b)	
	<i>Nymphaea lotus</i>	W Nepal; 100–300 m	–						
	<i>Nymphaea nouchali</i>	WCE Nepal; 88–1500 m	–						
	<i>Nymphaea odorata</i>	E Nepal; 1600 m	–						
	<i>Nymphaea tetragona</i>	WC Nepal; 100–300 m	–						
Water hyacinth	<i>Eichhornia crassipes</i>	WCE Nepal; 75–1500 m	Monsoon and winter/summer, winter and spring	9.58–31.27	1.43–16.62	8.85–13.32	17.78–21.34	Adelakun et al. (2016), Zakaria et al. (2023)	

(continued)

Table 1 (continued)

Common aquatic plants	Species found across Nepal ¹	Distribution across Nepal ¹	Season of abundance ²	Nutritional content of aquatic plants reported across the literature (% dry matter)					References
				Crude protein	Crude fat	Crude ash	Crude fiber		
Water spinach	<i>Ipomoea aquatica</i>	WCE Nepal; 200–280 m	Summer and winter	26.45	16.81	10.00	18.38	Adelakun et al. (2016)	
	<i>Ipomoea carnea</i>	WCE Nepal; 75–1350 m	/Summer and winter						
Duckweed	<i>Lemna minor</i>	W Nepal; 205–3000 m	Pre to post-monsoon	14.12–28.00	4.0–5.4	16.8	4.97	ABahnasy et al. (2016), Appenroth et al. (2017)	
	<i>Lemna perpusilla</i>	WCE Nepal; 72–2700 m	Monsoon and winter/summer and winter						
Lotus	<i>Nelumbo nucifera</i>	WCE Nepal; 90–800 m	Pre to post-monsoon/summer	8.55	3.95	21.35	4.97	ABahnasy et al. (2016)	

1: (Ghimire et al., 2020a); W: western, C: Central, E: Eastern
2: Based on the IVI (Importance Value Index) reported by (Ghimire et al., 2022; Joshi and Sharma, 2024)

BSFL production in the Nepalese context (Gautam et al., Upreti et al., unpublished data). Additionally, BSFL has also been successfully produced by farmers in other tropical and subtropical regions, such as India, Vietnam, Indonesia, Thailand, and Malaysia, which have similar climatic conditions to Nepal (Raheem et al., 2019; Yen, 2015). Furthermore, these insects have a short lifecycle, do not require high technical expertise or sophisticated technologies (Govorushko, 2019; Shah et al., 2022a, 2022b), and have proven to be a sustainable option for fulfilling essential requirements for livestock, particularly monogastric animals.

Table 2 Nutritional composition (% dry matter) of insect species that have the potential to go under commercial-scale production in Nepal

Common organic wastes produced in Nepal	Source of organic wastes	Insect species	Crude protein	Crude fat	Ash	References
Fruit and vegetable waste	Vegetable wholesalers and retailers	BSFL	31.12–48.01	20.1–36.1	18.06	Loho and Lo, (2023), Scala et al. (2020)
		House cricket	61.20	17.10	5.40	Pintér et al. (2022)
Municipal wastes	Household/ Restaurants	BSFL	33.00	34.30	9.6	Shumo et al. (2019)
		House cricket	16.00			
Agro-industrial byproducts	Food processing industries	BSFL	29.9–52.5	17.1–49.0	4.62–9.1	Chia et al. (2020), Galassi et al. (2021)
		House cricket	66.49	21.40	4.67	Jucker et al. (2022)
Livestock manure		BSFL	39.88–2.81	20.33–32.70		El-Dakar et al. (2021)
		House cricket	56.40–57.80	18.6–19.4	4.98–5.20	Pintér et al. (2022)
Slaughter waste		House fly	30.65–45.83	12.00–24.30		Eddy et al. (2021)

BSFL, black soldier fly larvae

4.3 *Single-Cell Proteins (SCPs)*

Single-celled proteins (SCPs), also referred to as bioproteins or microbial proteins, are derived from algae and microbes such as microalgae, fungi, yeast, and bacteria (Table 3). The proteins are harvested from the dried biomass of microscopic organisms, which can be cultivated using low-grade organic wastes as sources of energy and nitrogen (Ritala et al., 2017). For example, algae primarily utilize carbon dioxide and sunlight, whereas fungi thrive on various inexpensive waste substrates rich in carbon and nitrogen (Nasseri et al., 2011). Conversely, bacteria can grow on diverse organic wastes, including methane and petroleum fractions, and multiply in nutrient-supplemented water (Bogale, 2020; Sharif et al., 2021). Single-cell protein production is typically achieved through fermentation processes—solid, semi-solid, or submerged—using readily available agricultural and industrial waste materials. Nutritionally, SCPs are not only protein-rich but also packed with essential vitamins and amino acids, making them a promising alternative to traditional protein sources of animal feed, such as fish and soybean meals (Nasseri et al., 2011; Sharif et al., 2021). Biotechnological advancements, animal-based trials, and scaling up remain major challenges in exploiting SCPs as a viable source of animal feed protein (Bajić et al., 2022; Ye et al., 2024).

4.4 *Critical Factors Affecting the Utilization of Alternative Feed Sources*

While exploring the potential of novel feeding ingredients for production animals, it is crucial to pay close attention to health and safety considerations. The origin, processing, handling, and storage of these ingredients can significantly influence feed quality and safety (Pinotti & Dell’Orto, 2011). Aquatic plants and algae have the potential to accumulate heavy metals, pesticides, toxins, and other contaminants (Anand et al., 2019; Van der Fels-Klerx et al., 2018), which can enter into the food chain while using them as feed ingredients. Microbial and chemical contaminants originating from production substrates, e.g., organic wastes, pose substantial risks associated with insects and SCPs (Van der Spiegel et al., 2013). Insects are considered relatively safe nutrient sources, as they have a high tolerance to toxins and do not bioaccumulate toxins, critical minerals, or heavy metals when exposed to feed substrates rich in these materials (Bosch et al., 2017; Syahrulawal et al., 2023). Risks associated with these novel and valuable feed resources can be minimized through controlled rearing environments, including the choice of rearing substrates, proper handling, and postharvest processing to prevent bioaccumulation of toxic compounds (Mézes, 2018). In Nepal, it is important to characterize available freshwater plants and algae along with insects and their feeding substrates to ensure that any novel feed resources are safe and nutritious before using them for feeding or feed manufacturing.

Table 3 Commonly produced single-cell proteins (SCPs) in organic wastes and their nutritional value

Source of SCP	Type of organic wastes in Nepal that can be utilized	Recommended species	True Protein content (% dry matter)	Total Protein content (% dry matter)
Microalgae	Carbon dioxide	<i>Spirulina species and Caulerpa rocemosa</i>	40–60	45–65
	Wastewater discharge from sewage or industries	<i>Chlorella species</i>		
	Carbon dioxide and sunlight	<i>Chlorella salina, Sargassum, Dunaliella, Diatoms and Chlorella, and Porphyra</i>		
Fungi	Fruit processing waste	<i>Saccharomyces cerevisiae, Aspergillus niger, Kluyveromyces marxianus, and Trichoderma virideae</i>	30–70	35–50
	Molasse	<i>Saccharomyces cerevisiae, Kluyveromyces marxianus, and Candida tropicalis</i>		
	Cheese whey filtrate	<i>Trichoderma harzianum</i>		
	Animal waste and manure	<i>Candida utilis</i>		
	Brewery waste	<i>Saccharomyces cerevisiae and Kluyveromyces marxianus</i>		
Bactria	Fruit Processing waste	Various bacterial species	50–83	60–80
	Agro-industrial wastes	<i>Cellulomonas species</i>		
	Rubber waste	<i>Rhodopseudomonas palustris</i>		
	Brewery waste	<i>Rhizospheric diazotrophs</i>		
	Animal waste & manure	<i>Pseudomonas fluorescens</i>		

Source (Ravindra, 2000; Sharif et al., 2021)

Another critical aspect of utilizing alternative feed resources is to carefully evaluate the price competition between novel feed components and conventional feed items (Hossain & Bhuiyan, 2023). Some of these identified novel ingredients can be produced using low-grade cheap organic substrates, but scaling up the production is crucial to supply sufficient biomass at a reasonable cost (Joly & Nikiema, 2019). Scaling up would require a collaborative effort involving rigorous research, investments in infrastructure and technology, as well as the development of competitive human resources (Raman et al., 2022). Specific legal provisions are necessary to regulate the availability, health and safety, and utilization of these identified novel raw materials for various animal feed applications.

5 Legal Frameworks for the Utilization of Conventional and Novel Feed Resources in Nepal

5.1 Current Legal Frameworks

Over the last few decades, many laws, regulations, and directives have been introduced in Nepal to govern, guide, manage, and control the animal feed sector (Fig. 2). The first of these developments came in 1976 when Nepal introduced the Feed Act 1976 (2033 BS), the first legal document to define feed and contaminated feed, maintain purity in feed, and prevent adulteration, ensuring that specific feed standards are met. It also introduced penalties for the production, sale, and distribution of contaminated feed and misleading practices for feed adulteration (MoLJPA, 1976). The act also imagined the formulation of a feed standard fixation committee to fix feed standards in Nepal. The act had provisions to appoint and grant powers to feed inspectors, but the qualification of such inspectors was not specified (MoLJPA, 1976). Moreover, the act has never been subjected to concrete amendments to make laws more realistic in current world scenarios.

Based on the Feed Act 1976, the Feed Regulations 1984 (2041 BS) were introduced in Nepal to establish regulations and standards for the production and distribution of animal feed to ensure its quality and safety using the Central Food Laboratory under the Department of Food Technology and Quality Control (DFTQC) (MoLJPA, 1984). The regulation made feed analysis compulsory through a public feed analyst, designated duties and responsibilities to the feed inspector, and made a license compulsory for feed production, distribution, and sale through a village development committee or municipality. The regulation specified the qualifications and skills of a public feed analyst (BSc. or MSc in Chemistry) and feed inspector (ISc. or BSc. in food or lab technology) (MoLJPA, 1984). Moreover, the panel for the feed standard fixation committee, headed by the director of the Animal Development and Animal Health Department, was finalized through this regulation to fix the quality and quantity of feed production and advise the government. In 1999, the Animal Health and Livestock Services Act 1999 (2055 BS) was introduced to

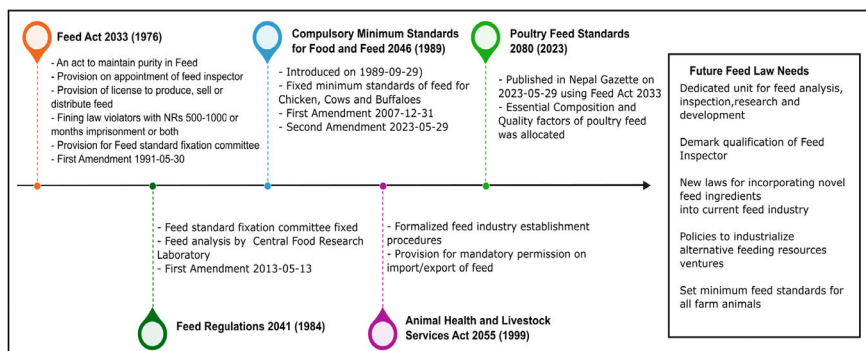


Fig. 2 Timeline of significant developments in legal frameworks in Nepal regarding the animal feed sector

provide necessary arrangements for the healthy production, sale, distribution, export, and import of animal products or animal production inputs under the Department of Livestock Services. The act has provisions for acquiring a recommendation letter from prescribed authorities to establish an animal feed industry and import/export pure animal feed in Nepal (MoLJPA, 1999).

For the first time, minimum compulsory feed quality standards were published in the Nepal Gazette in 1989 using clause 10 of the Feed Act 1976 (MoALD, 2017a). Since then, feed standards have undergone two amendments, the first in 2007 and the second in 2023 (MoALD, 2023a). The document has fixed minimum levels of dry matter, crude protein, crude fiber, crude fat, and other vital components in feeds, and requires feed to be free from insect infestation, foul odor, and fungal attack. For the time being, minimum standards of concentrate feed are specified only for layers, broilers, lactating cows, and buffaloes, but not for other farm animals (MoALD, 2023a). Although the National Agriculture Policy (NAP) 2004 (2061 BS) is considered a guiding document for agriculture in Nepal, it mentions nothing about feeds or related issues (MoALD, 2017b). However, the Agriculture Development Strategy (ADS) 2015–2035 has set goals to be self-reliant in food and feed in its strategic visions and to improve feed and fodder reserves for the food and nutritional security of Nepal, in particular by supporting maize farmers through enhanced irrigation facilities and breed improvement. Additionally, ADS has plans to strengthen and upgrade the feed analysis laboratory under the Department of Livestock (DLS) according to international standards (MoALD, 2015).

5.2 Revisions in Current Legal Provisions Regarding the Future Animal Feed Sector in Nepal

Although there have been some developments in the laws and policies relating to the feed sector in Nepal, they are too old, contradicting, and insufficient to address the challenges associated with establishing an economically viable and environmentally sustainable animal feed sector in Nepal and, hence, require revision. For instance, the Feed Act 1976 and Feed Regulations 1984 direct the Department of Food Technology and Quality Control to handle issues associated with feed quality. On the other hand, the Animal Health and Animal Service Act 1998 directs the Department of Livestock Services as a responsible authority to maintain the feed quality in Nepal under the National Animal Feed and Livestock Quality Management Laboratory (NAFLQML). Firstly, we suggest that NAFLQML should solely handle issues associated with animal feed safety and quality to effectively monitor and inspect feed quality in Nepal. DFTQC should be entitled to focus entirely on human-grade food ingredients. Secondly, we suggest merging the elements associated with the animal feed sector present in both the Feed Act 1976 and the Animal Health and Animal Service Act 1999 and establishing a new act called the Feed Safety and Quality (FSQ) Act under the Department of Livestock Services, Ministry of Agriculture. As the earlier feed-related Acts and Regulations do not imagine novel feeding components, the newly proposed FSQ Act should provide separate guidelines regarding the physical, chemical, and microbiological quality assessment of new and alternative feeding resources for feeding or feed production to improve self-sufficiency for feed in Nepal. Moreover, strict regulations should be put in place regarding the assessment of environmental impacts and carbon footprints of both traditional and new feed materials under the newly proposed FSQ Act. The act should lay the foundation for upcoming new policies in the future.

Proper governance structures and collaboration and coordination among governmental agencies are needed to properly implement the newly proposed FSQ Act under the federal governmental systems, as discussed below. Such changes in legal frameworks and governance structures could assist in identifying and utilizing various alternative feed resources based on their commercialization potentials (Fig. 3a). The upcoming new feed regulations, paved on the grounds of the FSQ Act, should accommodate feed standards of all farm animals prevalent in Nepal based on their body requirements, production objectives, animal species, age, and sex. Moreover, Nepal's future agricultural policies should focus on achieving feed self-sufficiency by boosting the domestic production of key ingredients such as maize and soybeans while also supporting the scaling of alternative feed resources. To ensure affordability and sustainability, policies should prioritize the use of low-grade and cost-effective resources for the production of alternative feeds, with provisions for regular updates to the list of such materials.

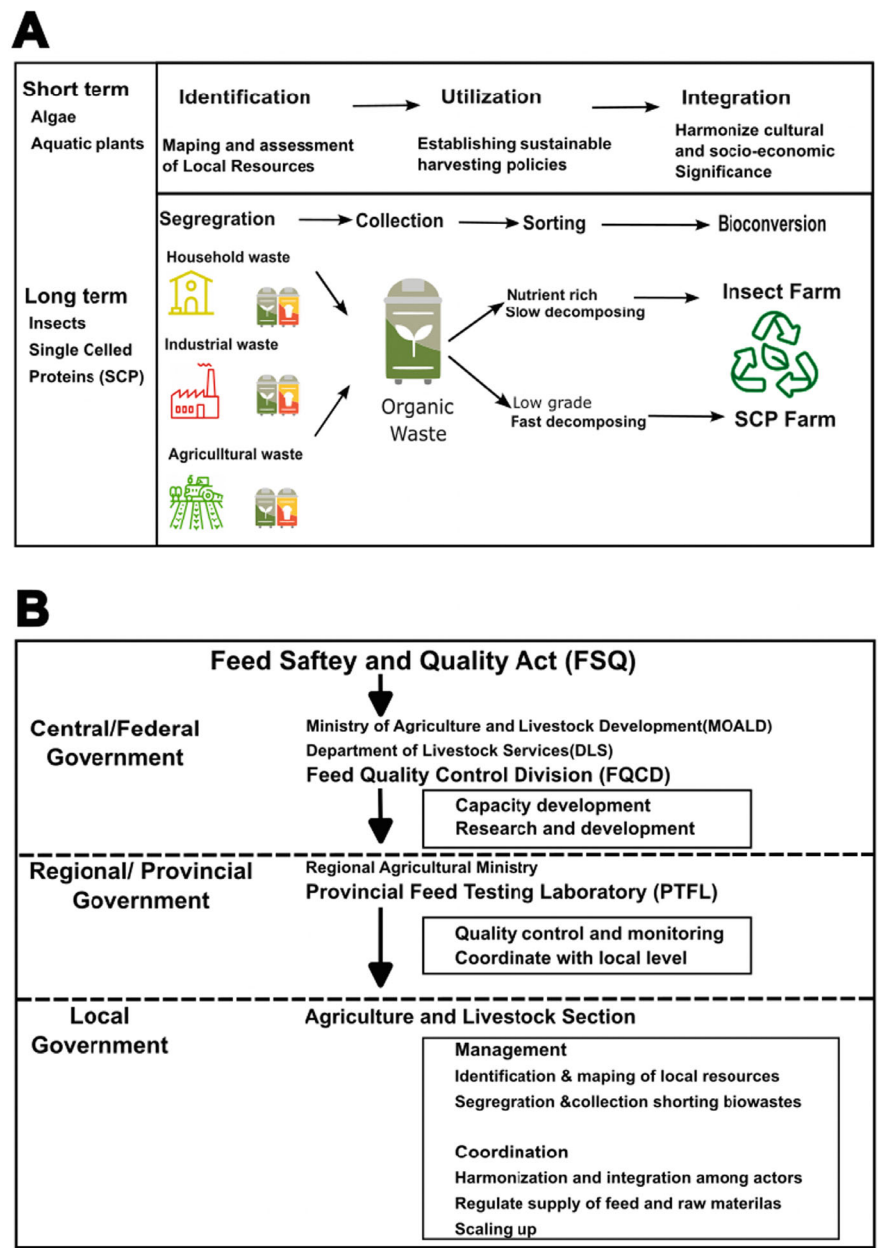


Fig. 3 a An approach for the commercialization of novel feed ingredients in the Nepalese context, and b A roadmap for revisions of feed-related governance structures towards a sustainable animal feed sector in the context of the current three-tier federal structure of Nepal

6 A Roadmap for Governance Structures, Feed Policies, and Institutional Responsibilities

Although many rules, regulations, guidelines, and policies have been introduced in Nepal to govern the feed sector, there is a conflict of interest among the governmental bodies regarding implementation responsibility, as indicated earlier. Thus, we suggest that there should be a clear division of duties and responsibilities of the three-tier federal governmental bodies (Fig. 3b).

We suggest establishing a new central governing body called the Feed Quality Control Division (FQCD) under the DLS to inspect, monitor, govern, and guide all of the issues related to animal feed availability, safety, and quality based on conventional and novel raw materials. We further suggest bringing NAFLQML under this new governing body for laboratory testing of raw materials and feed. The FQCD should specify a set of standards and criteria for feed raw materials rather than selecting a few raw materials to include any novel bioresources for potential animal feed applications. For this, FQCD should provide funding for research and development within the animal feed sector in collaboration with universities and research institutions, along with proper training and human capacity development and enhancement.

Each province should establish Provincial Feed Testing Laboratories (PFTLs) to ensure quality assurance, and evaluate nutritional, microbiological, and chemical characterization of feed ingredients. Local governments should assist with local resource mapping and identification for feed materials, providing recommendations to the central government for the registration of start-ups and companies dealing with both traditional and novel feed ingredients. They should also evaluate the environmental, economic, and social-cultural aspects of local resource utilization and industry development. Another critical role of local government should be periodic and ad hoc feed sampling and sending the samples to RFTLs. As scaling up poses the challenge of ensuring a regular supply of organic waste in large quantities, strict regulations for the disposal and collection of organic waste from households, industries, and other sectors are essential. Local government bodies can play a significant role by implementing effective segregation and collection practices. Additionally, local bodies can coordinate and link the supply of collected organic wastes to insect and SCP (single-cell protein) producers. This systematic approach would support the consistent supply of raw materials necessary for the large-scale production of novel feed ingredients. Moreover, local bodies could play a key role in managing existing forage and grasslands, which are on the brink of exhaustion due to overexploitation. They can play a critical role in maintaining these areas through fertilizer application, irrigation, re-plantation, and setting up regulations for overgrazing by issuing permits.

7 Conclusions

The identification of alternative nutrient sources is a critical issue in animal agriculture globally, given the rising global population and alarming effects of climate change on agriculture. We suggest that animal nutrition and feeding should receive a central focus to improve the self-sufficiency of livestock production in Nepal. In the short term, the livestock policy should focus on underutilized aquatic plants and algae. In the medium term, insects can be scaled up as alternative protein sources for monogastric animals, including fish. Finally, long-term policy should be towards the use of biotechnology advancements in the production of single-cell proteins from low-grade bioresources, such as organic wastes.

As previous Acts and Regulations have overlapping duties and responsibilities among government bodies, we propose a new FSQ Act to deal with issues associated with governance in the feed sector by establishing a new FQCD under DLS. The provincial government should be provided with the sole responsibility for feed quality evaluation by establishing RFTLs in each province. Local governments should play a critical role in the resource mapping and assessment of socio-cultural and environmental aspects of traditional and potentially new materials, along with periodic feed sampling and inspection in collaboration with RFTLs and scaling up technologies associated with novel feed resources. Considering the federal government structure in Nepal, a robust governance system is needed to clarify roles and responsibilities and establish collaboration among government bodies at different levels regarding the identification, characterization, and utilization of alternative feed sources.

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Chapter 19

Unlocking Aquaculture Potential: Strategic Pathways for Its Growth in Nepal



Ram C. Bhujel, Jharendu Pant, Madhav K. Shrestha, and Jagadish Timsina

Abstract Aquatic food holds significant cultural and nutritional value in Nepal. However, Nepal's per capita fish consumption (3.9 kg/year) is significantly lower than the global average (20.7 kg). Total fish supply in Nepal from catch and culture was estimated at 113,736 mt in 2023 and would require a supply of over 0.6 million mt to reach the global average. Given the rapid decline of fishery resources, accelerated development of sustainable aquaculture is crucial. With greater climate resilience, aquaculture can play a vital role in enhancing healthy ecosystems and the rural economy, providing significantly higher returns on land and labour. However, there is a need for a holistic approach to harness the country's aquaculture potential. There is potential to triple aquaculture production from the existing 15,000 ha of total aquaculture area if current fish productivity of 5.5 tons/ha/cycle could be increased to 17 tons/ha/cycle while halving the culture period from the current 12 to 6 months and allowing farmers to complete two production cycles annually. Transforming traditional low-input and low-output systems of carp culture and promoting the sustainable intensive culture of fast-growing, stress-tolerant species such as tilapia and pangasius is crucial for the scaling up of aquaculture. Setting the milestones of production targets, all the levels of the government of Nepal need to prioritize and promote aquaculture to utilize promising species, modern technologies and experience from various countries. Drawing from the research and development experiences of Nepal and other countries, a roadmap consisting of various sustainable aquaculture development models to unlock Nepal's aquaculture potential is

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proposed to significantly increase fish supply and consumption. This includes aquaculture suitability analyses, devising promising technologies for fast-growing and highly productive species, ensuring sustainable input supply and output marketing systems, and creating an enabling policy environment. Special focus needs to be given to public–private sector participation (PPP), especially for the establishment and expansion of hatcheries, nurseries, the feed industry, a network of local service providers (LSPs), transportation, storage, processing and marketing systems.

Keywords Aquaculture development · Policy · Productivity · Public–private partnership · Strategy

1 Background

1.1 Brief Introduction

Nepal has thousands of glaciers and rivers originating from the Himalayas. The major rivers, the Koshi, Gandaki, and Karnali, their tributaries, lakes, natural ponds, wetlands, ricefields and groundwaters provide water for drinking, irrigation, and hydropower generation. Many hydropower dams are being constructed on these rivers, creating many reservoirs. While damming rivers block, the migration of fish for breeding, causing their decline, these reservoirs could be utilized for cage aquaculture as an alternative livelihood for local communities (Gurung et al., 2009).

Fishing occurs during the rainy season or periods of flooding, especially by ethnic minority groups (Bhujel et al., 2008; Nepal et al., 2011). Annually, about 21,000 mt fish are caught, which is quite low compared to most Asian countries. More critically, wild fish have drastically declined due to overfishing, damming of rivers and pollution caused by pesticides and chemicals in run-off water and domestic/municipality waste. There are several laws and acts to protect aquatic animals and their habitats, namely the Aquatic Animal Protection Act, 2017 (1960), National Parks and Wildlife Conservation Act, 2029 (1973), National Wetland Policy 2059–2003 and Environment Protection Act, 2019 (2076) (Bista & Karki, 2022). However, their implementation and monitoring are very weak. Effective management of fishery resources could provide assistance, though the main thrust must be on developing and expanding commercial aquaculture to increase fish production.

1.2 Problems and Prospects

Fish or aquatic foods are rich in amino acids, omega-3 fatty acids, iron, zinc, and many other nutrients, which could help solve the malnutrition problem. Nepal is facing a decline in wild fish stock, but aquaculture is a promising solution for addressing

the country's food and nutrition insecurity problem. In Nepal, fish is already the third largest source of animal protein after buffalo and chicken, which accounts for about 20% of the total animal protein intake in Nepal. However, total production in Nepal is quite low, at 113,736 mt in 2022/23, which means that availability is only about 3.9 kg/per capita/year (CFPCC, 2024) and 5 times less than the global average of 20.7 kg (FAO, 2024). To fulfil the demand, fish is being imported from India and other countries. Although imports have declined from over 12,000 mt in 2013/14 to about 4,000 mt, the country still spent over one billion NRs or USD \$8 million in 2022/2023 (CFPCC, 2024; MoALD, 2023). Promoting fish culture and consumption could solve not only nutrition-related problems but also create jobs and increase the income of rural people. However, aquaculture is limited to traditional carp, which is less productive (5.5 ton/ha/year; MoALD, 2023) compared to the farming of new species such as tilapia and pangasius, which have a track record of higher production by 3–10 times (20–60 ton/ha) (Bhujel, 2014a, 2014b). Because many people are reluctant to eat fish due to small intra-muscular Y-bones, tilapia and pangasius would be the right species to promote, as their meat does not have those bones, and boneless fillets could be produced and marketed. However, a larger public awareness campaign is required regarding the health benefits of consuming fish and maintaining a healthy environment. Promoting fish consumption and creating more demand would encourage producers and input supplies.

Recently, the government of Nepal has tried launching some programs under the line ministry and the Prime Minister Agriculture Modernization Program (PM-AMP), focusing mostly on carps (PM-AMP, 2021). To enhance yield and profitability, there is a need for advanced technologies, high-yielding species (e.g. pangasius and tilapia), quality inputs, and skilled human resources. In addition, the most critical problem is the low survival of hatchlings, fry and fingerlings during breeding and nursing, as hapa nursing techniques are not applied and open ponds are instead used without covering the nets (Jha et al., 2015). Other problems include a lack of good feed and water management techniques (Pant et al., 2023b). Farmers have not realized the potential of pangasius and tilapia, but those farmers who know and want to utilize this potential are facing shortages of quality seed, feed, and technical support. Most fingerlings are imported, and there are only 1–2 hatcheries in Nepal. There are about 10 fish feeds manufactured in-country, but their quality is questionable, and some feeds are imported.

1.3 Objectives

The main objective of this chapter is to highlight the potential of aquaculture in Nepal and how it could contribute to solving the problems faced by the country. Specific objectives are to share the experience of aquaculture development and innovations occurring in other Asian countries, describe some practical models of commercial

aquaculture and highlight their potential, make a set of recommendations for accelerating the pace of aquaculture development, and provide a roadmap with an action plan for Nepal.

2 Status of Aquaculture

Aquaculture development started in the early 1980s. During those early days, four major successful attempts were reported: (1) about 200 families whose land was inundated by the Indra Sarowar (a reservoir created by Kulekhani hydropower) were given an opportunity to culture fish as an alternative livelihood option; (2) nearly 300 fishing families in the Pokhara valley were converted to cage farmers who were roaming around the lake and river areas and largely depended upon fishing for their livelihoods. They settled in communities, permanently purchased land, and sent their kids to schools and universities; (3) the introduction of Rainbow trout (*Oncorhynchus* sp.), its technology testing and commercial farming, i.e., breeding, nursing and grow-out; (4) the breeding of carps, and hatchery development in several government stations to supply fingerlings and supporting grow-out farmers by providing loans through banks for those who could construct a pond of at least 2,000 m².

Aquaculture was limited to relatively richer farmers who had large areas of land. Promotion of small-scale aquaculture (200 m² ponds) began in the early 2000s with the start of women in aquaculture (Bhujel et al., 2008), which helped expand aquaculture by further reaching out to small landholder farmers. With the foundation of these efforts and increased demand due to awareness about the health benefits of consuming fish, aquaculture grew rapidly after 2010 (Shrestha et al., 2022); however, due to shortages of suitable land for aquaculture, lack diversification in species (Gurung et al., 2021) and limited technological advancement, a low priority was given to the sector by the government, with the result that fish production and availability is very low compared to other countries. Over 95% of the fish in Nepal are produced using earthen ponds and are mainly carp species. Large amounts of fresh, frozen fish, dried and canned fish and fishery products are being imported annually, costing over one billion Nepalese rupees (CFPCC, 2024). Therefore, there is a need to expand aquaculture.

3 Nepal Has yet to Realize the Scope of Aquaculture

Globally, the aquaculture sector is rapidly evolving to play a critical role in food and nutrition security, improvement of livelihoods, and economic development. China and India grow carps massively in earthen ponds and rank first and second respectively, while Indonesia ranks third in terms of aquaculture production in the world. Among the various species, tilapia is the most widely farmed species across the globe and is grown in over 150 countries. It is the number-one species in Indonesia, the

Philippines, and Thailand, while pangasius is popular in Vietnam and Bangladesh (Bhujel, 2014b). In Nepal, rainbow trout has been considered an alternative fish especially for culturing in the hills and mountains due to their adaptability to cold environments (Gurung et al., 2017; Rai et al., 2005). However, the full scope of aquaculture has not yet been realized in Nepal, and lessons can be learned from other Asian countries.

The aquaculture in Nepal is mainly dominated by carps. All of the policies, plans, programs and recommendations are based mainly on carp culture, though trout culture has been promoted in cold water areas. Recently, small-scale aquaculture is being promoted in mid-hills. The doors are open to monosex tilapia and pangasius culture, but efforts are inadequate in terms of promotion, testing and development. Pond culture dominates the whole aquaculture, and though cage culture has been successful in some lakes and reservoirs, external feeding has not been allowed, and as a result, fish grow slowly. Policy should be made to promote intensive cage culture with feeding aiming to utilize more lakes and reservoirs created by hydropower plants. Like the carps, tilapia can also be cultured, utilizing green water in earthen ponds without commercial feed or with limited feed made locally using agricultural byproducts e.g., ricebran, oil cakes, etc., industry wastes, e.g., molasses, ami ami (a liquid waste from ajinomoto factory) and kitchen/restaurant wastes e.g., bread, rice, etc. These are century-old traditional systems and are less costly. Promoting this system could serve as a gateway to commercial farming; new farmers need to try to learn the basics first, then scale up by adding more input to increase productivity and profitability.

As available land is limited, productivity needs to be maximized. Realizing these needs, the Government of Nepal has given some priority to monosex tilapia and pangasius farming. However, due to shortages of technical human resources, seed availability and other shortages, production has not scaled up. Many farmers grow local catfish (magur) at high densities and in small areas, feeding them kitchen and slaughterhouse waste (Bhujel & Nepal, 2008). Hybridization of the type done in Thailand could enhance growth and benefit farmers (Na-Nakorn, 2004). There are many technological innovations in various parts of the world in culture species (e.g., genetic improvement), culture systems (e.g., aquaponics, bioflocs, in-pond raceways, RAS), feeds and feeding (e.g. probiotics, insect meals, local ingredients), water management (e.g., treatment and re-use, nanobubble aeration), health care (e.g. vaccines) and so on, many of which could be tested in Nepalese contexts and adopted.

In Nepal, aquaculture and fishery activities are primarily governed by the government's policy strategy. They are embedded in the broader Agriculture Development Strategy (ADS) (2015–2035), National Cooperative Policy 2069 (2012) and National Land Utilization Policy (2015) (Bista & Karki, 2022). The Central Fisheries Promotion and Conservation Center (CFPCC), formerly the Directorate of Fisheries Development (DoFD), formulates and implements national fisheries and aquaculture development plans and programs. The federal Government of Nepal provides overarching policy and program support to the aquaculture sector, which is under the Ministry of Agriculture and Livestock Development (MoALD) delegated to the “Department of Livestock Services”. They deliver services to each provincial government, including

its district and municipality levels, and promote aquaculture in limited areas, mainly the Terai regions as a part of agriculture and livestock technological interventions. They support programs for human resource development, technology dissemination and extension, and may provide subsidies, though with a limited budget and low priority among agriculture commodities. As the sector is considered a minor one among the agriculture subsectors, it receives negligible attention and support compared to other subsectors. Limited knowledge, technology, human resources, and low priority, in addition to limited land and water resources, are restricting the development of the aquaculture sector.

4 Choice of Aquaculture Species

Nepal has over 130 indigenous species of fish. However, very few of them have been artificially bred. Indigenous species, namely, Rohu, Catla and Mrigal, are commercially farmed (Table 1). Other indigenous species include Magur (*Clarias batrachus*), an airbreather fish that can be cultured at high density and easily sold live. The culture of Sahar (*Tor putitora*) is limited to research and development agenda, but commercial farming has yet to be developed. Farming of most indigenous species has been difficult, as they grow slowly and breeding is unpredictable. Indigenous carps are mostly cultured in polyculture with Chinese carps, which are popular in warm-water areas of Nepal, i.e., the Terai and inner Terai. Attempts are also made to culture carps and indigenous small-species (SIS) and prawns (Rai et al., 2012, 2014). Most farmers utilize less fertile land to dig ponds, realizing the high revenue potential of fish farming. However, farming methods are still dominated by the traditional culture of carps in ponds, which account for more than 90% of the aquaculture in Nepal (CFPCC, 2024). However, this aquaculture neither attracts youth nor produces sufficient food en masse to fulfil the ever-increasing demand for fish.

Food shortages and imports are growing, and agriculture, including aquaculture, contributes to food security, employment, and the income of rural communities. But more is required, as a large number of youth are going abroad to seek jobs and in search of good income. Therefore, agriculture must be intensive and more productive to be profitable enough, with modernized businesses to attract youths.

Aquaculture has this potential if it is promoted and given high priority. Especially, high-yielding species and technologies have to be explored and selected. This can be done in a number of ways: for example, by the promotion of high-yielding species such as pangasius (*Pangasianodon* sp.), Nile tilapia (*Oreochromis niloticus*) and sahar (*Tor* sp.) either in carp polyculture for the enhancement of the existing culture system or in specialized monoculture systems prioritizing high-yielding species and new techniques (Rai et al., 2014). Pond productivity could be enhanced two- to three-fold with the potential of increasing fivefold from the current level of 6 tonnes/ha per year (Bhujel, 2014b). In addition, these species can also be cultured in cages in lakes and reservoirs, water re-circulatory tanks and biofloc systems stocked at higher densities (Bhujel, 2019). Recently, biofloc systems, an advanced form of

Table 1 Summary of specific recommendations

Areas	Recommendations
Governance and planning	Upgrade Central Fisheries Promotion and Conservation Center to an independent department (Aquaculture and Fisheries Department) parallel to the Department of Livestock Services (DLS) under the line ministry at federal, provincial and district levels; develop short-, medium- and long-term policies and plans at all levels involving all stakeholders. An Aquaculture & Fisheries Development Board (AFDB) should be formed to develop a strategic plan for research and development, help formulate policies and oversee the entire sector
Education	Involving planners, researchers and other stakeholders, develop and include informative curricula in the academic programs at high school, vocational college, and university levels
Research	Promote and conduct independent, practical and applicable research based on the country's need in terms of species, systems design, feeds, water management, and health care; organize a research forum annually to share progress, propose new ideas for research and innovation
Extension	Engage stakeholders in planning and conducting the research and development; plan for the expansion and adoption of aquaculture technologies, promote highlighting the comparative socio-economic and environmental advantages of aquaculture and the health benefits of fish and aquatic animals and plants to increase consumption
Gender role	Emphasize the role of women in aquaculture, give high priority for training and demonstration
<i>Culture System</i>	
Existing carp polyculture	Enhance productivity by feeding (1–3% biomass daily), increasing the density to 5–7 fish/m ² by adding tilapia and/or Pangasius, giving aeration (3–6 am) and other techniques
Cage culture	Enhance productivity by allowing feeding and adding pangasius and tilapia; promote cage culture in lakes, reservoirs and rivers
Monoculture	Develop and expand the commercial culture of tilapia, pangasius and prawn in ponds, tanks and cages, promote
Integrated farming	Promote fish culture integrating with rice, vegetables, fruits, trees, poultry, ducks and livestock, buffalo, cattle, goat and pigs depending upon the suitability
Climate-smart system	While selecting a system, emphasize climate-resilient systems where the provision for adaptation and mitigation can be applied
<i>Species</i>	
Carp	Develop breeding programs to improve genetics, apply hapa nursing covering with bird nets
Tilapia	Establish at least 10 monosex fry hatcheries and nurseries; support and expand commercial culture in ponds, tanks and cages; promote its consumption and health benefits and export
Pangasius	Establish at least five good hatcheries, nurseries, grow-out farms, processing industry, transportation, cold storage and markets

(continued)

Table 1 (continued)

Areas	Recommendations
Sahar	Establish at least five commercial hatcheries, nurseries, develop commercial grow-out farming systems, angling farms, processing, packaging and value chain
Trout	Produce standard feeds commercially; develop markets and marketing systems; explore improved breeding, nursing, feeding, and health management; more potential sites
Magur catfish	Establish proper hatcheries and nurseries; monitor grow-out farms and markets
Prawn	Establish hatcheries and nurseries, develop grow-out culture systems, produce suitable feeds
Mollusks	Promote mussel and snail farming, their consumption and health benefits; establish more pearl farms and their economic benefits
Other species	Establish hatchery, nursery and grow-out farms, promote the culture and consumption of eel, snakehead, small-indigenous species, frogs, etc.
Aquatic plants	Develop farming of algae, duckweed, water spinach, water mimosa, etc. and promote their consumption and health benefits
Climate-smart species	While selecting culture species, emphasize climate-resilient species that can tolerate extreme heat, cold, droughts and floods, e.g., tilapia and pangasius are better than many other species
<i>Post-harvest handling and marketing</i>	
Harvest	Harvesting should be done with minimum harm to the fish. Whenever possible, live or freshly harvested fish should be sold. Ice should be made available if the fish are to be transported long distances, and proper transportation containers should be used
Markets	Post-harvest handling, transportation and storage of live and fresh fish markets should be well-organized
Processing	Processing of fish, value addition, product development (juices, powder, paste, skin snacks, etc.) and packaging should be emphasized, e.g., sun-drying, smoking, vacuum packing, chilling, blast freezing, etc.
Quality & safety	There is a need for regular quality tests of products for food safety, monitoring of the process, certification, e.g., GAP (Good Aquaculture Practices), sanitary/phytosanitary systems in place
<i>To achieve the target consumption (kg/capita/year)</i>	
5	Step 1: Enhance productivity of existing carp culture by feeding (1–3% biomass daily), proper nursing, increasing density to 5 fish/m ² and promoting fish consumption aggressively
8	Step 2: Step 1 + promote Pangasius, tilapia and sahar farming, establishing their hatcheries in the PPP model in their major culture zones and promote trout farming massively in cold water
11	Step 3: Step 2 + establish more feed plants, promote intensive aquaculture (higher feeding, aeration, probiotics, etc.), processing, quality control, certifications and specialized fish markets

(continued)

Table 1 (continued)

Areas	Recommendations
15	Step 4: Step 3 + carry out more research and genetic improvement of existing stock, indigenous species, promote other aquaculture species, e.g., silver barb, freshwater prawn, etc.
20	Step 5: Step 4 + promote advanced aquaculture systems, i.e., RAS, Aquaponics, Biofloc in greenhouses and promote other aquatic animal culture, e.g., crabs, frogs, mussels, snails, etc.

aquaculture, is becoming attractive among young entrepreneurs due to the potential for high productivity and the high-income potential of tilapia, pangasius and some carps while using small areas in backyards (Bhujel et al., 2022). However, there have been some problems due to the lack of technical know-how. Tilapia fingerlings should be strictly monosex and produced by properly managed hatcheries. The commercial farming of rainbow trout (*Oncorhynchus mykiss*) in hilly areas of Nepal utilizing cold water has also attracted many private investors (Gurung et al., 2017); as Nepal has over two-thirds of its total area covered by hills and mountains, commercial rainbow trout farming has high potential. Many trout farms are combined with restaurant and lodging businesses, creating additional jobs.

5 Aquaculture Systems and Choices

Pond culture is traditionally conducted in Asia and is the cheapest and most common method. It utilizes natural foods (phytoplankton and zooplankton) supplemented with various inputs. The pond culture system varies from low-cost extensive to super-intensive, with a high level of inputs and management. However, the availability of or access to land is the main limiting factor. The requirement of having large areas of land with abundant water is the biggest constraint, and the price of land near cities or transportation systems is prohibitively high. Starting aquaculture farms by purchasing land becomes very expensive; therefore, aquaculture farms are more suitable for rural areas, away from roads, which leads to several problems, including transportation for inputs and outputs, labour shortages, and technical managers being unwilling to work in remote areas. Therefore, alternative methods need to be explored that do not require much land. For example, cage culture requires no land, and can be done in communal ponds, lakes, reservoirs and slow-flowing rivers. People who do not own land can also raise fish by installing cages, though the access or use right must be arranged by the government using some sort of licensing or permit system. Current pond culture productivity is low (6 tonnes/ha/year) and requires enhancement by increasing stocking density, feeding, aeration and other management. However, waste from the aquaculture system should be re-used or recycled without draining natural waterbodies. Farmers can use them as fertilizer for growing vegetables and fruits on the dikes. Chicken, ducks and other animals can be raised on the dikes or

on nearby land to increase income by taking advantage of space. Different types of these integrated farming systems are more sustainable and have been practiced in various parts of the world. Chicken and ducks can be raised by building a shed over the pond so that their excreta becomes fertilizer for the fishpond.

Many other types of aquaculture can be incorporated into existing systems such as culturing fish in rice fields by making trenches along the dikes or across the plot. It can also be done in backyard tanks (e.g., concrete, tarpaulin) to apply advanced levels of management using a water re-circulatory aquaculture system (RAS), aquaponics, biofloc systems and so on. Aquaponic systems are popular as a hobby in which fish are cultured using a recirculatory system that passes water from fish tanks to vegetable beds, which can take the waste, filter the water and send it back to the fish tank/pond (Bhujel, 2017b). More recently, biofloc systems have been tried as they can be used in small backyards without having a large area for ponds (Khanjani et al., 2023). In this system, waste from the fish is converted to microbial protein by adding carbohydrates and probiotics without water exchange. These backyard aquaculture systems are good, as they do not require large areas. Small areas can easily be covered, making greenhouses create warm environments, especially during cold winters. They could overcome seasonality and help to produce throughout the year. Comparative advantages (Bhujel & Suharman, 2021) should be considered while developing different types of aquaculture systems in suitable pocket areas (also called aquaculture parks), that could attract people and possibly develop aqua-tourism. More businesses could be established to create jobs and an economic marketplace by developing resorts, restaurants, fishing ponds, and floating markets.

6 Aquaculture Development Approaches and Models

6.1 Regional Approaches

Aquaculture development intervention began in the early 1980s, realizing its need for a scientific base in Southeast Asia (AIT, 1994). The main objectives were to further develop the sector, utilizing the potential and exploiting the rich history of human civilization that was based on the livelihoods closely associated with aquatic resources, often referred to as rice-fish societies. Aquaculture development intervention began as a higher-degree academic program at AIT that integrated formal education with training, outreach, research and consultancy activities (Fig. 1, Bhujel, 2017a). This intervention was an attempt made by understanding the fundamental scientific roots, including production technologies and economic, social and environmental factors. Research was the main part of the intervention, which contributed enormously towards the development of aquaculture technologies and husbandry practices, e.g., seed production on a mass scale, hapa nursing techniques and growing by managing stocking and harvesting, feeding, water quality and preventing or curing diseases. This farmer-centered formal education was based on hands-on work and

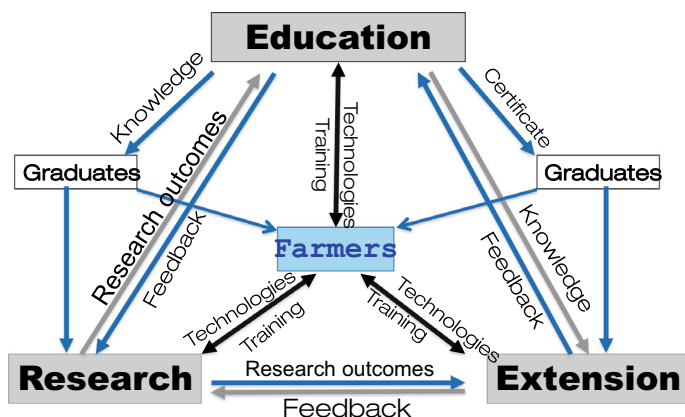


Fig. 1 Aquaculture development should be farmer-centered: education, research, and extension should have direct link with farmers and their welfare (modified from AIT, 1994)

practical research. Transfer of aquaculture knowledge and technologies also occurred through short-term training and outreach programs and offering consultancy services to public and private clients. The main lesson learned is that sustainable aquaculture is required to be reasonably productive, profitable, environmentally compatible and socially relevant. However, this model is vast and should be included in the long-term strategic planning at all levels, including the municipal, provincial and national levels.

6.2 Community Empowerment Model

There are over 50,000 national and international NGOs working in different parts and sectors of Nepal. Very few of them have realized the importance of aquaculture in nutrition, employment and income. Their roles could be impactful if they are well-equipped with technologies and skilled human resources. One of the successful projects launched by a local NGO, the Rural Integrated Development Society (RIDS), has been Women in Aquaculture (WiA) during the early 2000s (Bhujel et al., 2008). Designed and launched jointly by AIT and AFU (formerly IAAS – Institute of Agriculture and Animal Sciences), the project was launched involving mainly Tharu women. It started with 20 households in Kathar, Chitwan and later expanded to the neighbouring Nawalparasi district. During the initial phase, the project promoted carp and tilapia culture in small ponds (100–200 m²). In the second phase vegetable farming was integrated with aquaculture. Further, farming was expanded in terms of freshwater prawn species.

After having successful and meaningful impacts in the lowland areas, another phase was designed to expand to foothills of the mountainous regions in Lamjung and Gorkha. Women were trained and organized in groups and cooperatives. The

project established that small-scale aquaculture can be integrated not only into the subsistence farming systems in the Terai plains, but also in the mid-hills (Shrestha et al., 2012). The initiative has contributed to the communities in terms of family nutrition, income and employment. After having positive impacts, other NGOs (such as Plan International, Winrock International and others) started similar projects in different districts of Nepal. Similar programs are also found in other countries such as Bangladesh, Cambodia, and Myanmar (Bhujel et al., 2016). However, the development activities carried out by NGOs are normally short-lived, and plan to respond to immediate needs. Long-term planning is not done, and normally, these initiatives are not planned and implemented with sustainability as a consideration, causing them to come and go. They often fail due to lack of focus, long-term funding and required human resources. If they succeed during their project period, their impacts hardly remain afterwards. Most of the NGOs consider the amount of support they distribute and the number of people they train to be indicators of progress, and they may lack follow-up activities to monitor and report the actual impacts.

6.3 Holistic Approach of Aquaculture Development

This model (Fig. 2) has been recently tested in East Timor, a small half-island country with a high level of poverty (42%). People are chronically food insecure and suffer from malnutrition, where 58% of children under five are stunted, 60% are underweight, and 26% are wasting (Andersen et al., 2013). As a young nation with a history of conflict, it has faced many critical problems. Almost 90% of Timorese livelihoods depend on subsistence agriculture and livestock raising, similar to Nepal. Carbohydrate-based diets, e.g., maize, rice, cassava, taro, and sweet potato, are major sources of calories, while animal-source foods, e.g., chicken, beef, goat meat, and fish, are consumed occasionally, as they are in short supply. Because fish farming was thought to be a viable option to contribute towards meeting food and nutrition security, a strategic development plan (SDP) of Timor-Leste (2011–2030) was developed emphasizing sustainable aquaculture, which opened the door for development partners to take initiatives. WorldFish conducted a situational analysis of the aquaculture and fisheries during 2011–12 (NDFA-MAF, 2012) and revealed that the expansion and intensification of freshwater aquaculture in inland was largely constrained by the unavailability of inputs and viable technologies, and inadequate human resources. Considering these constraints, a stepwise holistic approach was applied in Timor-Leste. WorldFish assisted in developing the National Aquaculture Development Strategy (NADS) (2012–30), establishing a target of increasing aquaculture production to 12,000 tons annually and raising per capita fish consumption to 15 kg from 6 kg by 2030 (NDFA-MAF, 2012).

Initially, the need for high-quality fingerlings of fast-growing aquaculture species was realized, and a feasibility study was conducted to introduce Genetically Improved Farmed Tilapia (GIFT) broods in 2012 for rotational breeding. A government hatchery at Gleno in Ermera municipality was selected. The hatchery construction

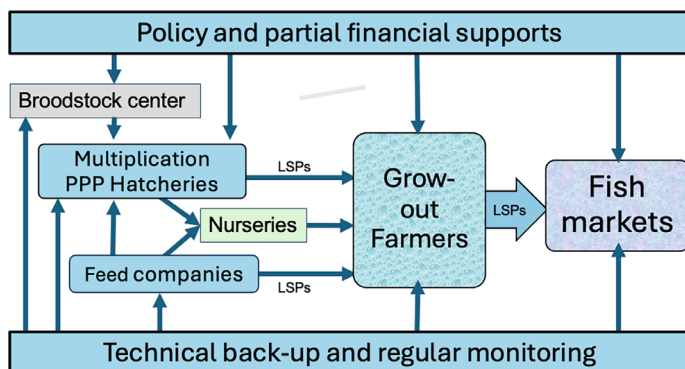


Fig. 2 Holistic approach of aquaculture development. *Source* Pant et al., 2024b

was completed in late 2015, followed by the introduction of four cohorts of GIFT broods, the rotational breeding of GIFT cohorts, and the production of monosex fry from early 2016. Potential farmers' clusters were explored and grow-out farming was expanded under the project "Partnership for Aquaculture Development in Timor-Leste" (PADTL), which was launched during 2015–2020. However, a government hatchery with limited capacity and space was not adequate to produce enough seed to supply thousands of grow-out farmers. The importance of private sector engagement was realized, and two private hatcheries were established in 2019 and 2020.

Scaling up of the aquaculture development in Timor-Leste was also constrained by shortages in input supplies, output markets, and technologies. High protein-containing ingredients, such as fish meal and soybean meal, are in short supply. If done properly, local solutions could have been the commercial production of insect meals from black soldier flies or field/house crickets (Perera & Bhujel, 2021). The second phase of the project, i.e. PADTL Phase 2, was developed focusing on the multiplication and dissemination of tilapia seed through the Public–Private Partnership (PPP) model. Preparation of local feed, arrangement for supplies of high-quality imported feed, maintaining green water, and introducing Better Management Practices (BMPs), and so on (Pant et al., 2023a, 2023b) were completed.

Farmers adopting BMPs achieved fish yield averaging 4.3 ± 1.5 ton/ha/cycle (Pant et al., 2024b). With an average production cost of USD \$1.5 per kg and sales of USD \$4.0/kg fish, farmers realized a net profit of USD \$2.5 per kg. Yields as high as 7.2 ± 1.2 ton/ha/cycle were achieved. However, scaling-up of tilapia production based on the feed from locally available resources (e.g., *Leucaena* leaves) was difficult due to the limited availability of feed ingredients in the country. It was not easy for farmers to put forth extra effort to produce only a small volume of feed of modest quality (Pant et al., 2023b).

In response to growing aspirations, efforts were made to devise a participatory trial to test higher stocking density, i.e., 5 fingerlings/m² and feeding fish with high-quality commercial pellets while maintaining green pond water. By adopting the new recommendations, tilapia farmers achieved an extrapolated fish yield of 12.4

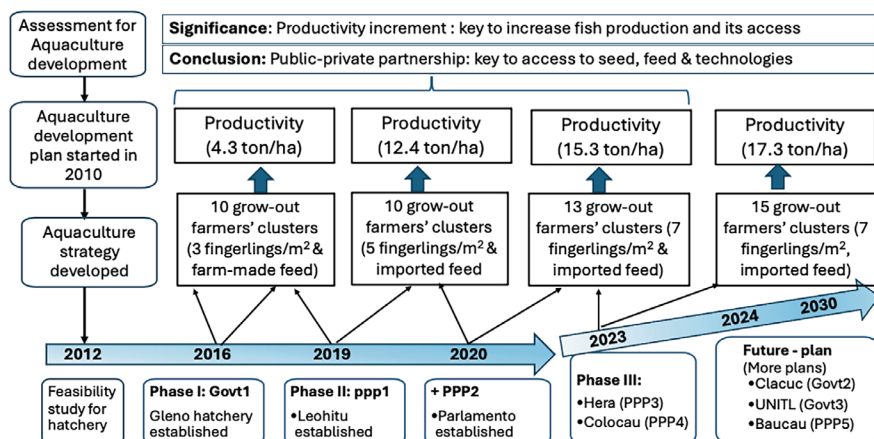


Fig. 3 Stepwise aquaculture development in Timor-Leste. *Source* Pant et al., 2024a

± 0.1 ton/ha/cycle, which is almost 3 times higher than from the previous cycles (Fig. 3). The average size of ponds and the net profit were 105 ± 34 m² and $135 \pm 3\%$ respectively. Demand for fish is high, and prices range between USD \$3.5–5/kg. Therefore, this semi-intensive tilapia production system proved to be viable, i.e. productive, as well as profitable. A total of 169 farmers from four municipalities were organized into 10 clusters who managed 417 ponds in this production cycle. Productivity continued to increase (up to 17 tonnes/ha) with a stocking density of 7 fingerlings/m² and higher (Fig. 3, Pant et al., 2024b).

The private sector was supported with high-quality feed imports made available at a reasonable price (US \$1.4/kg) and the PPP model for hatcheries to ensure a supply of high-quality fingerlings. However, when fish production increased, farmers faced problems with markets and input supplies, causing the project to establish live tilapia shops and recruit Local Service Providers (LSPs) to facilitate the seed and feed supply and fish marketing, which accelerated the scaling-up of aquaculture.

The aquaculture model in East Timor focused on sustainable and community-based practices, with an emphasis on building local capacity. The sector now holds significant potential for improving food security and driving economic development. Therefore, it is one of the best models of aquaculture development to test and adopt by other countries such as Nepal that have similar geographic, climatic and socio-economic contexts.

7 Roadmap

A roadmap for the development of aquaculture in Nepal is shown in Fig. 4, with a phase-wise development plan to achieve the aquaculture production estimated based on set target per capita consumption of 5, 8, 11, 15 and 20 kg per year by the year

2027, 2030, 2033, 2036 and 2039 adjusted based on population growth. The per capita consumption of 11 kg/year is the average value for the least developed countries, which should be achieved by 2033, and the world average of about 20 kg per year, which is likely to be met by 2039 if plans can be implemented well. These milestones could be achieved either by intensifying the existing culture systems to enhance productivity, or by expanding the area for aquaculture. Sustainable intensification in aquaculture is possible, and productivity can be increased up to fivefold (6 tonnes/ha up to 30 tonnes/ha) by choosing the right species, high-quality feed, and advanced technologies such as aeration. Digging more ponds to utilize unfertile lands is another option to increase production. Current production comes from about 15,000 ha of fish pond area, which is only 1% of the total irrigated land area (1.5 million ha) of Nepal. Converting another 1% of irrigated but less fertile land could double fish production. By improving management in existing carp systems, e.g., aeration, higher feeding, and polyculture, and promoting high-yielding fish species, e.g., pangasius, tilapia, and sahar, productivity could be enhanced. If fish could be grown in winter using greenhouses, targets of producing fish (Fig. 4) could be confidently achieved. However, government policy makers and all stakeholders need to realize this. More importantly, public–private partnerships (PPP) are a must and need to be effectively implemented.

The PPP model creates cooperative environments and mutual trust, rather than conflicts or competition for the same businesses/activities, dividing the work and with each side trusting each other for the common cause of a country’s development (Pant et al., 2024a, 2024b). Binding MoUs (memorandum of understanding) are signed between the parties (e.g., seed producers, feed suppliers, local service providers, fish producers, market operators) so that any party can go to court if it feels the agreed-upon terms and conditions are not respected.

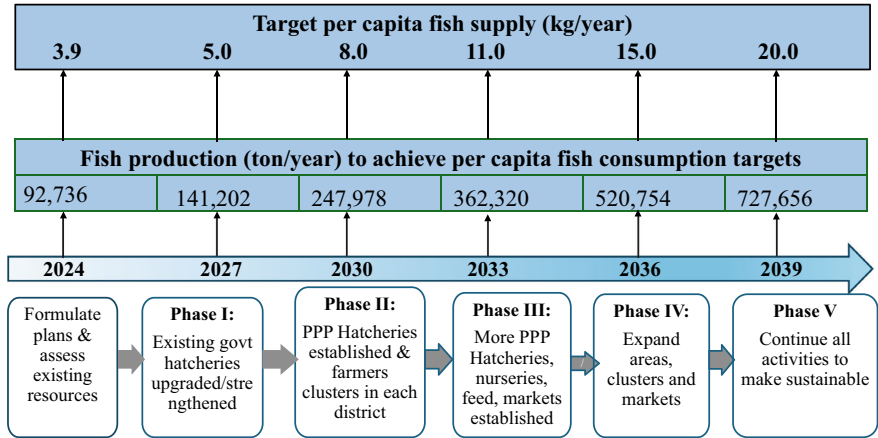


Fig. 4 Roadmap for aquaculture development in Nepal. *Source* Authors’ drawn

The role of the federal government should be to provide a business-enabling environment for the private sector and the necessary support by creating favourable policies and doing practical research for development, especially on the genetic improvement of important species, which requires long-term strategic investment. Provincial and district-level governments should help facilitate and coordinate PPP models, and municipalities and villages should provide door-to-door services to stakeholders. Semi-government and I/NGOs should help create demand by creating awareness campaigns to protect the environment and increase fish consumption as a sound way of maintaining better health. The public sector needs to help improve genetics for high-yielding, climate- and disease-resistant brood stock, establish large cold storages or supermarkets, create guidelines, conduct quality monitoring and enact the right policies and plans.

The private sector is set to invest or mobilize larger funds, mainly from banks and smallholder farmers to utilize government subsidies. As aquaculture is one of the most profitable businesses, and private corporations can be attracted to invest in establishing fish hatcheries, processing and feed manufacturing that could create employment and contribute to the overall economy. When the sector starts growing, investment in aquaculture normally comes along gradually with the development of poultry sector, such as fish hatcheries and feed manufacturing businesses as risk diversification, especially when bird flu hits poultry. The government should play a facilitating, coordinating and regulating role by making easy access to land and water bodies, low-interest loans, subsidized electricity and fuel, and support for skill development training so that entrepreneurs can make business plans to invest and implement. While engaging the private sector, women's role should be emphasized because they are the ones who feed the fish on most family farms. They also tend to be good at selling fish, handling money for the benefit of the family, and keeping all records.

Based on this roadmap, the aquaculture sector in Nepal could be developed and scaled up to achieve larger goals by selecting suitable species according to the ecological and geographical regions of the country: for example, Indian Major carps (IMC), tilapia and pangasius in the Terai and inner Terai plains; Chinese carps and local catfish (magur) in the mid-hills; and trout or local indigenous fish in the higher hills as shown in Fig. 5. The most important step to promote tilapia, pangasius and sahar is to establish specialized hatcheries in each aquaculture zone and pocket area. The holistic model described in Sect. 6.3 should be tested and applied through the stepwise establishment of PPP hatcheries and scaling along with seed and feed supplies.

8 Recommendations

The federal government of Nepal has developed a fisheries policy and should now develop a strategic plan involving all stakeholders. Considering the production and consumption targets (Fig. 5), a plan should include short-, medium- and long-term plans that include an assessment of the current situation and potential in each

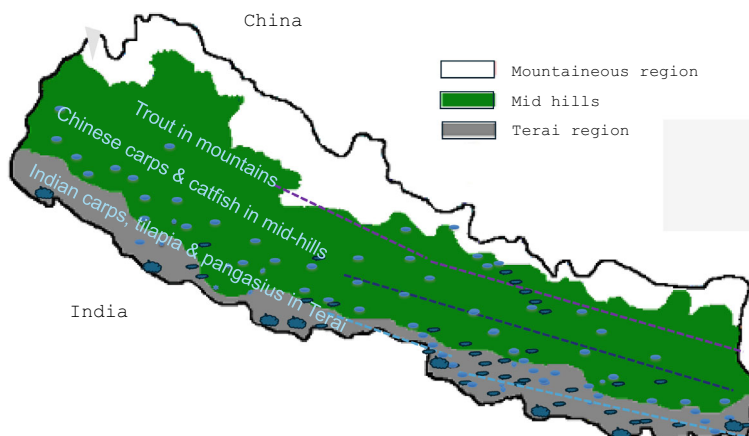


Fig. 5 Map of Nepal showing potential areas for aquaculture development (dark blue dots indicate fish farming intensities, and sky blue dots are potential for expansion). *Source* Authors' drawn

province, including an appropriate map using the geographical information system (e.g., Fig. 5), and develop clear stepwise development paths for each province. Policy gaps, technological problems, skill gaps and shortages of good seeds, feed, and specific recommendations are summarized in Table 1.

9 Conclusions

Aquaculture has huge potential to contribute to food and nutrition security, employment creation, income generation, and the overall livelihoods of the people and economy of Nepal. It has many options in terms of commodity (species with different varieties and tastes) and a wide range of possibilities in terms of farming techniques and systems for carrying out research and development, and doing business. Fish and aquatic animals are a lot healthier, and their farming is easier and more profitable compared to many other subsectors of agriculture. Constructing more ponds and reservoirs for storing water as well as growing fish in the water and fruits, vegetables and other plants on the dikes surrounding these areas serve as adaptation measures and help to mitigate the impacts of climate change and global warming and adaptation. The Government of Nepal needs to realize and give high priority to the sector by setting clear targets of increasing production and consumption with a roadmap and help launch coordinated efforts for creating an enabling environment, developing practical action plans (short-, medium- and long-term) and implementing them by involving the private and public sector, including NGOs and community-based organizations.

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Part IV

Agri-food Systems

Chapter 20

A Roadmap for Increasing Cereal Yields, Reducing Yield Gaps, and Achieving Food Self-Sufficiency in Nepal



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Abstract Nepal is increasingly facing food insecurity as demand for food is ever-increasing and the country is paying huge earnings in food imports. The current average yield of major cereal crops is inherently low (3.2 t ha^{-1}). The average national-level climatic potential yields of rice, maize and wheat estimated by crop simulation models are 8.9, 9.3 and 6.5 t ha^{-1} , average attainable farm-level yields are 5.6, 5.2 and 4.4 t ha^{-1} , and average farmers' field yields are 3.8, 3.0 and 2.8 t ha^{-1} , respectively. The attainable yields are not fully realized because of several yield-limiting factors. Our assessment revealed that the factors causing low yields and large yield gaps are weather-dependent farming with limited irrigation facility, inadequate fertilizer use, low use of quality seeds of improved crop varieties, pest pressures, and various socio-economic factors. Narrowing the current yield gaps requires increased yields in farmers' fields using appropriate crop, water, nutrient, and pest management practices, and high-yielding stress-tolerant varieties and climate-resilient farming practices. Our projections show that Nepal can achieve food sufficiency by increasing the current average yields of major cereal crops to around 4.1 t ha^{-1} by 2030, 4.6 t ha^{-1} by 2040 and 5.3 t ha^{-1} by 2050. Regulation of agricultural lands, dissemination of high-yielding, climate-resilient varieties with assured

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water and nutrient supply, and best management practices are recommended. Innovative extension, digital technologies, and agribusiness innovations are critical for rapidly scaling out technologies across the country. To achieve food self-sufficiency, government should improve supply of agri-inputs, i.e., seeds, fertilizer and irrigation. These require a substantial investment in irrigation, assured fertilizer supply through in-country establishment of a fertilizer plant, adoption of improved crop and soil management practices and farmers' access to quality seed of high-yielding varieties through efficient and innovative extension, and favorable policy and fiscal commitments from all levels of government.

Keywords Cereal crops · Climate change · Irrigation · Yield gaps · Yield-limiting factors

1 Introduction

Agriculture is the pillar of Nepal's economy, contributing about 25% of the gross domestic product (GDP) and employing 67% of its population for their livelihoods (NSO, 2023). Yet, crop yields are intrinsically low because of several geophysical, socio-economic, technical and environmental factors. Labor-intensive subsistence farming is practiced with inadequate inputs in small and fragmented lands under predominately rain-fed conditions, especially in hills and mountains. Consequently, farm productivity is low and yields are unpredictable. Meeting the ever-growing food demand while sustaining land productivity and maintaining resiliency at the farm level is the major challenge faced by the farmers, especially in the hills and mountains, which are highly vulnerable to environmental degradation and climate change (Subedi et al., 2016). Land degradation is also increasing trend in the inherently fertile lands of Terai and Inner Terai due to floodings, sedimentation, loss of soil organic matter (SOM), and soil acidification. The weather-dependent nature of farming is further impacted by the changing climatic conditions such as prolonged drought, extreme heat, erratic rainfall, and emergence of newer crop pests. In the context of climate change such as prolonged droughts and heat waves, crop failure and yield fluctuations are frequently experienced.

Cereal crops are the principal food and basic sources of food security in Nepal. Six cereal crops—rice, maize, wheat, millet, barley, and buckwheat—account for 28% of agricultural GDP and occupy over three-fourths of the cultivated area in Nepal (MoALD, 2023). Over the last 25 years, national-level average yields of rice, maize, and wheat have increased while those of finger millet and barley have decreased or stayed stagnant (Fig. 1). Even though the average yields of three major cereals have increased, their productivity is still low to meet the present and future demands of increasing population, especially in the hills and mountains (Gauchan et al., 2022). Further, the recorded crop yields are much lower than those in the neighboring countries (Table 1). Consequently, Nepal is in a food insecure state and hence has been importing food grains in ever-increasing trends to meet the growing demands.

In 2021, Nepal imported food products worth US \$ 3049 million with a negative net food trade balance of US \$ 2005 million (FAOSTAT, 2023), which is approximately a six-fold increase in the last 10 years and the trend is continuous. Cereal grains top the list of agricultural imports accounting for US\$ 766 million in 2021. The sharp increase of food imports in Nepal is certainly a concern as it costs hard-earned foreign exchange. To meet the rising food demands, Nepal will require substantial increase in farm-level yields and reduce the current yield gaps.

The three principal inputs of crop production—water, nutrients and quality seed—are always short in supply across the country. The majority of agricultural lands (~70%) are still weather-dependent, lacking irrigation. Chemical fertilizers are not available during the critical period of application and are generally applied in low amounts and imbalanced ways. Likewise, there is no adequate supply of quality improved seeds with very low seed replacement ratio of major cereal crops. Inadequate, poor-quality and untimely availability of these inputs, especially in the Terai and Inner Terai regions, results in national-level food insecurity since these regions

Fig. 1 Trend of cereal crops yields (t ha^{-1}) in the last 25 years (1995–2020) in Nepal. Source <https://www.fao.org/faostat/en/#data>

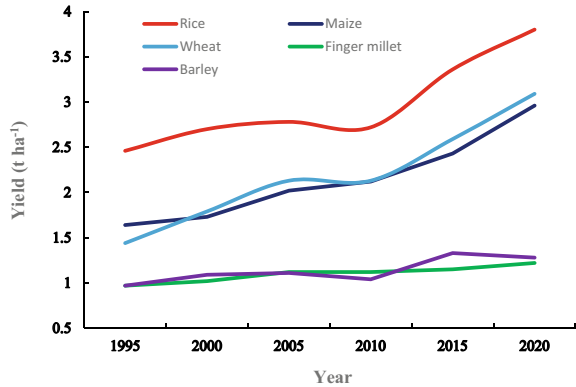


Table 1 Comparison of five years (2016–2020) average yields of major cereal crops in Nepal with its neighboring countries

Country	Average yield (t ha^{-1})			
	Rice	Maize	Wheat	Finger Millet
Bangladesh	4.7	7.96	3.10	1.01
Bhutan	4.10	3.46	1.54	2.21
India	3.92	2.90	3.31	1.24
Nepal	3.52	2.71	2.72	1.18
Pakistan	3.03	5.16	2.86	0.72
Average	3.85	4.43	2.71	1.27
Difference ($\pm$ %) from the average	− 8.7	− 38.8	+ 0.4	− 7.2

Source <https://www.fao.org/faostat/en/#data>

are food baskets of the country. On the other hand, lack of timely availability of inputs in hills and mountain regions results in household-level food insecurity in the predominantly subsistence farming. This chapter examines the current scenario of cereal crops production, their yield potentials and yield gaps, and factors causing large yield gaps in Nepal. The major yield-limiting factors and the research and development priorities and policy interventions to narrow down the yield gaps and attain self-sufficiency in cereal grains production in the context of changing climatic conditions are suggested.

2 Yield Potential and Yield Gaps of Major Cereal Crops

The climatic yield potential (Y_p) of a crop cultivar grown in a location under fully irrigated conditions is defined as yield of that cultivar grown without water and nutrient limitations, and free of biotic stresses (van Ittersum et al., 2013; Evans and Fischer, 1999). The Y_p is solely determined by solar radiation, temperature, atmospheric CO_2 concentration, and genetic characteristics. In water-limited environments, yield potential (Y_w) is determined by soil water availability for crop growth, which in turn depends on soil and terrain properties. Further, the nutrient-limited yield potential (Y_N) is determined under the constraints of both water and nutrients. The yield gap (Y_g) for a cultivar in any location can be determined in various ways: (i) difference between Y_p and Y_w , (ii) difference between Y_p and Y_N , (iii) difference between Y_p and research station yield (Y_r), (iv) difference between Y_r and farmer's field yield (Y_f), and (v) difference between Y_p and Y_f . Thus, in irrigated systems, Y_p can serve as the benchmark for Y_g analysis while in rain-fed system, Y_w can be the most relevant benchmark for Y_g . Thus, Y_g analysis provides a framework for contextualizing current farmer's yields against Y_p in different production environments, including at the cropping systems level (Guilpart et al., 2016; van Ittersum et al., 2013). However, Y_g analysis will be of limited use for interventions if the multiple causes of lower productivity at the farmer's level are not identified.

Through a review of simulation modelling work in Nepal, Devkota et al. (2023) reported the long-term mean Y_p of rice (12 t ha^{-1}), open pollinated variety of maize (15 t ha^{-1}), and wheat (7 t ha^{-1}), respectively, by ORYZA 2000, Hybrid-Maize and CERES models in Chitwan, under optimal crop planting, suitable varieties, non-limiting water and nutrient, and controlled pests and disease conditions. A summary of yield estimates for several districts by Krupnik et al. (2021) showed large Y_g between Y_p , and Y_r , Y_f , or nationally reported average yields each, with larger Y_p - Y_f (Y_g 3) than either Y_p - Y_r (Y_g 1) or Y_r - Y_f (Y_g 2). The Y_p was exceptionally high, ranging from 10 to 13 t ha^{-1} for rice, 11 to 13 t ha^{-1} for maize, and 6 to 8 t ha^{-1} for wheat (Krupnik et al., 2021; Table 2), while remarkably low national average yields of 3.76 , 2.85 , and 2.82 t ha^{-1} respectively, for those crops (FAOSTAT, 2023). These data indicate the existence of huge yield gaps between Y_p and Y_f (Y_g 3) of all crops and reveal an urgent need for the implementation of the science-led approach to maximize cereal productivity for food self-sufficiency. Results also suggest that

gaps between Yp and Yr (Yg 1) were larger for rice than that for wheat and OPV maize.

Devkota et al. (2021) showed that rice Yg in the Terai can be closed by 1.85 t ha⁻¹ (48%) through the use of integrated agronomic management packages. Gaps between Yr and Yf (Yg 2) were larger for wheat than the other two crops, suggesting that farmers' management for wheat was poor; thus, the extension of recommended technologies to farmers and their adoption would help increase wheat yields and reduce Yg. The large Yg in maize can be closed through improved varieties (by 1.4 t ha⁻¹), fertilizer (by 1.75 t ha⁻¹), optimal plant population (by 0.9 t ha⁻¹), integrated weed management (by 0.87 t ha⁻¹), and with the package of best agronomic management practices from 2.53 t ha⁻¹ (under farmers' practice) to 4.5 t ha⁻¹ in the rain-fed mid-hill region of Nepal (Table 2).

Solar radiation and temperature are not generally limiting factors in most of the production areas (up to 1000 m), where up to three crops per year can be grown. As the elevation ascends, temperature becomes limiting and growing seasons become shorter. Consequently, only two crops can be grown in mid-hills (up to 2500 m)

Table 2 Yields and yield gaps (t ha⁻¹) of rice, maize and wheat in three agro-ecological zones of Nepal

Crop	Agro-ecological zones	Potential yield (A)	Research station yield (B)	Farmers' yield (C)	Yg1 ^a (A – B)	Yg2 (B – C)	Yg3 (A – C)
Rice	Terai	8.7	5.06	3.78	3.64	1.28	4.92
	Terai	8.1	3.40	2.74	4.10	0.66	5.36
	Nepal	10–13	5.00	3.76	5–8	1–2	6–9
	Terai	12	5.06	3.50	6.9	1.56	8.5
	Mid-hill	11	5.00	3.12	6.0	1.88	7.88
	High-hill	10	4.00	2.34	6.0	1.66	7.66
Wheat	Terai	5.5	3.06	2.39	2.44	0.67	3.11
	Terai	5.03	3.50	1.88	1.53	1.62	3.15
	Nepal	6–8	4.00	2.82	2–4	1–2	3–5
	Terai	8.0	3.06	2.61	4.9	0.45	5.39
	Mid-hill	8	3.50	1.07	4.5	2.43	6.93
	High-hill	7	3.00	1.64	4.0	1.36	5.36
Maize	Terai	13.4	10.11	5.76	3.29	4.35	7.64
	Terai	6.3	3.30	1.82	3.0	1.48	4.48
	Nepal	11–13	8.00	2.85	3–5	4–5	8–10
	Terai	13	10.11	4.15	2.9	5.96	8.85
	Mid-hill	15	11.00	2.53	4.0	8.47	12.47
	High-hill	11	7.00	1.94	4.0	5.06	9.06

^a Yg1 = Yield gap 1; Yg2 = Yield gap 2; Yg3 = Yield gap 3

Source Devkota et al. (2023)

and only one crop per year or up to three crops in two years are possible in high hills and mountains (> 2500 m). Our assessment of Y_g suggests that although from climatic point of view, there is a considerable scope for cereal yield increase, reducing the gap between the potential yield and average farmer's yield and sustaining yields over time remains a challenge due to several technical, environmental and socio-economic factors. For example, farmers' decisions on resource allocation, prioritization, and crop management practices for closing the Y_g depend on objectives, resource constraints, synergies, and trade-offs between different components/activities, thus requiring an in-depth analysis at the farm level (Krupnik et al., 2021).

3 Food Demand and Supply Situation in Nepal

The demand for food is primarily influenced by population growth, income, urbanization, food prices, and changes in people's food habits. Population growth is the biggest driver of food demand. According to the 2021/22 national population census (NSO, 2023), Nepal harbors 29.2 million people. Nepal's food and nutritional security status is extremely poor, as it ranks at 74th position out of 113 countries in the Global Food Security Index (<https://impact.economist.com/>) and at 69th position out of 125 countries in the Global Hunger Index (GHI) (Grebmer et al., 2023). The current production level of cereals is not adequate to meet increasing internal food demand, resulting in import of food grains from overseas. Figure 2 shows that the total cereal demand is about 13 million tonnes, while the country currently produces only 11 million tonnes, with a deficit of 2 million tonnes. As a result, self-sufficiency ratio in cereals is only 85% implying that 15% of the food demand is met through import.

Increasing production and improving self-sufficiency ratio can be achieved either through expansion of land area or increasing yield per unit area. However, the growth rate of land area (horizontal expansion) for crop cultivation is extremely low and therefore, the only option is to increase production through productivity enhancement (vertical expansion). The agricultural land in Nepal is decreasing due to soil erosion, and rapid urbanization and land abandonment. Gauchan et al. (2022) reported that under the current growth rates of production and population and potentially negative effects of climate change, the productivity of crops should be increased by 24% by 2030, 33% by 2040, and 41% by 2050. They also estimated that the projected demand could be met by increasing the current productivity of cereals from 3.2 t ha^{-1} to 4.06 t ha^{-1} by 2030, 4.62 t ha^{-1} by 2040, and 5.25 t ha^{-1} by 2050, which could be possible through breeding better varieties resilient to changing climate and proper management of soil fertility and pests, and improve irrigation facilities.

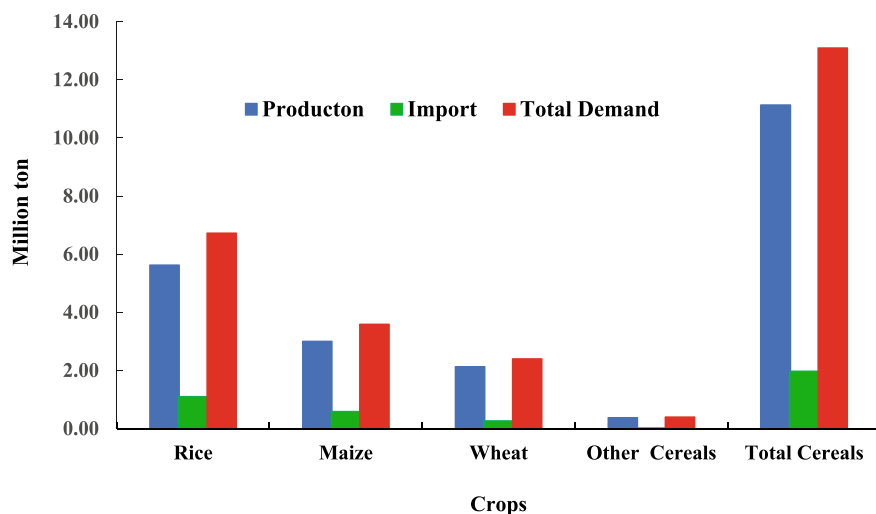


Fig. 2 Production, import and demand of cereals in Nepal (million tonnes) in 2021. *Source* MoALD (2023) and FAOSTAT (2023)

4 Factors Attributing to Low Yields and Larger Yield Gaps

The most important factors responsible for the low adoption of technologies and resulting lower crop yields and larger yield gaps are summarized as below:

(i) Lack of irrigation

Among the major yield-limiting factors, availability of water during the critical crop growth stages tops the list. When solar radiation, temperature, and plant nutrients are not limiting and pests are controlled, for a given cultivar with high yield potential, water is the most important yield-limiting factor. In the absence of water, nutrient efficiency decreases, and potential yield cannot be achieved even with improved seed, and nutrient and pest management (Lobell et al., 2009). In Nepal, about 80 to 85% of the annual rainfall occurs during the pre-monsoon and monsoon seasons (May–August), and most of this rainfall is wasted. The remaining rainfall of less than 20% is also not predictable. Prolonged droughts during the winter months cause significant impact on yields of winter crops, especially wheat, barley, potatoes and grain legumes. Therefore, unavailability of water during the growing seasons is the major cause of poor and unpredictable yields and large yield gaps.

Irrigation has been an effective tool for poverty reduction (Angood et al., 2002). However, despite presence of huge water resources, they have not been properly utilized for agriculture and in reducing poverty. About 1.80 million hectares of total agricultural land in Nepal (2.64 million hectare) is irrigable but only about 0.55 million hectares (30%) are currently provided with irrigation for year-round cultivation, irrigation efficiency is estimated at 35%, and water productivity is low (ADB,

2020). Of the total irrigated lands, Terai occupies about 81% share followed by 15% in the hills, and only 4% in the mountainous region (IMP, 2019).

(ii) Land degradation and deteriorating soil fertility

Land degradation entails a loss of productive capacity of land and is often induced by human activities, which have environmental, economic, and social consequences (Subedi et al., 2016). The extent of land degradation depends on the geology of the land, rainfall pattern, and land use practices. The mountain slopes are highly susceptible to soil erosion when exposed to intense rainfall. Such fragile land types combined with inappropriate farming practices lead to severe land degradation. Deforestation, overgrazing, and construction of roads without proper consideration of the fragility of the slope are some of the major human-induced factors of soil degradation in Nepal (Subedi et al., 2016). It is estimated that during the last 6–7 decades, over 35% of the total arable land has been degraded due to human-induced activities (Gupta, 2019).

Declining soil fertility as one of the major causes of poor crop yields is widely reported (Bajracharya & Sherchan, 2009; Subedi et al., 2015a). Soil fertility decline includes loss of productive soil due to erosion, depletion of soil organic matter (SOM) and soil nutrients, and alteration of soil physical, biological and chemical properties (Krupnik et al., 2021). Bajracharya and Sherchan (2009) reviewed a large set of soil analysis data and concluded that over 90% of soils in Nepal fall into low to medium classes with respect to SOM and total N. Subedi et al. (2015a) highlighted four key reasons responsible for soil fertility decline in Nepal: (i) erosion of topsoil, (ii) nutrient mining, (iii) depletion of SOM, and (iv) imbalanced use of chemical fertilizers (Fig. 3).

The loss of topsoil and nutrient leaching causes significant impact on soil fertility especially in the hills and mountains. Chalise et al. (2019) reported that intense rainfall and conventional tillage practices coupled with soil structure and steep slopes are the main drivers of soil erosion in hills and mountains, leading to loss of fertile topsoil, removal of plant nutrients and SOM, and thereby reducing soil productivity. The flooding and sedimentation not only damage the productive lands in flood basins and Terai but also damage infrastructures such as irrigation canals, dams and roads.

Nutrient mining occurs when soils are exhausted with multiple cropping without properly replenishing the nutrients. Nutrient deficiencies and soil acidification are widespread in all regions and cropping systems (Bajracharya & Sherchan, 2009). The most mined nutrient is nitrogen (N), although potassium (K), phosphorus (P), boron (B), copper (Cu), zinc (Zn) and molybdenum (Mo) mining are also reported in almost all districts. Bajracharya and Sherchan (2009) have reported that about 55% soils are acidic in nature and the plain areas with higher cropping intensity have low levels of SOM compared to the hills, where traditionally more organic manures are applied.

Maintaining a desired level of SOM should be the primary aim of sustainable soil management, which is observed as a challenge in most soils of Nepal. Traditionally, organic manures were the main sources of plant nutrients but in recent years, because of reduction in the number of livestock and shortage of farm labors, farmyard manure

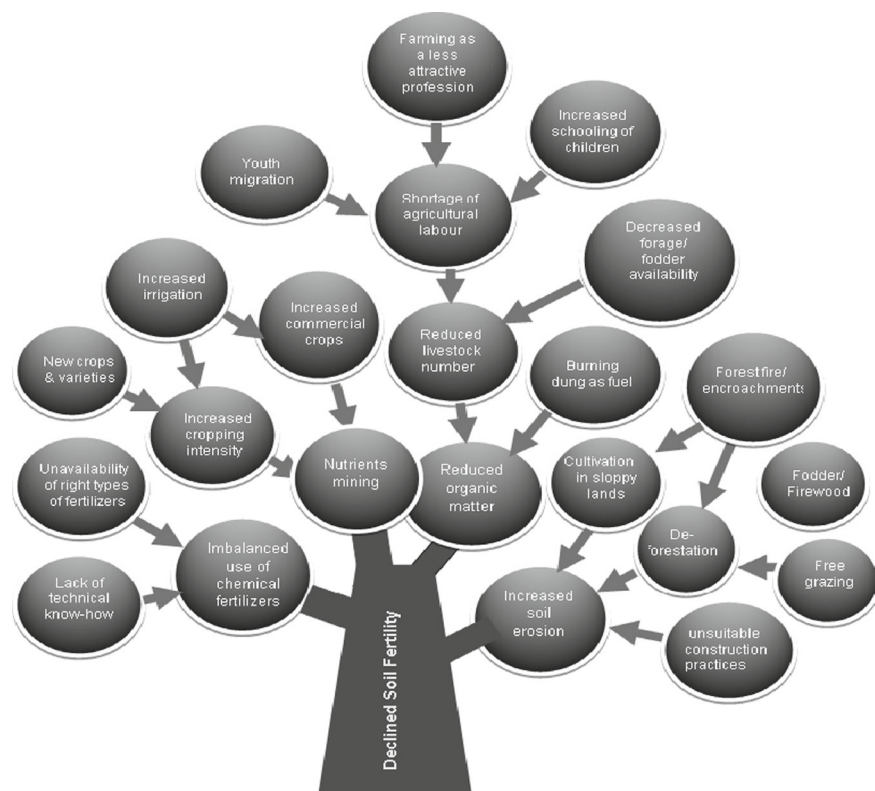


Fig. 3 Problem tree diagram for causes of soil fertility decline in Nepal. 2015a Adapted from Subedi et al.

(FYM) and the organic sources are no longer able to keep the balance of SOM and nutrients. Crop residues are also not recycled and the quality of FYM is poor. Burning of crop residues and weed biomass also reduces the organic matter recycling in soil. Chemical fertilizers are used as an alternative source of plant nutrients; however, they have never been supplied in adequate quantities, in required types and during the critical time of requirement. Compared to other South Asian countries, average fertilizer use in cereal crops in Nepal is low with about 41, 18 and 18 kg N, P_2O_5 and K_2O , respectively (Krupnik et al., 2021). The fertilizers made available are predominantly nitrogenous, and therefore nutrient imbalances are frequently observed.

(iii) Shrinking of productive agricultural lands

In Nepal, land is considered as the wealth and substance of livelihood. Decreasing productive agricultural land is another factor causing low food production in Nepal. The country's socio-economic circumstances have impacted agricultural land badly. The agricultural lands are shrinking because of (i) encroachment of fertile lands of

valleys and Terai by the unplanned urbanization, (ii) abandonment of productive lands especially in the hills and mountains due to out-migration, (iii) fragmentation as a practice of inheritance of land, (iv) plotting of agricultural land for residential use and/or investment, and (v) increasing human-wildlife (monkey) conflicts in the hills. The massive surge in rural-to-urban migration is identified as the primary proximate cause of the fast expansion of built-up areas (Ishtiaque et al., 2017). Devkota et al. (2023) found that over the past three decades (1990–2020), the built-up areas in 12 major cities have continuously increased mostly at the expense of agricultural lands. For instance, the built-in areas in Kathmandu, Pokhara and Heatuda have increased by 368%, 562% and 2203%, respectively during this period.

(iv) Low availability and adoption of improved crop varieties/seeds

The quality seeds of improved cultivars which are resistant to biotic and abiotic stresses, combined with proper nutrition, water and pest management, can increase crop yields. In Nepal, availability of quality seed of improved crop varieties is still low. Based on the Seed Quality Control Center, the Nepal Agricultural Research Council has developed and released 76 rice, 41 wheat, 23 maize, 5 finger millet, and 6 barely varieties among others and the improved varieties of rice, maize and wheat are estimated to be used at 35%, 73% and 94%, respectively (SQCC, 2024). The maintenance, spread and adoption of varieties and seed replacement rates for improved varieties are however still low.

(v) Pest and diseases

Various diseases, insect pests, weeds, rodents and wild animals (especially monkeys) that cause significant yield losses in different crops and many of such pest and diseases affect cereal crops in Nepal. Pesticides are used for disease and insect pest control but there are several concerns with their use. Using pesticides without proper knowledge of handling, storage, application, disposal practices and inadequate waiting period has caused harmful effects on human health and environment. Consequently, Nepal is heading towards irrevocable health risks and environmental hazards induced by misuse of pesticides (Subedi et al., 2015b).

(vi) Risks of climate change

In recent years, we have witnessed changing patterns of climate globally and Nepal is not an exception. The extreme weather phenomena such as prolonged drought, longer and more intense heat waves, and erratic rainfall are now more frequent than before. The unusual climatic events result in loss of land/soil, water cycle and emergence and spread of new or alien invasive species of pest, and result in significant impacts on agriculture and food security. Delaying in rice planting due to prolonged drought, occurrence of post-monsoon rains causing flooding at crop maturity and to harvested rice crop, and occurrences of heavy rainfalls are some of the examples of extreme and changing weather patterns. As reported by Acevedo et al. (2020), rural communities with high population of small-scale producers in rain-fed agriculture are highly vulnerable to climate change effects. Therefore, small-scale farmers who rely mostly on rain-fed farming are highly vulnerable to such extreme climatic conditions.

5 Research and Development Priorities and Policy Recommendations

Land productivity can be increased with a combination of factors namely, adequate water, quality seed, availability of plant nutrients during the critical time, and free from pests, drought, heat, and cold stresses. The key focus or priority areas to increase cereal yields, reduce yield gaps, and achieve food self-sufficiency, which are also considered requirements for developing a roadmap for agriculture sector transformation in Nepal (see Sect. 6), are discussed below.

(i) Investing in irrigation and water management

Irrigation plays a critical role in increasing crop productivity; thus, emphasis should be given on improving and expanding the irrigation systems where it is technically feasible and economically viable. With assured irrigation, three crops in a year can be grown in all areas of foothills, Tars and Terai, and cropping intensity can be increased to 300%. The area of spring (*Chaite*) rice, spring and winter maize, and other crops can also be increased. Assured irrigation combined with other production inputs can substantially increase crop productivity in the uplands or rain-fed systems and can also reduce drought hazards and crop yield fluctuations.

There are ample sources of water for irrigation and prospective irrigable lands in Terai, Tars, and foothills across the country. Depending on the source of water and land suitability, small to large irrigation projects including canals, tube-wells, and rainwater harvest and reservoirs should be constructed where appropriate, and all irrigable lands should have year-round water supply. We must learn lessons from other successful examples elsewhere such as California, Egypt, Israel, and Punjab and Haryana, how desert-like lands have been converted into most productive farmlands. With the assured water supply, farmers can best utilize their land with appropriate crops/varieties, fertilizers, and other crop management practices. We stress that irrigation must receive the top priority in government investment and all scattered funding in the name of agriculture development must be switched towards improving and expanding irrigation systems for at least for the next 10 years. As Nepal has a natural gift of solar radiation and temperatures for year-round crop production in tars, terai and foothills, land productivity can be increased and three crops in a year can be easily produced with irrigation. Thus, Nepal can produce sufficient cereal grains and other crops. In addition to its role in increasing crop yields, irrigation should also be considered as an important component of improving rural livelihood. Angood et al. (2002) studied three small farmer-managed irrigation schemes at Yampaphant, Tanahun and showed how irrigation becomes a principal part of a package of rural development and poverty reduction. Therefore, unless investment on irrigation infrastructure and effective water management is contemplated seriously, the aim of agriculture development and attaining self-sufficiency in food grains production remains just like a daydream.

(ii) Adopting proper soil fertility and nutrient management

Declining soil fertility resulting from higher rates of soil and nutrients losses, inadequate SOM replenishment, and imbalanced use of fertilizers are well recognized. Depleting SOM without its replenishment is a big concern for sustainable soil management. Traditionally organic manures were the primary sources of sustaining soil fertility, but they alone cannot meet the plant nutrient demand for higher yield and can't sustain soil fertility due to shortage of farm labors and reduced number of livestock. Therefore, with the current state of soil fertility, improving and sustaining crop productivity seems to be a big challenge.

Chemical fertilizers are appearing as the major sources of plant nutrients due to their higher nutrient contents, increasing yield responses and easiness in application (Timsina, 2018). However, there is always fertilizer shortage and hue and cry during the planting seasons. The imported amounts of fertilizers have never met the actual demands. The current public policy is more focused on import and supply of chemical fertilizer without adequate focus on integrated plant nutrient management that employs both organic and inorganic sources. A huge sum of government resources (half of the agricultural budget) is currently being invested in subsidies for chemical fertilizers. The Kathmandu Post projected that the chemical fertilizer subsidy bill in Nepal was a record of Rs 39 billion in 2023/24. This is a huge economic burden on top of already faced difficulties and challenges in import and distribution of fertilizers.

Various studies were conducted by the Government of Nepal on the prospect of establishing a chemical fertilizer plant in Nepal (IBN, 2021). The first feasibility study conducted by the Japan International.

Cooperation Agency (JICA) in 1984 focused on using water electrolysis technology to produce urea fertilizer. The second study was done in 2015 by the consortium of Infrastructure Development Corporation (Karnataka) Ltd., India, the Institution of Agricultural Technologists, and Shah Consult International Pvt. Ltd. (IDECK). The study focused on using natural gas technology as a suitable option to produce urea in Nepal and compared three feedstock options—natural gas, coal, and water using electrolysis for ammonia and urea synthesis. A cost–benefit analysis was carried out to assess the option of importing fertilizers vis-à-vis domestic production. It estimated that the net annual outflow after setting up a 700,000 metric ton per year capacity urea plant would be about USD 86.6 million which is significantly less than the corresponding outflow when importing urea. The current Government of Nepal figures for net outflow is as high as USD 186 million. Therefore, while improving in-country fertilizer supply system is important, especially for short-run, Nepal must manufacture fertilizers without any delays for consistent and reliable supply of fertilizers in the long-run, as it is estimated that the subsidy paid on fertilizers for five years could be enough to establish a fertilizer factory within the country.

There are empirical evidences to show how appropriate nutrient management improves crop yield and profitability. Devkota et al. (2018) reported that wheat yield could be increased by 144–366% in hills and by 95–184% in Terai with the balanced nutrients and best management practices. Similarly, Timsina et al. (2021) using Nutrient Expert-based fertilizer recommendations demonstrated that yields of maize, wheat and rice can be increased by 3.5 t ha⁻¹, 1.4 t ha⁻¹ and 1.3 t ha⁻¹,

respectively, over the farmers practice. In the absence of balanced plant nutrients, crop yields cannot be fully realized even with assured irrigation as high-water productivity requires adequate supply of fertilizer nutrients, especially N. Therefore, balanced use of nutrients is one of the most important means to increase crop yields and narrowing the yield gaps.

The improved quality of organic manures combined with fertilizers based on crop and location-specific needs seems to be a plausible alternative (Krupnik et al., 2021). The most efficient and practical way to supply nutrients to meet crop nutrient demand is to apply the organic and inorganic sources in combination with right proportions in an integrated manner (Timsina, 2018). The objective of any sound and responsible nutrient management should be to keep nutrients and SOM in positive balance while improving soil chemical, physical and biological properties. Nutrient management-related decisions support tools such as Nutrient Expert (NE) have the potential to predict fertilizers based on the principles of site-specific nutrient management (Pampolino et al., 2012; Timsina et al., 2021). The potential of such tools has been well demonstrated for maize, wheat and rice in different agro-ecological regions in Nepal (Amgain et al., 2021; Devkota et al., 2023; Timsina et al., 2021). In the mountain and hill farming systems, however, fertilizer and nutrient management practices must be aligned with proper soil conservation practices.

(iii) **Increasing genetic enhancement and quality seed supply**

Genetic enhancement of crops has a vital role to play in achieving yield potential as this is considered the cheapest means to contribute to increased crop productivity. Crop yields can be increased substantially if improved seeds are combined with assured irrigation, adequate plant nutrients, and proper crop protection measures. Quality seed of improved crop varieties with high yield potential, and increased stress tolerance and nutrient use efficiency can result in high yields. Considering the current and projected future climate change and the occurrence of extreme climatic events, more research work needs to be conducted to develop high-yielding crop varieties with drought and heat tolerance that are water and nutrient efficient. Modern biotechnology tools should be combined with the conventional plant breeding techniques to enhance crop genetic advancement, which requires increased investment in infrastructure and capacity building.

Seed supply system in Nepal is not properly regulated and seed replacement rate is low. There is also low or limited access and availability of improved and quality seed through formal/public sources. Therefore, farmers seek informal or private sources for hybrid seeds such as maize, rice and vegetables. Hence, quality seed supply and their maintenance should be properly regulated.

(iv) **Regulating productive agricultural lands**

Decreasing agricultural land is a big concern for food production. There is already a substantial loss of productive land due to abandonment, encroachment, construction, and urbanization. If the rate of land loss continues with the current trend,

Nepal will face a serious food crisis. Therefore, it is strongly recommended that the country's land be properly regulated, zoned, and safeguarded. The acts and regulations pertaining to agricultural land protection should be strictly enforced to safeguard productive agricultural lands.

(v) Promoting sustainable and integrated pest management

Various cultural, physical, biological and chemical measures are being used to control pests. However, in recent years, there is an increasing and indiscriminate use of pesticides in Nepal. In the absence of proper regulatory compliance systems for registration, import, marketing, storage, and use of pesticides and proper training, education and public awareness, pesticides are rather misused (Subedi et al., 2015b). The integrated pest management (IPM) approach comprising of setting action thresholds, monitoring and identifying pests, preventing pests from becoming a threat, and determining an effective control method for the target pest, should be promoted to reduce the impact of pesticides on public health and environment. The use of safer alternatives such as biological control, bio-pesticides and reduced-risk pesticides, appropriate crop rotations, diseases/pest tolerant/resistant crop varieties are among the different management tools that can be useful in lowering the pest pressure. Strict regulations and their enforcement are required for responsible trade and use of pesticides. Farmers should also be trained to apply pesticides in a responsible manner including to follow IPM.

(vi) Promoting farm mechanization

The traditional agricultural practices in Nepal are labor-intensive and with drudgery on farm labors. Therefore, one of the reasons for keeping land fallow is because of physical burden on farm labors, particularly to women. Due to such burden, the young generation, in particular, is not attracted towards farming. Farm mechanization is important to (i) reduce the drudgery on farm labor, (ii) increase the efficiency of work, (iii) lower the cost of production, and (iv) attract and retain young people in farming. In addition, the adoption of modern technologies such as precision agriculture practices, digital applications and ICTs in agriculture can improve productivity, reduce labor, and improve quality of farmers' life. Where technically feasible, it is important to modernize and mechanize farms with tools, equipment, and technologies suitable for different farming settings.

(vii) Promoting climate-resilient agriculture practices

Due to predominant weather-dependent farming and low level of adaptive capacity of farmers to unpredictable climatic patterns, the impacts of climate change on crop production are huge. The agricultural practices should be targeted towards strengthening and sustaining land productivity and reducing greenhouse gas emissions. The vulnerability of farmers to climate change can be reduced by adopting the climate-smart and resilient production practices, which can simultaneously boost productivity, enhance resilience, and reduce greenhouse gases emissions. Some of the technologies and practices that can be helpful in tackling climate change are conservation agriculture, cover cropping or inter/mix-cropping with legumes in the cropping

systems, cultivating less water requiring crop varieties, adjusting the planting dates, adopting water-smart and precision water management strategies, and practising agroforestry and terracing (Krupnik et al., 2021). Climate-smart agriculture technologies should be tailored to specific agro-ecological conditions and socio-economic contexts.

Development of climate-resilient crops/varieties such as early-maturing, deep rooting, tolerance to drought and heat, and appropriate agronomic practices such as planting method, planting time adjustment to escape extreme heat or drought periods, adaptive water management techniques, and high-quality weather forecast systems are urgently needed. Building farmers' adaptive capacity to extreme weather and climate change is important in mountains and hills, which will make them aware of the impacts of climate change and prepare them to cope with such threats (Subedi et al., 2016). The adoption of climate-resilient crops and management practices depends on availability and effectiveness of extension and outreach services (Acevedo et al., 2020).

(viii) **Support market and value-chain development**

Adequate investment in rural infrastructures and markets is essential to increase farmers' access to inputs, adoption of improved technologies, and farmer-market linkages. Timely announcement and implementation of minimum support prices on major cereals is critical to ensure markets and provide incentives for farmers. Promotion of cereal-based agribusiness and value-chain support help create employment opportunities to youth in rural areas. In addition, necessary policy and institutional support is needed to attract private sector investment in cereal-based processing industries, technologies, and trade to improve national self-sufficiency by reducing import of cereal grains and processed foods products.

6 The Roadmap 2040

The focus of this chapter is to provide our perspective to meet the goal of achieving self-sufficiency in cereal grain production in Nepal by narrowing the yield gaps at various levels by 2040. This requires policy and institutional reforms, and implementation of priority research areas as discussed above (Sect. 5) with a focused plan of actions and involvement of various stakeholders as follows:

- By 2035, ensure at least 50% of the current rain-fed lands have irrigation facility and at least two-third of the irrigable lands have assured year-round irrigation facility. For this, there should be a focused investment in developing appropriate irrigation infrastructures.
- By 2030, establish a manufacturing facility in the country to ensure the required quantity of chemical fertilizers are made available to farmers.

- Institutional reforms should be aimed at improving governance and enhanced institutional quality by equipping the research organizations with modern scientific equipment and developing skilled human resources. This should be a continuous process, and all reforms should be completed by 2040.
- There should be focused research and development on improved, high-yielding and pest and stress-tolerant crop varieties, and make their seed availability to farmers. This should be done in collaboration with international research organizations and universities.
- Strong policy interventions and institutional support and commitments are required for institutional reforms and agricultural transformation. All levels of government should be involved in agricultural development with resources allocation including financial and human resources to achieve the goal by increasing cereal yields, reducing yield gaps, and achieving self-sufficiency in cereal grains.
- Public–private investment in agriculture development programs should be promoted to achieve the goal by increasing cereal yields, reducing yield gaps, and achieving self-sufficiency in cereal grains.
- As transfer of technologies is an important component to boost crop production, farmers' access to agriculture extension services should be substantially improved to adopt new and improved crop varieties and best management practices to increase yields, reduce yield gaps, and achieve self-sufficiency in cereal grains.

7 Conclusions

The analysis of yield potentials and yield gaps of major cereal crops showed large yield gaps between the potential, achievable and farmers' field yields. The major factors causing yield gaps are identified as limited water and nutrient supply, use of poor-quality seed of low-yielding varieties, low seed replacement rates, growing crops in degraded lands, vulnerability of crops to adverse climatic variables, and incidence of pest and diseases. The only practical option to increase food production and achieve self-sufficiency is by increasing yields per unit area, reducing yield gaps, and increasing cropping intensity. Nepal can attain food self-sufficiency by 2040 if cereal yields are increased and yield gaps are reduced or closed. However, the current levels of investment in research and development are not adequate to increase yields and reduce yield gaps. Hence, major thrusts of the government should be prioritized investments in irrigation infrastructure, improved fertilizer supply either by in-country production or improved supply chain systems, research and development of high-yielding climate-resilient varieties, adaptation of climate-smart agricultural practices, and effective technology transfer measures.

In addition, the remaining agricultural lands should be safeguarded from further loss. There will also be a need for institutional reforms and development of skilled human resources in agricultural research and extension institutions. Agricultural policies and programs should emphasize capacity building of researchers, extension

workers, and farmers. Innovative extension and agribusiness systems and use of digital technologies are critical for rapidly scaling up technologies across the country to achieve food security. With the suggested approaches in place, Nepal can produce enough food and turn into a food-self-sufficient country. This will enable us to cut the imports of food grains thereby saving the hard-earned foreign exchange.

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Chapter 21

Climate-Smart Agroforestry for Sustainable Landscapes and Agri-Food Systems' Transformation in Nepal



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Abstract Increasing demand for food and non-food products by a growing population accompanied by shrinking area of agricultural land—with 17% abandoned or underutilized—has challenged sustainable agricultural development in Nepal. Yet agriculture, which occupies 24.2% of the land area, contributes 23.9% to GDP, engaging two-thirds of the population. Agricultural practices often combine forestry activities across landscapes, forming agroforestry systems. Application of an innovative, climate-smart agroforestry (CSAF) approach to agricultural landscapes can produce a wide range of ecosystem goods and services. A wide range of policy instruments have made clear provisions for utilizing abandoned and marginal land through agroforestry practices that contribute to climate and livelihood goals. However, abandonment of agricultural land is ever-increasing owing to low productivity, out-migration and lack of labor, off-farm income sources and enhanced purchasing power, unscientific land management policies, rugged terrain and harsh climatic conditions, invasive plants and land fragmentation. We recommend policy and institutional reforms through the development of a national roadmap based on a nexus approach to support land-sector policies and priorities, such as strengthening climate and agricultural information services; conservation and sustainable use of agrobiodiversity through site-specific crops in CSAF; development of value chains of CSAF products in partnership with the larger private sector; subsidies and safety nets for resource-poor smallholding and marginalized farmers; building capacity in CSAF technologies and practices; provision of infrastructure and other facilities for commercial

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CSAF; establishing CSAF as wildlife corridors; and research into the full set of ecosystem services, including carbon and ecotourism, provided by CSAF. This will not only support the agri-food sector but also contribute to climate, livelihood and development goals. This chapter presents the authors' perspectives on the key challenges facing the agricultural sector and, particularly, the agroforestry sub-sector, and recommends ways for maximizing economic, social and environmental benefits from a CSAF approach.

Keywords Agricultural transformation · Climate-smart agroforestry · Degraded land · Sustainability · Roadmap

1 Introduction

Nepal has 2.22 million hectares of agricultural (crop land and pasture combined) land (37.3% of total land), with 62% of its households' livelihoods (with over 70% as women farmers) depending on agriculture (NSO, 2023a). Almost 50% of households are food insecure, nearly one-fourth are poor and 14% are undernourished (MoALD, 2018). The average land parcel size has decreased from 0.21 ha in 2011/12 to 0.19 ha in 2021/22 (NSO, 2023a), leading to increased land fragmentation with negative impact on productivity, thereby reducing economic opportunities for farmers. Further, owing to a lack of management of rural migration and lack of development and implementation of science-based land-use policy, large acreages of agricultural lands (17% of total agricultural land) are abandoned (MoALD, 2023). Further, there is an increasing trend of arable land being fragmented and used for the construction of houses and industries, especially in the Terai region and peri-urban areas (MoF, 2023).

The dominant land cover in Nepal is forest (43.4%) followed by cropland (22.6%) and grassland (14.7%). The remaining 19.3% of total land area is covered by snow, bare rock, other wooded land, glaciers, riverbeds, water bodies and built-up areas (FRTC, 2024). Nepal has been predominantly an agrarian economy but is undergoing a shift, with a decreasing contribution from the agricultural and industrial sectors to Gross Domestic Product (GDP) and an increasing contribution from the services sector. A decreasing population in the agricultural sector driven by high numbers of rural residents, mainly men, migrating for foreign employment and subsequently increasing amount of abandoned arable lands, are the major reasons for the decrease in production and, hence, declining contribution of the sector to GDP (MoF, 2024).

Nepal is ranked as one of the most vulnerable countries for climate-related disasters owing to its diverse geo-climatic system, featuring heavy monsoons, steep and high-altitude terrain and remote locations. Further, the agricultural sector largely lacks adequate resources for adaptation. Nepal has formulated a wide range of policies, procedures and guidelines that are directly or indirectly related to climate change mitigation, adaptation and building resilience of agricultural and natural resource

systems. However, integration of these policies is weak and, in some cases, lacking, which has constrained realization of the anticipated outcomes.

Fragmented land holdings, land abandonment and scattered production are key challenges for Nepal's agricultural sector (NPC, 2021). Further, the increasing population and associated demand for food, agricultural non-food products and biomaterials with new consumption patterns and out-migration of the traditional agricultural labor force are substantial challenges in themselves. The agricultural sector in Nepal is highly vulnerable to climate change, especially owing to increasing temperatures and changes in precipitation patterns affecting crop and livestock production (MoFE, 2021). Climate change is threatening agri-food and biomaterial production, food security and sustainable supply of raw materials (MoFE, 2021). Increasing land abandonment and climate change impacts have severe implications for sustainable land use, agricultural development and food security in Nepal.

2 Agroforestry and Climate-Smart Agroforestry Systems

Agroforestry is a common and traditional farming system across all agro-ecological regions in Nepal but more particularly in the hills and mountains. It is practiced in various forms by integrating crops, livestock and trees and, in some cases, fisheries. Agroforestry systems are practiced by farmers and communities around the world for millennia. In Nepal, a study identified seven agroforestry systems and 35 agroforestry practices in eastern, central and far-western regions of the country (Amatya et al., 2018). Similarly, FRTC (2019) found that altogether 12 agroforestry systems and 41 agroforestry practices were practiced in 44 districts of the Terai and Mid-hills physiographic regions. In the Terai, there were tree-based commercial agroforestry practices focusing on timber species, such as eucalyptus, teak and poplar. On the other hand, in the central parts of the Mid-hills, there were farm-based subsistence practices dominated by fruit and fodder trees, and in the western and eastern Mid-hills, they were farm-based commercial practices dominated by tea, coffee, cardamom and some minor forest products.

One of the most practiced agroforestry systems in Nepal—agrisilviculture—has four different practices based on species such as (i) *Camelia sinensis* (tea) under *Albizia procera* and *Dalbergia sissoo*; (ii) turmeric and ginger under *Eucalyptus camaldulensis*; (iii) seasonal agricultural crops under *Tectona grandis*; and (iv) seasonal agricultural crops along with mixed tree species in the Terai. Whereas ten different practices—e.g., tea and cardamom under *Alnus* species—are featured in the Mid-hills. Khatri et al. (2023) found five different agroforestry systems, namely (i) silvopasture; (ii) commercial crops under tree shade; (iii) home gardens; (iv) trees in and around farmland; and (v) fruit tree orchard. Limited technical know-how among farmers, the farm labor shortage, limited market links, fragmentation of land and increasing number of dry days are considerable challenges facing traditional agroforestry practices in the Terai and Mid-hills regions (FRTC, 2019). Nevertheless, the

key barrier for agroforestry adoption is the lack of technical knowledge in cultivating, managing and harvesting agroforestry species (Regmi & Thapa, 2023).

“Climate-smart agroforestry” (CSAF) is a relatively new terminology used for a farming system that integrates trees, crops and/or livestock on a unit of land and is expected to provide benefits to farmers under a changing climate. CSAF refers to a range of systems, including isolated trees within agricultural fields, hedged farmlands, small woods adjoining fields, tree fallows in shifting cultivation systems, oases in deserts, trees in savannas and forests shaped by agropastoral practices (Ntawuhunga et al., 2023). CSAF can be defined as an approach to transforming and reorienting agricultural systems through the integration of trees on farms to increase, sustain and diversify production for increased food security under the new realities of climate change. The Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) in partnership with a wide range of stakeholders has been researching and demonstrating locally appropriate CSAF models by integrating trees with crops, livestock and fish globally for decades, based on the “right tree in the right place for the right purpose with respect for rights” principles, which have huge potential to be applied in the Nepalese context to drive a sustainable transformation of landscapes and agri-food systems (CIFOR-ICRAF, 2024).

Several policy instruments—such as the 16th Five-year Periodic Plan, National Agroforestry Policy 2019, National Agriculture Policy 2004, National Climate Change Policy 2019, Agriculture Development Strategy (2015–2035)—have made provisions for utilizing abandoned and marginal land through agroforestry practices. The Agriculture, Forestry and Other Land Use (AFOLU) section of Nepal’s Nationally Determined Contribution has highlighted targets related to agroforestry, such as (i) afforest/reforest viable public and private lands, including agroforestry; (ii) promote intercropping, agroforestry, conservation tillage, and livestock and agricultural waste management; (iii) ensure increased access of climate-smart agricultural technologies by women, indigenous people, smallholder farmers and marginalized groups (MoFE, 2020). However, agricultural land abandonment is influenced by both socio-economic and bio-physical factors, such as out-migration, lack of agricultural labor, access to off-farm income sources, enhanced purchasing power, unscientific land management policies, rugged terrain, low agricultural productivity, harsh climatic conditions, invasive plants and land fragmentation (Paudel et al., 2020).

Considering above issues and continuing increase in land abandonment, we see there is a huge opportunity to utilize abandoned and underutilized agricultural lands to produce food and non-food products to satisfy increasing demand, while maintaining ecological functions, through deployment of CSAF, which has been demonstrated to be a win-win solution for many climate, livelihoods and development challenges, such as those Nepal faces. If applied and managed appropriately, CSAF can deliver positive, transformational changes to the agricultural sector. Based on a review and synthesis of peer-reviewed journal articles and grey literature—policy and regulatory frameworks, economic surveys, agricultural and population census reports—we provide our perspective on the key drivers and challenges facing the agricultural sector, policy responses and possible solutions for transformations of landscapes

and agri-food systems sustainably through alternative land management such as the CSAF practices.

3 Drivers and Challenges of the Agroforestry Sector

There are socio-economic and bio-physical drivers for non-adoption of agroforestry systems in Nepal. Socio-economic drivers include high initial costs for adoption of agroforestry systems, limited knowledge of the full benefits of agroforestry, limited information on the benefit–cost analysis of agroforestry practices, and limited markets and marketing information (Atreya et al., 2021). Fragile terrain, land fragmentation and small landholdings, depletion of the natural resource base and climate-induced hazards are some of the bio-physical drivers (Pandit et al., 2014). Complexes of technological and institutional factors also act as the underlying drivers for non-adoption of agroforestry systems. Dissemination and adoption of technology, introduction of exotic species, and poor site and species suitability are some of the technological drivers. Harmonization of policies to support agroforestry practices, taxation of agroforestry products, hurdles in transportation of agroforestry products, inadequate institutional arrangements at national and sub-national levels for supporting farmers in adopting agroforestry practices, and limited knowledge and capacity of farmers in practicing scientific agroforestry are some of the policies and institutional drivers.

Out-migration, agricultural land abandonment and community forest mismanagement have been identified as drivers of afforestation of privately managed land in Nepal (Smith et al., 2024). Declining rural populations and land abandonment, fragmented land holdings, land conversion, and scattered and low production are the key challenges (NPC, 2021), resulting in farming alone being insufficient for sustaining the livelihoods of rural households (Paudel et al., 2014). In 2021, Nepal's population was 29.16 million with an annual average growth rate of 0.92% (NSO, 2023b) but as of mid-March 2024 around 5.97 million people (mainly men) took labor permission for foreign employment (MoF, 2024). There is limited technical know-how, including agro-meteorological services, among farmers to encourage development of CSAF. A shortage of quality planting material and poor market information systems are also hindering development. Further, farmers face challenges in selling tree products grown on farmland and lack insurance and subsidized credit facilities from financial institutions. There are also challenges in selecting site-specific, appropriate CSAF systems and enhancing study, research and extension services of appropriate species. Weak institutions and governance systems are seen as crosscutting challenges for the sector. Overarching all, climate change is negatively impacting the agricultural sector and acts as an imperative for wide-scale development of CSAF.

4 Policy and Institutional Responses

Nepal has formulated several sectoral and cross-sectoral legislation, policies, strategies and plans related to agricultural development and promotion of agroforestry systems. Some of the major policy and legislative instruments include the Constitution of Nepal 2015, the 15th Five-year Development Plan (2019/20–2023/24), the 16th Five-year Development Plan (2024/25–2028/29), National Agriculture Policy 2004, National Agroforestry Policy 2019, Agro-biodiversity Policy (First Amendment) 2014, Rangeland Policy 2012, National Fertilizer Policy 2001, Agriculture Mechanization Promotion Policy 2014, Agriculture Commercialization Promotion Policy 2006, Food Safety and Standard Act 2024, Pesticide Act 1991, Animal Health and Livestock Services Act 1999 and Regulations 2000, Right to Food and Food Sovereignty Act 2018 and Regulations 2023, Feed Act 1976 and Regulations 1987, Seed Act 1988 and Regulations 2013, and the Agriculture Development Strategy (2015–2035). Major policy instruments and salient features associated with agroforestry and associated gaps are summarized in Table 1.

The Ministry of Agriculture and Livestock Development (MoALD) is the mandated government agency for the overall growth and development of the agricultural, livestock and agroforestry sectors. There are seven ministries responsible for agriculture and livestock with their offices under the provincial government. The Constitution of Nepal has provided exclusive right to local governments to oversee the agricultural and livestock sectors, with metropolitan cities, sub-metropolitan cities, urban municipalities and rural municipalities establishing dedicated units to oversee agricultural- and livestock-related works within their jurisdictions.

In particular, the National Agroforestry Policy 2019 aims for the development, expansion and commercialization of CSAF system. The policy envisages the integration of agricultural and forestry components at a range of scales: in fields, on farms and across landscapes. The objectives are (i) increasing agricultural, livestock and forest products by enhancing productivity and multipurpose use; (ii) conserving environmental and biological diversity by reducing pressure on forests, maintaining environmental quality and supporting climate-resilient ecosystems; (iii) creating opportunities for livelihoods, employment and income generation along with food security; (iv) commercialization and facilitation of investment opportunities; and v) research and capacity enhancement. The Policy states that the Government shall form an Agroforestry Inter-Ministerial Coordination Committee at central level that includes members from a wide range of institutions, such as MoALD, Ministry of Forests and Environment (MoFE), National Planning Commission, Agricultural Research Council, National Farmers Groups Federation, National Cooperative Federation and the Federation of Community Forestry Users.

Table 1 Salient features of different policy instruments related to agroforestry in Nepal

S. No.	Major policies	Provisions for agroforestry	Gaps
1	Constitution of Nepal 2015	Food sovereignty as fundamental right; optimum utilization of agricultural land	
2	16th Five-year Periodic Plan (2024/25–2028/29)	Optimum utilization of abandoned agriculture land; implementation of climate-smart agriculture practices; establishment of agroforestry-based enterprises; agroforestry promotion in degraded forests and unutilized Government land, including public land	Came into effect in fiscal year 2024/25
3	National Agroforestry Policy 2019	Encourages commercial and collective agroforestry systems; facilitate research into agroforestry, value chains and farmers' access to markets; promote industry based on agroforestry production and market arrangements; provide financial incentives for the agroforestry sector; promote agroforestry systems on abandoned, fallow and marginalized land; develop and implement appropriate agroforestry models; and invest in research and development of agroforestry	Despite the policy provisions, there is limited implementation of programs by national and sub-national governments
4	National Forest Policy 2018	Incentivize through subsidized loans for promotion of agroforestry; implement activities related to publicity, technology handover and capacity building of agroforestry owners	There are still issues with providing subsidized loans for promoting agroforestry in Nepal
5	National Climate Change Policy 2019	Promotion of agroforestry with multipurpose tree species on abandoned agricultural land	Around 17% of total agricultural land remains abandoned, which could be utilized for appropriate agroforestry models
6	National Agriculture Policy 2004	Promote agroforestry systems on abandoned, fallow and marginalized land for twin objectives of land improvement and contributing to poverty reduction	Around 17% of total agricultural land remains abandoned, which could be utilized for appropriate agroforestry models

(continued)

Table 1 (continued)

S. No.	Major policies	Provisions for agroforestry	Gaps
7	Agrobiodiversity Policy (First Amendment) 2014	Identification, protection, promotion and sustainable utilization of agrobiodiversity and traditional knowledge; equitable sharing of benefits arising from agricultural genetic resources and traditional knowledge	Bill has not yet been enacted for equitable sharing of benefits arising from agricultural genetic resources and traditional knowledge
8	Agriculture Development Strategy (2015–2035)	Restore degraded land, enrich public lands and increase productivity of low-yielding farmlands with appropriate pro-poor agroforestry models to achieve the goals of food security, environmental sustainability and poverty alleviation	Around 17% of total agricultural land remains abandoned, which could be utilized for appropriate agroforestry models
9	Forestry Sector Strategy (2016–2025)	Exempts forestry products originating from private land from value-added tax (similar to agricultural products); encourages generation and provision of new knowledge, information and technologies on farming of high-value, non-timber forest products and multipurpose and fast-growing tree species	Forest Regulations 2022 simplified the transportation of forestry products from private land, but issues remain about the free transportation of such products, similar to agricultural products. There is inadequate technical backstopping from concerned Government agencies for the promotion of agroforestry and private forestry

Source Compiled by authors

5 Possible Solutions and Ways Forward

The shrinking area of cultivable land and increasing abandoned land, growing population, declining agricultural workforce, shrinking incomes from farming, food insecurity and climate change are major challenges that require immediate attention. These challenges are also an opportunity for promoting CSAF practices for landscape restoration, carbon sequestration and improving farmers' livelihoods. CSAF deployed as a rehabilitation measure and for greening the hills and plains will also sequester carbon and utilize abandoned and underutilized land while the related development of CSAF value chains is a crucial component.

6 Climate-Smart Agroforestry

There are various types of agroforestry or CSAF systems practiced globally, many of which are either already practiced in, or have potential for, Nepal (Tables 2 and 3; Dhakal et al., 2022; FRTC, 2019). Many of these systems need site-specific evaluation. CSAF increases functional diversity and scope for synergy among components, supports recycling and economic diversification, enhances soil and animal health, and reduces inputs. CSAF provides numerous benefits for many aspects of human life and the environment (Table 4, Fig. 1). The various practices can play a major role in providing a community's daily needs, enhancing biodiversity of flora and fauna, moderating microclimates, mitigating and adapting to climate change, conserving soil and water and maintaining soil health, and restoring degraded landscapes (CIFOR-ICRAF, 2024; Hagazi et al., 2023; Ntawuruhunga et al., 2023; Octavia et al., 2022).

Sustainable food systems achieved through CSAF help countries and communities to adapt, build resilience and mitigate emissions, thereby ensuring food security and nutrition while reversing environmental degradation. To realize these benefits, Nepal needs to develop holistic and integrated approaches from its various national strategies to address the interlinked challenges of climate change, food and nutrition insecurity, quality and quantity of water supply, degraded land, reduction of biodiversity and energy transformation (FAO, 2023). CSAF systems provide carbon sequestration services, as demonstrated in many studies, including a recent study in India that found that commercial agroforestry systems were emerging as a practical and eco-friendly solution for mitigating climate change (Chavan et al., 2023). However, it is important to note that CSAF initiatives that aim to sustainably increase productivity, enhance resilience, and reduce or remove greenhouse gases require planning that addresses trade-offs and synergies between productivity, adaptation and mitigation (FAO, 2013).

7 Commercialization and Modernization

Nepal's Agriculture Development Strategy has four strategic components of (i) improved governance; (ii) higher productivity; (iii) profitable commercialization; and (iv) competitiveness. The Strategy defines agricultural commercialization as "the transformation from subsistence production (production for own consumption) to production for sale of surplus products and services" (MoAD, 2015).

Agricultural commercialization has long been viewed as an effective strategy for reducing poverty in the poor rural areas wherein farmers grow crops not only for home consumption but also sell some or all their production. Commercialization itself, as the National Agriculture Policy advocates, implies transformation of the entire agricultural sector into a competitive, climate-resilient, self-reliant and export-oriented industry.

Table 2 Types of agroforestry or climate-smart agroforestry practices around the world

S. No.	Major system	Sub-category	Description
1	Agrisilviculture (including shrubs, vines, crops and trees)	Improved fallow	Woody species planted and left to grow during a “fallow phase”
		Taungya	Combined stand of woody and agricultural species during initial stages of establishment of plantations
		Alley cropping	Woody species in hedges; agricultural species in alleys in between hedges; micro-zonal or strip arrangement
		Multilayer tree garden	Multispecies, multilayer, dense plant associations with no organized planting arrangements
		Multipurpose trees on crop land	Trees scattered haphazardly or according to a systematic pattern on bunds, terraces or plot/field boundaries
		Plantation crop combinations	(i) Integrated, multistory (mixed, dense) mixtures of plantation crops (ii) Mixture of plantation crops in alternate or other regular arrangement (iii) Shade trees for plantation crops; scattered shade trees (iv) Intercropping with agricultural crops
		Homegarden	Intimate, multistory combination of various trees and crops around a homestead
		Trees in soil conservation and reclamation	Trees on bunds, terraces, raisers, etc., with or without grass strips; trees for soil reclamation
		Shelterbelt, windbreak, hedge	Trees around farmland/plots
2	Silvopastre (trees, pasture and/or livestock)	Fuelwood production	Interplanting firewood species on or around agricultural land
		Trees on rangeland or pasture	Trees scattered irregularly or arranged according to a systematic pattern
		Protein bank	Production of protein-rich tree fodder on farm/rangelands for “cut and carry”
3	Agrosilvopasture (trees, crops, pasture, livestock)	Plantation crop with pasture and livestock	Cattle or other livestock grazing under tree crops
		Homegarden involving livestock	Intimate, multistory combination of various trees, crops and animals around a homestead

(continued)

Table 2 (continued)

S. No.	Major system	Sub-category	Description
		Multipurpose, woody hedgerow	Woody hedge for browsing, mulch, green manure, soil conservation
		Apiculture with trees	Flowering trees for honey production
		Aquaforestry	Trees lining fishponds, with leaves used as forage for fish
		Multipurpose woodlot	For various purposes (e.g., firewood, timber, fodder, soil protection, soil reclamation)

Source Adapted from Dhakal et al. (2022)

To achieve these multiple economic, environmental and social goals, such a transformation needs to be led by CSAF owing to the concept’s inclusiveness and production of multiple benefits. To do so, farmers will need technical support and services; digital and other advanced technologies; easy access to markets, input suppliers and service providers; capacity to adopt high-value crops; and knowledge of productive combinations. Concurrently, development should include targeted enhancement of rural infrastructure, establishment of market information systems, support for entrepreneurship, improvement of mechanization in collaboration with the private sector and cooperatives, and provision of credit, insurance and agro-meteorological services to promote and commercialize CSAF systems.

8 Sustainable Use of Abandoned and Underutilized Agricultural Lands

Nepal suffers from widespread land abandonment and underutilization of productive land owing to rural depopulation, with traditional farming systems producing conventional agri-food crops being proven to be less profitable, also a contributing factor to a decrease of interest in farming among younger generations. CSAF that combines local and scientific knowledge with advanced practices to produce high-value products—such as nuts and fruits, medicinal and aromatic plant materials—from previously barren or underutilized land can be an exciting venture for younger people seeking opportunities to contribute to the financial and nutritional wellbeing of their families, communities and the nation.

There are several studies that demonstrate the utilization of abandoned lands for increasing productivity and attracting youth to agriculture in Nepal. For example, Subedi et al. (2021) found that farmers identified seven options for reutilization of abandoned cropland: (i) cash cropping; (ii) fruit crops; (iii) spices and medicinal crops; (iv) fodder trees; (v) cereal crops; (vi) woodlots; and (vii) mixed subsistence farming. Another study, from western Nepal, identified CSAF options to reutilize

Table 3 Various agroforestry or CSAF systems and practices in the Terai and Mid-hills regions of Nepal

Agroforestry system	Agroforestry practices in Terai region
Agrisilviculture	<i>Camelia sinensis</i> (tea) under <i>Albizia procera</i> and <i>Dalbergia sissoo</i>
	Turmeric and ginger under <i>Eucalyptus camaldulensis</i>
	Seasonal agricultural crops under <i>Tectona grandis</i>
	Seasonal agricultural crops with mixed tree species
Hortisilviculture	Banana with <i>Eucalyptus camaldulensis</i> and <i>Tectona grandis</i>
	Mango with <i>Eucalyptus camaldulensis</i> and <i>Tectona grandis</i>
	Avocado and pomegranate with various tree species
	<i>Eucalyptus camaldulensis</i> and <i>Mangifera indica</i> with asparagus, citronella, palmarosa and mentha
Hortiagriculture	Fruit trees with seasonal agricultural crops
Agrisilvihorticulture	Agricultural crops with banana and tree species
	Fruit trees and agricultural crops with <i>Tectona grandis</i> , <i>Shorea borneensis</i> and <i>Dalbergia sissoo</i>
	Fruit trees, agricultural crops and seasonal vegetables with <i>Eucalyptus</i>
	Mango and agricultural crops with <i>Eucalyptus camaldulensis</i> , <i>Tectona grandis</i> , <i>Populus</i> spp., <i>Melia azedarach</i>
Agrosilvipasture	Agricultural crops with <i>Acacia catechu</i> , <i>Elaeocarpus ganitrus</i> and pig farming
	Agricultural crops, tree species along with grasses and livestock
Silvofishery	Fish farming with <i>Eucalyptus camaldulensis</i> , <i>Tectona grandis</i> , mango and <i>Dalbergia sissoo</i>
	Fish farming with <i>Tectona grandis</i> , <i>Paulownia tomentosa</i> and <i>Shorea borneensis</i>
Agrosilvofishery	Fish farming with <i>Eucalyptus camaldulensis</i> , <i>Tectona grandis</i> and seasonal crops
Apiculture	Bee farming in conjunction with <i>Tectona grandis</i> and <i>Paulownia</i> spp.
Agrohortisilvopasture	Agricultural crops and <i>Areca catechu</i> with <i>Tectona grandis</i> , <i>Eucalyptus camaldulensis</i> , <i>Elaeocarpus sphaericus</i> , <i>Shorea borneensis</i> , <i>Acacia catechu</i> and livestock
<i>Agroforestry practices in the Mid-hills Region</i>	
Agrisilviculture	Tea under <i>Alnus nepalensis</i>
	Cardamom under <i>Alnus nepalensis</i>
	Cardamom with <i>Thysanolaena maxima</i> , <i>Elaeocarpus ganitrus</i> , <i>Alnus nepalensis</i> , <i>Schima wallichii</i> and fodder tree species
	Cardamom and coffee under <i>Alnus nepalensis</i>
	Coffee under multipurpose tree species
	Coffee, maize and seasonal vegetables under <i>Elaeocarpus ganitrus</i>
	<i>Cinnamomum tamala</i> with agricultural crops
	<i>Thysanolaena maxima</i> with <i>Cinnamomum tamala</i>

(continued)

Table 3 (continued)

Agroforestry system	Agroforestry practices in Terai region
	Kiwi, cardamom and <i>Swertia chiraita</i> with <i>Taxus wallichiana</i> , <i>Elaeocarpus sphaericus</i> , <i>Michlia champaca</i>
	Non-timber forest products with agricultural crops and various tree species
Hortosilvipasture	<i>Swertia chiraita</i> , <i>Zanthoxylum armatum</i> with fodder and fruit trees
	Multipurpose trees, fodder trees, fruit trees, grasses along with livestock
Hortiagriculture	Mango and banana with maize
	Pear with maize and seasonal vegetables
	Seasonal crops and vegetables under orange and sweet orange
	Coffee under orange, banana, walnut and jackfruit
	<i>Zanthoxylum armatum</i> with orange and agricultural crops
Homegarden	Seasonal vegetables, fruit trees and multipurpose trees
Silvopastoral	<i>Santalum album</i> , <i>Ziziphus budhensis</i> , <i>Schima wallichiana</i> , <i>Litsea monopetala</i> , <i>Ficus semicordata</i> , <i>Toona ciliata</i> and grasses with goat farming
Agrosilvihorticulture	Non-timber forest products with fodder and fruit trees
Agrosilvipasture	<i>Thysanolaena maxima</i> with fodder trees and livestock
	Cardamom and <i>Cinamomun Tamala</i> with <i>Elaeocarpus ganitrus</i> and banana

Source Adapted from FRTC (2019)

abandoned land that are less labor intensive and provide better production (Dahal et al., 2020). Ojha et al. (2022) identified agroforestry, alternative farming practices, crop diversification, medicinal and aromatic plants, and private forests as options for restoration of abandoned land. Another study recommended enhancing access to markets and Government incentives for farmers to cultivate high-profit commercial crops on abandoned farmland (Chaudhary et al., 2020).

Learning how to produce a wide range of food and non-food biomaterials while supporting multiple ecosystem services for the benefit of both humanity and the natural environment elevates farming into a new sphere of opportunity for young people. Access to credit, subsidized interest rates and support for access to domestic and international markets are enabling factors for attracting young people to the CSAF sector.

Table 4 Key social, economic and environmental outcomes of CSAF practices

Criterion	Benefits
Social	Enhanced social cohesion through participatory planning, management and value addition Improved living standards from increased incomes Improved nutrition and health through quality and diversity of food, with associated reduction of malnutritional disorders Empowerment of women and youth through planning, management and value addition
Economic	Sustainable intensification of land through multi-level systems that provide increased production from a unit of land while reducing external input costs Enhanced land productivity with diverse products and services for home use and domestic and international consumption Efficient systems of resource use to achieve environmental benefits and high economic return New product opportunities for industry Increased spending power of rural communities Increased Government revenue Increased opportunities for engagement by the larger financial and industrial sectors
Environmental	Adaptive to climate change through spreading risk across multiple species and practices selected for resilience Enhanced biodiversity through increased number of species on a unit of land with opportunities for connectivity of natural forests across agroforested landscapes, increases in pollinators and creation of habitat Reduced pressure on natural forests leading to reduction of deforestation and contribution to achievement of Land Degradation Neutrality and Net Zero Effective and efficient sustainable agricultural practices that reduce costs and increase diversity, quantity and quality of production Intensive management that provides sustainable products from formerly degraded land, leading to reduction of pressure for extensification
Knowledge	Local and scientific ecological, forestry and agricultural knowledge combined to achieve harmonious synergies at plot, community and landscapes scales Entry points for advanced technologies through nationwide promotion of CSAF Increased capacity for planning and managing proven, sustainable agricultural practices, such as conservation agriculture with trees and good agricultural practices, under the umbrella of CSAF

Source Adapted from (CIFOR-ICRAF, 2024; Ntawuruhunga et al., 2023; Octavia et al., 2022)

9 Ways Forward for an Agricultural Transformation in Nepal

The key challenges in the Nepalese agricultural sector can be overcome under the umbrella of CSAF, which necessarily includes conducive policy and institutional arrangements. We suggest that an efficient and effective measure is to develop a roadmap for fully operationalizing the National Agroforestry Policy 2019, which we outline below.



Fig. 1 Example of well-designed agroforestry practices with associated provisioning, regulating, cultural and supporting ecosystem services in South Sumatra, Indonesia. *Source* Left, authors drawn; Right, WWF (2016)

This would include developing research programs based on challenges faced by the sector, including a genetic resource conservation and development program to support priorities such as strengthening climate and agricultural information services; conservation and sustainable use of agrobiodiversity by promoting site-specific crops in CSAF systems; value chains and market development of CSAF products in partnership with the private sector; investment in a “nexus approach” (integrated food, water, energy, biodiversity and health); restoration of degraded ecosystems and soil and watershed protection through CSAF; subsidies and safety nets for resource-poor smallholding and marginalized farmers; building the capacity of farmers in climate-smart technologies and practices; provision of infrastructure and other facilities for commercial CSAF; establishing CSAF systems for wildlife corridors and connectivity; and research into the full set of ecosystem services, including carbon and ecotourism, provided by CSAF. For example, Neda and Azimi (2012) observed that many small-scale farmers have found agritourism to be an effective means to add to their declining farm incomes with manageable farm resources and rural advantages. Similarly, a study from Indonesia highlighted that climate-smart agroforestry has contributed to promoting tourism activities in Batur UNESCO Global Geopark, Bali (Astarini et al., 2024).

10 Creation of a Roadmap Toward Agricultural Transformation Through CSAF

Based on the challenges identified in the agricultural sector and the recommendations outlined above, we propose that there is a need to develop a clear, step-by-step, national roadmap for the transformation of the agricultural sector into one of sustainable landscapes and agri-food systems through adoption of CSAF. The Government's annual policy and program for fiscal year 2024/25 already emphasizes development of such a roadmap (GoN, 2024), which should run in parallel with a strategic review of the Agriculture Development Strategy (2015–2035), given the changing context of federalization, and use the National Agroforestry Policy as a basis for integration of all elements needed to effect such a comprehensive transformation.

The vision of such a roadmap could be, “A CSAF sector is developed that provides sustainable income and employment opportunities for farmers, thereby contributing toward sustainable landscapes and green, resilient and inclusive development,” with possible strategic pillars of (i) creating an enabling environment through conducive policy and institutional arrangements; (ii) restoring degraded ecosystems and protecting soil and watersheds; (iii) developing value chains for CSAF products; and (iv) research, awareness and capacity building.

Given the complexity of effecting a real transformation to meet the needs of Nepal, the roadmap could include the following aspects.

- i. Identify the steps needed to bring into full and effective operation the Agroforestry Inter-Ministerial Committee to clarify outstanding policy issues and concerns and guide the transformation.
- ii. Describe the governance and institutional arrangements, financial and legal requirements, and human resources, and training and capacity building needs so that the roadmap can be implemented by the Government and related stakeholders without any confusion.
- iii. Adopt a nexus approach, that is, establishment of a strong, inclusive mechanism to ensure collaboration between Government agencies responsible for planning, and agriculture, forestry, land, water, energy, climate, irrigation and finance and other critical actors, such as community associations and the private sector.
- iv. Define responsibilities for improving the capacity of stakeholders in designing and implementing integrated CSAF at plot, community and landscape levels and identifying and promoting market opportunities.

We recommend that the Government of Nepal gives priority for creating and subsequent implementation of the roadmap as a matter of urgency.

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Chapter 22

Pollinator Policy Integration in Nepalese Agricultural Systems



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Abstract Pollination is an important regulating ecosystem service, though it has yet to be fully recognized as a significant agricultural input to the Nepalese agricultural system and beyond. This chapter describes the current status of pollinators and their importance for food and nutrition security nationally and globally, and suggests strategies for reversing pollinator decline by firmly integrating pollination into the Nepalese agricultural systems. Many crops would produce fewer or substantially lower quality fruits or seeds without animal pollination. Pollination plays a vital role in crop production that directly contributes to the conservation of agrobiodiversity and human well-being. In Karnali province, 70% of commonly grown crops are pollinator-dependent. However, pollination is absolutely neglected in the Nepalese agricultural system. Research, education and extension have paid insufficient attention to the management of pollination services, with serious implications for food and nutrition security. Similarly, universities and research institutions have insufficiently prioritized pollination-related studies and research, and these topics find limited space in the national curriculums and extension programs. These omissions stem from the lack of integration of pollinator conservation topics into relevant policy documents from the agriculture and forestry sector. We reviewed the existing literature on pollinator decline across the world, including findings from some research conducted in Nepal during different periods. In addition, we also reviewed important policy documents that include acts, policies, strategies and programs prepared by the Government of Nepal in the agriculture and forestry sector, and realized there is no integration of pollination management and pollinator conservation in our policy landscape. In this context, pollinator policy integration could provide a solution by driving the prioritization of pollinator conservation and management by government and non-government stakeholders, potentially leading to a reverse in the decline of pollinators and pollination deficits in the Nepalese agricultural systems. Therefore, this situation calls for concerted efforts from concerned stakeholders to integrate

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pollination into the national research, education and extension system so that it will play a key role in transforming the Nepalese agricultural sector.

Keywords Agriculture · Conservation · Education · Extension · Pollination · Pollinators

1 Introduction

Animal pollination—the transfer of pollen grains from male to female flower parts by biotic agents—contributes to the reproduction of 75% of global crops and 80% of wild plants, ensuring productive crop yields and maintaining the diversity of both crop plants and wild plants (Klein et al., 2007; Ollerton et al., 2011). Pollination is, therefore, a crucial regulating ecosystem service offered by nature free of cost that must be promoted and utilized efficiently to benefit multiple sectors such as agriculture and forestry. Insects—including bees, flies, wasps and beetles—are the most important group of pollinators though other animals such as birds and bats can also play an important role (Rader et al., 2016).

Pollination is an essential service for ensuring optimal yields of cross-pollinated crops such as apples (*Malus domestica*), squash (*Cucurbita pepo*) and almonds (*Prunus dulcis*). However, many self-pollinated crops such as soybeans also show increased yields in response to frequent visitation of insects (Santone et al., 2022). Pollinator-dependent crops provide a large proportion of many of the key vitamins and minerals (micronutrients) in our diets and are therefore essential for ensuring the nutrition security of the population (Chaplin-Kramer et al., 2014; Smith et al., 2015). Pollinators contribute to 35% of global food production, including 40% of the world's supply of vitamin A (Eilers et al., 2011).

In the last ten years, Nepal's economic reliance on crop pollination has increased five-fold, reaching US\$477 million annually (Devkota et al., 2024). It is clear that

Fig. 1 Difference in crop yields (%) between open pollination and pollinator exclusion



if pollinators continue declining in Nepal, levels of poverty and malnutrition will worsen, further exacerbating existing pressures on natural resources and biodiversity. As an example, field experiments from the Micro-poll project (2020–2022) conducted in the Jumla district of Nepal show the decline in crop yields of major economically and nutritionally significant crops (see Fig. 1) in the absence of insect pollinators (Kortsch et al., 2024).

2 Worldwide Status of Pollinators

In the 1960s and 1970s, the green revolution was initiated in the world based on the concept of intensifying the use of agricultural inputs, especially high-yielding varieties and agrochemicals to increase food crop production (Eliazer Nelson et al., 2019). Many years later, unintended consequences such as air and water pollution, soil quality degradation, agrobiodiversity loss and insect population decline, among others were observed (John & Babu, 2021). One of the significant consequences of industrialized agricultural intensification has been the decline of insect pollinators, resulting from habitat loss, monoculture farming and the heavy use of pesticides. This has greatly impacted the important ecosystem service of pollination by driving the ongoing decline of insect pollinators (Kosior et al., 2007; Potts et al., 2016).

Studies have reported rapid declines of managed honeybee colonies across many countries, largely driven by the incursion of pests and diseases (Brutscher et al., 2016). Meanwhile, native bees and other insects have also shown rapid rates of decline in many countries (Biesmeijer et al., 2006; Potts et al., 2016; Powney et al., 2019). This is a serious concern in relation to food production, as these are significant pollinators of major global crops. Similarly, Soroye et al. (2020) revealed a decline in bumblebee populations of 46% in North America from 1901 to 1974 and 17% in Europe from 2000 to 2014. This decline in insect pollinators can be attributed to different factors such as pesticides, habitat depletion, climate change, agrobiodiversity loss, overgrazing and forest fires, among others (Williamson, 2020). The situation is similar in the context of Nepal: many crops in the Karnali region (e.g., apples, buckwheat and pumpkins) are pollinator-dependent and reliant on a range of native syrphids (primarily *Eristalis spp.*), solitary bees (primarily Halictidae), bumblebees (*Bombus spp.*), and most importantly, the native honeybee *Apis cerana*, which are declining in this region (Kortsch et al., 2024; Timberlake et al., 2024). In addition, Partap and Partap (2001) also reported a decline in insect pollinators and apple yields in apple farming regions, including Jumla district and the wider Hindu Kush Himalaya (HKH) region. In a context where 70% of commonly grown crops in Karnali are pollinator-dependent, this decline is likely to have negative impacts on the local food system, worsening the food and nutrition insecurity of the province.

The conservation and management of wild pollinators has been hindered around the world by the common myth that honeybees are the only important crop pollinators. Numerous wild insects—including wild bees, bumblebees, flies, wasps, beetles

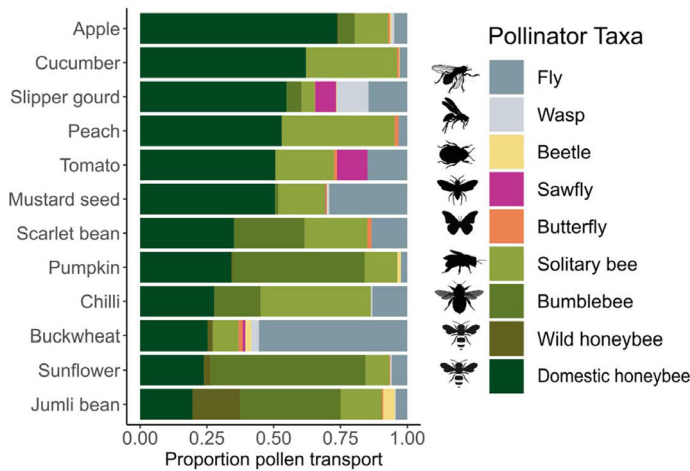


Fig. 2 Pollinator diversity in major crops grown in the Jumla district of Karnali province (adapted from Timberlake et al., 2024)

and butterflies—are also extremely important pollinators and are often far more effective in delivering pollination services (Garibaldi et al., 2013; Lemanski et al., 2022; Rader et al., 2016). This was confirmed by a study in the Jumla District of the Karnali province, which found that many key crops such as buckwheat (*Fagopyrum esculentum*), beans (*Phaseolus vulgaris*) and slipper gourd (*Cyclanthera pedate*) were heavily reliant on non-honeybee pollinators, including bumblebees and hoverflies (see Fig. 2 from Timberlake et al., 2024).

Another common myth is that pesticides are the only factor driving pollinator declines. While they are undoubtedly an important risk factor, there are many other stressors that are often more of a threat for pollinators. The most important of these are the habitat loss and degradation resulting from agricultural expansion and intensification, forest clearing, overgrazing and fires. The loss and degradation of native habitats diminishes food and nesting sites available to pollinators that are crucial for their survival and reproduction (Goulson et al., 2015; Potts et al., 2010, 2016; Soroye et al., 2020).

3 Integration of Pollination in Agricultural Systems

The inadequate pollinator awareness among key stakeholders such as farmers, extension workers and agricultural training centers has meant that pollination is largely ignored as an agricultural input in the Nepalese agricultural systems (Neupane et al., 2023). This is for various reasons, such as insufficient public understanding, inadequate management capacity and no evidence to find policy solutions, which contribute to the limited integration of pollination into our agricultural systems. Moreover,

current awareness of pollinators is mostly limited to managed pollinators such as honeybees, which are not sufficient to ensure optimal pollination services across the country (Mashilingi et al., 2022). Few people are aware of the value of wild pollinators, which have limited efforts to conserve and promote wild pollinator populations. Within Nepal, there are a few initiatives from different sectors that have considered pollination, which are outlined below.

Universities in Nepal such as Agriculture and Forestry University, and Tribhuvan University have integrated courses on honeybees, pollinator conservation and pollinator-friendly practices in their course curricula at the undergraduate and graduate levels, though the scope and content is still limited.

The Global Pollination Project, run by the Food and Agriculture Organization (FAO) in Nepal, enhanced farmer awareness on pollination through Farmer Field Schools (FFS); strengthened the capacities of government extension workers; established a pollination bibliography; and assessed the pollination deficits in vegetables, buckwheat and mustard in collaboration with the Institute of Agriculture and Animal Sciences (IAAS) under Tribhuvan University (TU).

The International Centre for Integrated Mountain Development (ICIMOD), through its regular program on bees and pollination, has been engaged in various strategies to promote managed and wild honeybees for their pollination services in mountain crops, especially in the Hindu Kush Himalaya (HKH) region. Raising awareness of the significance of pollination and pollinators, policy influencing, capacity-building and mainstreaming pollinator concerns in Research and Development systems are some strategies they have adopted over the years.

The Center for Industrial Entomology Development (CIED), a government entity, functions under the Department of Agriculture with the mandate to promote bees and silkworms, which are economically important insects. They have been working to promote commercial beekeeping across the country in coordination with provincial ministries. In March 2024, they signed a quadripartite agreement with the Ministry of Land Management, Agriculture and Cooperatives (MoLMAC) Karnali, Agriculture and Forestry University (AFU) and Mid-West University to establish a beekeeping resource center to promote wild and native bees in the Karnali province of Nepal.

Very few non-government institutions such as Local Initiatives for Biodiversity, Research and Development (LI-BIRD) and HERDi are known to have worked in the pollination sector. LI-BIRD, with its strategic theme, biodiversity and ecosystem health, engages in promoting the integration of honeybees and other non-bee insects for their pollination benefits in agricultural systems as well as promoting agroecology. HERDi has also been working to explore the interrelation of nutrition with pollination, especially in the Karnali province for several years. This initiative has also generated a few important insights that are significant to establish the nutritional and economic importance of pollination.

However, our research, education and extension systems are largely responsible for this lack of public awareness and the fact that pollination is not managed as an important agricultural input alongside pest management, water and nutrient provision. There is limited content in the curricula on crop pollination management including wild pollinator conservation being offered in technical schools and

universities. The situation is similar in research departments of universities and research institutions such as the Nepal Agricultural Research Council (NARC), where pollination-related research work receives less priority. There is an insufficient number of pollination promotion and pollinator conservation programs embedded into our national extension program, whose prime responsibilities include increasing knowledge and strengthening the capacities of farming communities through district-based Agriculture development offices and Agriculture sections established under local governments. The Ministry of Agriculture and Livestock Development (MoALD) at the federal level would benefit farmers and other stakeholders across the country by redesigning its programs to ensure the integration of pollination-related programs into regular government actions.

4 Policy Recommendations for Pollination Promotion in Nepalese Agricultural Systems

Pollination is a cross-sectoral issue affected by multiple domains such as agriculture, forestry and infrastructure development. This must be considered when formulating policies and programs that directly or indirectly affect the insect pollinator population. Policy documents in the form of acts, policies and strategies issued by the government in these multiple domains have neglected the pertinent issue of pollination. Aside from the Bees Promotion Policy (2016), few other policy documents have explicitly mentioned pollination and pollinators (Neupane et al., 2023), and even the Bees Promotion Policy mentions only honeybees and the pollination service offered but fails to address diverse and wild pollinators, which are as effective and important as managed pollinators. The Agrobiodiversity Policy (2007) also mentions pollinators as an important part of agrobiodiversity and focuses on their conservation, but there is lack of integration of pollinator conservation in other related policy documents that directly spell and focus on pollination and pollinator promotion.

- Agrobiodiversity Policy (2007) emphasizes conservation, promotion and sustainable use of agrobiodiversity, and also mentions pollinators.
- Agriculture Development Strategy (2015–2035) emphasizes sustainable biodiversity-friendly farming practices.
- Nature Conservation National Strategic Framework for Sustainable Development (2015–2030) focuses on nature conservation, sustainable use of natural resources and equitable distribution of their benefits.
- National Forest Policy (2019) aims to enhance sustainable forest management and improve the productivity of all types of forests.
- National Biodiversity Strategy and Action Plan (2014–2020) promotes diversity-rich farming systems and practices.
- National Agroforestry Policy (2019) seeks to contribute to making agriculture and forestry more productive and sustainable.

- Bees Promotion Policy (2016) focuses on promotion of honeybees for sustainable beekeeping, pollination and associated products for poverty reduction.
- Karnali Organic Agriculture Policy (2018) prioritizes organic agriculture through agroecological approaches in the province.
- Food Security and Sovereignty Act (2020) aims to enhance food security and sovereignty of people by promoting local production in Karnali province and also dictates the judicious management of agricultural and pasture lands.
- Province Environment Act (2020) ensures Karnali citizen rights to live in a healthy and clean environment and maintain balance between development and the environment. It also provides climate adaptation plan for agriculture and forestry.
- Pesticide Management Act (2019) regulates pesticide registration, imposes restrictions on the use of harmful chemical pesticides, and encourages the wider adoption of home base pesticides in Nepal.

This lack of recognition and guidance by existing policy documents has meant that pollinator conservation and pollinator-friendly farming practices have never been promoted adequately in Nepal, thus avoiding the urgent priority of reversing pollinator declines. Indeed, many of the agricultural changes that have been promoted in government strategies—including the expansion of crop monocultures and the intensification of farming practices—have negatively affected the food, habitat and health of pollinators, likely contributing to their ongoing decline. These elements must be carefully considered to support pollinators and the essential services they provide. This requires certain strategies that must be explicitly mentioned in policy documents for wider implementation.

5 Strategies that Could Be Adopted to Reverse the Decline

The core of these conservation strategies must be based on a three-pronged approach revolving around the food-, habitat- and health-related requirements of pollinators. All of the strategies need to have specific actions based on these three important elements.

5.1 Improve Pollinator Understanding through Research and Evidence

This is the first and foremost priority that we must focus on, as there is no adequate information or evidence on our native and wild pollinators that exist across the agroecological regions. Lack of adequate funding support for research institutions and universities to engage in pollinator-related research is one of the important reasons for this. This can be solved with interventions from the government providing a budget allocation for pollinator research. The three-tiered government must set up the

required facilities and facilitate establishing an enabling environment for researchers to engage in generating new knowledge on pollinators and crop pollination management. The research should focus on co-production of knowledge, thereby promoting exchange among farmers, scientists, Indigenous communities and policymakers to bring effective results to pollinator conservation (Dicks et al., 2016). The research must also consider exploring the food-, habitat- and health-related requirements of pollinators. Potential areas can include ecological pest management farming systems that support insect pollinators and promote their pollination services (Potts et al., 2016). In addition, honeybee disease and pest prevalence, stingless bee colony propagation, pollination efficiency of stingless bees and other wild pollinators can be a few potential areas of research, among others. Research institutions and universities can play an important role in generating novel information and findings on these aspects of pollinators. Independent researchers also hold potential to explore new knowledge on pollinators, who also need support and promotion.

5.2 Pollinator Awareness and Management Capacity

Pollination- and pollinator-related information and programs should receive sufficient space in our national extension programs. We should engage in raising awareness through developing information, education and communication (IEC) materials such as audio-visuals and strengthening capacity-building through trainings, farmers field school, exposure visits, etc. Most extension workers focus only on educating farmers on the use of fertilizers and pesticides as important agricultural inputs, resulting in farmers' limited knowledge about pollination services (Gollin, 2014). Agricultural extension programs and services must embed the promotion and demonstration of pollinator-friendly practices into their annual plans and actions through district-based agriculture offices and local agriculture units, which can help increase adoption of such beneficial approaches (IPBES, 2017; Potts et al., 2016). Similarly, development agencies also need to integrate pollination in their programs so that pollination can reach a wider group of people. Pollinator awareness should not be limited only to farmers; instead, there should be wider campaigns to engage multiple stakeholders—including input traders such as agrovets, schools, environment agencies, infrastructure developers and other private bodies—whose actions are important for pollinator conservation (Baldock, 2020). These stakeholders can be effective agents in promoting pollinator food, health and habitats by establishing green belts, parks, diversified flower strips, and other areas, especially in the peri-urban and in cities. For instance, we can enhance our backyards and balconies through flowers, nesting sites and other vegetation, which acts as a refuge for insect pollinators in cities and helps to maintain biodiversity and a clean environment (Hall et al., 2017).

5.3 Pollinator-Friendly Habitat Conservation and Practice

Forests are an important natural habitat for pollinators, which should be prioritized for protection and restoration. Pollinators not only require forests for habitats, but also to complete the pollinator lifecycle (Ulyshen et al., 2023). Farmer groups and agriculture cooperatives, Community Forestry User Groups (CFUGs) and others residing at the interface of agricultural land and forests need to understand the importance of pollinators and thus engage in their conservation by integrating pollinator-friendly flowering plants in their operational plans. Managed pollinators—including native honeybees and stingless bees—can be a valuable and cost-effective input into farming systems (Heard, 1999): for example, the integration of honeybee colonies into orchards and agricultural fields. Other techniques can also be employed to manage pollinator habitats such as promoting hedgerows and flower strips along the edges of pollinator-dependent and independent crops in agricultural landscapes (Albrecht et al., 2020; Von Königslöw et al., 2022). Similarly, the artificial modifications of habitats such as nesting piles, hoverfly lagoons, bee hotels, bee scrapes and other habitats in our agricultural lands can be crucial for providing habitats for pollinators in the agricultural landscape.

All of these strategies require packaging in the form of a pollinator strategy and action plan that provides solutions for reversing pollinator decline (see Fig. 3) through common understanding and wider implementation from various stakeholders. Such strategies need to be evidence-based with recommendations of actions for different tiers of government to look into the elements affecting pollinator declines and improve these situations.

The recently formulated pollinator strategy of Karnali province in 2024 is an excellent example in Nepal to be scaled up where multiple diverse stakeholders work together to achieve the comprehensive integration of pollinator conservation and management into policy.

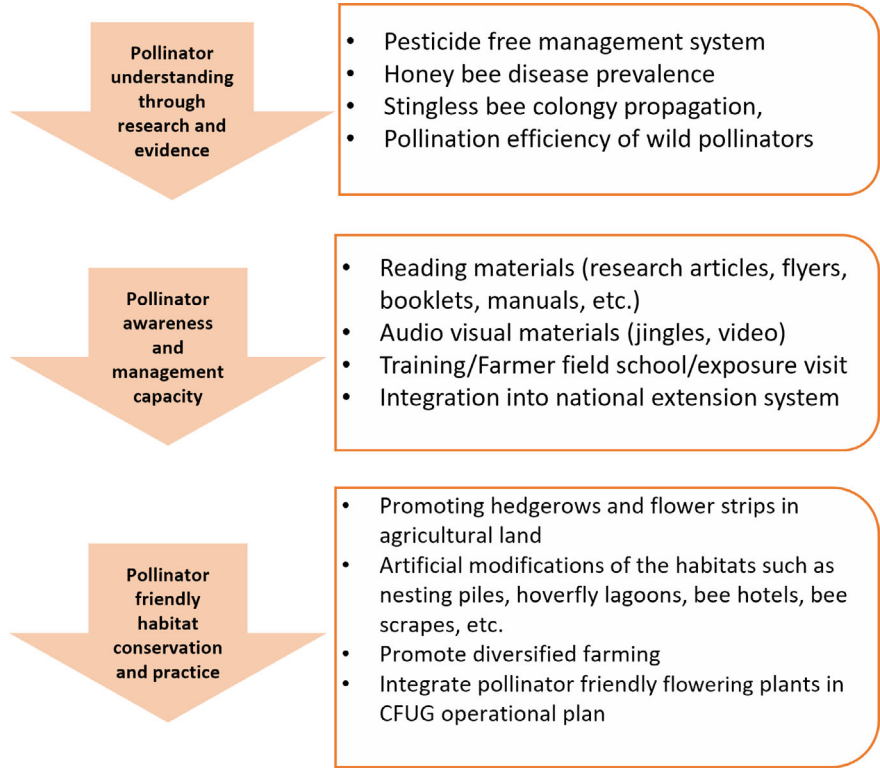


Fig. 3 An outline for implementing pollinator conservation strategies

(continued)

(continued)

Case—Karnali pollinator strategy

The Ministry of Land Management, Agriculture and Cooperatives (MoLMAC) led an initiative to formulate a pollinator strategy targeting to ensure the safeguarding and management of pollination services in Karnali province. This policy initiative was supported by the Darwin Initiative through a project **“Embedding Sustainable Pollination Management into Nepalese Agricultural Systems,”** which was implemented jointly by University of Bristol, LI-BIRD, HERDi and AFU Nepal. The rationale behind the formulation of this strategy was that Karnali province is aiming towards transition to organic, and this strategy, prioritizing pollinator conservation and pollination management, can significantly contribute to promote organic farming in the region. For this initiative, institutions such as the Directorate of Agriculture Development (DoAD), Agriculture Training Center, Integrated Agriculture Laboratory, Agriculture Research Directorate, development agencies, beekeepers, academic institutions and universities such as Agriculture and Forestry University, Tribhuvan University, Mid-West University and the University of Bristol came together to share their expertise and experiences. Previous studies have reported pollinator decline in the region, which is vulnerable to food and nutrition insecurity. The pollinator strategy incorporates various strategic themes and corresponding actions that have the potential to solve the grave problem of pollinator decline, including the negligence of relevant stakeholders in mainstreaming pollination into our agricultural systems. This strategy formulation follows a participatory process with a series of meetings and consultation with stakeholders and will be endorsed by the provincial cabinet to induce its enactment.

6 Conclusions

Pollinators are a crucial component of sustainable agricultural production. To safeguard and enhance this crucial ecosystem service, policymakers and other relevant stakeholders need to prioritize the integration of pollinators and pollination into the research, education and extension system with utmost importance. More importantly, pollination should be recognized as an important low-cost agricultural input for food production, just like fertilizers, irrigation and pesticides. This can only be achieved by preparing and enforcing an evidence-based National Pollinator Strategy to safeguard pollinators and integrate pollination management into the agricultural systems of Nepal, providing long-term benefits to farmers, biodiversity and the economy.

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Chapter 23

Dairy Dynamics: Exploring Nepal's Pathways to Prosperity



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Abstract The dairy industry in Nepal, a vital part of the Nepalese agricultural sector, has witnessed significant development in recent years, marked by substantial investments from both the governmental and private sectors aimed at its modernization and expansion. This effort culminated in the country's attainment of self-sufficiency in milk production by the year 2021. Previously, the industry was limited to the production of processed milk, milk-based confections, yogurt, and ghee. However, the sector has diversified with the introduction of various processed milk products in recent years, including cheese, churpi (dog chew), powdered milk, and chocolates, with churpi emerging as a prominent agricultural export, surpassing 3 billion rupees in export value in fiscal year 2023/24 and exhibiting a rapid escalation in both volume and worth. Nevertheless, the sector is not devoid of challenges. Delays in payments to milk producers have surfaced as a pressing issue, and one major reason behind this is the significant stockpiles of powdered milk, nauni, and ghee due to impediments in sales and distribution channels. In response to the cessation of milk price payments, producers in various regions have resorted to public demonstrations, notably by symbolically pouring milk onto the streets. Concomitantly, the dairy industry has curtailed milk consumption and implemented partial milk holidays nationwide. While immediate redressal efforts are underway, including substantial financial injections into the government-operated Dairy Development Corporation (DDC), such interim measures may prove unaffordable and unsustainable in the long term. There are several possibilities for strengthening the organizational, competitive,

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profitability, and sustainability dimensions of Nepal's milk production and processing enterprise, which serves as a reliable source of livelihood for millions of farmers. This chapter explores strategies aimed at enhancing the competitiveness, profitability, and sustainability of Nepal's dairy sector through product diversification, efficient management practices, and innovation across financial product offerings. Furthermore, it also covers requisite policy and administrative reforms at the governmental level, delineating a roadmap toward the realization of a robust and resilient dairy sector.

Keywords Competitiveness · Dairy · Innovation · Policy reforms · Profitability · Resilient · Self-sufficiency

1 Introduction

Nepal's dairy industry has long been a cornerstone of the country's agricultural sector, accounting for about one-tenth of the national GDP, a significant contribution (Chaudhari et al., 2021). Over the past few decades, the industry has experienced substantial growth and transformation driven by extensive investments and efforts from both the government and private sector. These initiatives have focused on modernizing the industry and expanding its reach, resulting in key advancements that have reshaped its trajectory.

The dairy sector is not only crucial for food security, but also plays a vital role in rural development and economic stability. It provides significant employment in rural areas and supports local economies. However, the sector faces persistent challenges, such as structural inefficiencies and seasonal fluctuations, that hinder sustained growth. Despite these obstacles, there is considerable potential for further development, fueled by increasing domestic demand and expanding opportunities in international markets. To unlock this potential, enhancing dairy processing capabilities and addressing supply chain constraints are critical.

This chapter explores the transformation of Nepal's dairy industry, analyzing its achievements and challenges. It traces the sector's journey toward modernization and highlights key milestones. Additionally, it offers a forward-looking perspective on the industry's future, stressing the need for strategic policy frameworks, strong governance, skilled human resources, and adequate legal provisions. These elements are essential for driving sustainable growth and ensuring the continued importance of the dairy sector in Nepal's economic development.

2 Evolution of the Dairy Sector

2.1 *Historical Context*

Nepal's dairy sector has a rich history deeply intertwined with the nation's agrarian traditions. Traditionally, dairy farming in Nepal was characterized by small-scale, subsistence-level practices. Farmers primarily produced milk for household consumption, with any surplus being sold informally in local markets. This landscape began to shift in the mid-twentieth century, marking the start of a more organized and structured approach to dairy farming. Recognizing the potential of the dairy sector to contribute to national development, the government initiated several key interventions.

In 1952, the establishment of the Department of Livestock Services signaled the beginning of government-led initiatives to support animal husbandry and dairy farming. This was followed by the creation of the Dairy Development Board in 1955 to structure and promote the industry. The First Five-Year Plan (1956–1961) highlighted dairy sector development as part of its agricultural focus, leading to the establishment of the Central Dairy Plant in 1956 with support from New Zealand and FAO to pasteurize and supply milk in the Kathmandu Valley. In 1969, the Dairy Development Corporation (DDC) was formed to manage milk collection, processing, and distribution, shaping the formal dairy sector (Dahal & Thapaliya, 2010). The National Cooperative Development Program, introduced in 1974, promoted dairy cooperatives and supported smallholder farmers, encouraging them to collaborate, pool resources, and collectively enhance their productivity and market access (Shingh et al., 2020). The 1981 expansion of the DDC marked significant growth, with new collection centers and processing facilities. The 1990s saw liberalization policies that allowed private sector participation, leading to the growth of private dairies and cooperatives alongside the DDC. In 1992, the National Dairy Development Board (NDDB) was established to regulate and strategically develop dairy production, processing, and marketing (Upadhyay et al., 2021). The Dairy Development Policy, introduced in 2010, focused on modernizing the industry, improving quality control, and commercializing dairy products. By 2021, Nepal achieved self-sufficiency in milk production, a milestone resulting from decades of policy support and investments.

As we further explore the evolution of Nepal's dairy sector, it becomes evident that these early initiatives laid the groundwork for subsequent advancements. They highlighted the importance of organized structures and external support in fostering growth and resilience within the industry. This historical overview provides a foundation for understanding the current dynamics and future potential of Nepal's dairy sector as it continues to evolve and adapt to changing economic and social landscapes.

2.2 *Modernization and Expansion*

The transformation of Nepal's dairy sector has been marked by a significant shift from informal to formal marketing channels for fresh milk. Traditionally, milk was sold directly by smallholder farmers in local markets without standardized quality checks or pricing. However, the establishment of formal collection centers and dairy cooperatives over recent decades has brought about a transformation, enabling more organized milk collection, quality control, pricing transparency, and the development of standardized processes. This change has enhanced consumer trust in Nepalese dairy products, setting the stage for further growth.

Substantial investments in infrastructure, technology, and training have driven this transformation. The establishment of modern dairy processing plants has revolutionized the industry by allowing for the production of a wider variety of dairy products. These include pasteurized milk, traditional items such as yogurt and ghee, and value-added products such as cheese, churpi (dog chew), powdered milk, and dairy-based confections. This diversification not only meets changing consumer preferences, but also helps maximize resource use and access to export markets. The implementation of cold chain systems has played a vital role in maintaining the quality and safety of dairy products, ensuring compliance with domestic and international standards. Robust quality control mechanisms have also strengthened consumer confidence in Nepalese dairy products, aiding their acceptance in new markets. These developments have linked small-scale producers to broader markets, contributing to Nepal's goal of achieving dairy self-sufficiency.

This modernization process has been a collaborative effort, with both public and private sectors playing key roles. Government initiatives have supported infrastructure development and regulatory improvements, while private enterprises have brought innovation and capital. This synergy has positioned Nepal's dairy industry as a significant contributor to the national economy, and the sector's continued growth offers promising prospects for the future.

3 Achievements and Milestones

3.1 *Self-Sufficiency in Milk Production*

According to the Ministry of Agriculture and Livestock Development (MoALD, 2022), Nepal's dairy sector has grown, with an average annual milk production increase of 4.9% from 1.62 million tons in 2011/12 to 2.48 million tons in 2020/21. Achieving self-sufficiency in milk production by 2021 marks a significant milestone. This success reflects the impact of targeted interventions such as improving milk yield, animal health, and farm management practices. It ensures a stable domestic milk supply, reduces reliance on imports, and positions Nepal as a potential dairy exporter, opening new economic opportunities.

The journey toward self-sufficiency has been both challenging and rewarding. Key government initiatives have been instrumental in driving this progress, particularly those focused on improving breeds through artificial insemination (AI) and the use of sexed-semen, improving animal health and farm management practices (MoALD 2021, NLBO, 2022; Sah et al., 2020). Training programs for farmers have been essential, providing them with the knowledge and skills needed to optimize dairy production. These efforts have been complemented by improved access to veterinary services and quality feed, which have collectively contributed to significant increases in milk yield. Introduction of high-yielding breeds such as Jersey and Holstein from foreign countries is another important factor contributing to this achievement. Furthermore, buffalo milk, with its higher fat content, is becoming increasingly important in Nepal's dairy sector, particularly for value-added products such as ghee and churpi. While cattle milk is primarily used for regular consumption, buffalo milk's role in high-value dairy products underscores its growing significance.

Achieving self-sufficiency in milk production not only ensures food security, but also strengthens Nepal's economic stability, demonstrating its capacity to sustainably meet dairy needs and fostering resilience against external shocks. This milestone highlights the importance of continued investment to further develop the sector and unlock its potential for global market expansion.

3.2 Product Diversification

The diversification of dairy products has played a crucial role in the growth of Nepal's dairy industry. Innovations in product development have introduced a range of value-added items, including various types of cheese, churpi (dog chew), powdered milk, and chocolates. Among these, churpi has become a particularly significant product, emerging as a high-value export commodity. In fiscal year 2023/2024, the export value of churpi exceeded 3 billion rupees, demonstrating its economic importance and the industry's ability to access international markets. A large portion of milk production is also used for traditional and modern products such as peda, barfi, and rasbari, driving year-round milk demand and supporting small dairy farmers while creating jobs in the sweet-making sector. Additionally, products such as yogurt, ghee, paneer, and flavored milk cater to changing consumer preferences, broadening market opportunities.

The introduction of these value-added products marks a key development for Nepal's dairy sector, enhancing its resilience to market fluctuations and diversifying its revenue sources. This diversification reduces reliance on a limited range of products, improving the sector's stability and growth prospects. The success of churpi as an export highlights the potential for other Nepalese dairy products to achieve international recognition, and the sector's focus on value addition has enhanced domestic consumer options, contributing to improved nutrition and positioning Nepal's dairy industry for long-term success.

4 Current State of the Dairy Sector

4.1 Production and Market Landscape

Nepal's dairy sector plays a crucial role in the country's agricultural economy, employing approximately 130,000 individuals and contributing 9% to the national GDP, as well as 33% to the agricultural GDP. Among the 3.8 million farming households across the nation, a substantial 95% own dairy animals (Dairy Sector Strategy—Nepal, 2020). These animals are not only vital for household subsistence and nutrition, but they also provide essential draft power and local transport services.

Despite the sector's significant contribution, the majority of dairy production remains at a subsistence level. Most households primarily produce milk for home consumption, with only limited sales occurring during peak production periods. The commercialization of dairy farming is relatively low, with only about 14% of milk-producing households engaging in both production and sales (Dairy Sector Strategy—Nepal, 2020). This scenario underscores the potential for substantial growth within the sector. Expanding beyond subsistence farming to enhance commercialization could unlock new opportunities and further bolster the sector's economic impact. The current reliance on traditional practices presents an opportunity for targeted interventions to support farmers in transitioning toward more commercially viable operations, thereby enhancing the overall contribution of the dairy sector to Nepal's economy.

4.2 Supply Chain and Market Dynamics

Nepal's dairy sector is characterized by notable seasonal fluctuations in milk production, with distinct flush (surplus) and lean (deficit) seasons. On average, there is a daily shortfall of 550,000 L, highlighting a substantial opportunity for smallholders to increase their production and address this supply gap (Dairy Sector Strategy—Nepal, 2020). This seasonal variability underscores the potential for growth and improvement within the sector.

The sector's structure is diverse, encompassing a broad range of production and processing units. It includes numerous small-scale subsistence producers as well as micro- and small-collection-and-processing units. While there are a few large-scale industrial processing facilities, the presence of small and medium-sized enterprises (SMEs) is growing, particularly in response to emerging trends in commercialization and market demands.

Despite this diversity, challenges remain in terms of supply chain efficiency and market access. Seasonal fluctuations can disrupt supply consistency, and the sector's varying scales of operation—from subsistence farming to industrial processing—can complicate coordination and logistics.

4.3 Neighboring and Global Dairy Landscape

Nepal's dairy industry lags behind global leaders such as India, China, New Zealand, and the Netherlands, who have excelled through strategic investments in technology, cooperative models, and policy reforms. Learning from these countries can help Nepal build a sustainable growth model for its dairy sector. India's dairy success is rooted in its cooperative model, exemplified by Amul, where smallholder farmers access veterinary services and secure milk prices (Barot & Bose, 2023). Programs like Operation Flood transformed India into a top milk producer (Kurien, 2004), and Nepal could adopt a similar cooperative approach, focusing on support services and financial products for dairy farmers. China, meanwhile, has advanced its dairy sector through technology such as automated milking and selective breeding, boosting productivity. Nepal could benefit from small-scale milking machines and partnerships for genetic improvements, particularly in peri-urban hubs. New Zealand's dairy sector thrives on exports, with a focus on high-value products.

4.4 Import and Export Dynamics of Milk Products

The dairy sector in Nepal presents a complex picture characterized by rising import costs, fluctuating volumes, and expanding export markets. Analyzing the trends in dairy product imports and exports reveals significant insights into the sector's evolving dynamics. Data from customs (Foreign Trade Statistics, 2024) reveal that milk powder imports in Nepal have experienced notable fluctuations in volume while showing a consistent rise in value. In 2018/19, the import volume was 2590 metric tons (MT), but it declined to 1742 MT in 2020/21 before recovering slightly to 1833 MT in 2023/24. Despite these variations in volume, the import value surged from NPR 1110.87 million to NPR 1881.58 million over the same period. This discrepancy between volume and value suggests an increase in the per-unit cost of milk powder, reflecting rising international prices or changes in product quality. Cheese imports displayed a generally upward trend, increasing from 302 MT in 2018/19 to 534 MT in 2022/23, although a subsequent decline to 405 MT was observed in 2023/24. Butter imports, on the other hand, have decreased significantly both in volume and value, falling from 234 MT in 2018/19 to just 49 MT in 2023/24, with the value dropping from NPR 121.19 million to NPR 40.46 million. This decline could indicate either reduced demand for imported butter or a rise in local production capacity. Ghee imports were minimal after 2018/19, with only 1 MT imported in 2020/21 and 2 MT in 2023/24, and the import value plummeted from NPR 249.89 million to NPR 2.02 million. This sharp decline suggests a significant decrease in demand for imported ghee, likely due to a surge in local production.

In contrast, export dynamics show a more promising picture. The export volume of cheese exhibited considerable fluctuations, starting at 46 MT in 2018/19, dropping to 8 MT in 2019/20, and rising significantly to 121 MT in 2023/24. The export

value of cheese correspondingly increased from NPR 62.98 million to NPR 180.74 million, indicating a strengthening of Nepal's cheese industry and its competitiveness in international markets. This growth might be attributed to improvements in product quality, certification, or branding. Butter exports were minimal and variable, ranging from 15 MT in 2018/19 to no exports in 2020/21, before reaching 42 MT in 2023/24, with a peak value of NPR 12.63 million. Ghee exports began in 2020/21 with 12 MT and increased to 19 MT by 2023/24, with the export value growing from NPR 12.32 million to NPR 18.92 million. This steady growth suggests a niche market for Nepali ghee, potentially valued for its traditional production methods or unique flavor. The export of dog chews, a by-product of dairy processing, saw substantial growth, increasing from 636 MT in 2018/19 to 1647 MT in 2023/24, with the export value rising from NPR 1053 million to NPR 3184 million (Fig. 1). This segment's growth highlights a thriving niche market, possibly due to the unique qualities of Nepali dog chews, such as being natural and preservative-free. The growth in this segment highlights the potential for diversification and value addition within the dairy sector.

The total import value of dairy products rose from NPR 2,035.51 million in 2019/20 to NPR 2,292.66 million in 2023/24, reflecting a growing reliance on imported dairy products. This increase is likely driven by rising consumer demand, changing dietary habits, increasing dog owners, and possibly insufficient domestic production. Conversely, the total export value (with the exception of dog chew), though smaller, increased from NPR 171.07 million to NPR 264.59 million over the same period. This growth suggests that Nepal's dairy sector is gradually establishing a foothold in international markets, particularly for niche products such as cheese and ghee. The data reveals a dichotomy between rising import costs and growing export volumes and values. While rising import costs, especially for milk powder, could pressure

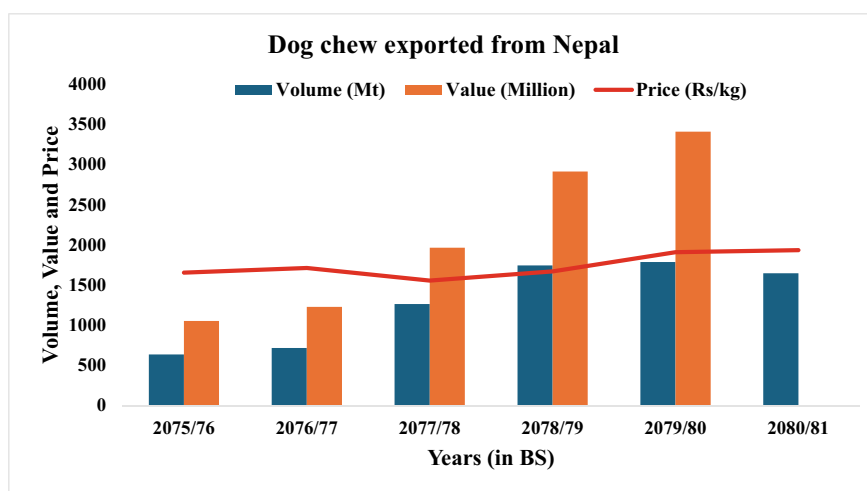


Fig. 1 Dog chew export from Nepal. *Source* Foreign Trade Statistics, Nepal

domestic markets and elevate consumer prices, the expanding export opportunities indicate potential for local producers to enhance their market presence and product offerings. These trends underscore the need for ongoing investment in both production and marketing strategies to capitalize on emerging opportunities in the global dairy market.

Dog chew industries and milk consumption: By using 25 L of milk, dog chew producers produce one kg of dog chew (churpi) and one kg of nauni. Most dog chew producers collect milk within a 20 km. perimeter of the factory. Sometimes, during scarcities, Ilam's dog chew producers brought milk from the Jhapa and Morang districts, though they preferred skim milk (without fat) to whole milk. Based on this information, our dog chew exported volume is equivalent to 41 million liters of milk

4.5 *Investment Climate*

Despite the sector's growth, SMEs face various challenges in accessing commercial finance and investment to exploit opportunities. The sector's expansion and potential are increasingly attracting interest from both domestic and international investors, contributing to a gradually improving investment climate. The evolving investment landscape includes initiatives such as incubators specifically designed to support agribusinesses. These incubators aim to enhance the investment readiness of dairy enterprises by providing crucial resources, mentorship, and networking opportunities. They play a vital role in helping SMEs navigate the complexities of securing funding and preparing for investment.

Nonetheless, accessing finance remains a significant hurdle for many Small and Medium Enterprises (SMEs) in the dairy sector. Limited financial resources, insufficient collateral, and a lack of comprehensive business plans often hinder their ability to attract investment. Addressing these challenges is essential for the sector's continued growth and modernization. By improving access to finance and investment, the dairy industry can better leverage its opportunities, drive further innovation, and enhance its overall competitiveness. Increasing interest from investors, coupled with supportive initiatives, presents a promising outlook for the dairy sector. However, sustained efforts to address financial barriers and foster an inclusive investment environment will be crucial in ensuring that SMEs can contribute fully to the sector's development and reap the benefits of its growth.

5 Challenges and Constraints

5.1 *Payment Delays and Stockpiles*

Payment delays and stockpiles are significant issues facing Nepal's dairy sector, with producers currently owed over 6 billion rupees (Republica, 2024). These challenges stem from several interconnected factors. Seasonal fluctuations lead to surplus milk production, which often exceeds processing and storage capacities, resulting in stockpiles of powdered milk, ghee, and nauni. Limited storage facilities and distribution networks further complicate the supply chain, slowing the movement of products to consumers. Financial difficulties, especially within entities like the DDC, exacerbate these issues, as cash flow problems and delayed payments to distributors prevent timely compensation for producers. Inefficiencies in supply chain coordination and limited market outlets also contribute to recurring distribution bottlenecks. In protest against delayed payments, producers in various regions have resorted to public demonstrations, even pouring milk onto the streets. Furthermore, the dairy industry has been forced to reduce milk consumption and implement nationwide partial milk holidays. These challenges underscore the urgent need for improved supply chain management and market access to ensure timely payments and mitigate stockpiles.

5.2 *Production and Post-Production Issues*

Smallholder farmers in Nepal face limited incentives to commercialize dairy production due to high production and investment costs, such as upgrading to better breeds and feed, and low market confidence. Investments needed for improvements must be sourced from the farmers' own resources, as access to loans and financial support is minimal. Many farmers still use traditional animal husbandry practices, which do not maximize productivity. A significant challenge is the genetic quality of livestock, as many smallholder farmers lack access to high-genetic-merit cows and bulls, limiting milk yield and overall productivity. The availability of quality semen and advanced breeding options is also scarce, hindering genetic improvements. To address these issues, investment in genetic research, farmer training in breeding practices, and a regulated system for distributing high-quality semen and livestock are needed. Strengthening genetic resources and implementing ongoing breeding programs can improve milk yields, disease resistance, and profitability, ensuring long-term growth. On the post-production side, collection centers and processing units often operate below capacity due to supply chain challenges. The quality of raw milk is another concern for consistent bulk processing and value-added products. Competition for private businesses is intense, with the state-run DDC and numerous informal processors dominating the market, often bypassing price controls.

6 Strategic Pathways for Growth

To enhance the competitiveness and sustainability of Nepal's dairy sector, a strategic approach is essential, focusing on product diversification, efficient management practices, innovative financial solutions, and robust policy reforms. Product diversification, such as expanding into cheese, powdered milk, and churpi, helps meet consumer demands and creates new market opportunities, improving resilience against market fluctuations. Efficient management practices, including advancements in animal husbandry, feed and breed management, disease control, and modern technologies such as robotic milking, are critical for addressing production and post-production challenges. Enhancing infrastructure for milk collection and processing is also vital for reducing losses and ensuring quality control.

Innovative financial solutions, such as tailored loans, insurance, and flexible repayment schemes, are crucial for enabling modernization and growth. These financial tools empower farmers to invest in technology and increase productivity while reducing exposure to risks. Microfinance and public-private partnerships can support equipment upgrades and expanded processing capacities. Policy reforms are essential, including revising milk pricing mechanisms to ensure fair compensation, strengthening regulatory frameworks for market formalization, and investing in research and development to drive innovation. Government support, through subsidies, tax incentives, and infrastructure development, is necessary to foster sustainable growth. Together, these strategies form a comprehensive blueprint for advancing Nepal's dairy industry, ensuring its competitiveness in the global market.

7 Envisioning the Future of Nepal's Dairy Sector

7.1 Policy Directions

To further strengthen Nepal's dairy sector, comprehensive policy interventions are necessary. These should include regulatory frameworks that promote fair competition, protect smallholder farmers, and ensure market transparency. At the local level, equitable competition among smallholder farmers, cooperatives, and local processors is crucial for securing fair pricing and market access. Regionally, supporting SMEs to expand dairy processing facilities requires creating fair competition with larger cooperatives and distributors. Nationally, strong regulations are needed to prevent market monopolies, including from state entities such as the DDC, and to ensure equal opportunities for private and cooperative sectors.

In addition, policies should enforce quality standards and traceability systems to build consumer trust and open international markets. Subsidies at both input and output levels can incentivize investment in modern dairy practices and technologies. Input-level subsidies could focus on resources such as high-quality feed and veterinary services, while output-level subsidies, such as tax breaks for processing

plants and export incentives, would stimulate market expansion. Furthermore, developing trade policies to facilitate dairy exports by reducing tariffs and offering export incentives for high-value products such as Churpi and cheese is essential for global market integration. These combined policy measures would foster a more resilient, innovative, and inclusive dairy sector in Nepal.

7.2 Institutional and Governance Arrangements

Effective institutional and governance structures are vital for implementing dairy sector policies in Nepal. Strengthening cooperatives is key, enabling them to better serve members with credit access, technical support, and market insights through targeted training, financial backing, and regulatory reforms. Public–private partnerships (PPPs) also play a crucial role, combining public resources with private sector expertise to drive infrastructure investments, technology transfers, and market expansion. Coordination among stakeholders—government entities, private companies, cooperatives, and NGOs—is essential for aligning efforts and addressing shared challenges. Streamlined roles at various government levels ensure efficient support: local agencies can work with cooperatives to provide farmers with resources such as veterinary services and feed, addressing grassroots needs directly. Regional bodies, e.g., provincial ministries, should focus on infrastructure improvements, such as cold chains and transport networks, ensuring seamless dairy distribution. At the national level, federal agencies can establish policies, regulations, and incentives to promote sustainable growth, including pricing and quality standards. Interagency working groups and digital information-sharing platforms enhance transparency and coordination, maximizing the impact of dairy initiatives across Nepal.

7.3 Human Resource Development

A skilled workforce is vital for the sustainable growth and diversification of Nepal's dairy sector. Key strategies for human resource development include offering training and education for farmers, processors, and other stakeholders. Vocational training in modern farming techniques, quality control, and business management is essential. Establishing dairy training centers and integrating dairy science into agricultural curricula can help build a competent workforce. Strengthening extension services is also crucial, as extension agents assist farmers in adopting the best practices, solving issues, and accessing resources. Ensuring well-funded and staffed extension services enhances their effectiveness. Additionally, investing in research and innovation to develop new technologies and improve productivity is vital. This includes supporting research institutions and fostering collaboration between industry and academia. Establishing Dairy Development Institutes for specialized training and

research will enhance skills in processing, quality control, and animal husbandry, fostering a competitive and resilient dairy sector.

7.4 *Legal Provisions*

Legal frameworks are essential for developing Nepal's dairy sector, providing standards and protections that benefit both producers and consumers. Key legal provisions include enforcing quality standards for milk and dairy products, covering aspects such as hygiene, packaging, and labeling. These standards ensure consumer safety and increase market trust, making products compliant for wider markets. Rigorous quality controls, supported by regular inspections, safeguard against contamination and build credibility, benefiting consumers with safe dairy products and enabling producers to access broader markets domestically and internationally.

Another critical legal aspect is contract farming, which offers farmers stable, fair agreements with processors. Contract farming, especially with buy-back agreements, strengthens sector efficiency by securing a steady supply of milk for processors and consistent income for farmers. Vertical linkages between producers and processors provide assured markets, while horizontal linkages among cooperatives enhance collective bargaining and resource access. This interconnected value chain promotes sector stability and growth.

Additionally, protecting intellectual property rights (IPR) for innovative dairy products is vital. This includes patents, trademarks, and geographical indications (GI) for unique items such as churpi, boosting market value and supporting product differentiation. Together, these legal frameworks create a robust, transparent dairy ecosystem that fosters long-term growth, ensuring safe, quality products for consumers, and reliable income for producers.

8 Identifying Enabling and Inhibiting Factors

8.1 *Enabling Factors*

1. **Government Support:** Government support is crucial for the growth and sustainability of the dairy sector, involving policy reforms and subsidies to create a favorable environment for farming, processing, and marketing. Subsidies help offset the costs of high-quality feed, veterinary services, and advanced equipment. Additionally, investments in quality breeding resources—such as high-yielding animals, sexed-semen, and embryo transfer technologies—can significantly enhance productivity. However, these inputs are often expensive, posing challenges for smallholder farmers. Government financing or subsidies for breeding inputs could improve access to genetic resources, boosting herd

productivity and sector profitability. Infrastructure investments in roads, electricity, water, and cold chains are essential for efficient production and distribution. Finally, regulatory frameworks that ensure fair competition and protect smallholder interests are vital for sustaining growth in Nepal's dairy industry.

2. **Market Demand:** The growing domestic and international demand for dairy products is a significant driver of the dairy sector's expansion. Rising incomes, urbanization, and changing dietary preferences are contributing to increased consumption of milk and dairy products. In many developing countries, urbanization is leading to a shift toward more protein-rich diets, including dairy. Internationally, there is a rising demand for high-value dairy products such as cheese, yogurt, and butter, especially in emerging markets. This growing demand provides opportunities for dairy farmers to expand production and for processors to innovate and diversify their product offerings.
3. **Technological Advancements:** Technological advancements are transforming Nepal's dairy sector by improving productivity, quality, and efficiency. Innovations in breeding, animal nutrition, and disease management enhance herd health and output. Milking machines, automated feeding systems, and precision farming tools boost efficiency and reduce labor costs. Improved processing technologies produce high-quality dairy products with longer shelf lives. Additionally, digital tools help farmers access market information, manage operations more effectively, and connect with value chains, further enhancing the sector's competitiveness.
4. **Cooperative Movement:** The cooperative movement is essential for Nepal's dairy sector. Cooperatives mobilize resources, provide services, and advocate for farmers' interests. They aggregate milk from smallholders, enabling economies of scale in processing and marketing. Cooperatives also offer access to credit, technical assistance, and market information, helping farmers negotiate better prices with processors and retailers. Additionally, they serve as platforms for collective action, allowing farmers to address common challenges and influence policy decisions.

8.2 *Inhibiting Factors*

Access to Finance: Limited access to finance for smallholder farmers and small and medium-sized enterprises (SMEs) presents a major obstacle to the modernization and growth of both the dairy and broader agriculture sectors (Nepal, 2015). Smallholder farmers often lack collateral and have limited credit history, making it difficult for them to secure loans from formal financial institutions. Without adequate financing, farmers struggle to invest in modern dairy equipment, high-quality feed, veterinary services, and other inputs necessary for improving productivity and quality. This financial constraint also hampers SMEs involved in processing and distribution, limiting their ability to upgrade facilities, expand operations, and innovate.

Market Volatility: Price volatility and market uncertainties pose significant risks to the income and stability of dairy farmers and processors. Fluctuations in milk prices can be driven by various factors, including seasonal variations in supply and demand, changes in input costs, and global market trends. These price swings can lead to unpredictable income for farmers, making it challenging to plan and invest in their operations. Processors also face risks as they navigate unstable markets, which can affect their profitability and long-term viability.

Infrastructure Gaps: Inadequate infrastructure for milk collection, processing, and distribution is a critical challenge that leads to post-harvest losses and quality issues in the dairy sector. Poor road networks, limited access to electricity, and insufficient cold chain facilities hinder the efficient transportation and storage of milk. As a result, a significant portion of milk can spoil before reaching processing plants or consumers, leading to economic losses for farmers and processors. Moreover, the lack of modern processing facilities affects the quality and safety of dairy products, limiting their marketability.

Regulatory Challenges: Weak regulatory frameworks and enforcement mechanisms undermine quality standards, market transparency, and fair competition in the dairy sector. Inconsistent implementation of regulations can result in varying levels of compliance among producers and processors, leading to quality disparities and safety concerns. Ineffective enforcement also allows for unfair practices, such as the adulteration of milk and undercutting prices, which can harm legitimate businesses and erode consumer trust.

9 Future Perspective and Roadmap

To realize the vision of a robust and resilient dairy sector in Nepal, a comprehensive roadmap is required. This roadmap should focus on:

9.1 *Enhancing Productivity*

Implementing programs to improve animal health, nutrition, and breeding practices is crucial for enhancing productivity in the dairy sector. This includes promoting the use of high-yielding breeds, quality feed, and veterinary services. Developing breeding programs to improve the genetic quality of dairy animals through artificial insemination, cross-breeding with high-yielding breeds, and selective breeding to enhance traits such as milk yield and disease resistance is essential. Improving the availability and quality of feed through research, extension services, and subsidies is also vital. Promoting the use of balanced diets, mineral supplements, and forage crops can significantly improve milk yield and animal health. Additionally, strengthening veterinary services to provide timely and affordable healthcare for dairy animals is critical. This includes training veterinary professionals, establishing

veterinary clinics, and promoting preventive healthcare practices such as vaccination and deworming.

9.2 Promoting Value Addition

Investing in value-added dairy products through processing facilities, technology transfer, and market development can boost the sector's profitability and open new market opportunities. Modern technology such as pasteurization, refrigeration, and packaging enhance product quality and shelf life, making dairy products more competitive both domestically and internationally. Supporting research and development to create innovative dairy products, including low-fat, lactose-free, and organic options, is vital to meeting changing consumer demands. Effective marketing strategies, such as developing strong brands, using Geographical Indications (GI) for unique regional products such as Yak cheese and Nepali ghee, and leveraging digital marketing, are essential for sector growth. GI recognition enhances product value, allowing premium pricing and access to niche markets. This branding strengthens market identity, boosts rural economies, supports high standards, and promotes tourism, improving the competitiveness of Nepal's dairy sector.

9.3 Improving Market Conditions and Access to Finance

Improving market access for dairy farmers is essential for sector growth, requiring better infrastructure, logistics, and market information systems. Expanding rural road networks to reduce transportation costs and improve access to markets is crucial, including the construction and maintenance of roads, bridges, and other infrastructure that connects farmers to processing facilities. Establishing cold chain systems, including refrigeration, storage, and insulated vehicles, ensures product quality during transportation. Developing digital platforms such as mobile apps, online marketplaces, and real-time market information systems is key for facilitating trade and connecting farmers to buyers. Implementing price stabilization funds, forward contracts, and insurance schemes will help to mitigate market volatility, while strengthening market information systems enables better decision-making and risk management for farmers and processors. Additionally, tailored financial products such as microloans and credit guarantees, along with partnerships with financial institutions, can improve access to capital for dairy stakeholders, supporting the sector's sustainable growth.

9.4 Fostering Innovation

Supporting research and innovation to address emerging challenges and seize new opportunities is crucial for the growth of the dairy sector, and providing funding for research projects focused on improving productivity, quality, and sustainability in the sector is essential. This includes supporting research institutions, universities, and private sector research initiatives. Establishing innovation hubs that bring together researchers, industry experts, and entrepreneurs to collaborate on innovative solutions can facilitate knowledge sharing, testing of new technologies, and development of novel products and processes. Additionally, promoting the transfer of technology from research institutions to farmers and processors is vital. This involves offering extension services, demonstration projects, and training programs that assist stakeholders in adopting new technologies and best practices.

9.5 Strengthening Governance

Enhancing the capacity and effectiveness of institutions and governance mechanisms is critical for the successful implementation of dairy sector policies. Strengthening the capacity of institutions involved in the dairy sector, including government agencies, cooperatives, and NGOs, is essential. This involves providing training programs, technical assistance, and financial support to improve their ability to effectively deliver services and implement policies. Establishing mechanisms for policy coordination across different levels of government and among various stakeholders is also crucial. This includes creating interagency committees, task forces, and working groups to ensure alignment and collaboration. Furthermore, promoting transparency and accountability in the dairy sector through rigorous monitoring and evaluation, public reporting, and stakeholder engagement is necessary. This involves setting up systems for tracking progress, evaluating outcomes, and ensuring that stakeholders are informed and involved in decision-making processes.

9.6 Ensuring Sustainability

Promoting sustainability in dairy farming requires Good Animal Management Practices (GAMPs) across production, processing, and marketing. GAMPs—such as proper nutrition, health management, and ethical treatment—enhance productivity, reduce waste, and improve animal longevity. In processing, they ensure that milk products meet quality standards, boosting consumer trust and market access. GAMPs also support environmental sustainability and economic viability by lowering resource use, costs, and enhancing product quality (Sah et al., 2020). Building climate resilience in Nepal's dairy sector through climate-smart practices,

climate-resilient breeds, and durable infrastructure further strengthens the industry's sustainability, ensuring a resilient and profitable future for dairy farming.

10 Conclusions

Nepal's dairy sector faces a complex mix of rising import costs, particularly for milk powder, alongside growing export potential in products such as cheese, ghee, and dog chews. To achieve sustainable growth, strategic measures such as product diversification, efficient management, financial innovation, and policy reforms are essential. Scaling up smallholder farms can drive economies of scale, with high-yielding breeds and cost-effective technologies such as automated milking and feed management improving productivity and reducing labor. These advancements can enhance the sector's competitiveness, boost farmer incomes, and ensure a steady supply of quality dairy products.

Nepal's dairy industry holds significant promise for economic prosperity and rural development. However, realizing this potential requires addressing challenges through focused interventions and supportive policies. A comprehensive roadmap that emphasizes institutional arrangements, human resource development, and legal frameworks is essential to foster a profitable and sustainable dairy sector. This roadmap calls for strong collaboration among the government, private sector, and cooperatives, promising substantial gains in food security and economic growth. In conclusion, the future of Nepal's dairy sector depends on a holistic approach integrating technology, policy support, and sustainable practices. By addressing both enabling and inhibiting factors, Nepal can transform its dairy industry into a major economic pillar, improving rural livelihoods and national resilience. The path forward demands a committed, coordinated effort across all stakeholders, but the potential rewards in economic growth, food security, and rural development make it a valuable endeavor.

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Chapter 24

Certification and Labeling in the Development and Promotion of Nepal's High-Value Agricultural Products



Kiran Mainali and Deepak Ratna Tuladhar

Abstract Nepal has enormous commercial potential for development in the agricultural sector by virtue of its diversity in topography, altitude, climatic conditions, and the heterogeneous multi-ethnic fabric of Nepalese society. Despite the endowed benefits, the country's agriculture and high-value commodities have floundered to achieve a substantial position in the global market landscape due to quality control issues and inadequate systematic and institutional arrangements. In this context, the chapter aims to discuss the importance of quality standards and certifications for promotion and marketing of unique Nepalese agricultural products, providing a comprehensive overview of the role of certification and branding in the expansion of development and promotion of Nepalese agricultural products. Additionally, it also sheds light on action plan strategies for facilitating certification processes and capacity building for institutions through regulated policy interventions. It also explores how to support the marketing of high-value agricultural products and recognition of quality standards and certifications such as geographical indications (GI), organic, mountain products, fair trade certification, rainforest alliances, NepalGAP, ISO22000. The chapter defines the certifications and quality assurances that are applicable to high-value agricultural products atypical to the production zone in Nepal. Similarly, it emphasizes potential areas for improvement and innovation to enhance the competitiveness of Nepal's agricultural sector in the global marketplace. Finally, it calls out for policy-level improvements to develop and align policies in the agrifood sector in harmony with international standards.

Keywords Certification · Labeling · Geographical indication · Organic · HVAP · Market · Standards

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1 Introduction

The agriculture sector in Nepal is the mainstay of Nepal's economy, which contributes around 24% to GDP, employs two-thirds of the population and over 62% of the labor force, and encompasses a diverse agroecological zone. Despite its pivotal role in the country's development, the sector has confronted challenges such as smallholder and fragmented land holdings, inadequate physical and organizational structures, and limited access to modern farming machinery, techniques, and inputs. Similarly, predominant issues in the agricultural sector include access to finance, access to quality seeds and fertilizers, access to markets, and access to extension services (Gyawali & Khanal, 2021).

The agriculture sector holds immense potential for transformation, mainly considering its emerging nature in the context of Nepal. Nepal's agrifood system is mainly characterized by smallholder farming communities, domestic food production, and import (Tripathi & Kaini, 2022). This persisting subsistence nature of the agriculture system is slowly striving towards commercial and market-based food systems. According to Malla (2008), this transformation of the agriculture sector is not that simplified, as the sector is vulnerable to natural disasters, erratic rainfall patterns, and an increase in plant infestations, aggravated by climate change. Similarly, existing literature stresses that the Nepali farming system is facing social challenges, including outmigration, the feminization of agriculture, and land abandonment (Ojha et al., 2017; Tamang et al., 2014).

Notwithstanding these challenges, there is significant potential for the production and commercialization of high-value products in Nepal. High-value agricultural products (HVAP) are defined here as products that are typically perishable, of specific high value, and sold through specialized markets. Products such as large cardamom, ginger, turmeric, orthodox tea, coffee, honey, fresh vegetables (e.g., tomatoes and cauliflower), fruits (e.g., apples and kiwi), spices (e.g., black pepper and cinnamon), and medicinal and aromatic plants (e.g., chiraito and lemongrass) can be categorized as HVAP. Diversification of crops to HVAP can benefit producers in developing countries like Nepal by increasing production, rural income, and employment opportunities (Matthys et al., 2023). Despite the plunge in the agriculture contribution to Nepalese GDP; interest in high-value agricultural product (HVAP) farming has soared among farmers over the years, encouraged by high prices (Sedhain et al., 2014). According to Acharya et al. (2021), growth in the production of HVAP in Nepal is taking place at a much faster rate, production of vegetables increasing by 50% and spice crops by 25% from 2008 to 2018. The diverse agroecological conditions of Nepal allow the cultivation of a wide range of crops across the country. The interest of farmers and producing groups has recently shifted to the production of HVAP because of its benefits of increased income and employment generation across the value chain (Thapa et al., 2018). High-value agricultural products in Nepal include tea, coffee, spices, medicinal and aromatic plants, honey, mountain-based subsistence products such as millet, buckwheat, and barley, as well as fruits

and vegetables, which have significant market potential due to their unique qualities and increasing demand. Although good initiatives have been implemented to promote HVAP in Nepal, systematic challenges such as price instability and an inadequate marketing system persist, requiring immediate remodeling; certification can serve as a key tool to address these issues by enhancing transparency, standardization, and market confidence. Certification guarantees the quality and authenticity of high-value agricultural products and facilitates better market access. Addressing these challenges not only requires policy interventions but also active collaboration between stakeholders, including farmers, traders, and policymakers. To unlock the potential of HVAP in Nepal, a structured and robust framework of certification and labeling mechanisms is essential. Certification and labeling on food labels play a vital role in ensuring the quality, safety, and authenticity of agricultural and food products, and certification schemes are used to ensure marketing claims for unobservable quality attributes (Kaczorowska et al., 2021). Standard certification mechanisms such as organic, geographical indication (GI), fair trade, and Good Agricultural Practices (GAP) good agricultural practices can largely contribute to differentiating Nepalese products in the market and enabling the producers associated with its production to fetch higher prices and access lucrative foreign markets. In addition, this kind of certification supports the notion of sustainable agricultural practices, protects traditional farming methods, and contributes to better traceability within Nepal's agro-food chain. With evolving consumer demands and the requirements of naturally grown food products and origin-linked food products in Nepal, Steingolt et al. (2018) believe that this type of labeling and certification guarantees that food products address this evolving segment of the environment and origin-conscious consumers.

In this context, the objective of the chapter is to contribute to Nepal's agricultural transformation by specifically highlighting the strategic importance of certification and labeling to fully exploit the potential of HVAP originating in Nepal. Furthermore, it delves into the systematic challenges and opportunities of implementation of certification schemes in Nepal alongside identifying key policies, actors, and institutional arrangements that need to be established for the effective functioning of the labeling schemes.

2 Current State of Certification and Labeling Mechanism in Nepal

Certification of agro-food products provides an alternative to the individual producers to be included under an established umbrella program and labels. In the globalized world, as consumers are more concerned about their food choices, the significance of certification and adequate labeling increases. According to Boja and Morina (2017), certification has proven to be an effective tool for providing market support to farmers/agribusiness and at the same time apprise consumers about the means of production by ensuring the product's safety, nutritional value, and organoleptic qualities.

The evolution of consumer consciousness in their choices of food products, and the integration of environmental impact and social equity have resulted in a proliferation of certifications globally, each with their own unique standards (Kononets et al., 2023). There are various certifications for quality management, origin of the product, environmental sustainability, ethical production practices, food safety, and so on.

2.1 Overview of Existing Certification Schemes in Nepal

To fully realize the potential of high-value agricultural products in Nepal, certification and labeling can serve as a tool for quality assurance and market differentiation. While Nepal has made considerable strides in the development of its agricultural sector, particularly focused on tackling the effects of climate change, the landscape of certification and labeling in HVAP is still in its nascent stages. While certification initiatives such as organic, fair trade, and Good Agricultural Practices (GAP) have seen some advancements in Nepal as an outcome of the efforts made by the development sectors, their reach and impact remain unevaluated and limited, offering possibilities for growth in Nepal. These certifications in Nepal were aimed at ensuring the product's quality, building consumer trust in products, and enabling better market opportunities for Nepalese HVAP. To accelerate the process of certification and its adoption in Nepalese products, capacity development for farmers, improving the certification process by empowering certification bodies, and increasing awareness among consumers is imperative. A description of some of the certification schemes currently in practice and some probable certification schemes that can be explored are outlined and discussed in Table 1.

According to Bhat (2009), in Nepal, certification can help differentiate preferred organic products from other products, which can be helpful in promoting organically grown products in the market. Also, Hejkrlik et al. (2013) mention that market share and consumer recognition of fair trade products are growing in the majority of developed countries, which adds opportunity for high-value products from Nepal to successfully gain access to premium markets in exporting countries. These outcomes from the literature highlight the transformative potential of certifications in Nepal, underlining the role of regulatory support and policy framework in addressing systematic challenges of agrifood systems. Nepal has initiated policy and regulatory support to govern the management and certification of agricultural product certification schemes, and while some progress has been made, the existing policy landscape is insufficient to fully support the adaptation and development of labeling practices in Nepal. Some of the supporting policy frameworks for different certification schemes as presented above are indicated in Table 2.

Table 1 Overview of existing certification schemes in Nepal

Certification schemes	Description	Benefits	Formalized in Nepal	Examples in the case of Nepal (existing or prospective)
<i>Origin-related certification schemes</i>				
Geographical Indication (GI)	Protects the name of the product that has a specific origin and reputation attributable to the origin of the products	Ensures authenticity, enhances marketing and branding of the products through value addition	No. There is no existing legal framework for facilitating GI certification; however, under the IP Act 2022, there is a separate GI Provision that is pending parliamentary approval	Bhaktapur JuJu Dhau, large cardamom from the Eastern Hills, tea from Illam, etc.
Mountain Labels	Certifies products grown in mountain regions emphasizing unique production and protection of traditional practices	Supports mountain economies, enhances product value and differentiates it from products produced in low hills and flat areas with low slope and elevation	Yes, optional quality term	Initiated by Mountain Partnership of the UN in the case of Jumla Beans. Currently marketed and traded by Organic World and Fair Future under the Mountain Partnership Product Initiative (MPP)
<i>Environment and sustainability-related certification schemes</i>				
Organic Certification	Ensures that products adhere to organic production practices and principles of production	Access to premium prices and markets, advocates sustainability	Yes. Nepal formalized its standards on organic farming directive and formation of Organic Certification Nepal (OCN) as an independent controlling body accredited by the National Organic Agriculture Accreditation Board (NOAAB) of Nepal. Also, there are international certification bodies like Ceres Gmbh, Ecocert, spearheading organic certification process in Nepal	Coffee, tea

(continued)

Table 1 (continued)

Certification schemes	Description	Benefits	Formalized in Nepal	Examples in the case of Nepal (existing or prospective)
Fair Trade Certification	Ensures producers are paid fairly with good labor conditions	Fair wages and ethical treatment to producers, differentiates among evolving socially just and ethically conscious consumers globally	Voluntary certification recognized worldwide	One tea garden has taken up the certification
Rainforest Alliances	Focuses on sustainable agriculture, forestry practices, protecting the ecosystem and biodiversity	Protection of biodiversity and market accessibility of the products	Voluntary certification recognized worldwide	Five tea gardens in Nepal are registered under this voluntary scheme
NepalGAP	Farm assurance programs certifying good agricultural practices are employed in production	Improves farm management, focuses on sustainability	Voluntary certification, officially formalized by the Government of Nepal (GoN) with adequate standards to certify the farm	Three farms are registered as displayed on the DFTQC registration directory
<i>Food safety-related certifications</i>				
ISO 22000	Combines ISO 9001 and HACCP to ensure food safety along the supply chain	International market access, reduces foodborne risks and assures food safety	Voluntary standard recognized globally	Mainly focused on food manufacturers, processors, and food service providers

Source Author Compiled

2.2 Challenges in Implementation

Although some advancements in developing conducive policies have been effectuated by concerned authorities in the organization, the progress of implementation of certification and labeling schemes in Nepal is fraught with challenges. Some of these are described below:

Table 2 Relevant policies and regulations of different certification schemes in Nepal

Certification schemes	Policy framework	Key aspects (Governing Institutions)
Geographical Indication	The government of Nepal has approved the National Intellectual Property Rights Policy (2017), which includes Copyrights, Patents, Industrial design, Trademarks, GI, Varietal protection, Trade secrets, and Traditional knowledge policy (Joshi et al., 2020) Related Policy Instruments: Copyright Act, 2002 (2059) The Patent, Design and Trademark Act, 2022 (1965) GI draft is ready to be billed in the parliament	GI-related national laws, and marketing support for GI products MOICS, MOALD, Intellectual property protection office
Mountain Label	No specific policies/laws related to the promotion of mountain products from mountain areas However, broad laws related to the Annapurna Conservation Area project stress the promotion of green enterprises such as tea, coffee, cardamom, menthe, and other high-value cash crops and non-timber forest products. Similarly, the National Climate Change Policy introduced in 2011 has provisions for the promotion of climate-friendly agricultural practices and sustainable agricultural practices in vulnerable mountainous areas	Unique products from the mountain regions can be promoted under this scheme, with integration into territory and the mountain region development policies
Organic Agriculture	The Tenth Five Year Plan (2056/60–2063/64) for the first time prioritized the promotion of organic agriculture in Nepal officially (Tamang et al., 2011) The National Agricultural Policy of 2064 also had policy statements and objectives for encouraging and promoting organic agriculture, supporting organic product certification, and minimizing the adverse effects of agrochemicals on the land, water, environment, and livestock (Baral et al., 2020) National Standards of Organic Agriculture Production and Processing 2008 was formulated The Fiscal Budget Speech, 2020 presented by the Government of Nepal has also devised a legal framework for the promotion and regulation of quality food production, organic production, and organic product branding The National Agriculture Policy 2004 clearly states that the promotion of organic agriculture is only for export In addition, different programs and policies such as PMAMP, HVAPP, the National Biosafety Framework 2006, the Digital Nepal Framework 2018, the Agro-biodiversity Policy 2007 (updated 2014), the National Biodiversity Strategy and Action Plan (NBSAP) for 2014–2020, the Climate Change Policy 2011, the National Adaptation Plan (NAPA) 2018 and others also place special emphasis on modernizing and advancing organic agriculture in Nepal	Standard farming practices, certification procedures, inspection, and monitoring audits Government-accredited organizations such as Organic Certification Nepal and private auditing companies for enhancing the width of certification, inspection, and control of organic agriculture in Nepal

(continued)

Table 2 (continued)

Certification schemes	Policy framework	Key aspects (Governing Institutions)
Fair Trade Certification	Voluntary certification; no specific national policy	International independent certification organizations such as FloCert, Fair Trade International, and EcoCert Fair Trade set global standards for fair trade, supporting producers in developing countries to achieve better trading conditions
Rainforest Alliances	Voluntary certification; no specific national policy; adherence to international standards for certification	CERES, INDOCERT, and IMO control India are some of the authorized certification bodies for the Rainforest Alliance 2020 Sustainable Agriculture Standard
Nepal GAP	Nepal endorsed the Nepal Good Agriculture Practices Implementation Directive in October 2018 based on the Agriculture Development Strategy (ADS), the Nepal Agro Business Policy 2016 and GAP prepared for SAARC countries by FAO (Joshi, 2019) Four modules to be fulfilled by farms: Food safety module, environment management module, produce quality module, workers health safety and welfare module, and the general requirement module	MOALD, DFTQC operates as a responsible certification and auditing entity
ISO 22000	International food safety standards. The Nepal Bureau of Standards and Metrology (NBSM) is the primary national body overseeing the adoption and implementation of ISO standards in Nepal	Accredited international and national third-party certification bodies conduct planned assessments and audits to ensure that organizations comply with the standards

Source Author Compiled

- Limited awareness:** According to Mazariegos et al. (2022), there is a growing demand for safety and quality in food products, and national and private certification standards have private certification programs that respond to the high requirements of consumers whose tastes and preferences are inclined to sustainable and healthy origin food products. However, limited awareness of these certification schemes among farmers and producing groups impedes the adoption of standards related to the schemes of certification. Research conducted among the farmers of Kathmandu Valley indicated that 89.18% of farmers lacked any form of organic certification, which can be attributed to a limited understanding of the scope of the certification (Nandwani et al., 2021). Certification and labeling

can enhance the market accessibility of agricultural and food products and thus increase product value. Similarly, due to adherence to strict internationally recognized guidelines, the agri-food products with certification as a guarantee open pathway for international trade benefiting farmers. However, many farmers across Nepal lack adequate knowledge of the prospective advantages that the labels and certification can induce. Their limited awareness of the products often results in low adoption of these schemes and possible missed opportunities for economic and social development.

- **High costs:** The certification expense can also prove to be prohibitively expensive for farmers in most cases, proving to be a point of restriction for their acceptance. For reference, developing, registering, and enforcing, through litigation or other administrative action, a GI can be time-consuming and costly (Musungu, 2008). Similarly, Khanna and Tripathi (2018) have reported that external certification is very expensive, and small farmers who have less land—especially in the mountainous and remote areas—cannot afford the high cost due to scale factors. Furthermore, the high certification costs challenges are compounded by the maintenance of record-keeping, conformity to certification standards, and education, which can be discouraging to farmers.
- **Limited infrastructure:** Inadequate infrastructure in Nepal, including testing facilities and regulated traceability systems, obstructs the implementation of the certification system mechanism. For products to be certified organic and food-safe, testing laboratories accredited by trusted entities are prerequisites for certification and conformity to compliance. According to Parikhani et al. (2015), several barriers related to infrastructure, management, socioeconomic, institutional support, training, and skill are responsible for farmers not adopting GAP. Similarly, the limitation of institutional infrastructure such as control and verification bodies discourages the adoption of certification mechanisms. Control bodies are responsible for overseeing the certification process and ensuring that standards are maintained, and compliance is verified through inspection and audits.
- **Weak enforcement mechanisms:** Consumer trust is considered ideal for the success of any certification and labeling mechanism. Consumers rely on the information displayed on the labeling arrangement to make informed choices on the quality, sustainability, authenticity, or origin of products. However, due to the weak institutional arrangement and enforcement mechanisms because of inadequate controlling and monitoring organizations—mainly in the case of organic, GAP, and ISO 22000 that are already operational in Nepal—consumers may lose confidence in the authenticity of products. Similarly, the potential scope of the international market that Nepalese HVAP is targeting also becomes diminished due to weak enforcement mechanisms. Similarly, weak institutional enforcement of the certification also permits producers with substandard products not fully meeting compliance to be marketed, diminishing the advantage of genuinely certified agricultural products.
- **Limited market access:** Nepal's status as a least-developed country allows it to benefit from preferential trade terms such as lower tariffs and reduced quotas on its exports to the developed countries of the world. The certified products can qualify

for preferential access to the markets of developed countries. Despite these preferential lower tariffs, Nepalese high-value agricultural products face significant non-tariff barriers such as sanitary and phytosanitary (SPS) standards, technical regulations, and certification requirements. Lack of institutional and infrastructural capacity, including testing laboratories, use of improved technology in improving accessibility, and inadequate control bodies obstruct the full leveraging of this international exemption of quota and tariffs. The absence of market information on evolving consumption practices, limited exposure at trade shows, and inadequate pricing knowledge in target markets prevent producers from registering for certification schemes to market their HVAP. According to Ghimire et al. (2021), Nepal's agricultural extension system suffers from poor coordination between extension services, research institutions, educational bodies, farmers, and private sectors. This lack of synergy disrupts the flow of information and weakens communication, limiting producers' ability to effectively adapt to evolving market dynamics.

2.3 Consumer Awareness and Perception of Certified Foods in Nepal

In developing countries like Nepal, consumer awareness about certification and labeling is gradually increasing; however, significant gaps exist in understanding various certifications and the meaning they convey. In the case of organic certification, according to Bhat (2009), lack of recognition by both government and non-government institutions, and the certification of international organic product chains has become a complicated and costly service for producers and consumers. The gap in understanding the significance behind certification can hinder the success of certification initiatives, as consumers may not fully trust the benefits associated with the certified products. A study conducted by Khanal (2020) identified that consumers associated confusion (regarding terminology and premium amount), insufficient information on the product, and the high prices of organic products as some reasons for consumers' unwillingness to pay premium prices for organic products. Consumers in Nepal may recognize certification labels due to globalization and their increasing consciousness, but they often lack in-depth knowledge about the significance of the label. Because different certification standards, such as organic, fair trade, or geographic indications, have unique criteria and benefits behind their validation, consumers need to be aware of their primary distinctions and the contribution they will be making by making these informed purchase decisions. Also, to ensure trust of the consumers in their purchase decision of HVAP, the benefits associated with the certification need to be effectively communicated on the label.

2.4 Case Reference

Case from Nepal: Tea and Coffee: Organic Certification

A comprehensive econometric analysis conducted by Kattel (2017) on the impact of group organic certification on Nepal's coffee sector revealed that group organic certification of coffee producers plays a significant and positive role in annual household income from coffee. The research also concluded that group organic certification is considered a catalyst to increase exports, with farmers benefiting from economic (price premium), environmental, and social development. Similarly, research by Mishra and Kattel (2021) on organic certification and its likely impact on the income of tea producers in eastern Nepal revealed that the price premium received by farmers for organic-certified orthodox tea was almost 1.7 times the price premium received for organic non-certified orthodox tea in both the national and international market combined. Similarly, certified orthodox tea growers have a guaranteed market to sell their products to contracted tea processing factories while non-certified tea growers face issues of market accessibility.

International Case: Spices Pepper: Geographical Indication

One classic example of how certification and labeling can assist producers and all actors within the product supply chain of the product is Penja pepper from Cameroon, a lower-middle-income country located in Central Africa. It was first protected under the African Intellectual Property Organization in 2013 and later protected under the EU GI system, increasing its market accessibility. Penja peppers are one of the finest peppers produced in the world, with a pungent, spicy taste and flavor profile. This flavor profile is mainly attributed to the volcanic soil in which it is grown, and to specific production techniques (manual harvesting, rinsing, soaking, drying). Initially, the process of GI was initiated with 20 actors, of whom 2 main producers, and later 200 producers, joined after the GI tag. One hundred other supply chain actors (nurseries, distributors) are part of the GI group. After the formalization of the product's GI status, noticeable changes were observed in the production area and the number of producers. According to Balineau and Faure (2018), the price of the product increased from 2000 FCFA/kilo to 13,000 FCFA/kilo, equivalent to an increase of USD 3.32 to USD 21.51). Other researchers also indicate a significant increase in the overall producer income as assisting the development of the value chain and international marketing of the product.

The cases of Nepal's organic-certified tea and coffee and Cameroon's GI-certified Penja pepper highlight how certification enhances market access secures price premiums and boosts producer incomes. Certification mechanisms also drive value chain development and international marketing, showcasing their potential to economically and socially benefit producers.

3 Development and Promotional Strategies of Certification and Labeling—Policy Implementation Plan

To fully harness the potential of marketing high-value agricultural products in Nepal, a concerted, multifaceted effort between multidimensional stakeholders is required to strengthen the certification and labeling mechanism. This multifaceted approach will encompass capacity building, infrastructure development, market promotion, consumer education, and policy alignment. The missing policy alignment includes establishing clear standards and guidelines for certification, ensuring alignment with international certification systems, providing subsidies or incentives for certification adoption, streamlining regulatory processes, and integrating certification into broader agricultural and trade policies to enhance its accessibility and effectiveness for all stakeholders. Nepalese HVAP will thus have better access to domestic and international markets with premium value for these HVAP to strengthen these interconnected elements associated with certification and labeling.

3.1 *Strengthening Institutional Structure*

3.1.1 **Enhancing the Capacity of the Certification Bodies**

- **Standardization:** The first step in improving the certification schemes and their credibility in the national and international market is developing and implementing certification standards that align with international best practices. According to Poudel (2020), it is hard for local certification bodies to compete with international certification bodies (CBs) in organic export certification. In the case of organic certification, Baral et al. (2020), pointed out that governments must rely on/endorse the certification standards set by private sectors that are mainly voluntary, and the National Regulation on Organic Production has not yet been enacted. Similarly, Nepal's GAP standards have been adopted from the master version of SAARCGAP (GC, 2018). In the case of other standards such as mountain and GI, Nepal has yet to define any standards. Meanwhile, for other certifications such as fair trade and rainforest alliances, Nepal adopts international certification bodies and adheres to standard regulations for product certification. In the case of alignment of national standards within the case of certification with other international certifications, trust among stakeholders is strengthened. Similarly, the harmonization of the standards with international regulations ensures better market and trade access to Nepalese HVAP, enhancing economic opportunities and overall sectorial development.
- **Accreditation:** Once strict standards are set, specific regulations need to be formulated for accreditation of the certification bodies. A robust accreditation system ensures the certification bodies enhance their credibility and ensure adherence to high standards. In contrast to governmental organizations such as DFTQC

that serve as certification bodies for Nepal GAP and Organic Certification Nepal (OCN), certification responsibilities can be handed down to private, independent, and impartial national bodies for compliance and auditing. International auditing/certification bodies can also be consulted for the same purpose; however, their charges for foreign accreditation of their products are expensive. According to an organic farmer as reported by myRepublica (2020), certifications produced in Nepal are not valid in the global arena, and entrepreneurs are required to produce international certifications for their products to be sold globally. Therefore, there is an urgent requirement to develop standards aligning with international frameworks and empower local certification bodies to eliminate possible barriers to trade due to lack of certification.

- **Training and resources:** Once the accredited institutions are formalized in Nepal and delegated the authorization to conduct on-field audits and technical inspections for different certifications of HVAP, comprehensive training and capacity enhancement programs need to be provided to the certification bodies such that they can effectively manage and enforce the certification standards. The training and resources need to be conducted periodically by responsible authorities such that the auditors and inspectors of the certification bodies are well acquainted with any updates on standards to streamline the certification process.

3.1.2 Government Support and Policy Development

- **Policy framework:** To accelerate different types of certifications of HVAP for their promotion and uptake in Nepal, a comprehensive policy framework is of paramount importance. The framework should create an enabling and conducive environment that supports farmers, associated producers, and producers' groups to pursue certifications; address existing trade barriers; and promote the growth of the certification ecosystem. Some common ways of promoting the certification from a policy standpoint could be providing incentives and capacity building for farmers and producers.
- **Financial assistance:** Initially, to drive the uptake of certification, it is imperative to provide financial assistance in the form of subsidies, grants, or low-interest loans that cover the costs of certification. This assistance facilitates the certification process for smallholder farmers by considering the financial burden associated with production. Currently, there are limited policies that incentivize the promotion of registering labels, which leads farmers and producers to not effectively consider displaying these labels on their products during marketing.

3.2 Infrastructure Development

- **Building testing and certification-related institutional arrangements:** Testing facilities must be developed across different regions of the country, be strategically

based, and serve almost all parts of the country. Advanced testing facilities can provide farmers and producers with crucial data on their HVAP quality, safety, and compliance with certification standards, which is critical for the success of certifications such as NepalGAP, ISO22000, and organic labels. Similarly, different independent institutions such as accredited bodies under the government can be established that overall govern the certification bodies, and legal provisions for the establishment of nationally accredited bodies alongside international certification bodies can be mandated to create a chain of standardization in certification-related activities.

- **Improving logistics and supply chain:** Investing in the improvement of transportation infrastructure such as roads and storage facilities is crucial for ensuring the efficient movement of certified HVAP products from local and rural farms to markets. According to Chaudhary (2018), agriculture in Nepal is being less commercialized because of the low level of technology, infrastructure, and poor market facilities; therefore, policymakers also need to emphasize these aspects to provide better market accessibility in Nepal to certified products from remote hills and mountains.

3.3 *Market Access and Promotion*

3.3.1 *Enhancing Domestic Market Awareness*

- **Consumer education campaigns:** Although there is increasing awareness of certified products in Nepal, the level of awareness among consumers is still low, and consumers are easily deceived by names such as “organic,” “fair trade,” and “safe food” that in practice have been used generically without falling into the purview of regulations. One study conducted on consumer willingness to pay for organic products conducted by Regmi et al. (2023) suggested that government policy should focus on education and skill-building programs to raise awareness and consumer willingness to pay for organic products. Similarly, certification from authorized organizations is also necessary to build trust and increase demand for organic products in local, national, and international markets. Focused interviews conducted by Kharel et al. (2023) among Nepal GAP-certified farmers also indicated that consumers’ lack of awareness of the certification is resulting in a lack of implication on prices for products despite the management challenges associated with production. Therefore, it is required for policymakers to mandate and support the development of comprehensive consumer education campaigns to raise awareness about the benefits associated with certified products. The government needs to allocate public funds and resources and ensure that these campaigns utilize a variety of media channels, including TV, radio, social media, and print, to reach a broad and diverse audience.
- **Retail partnerships:** Supportive policy frameworks can be introduced to promote certified food products through retail chain partnerships. The leading retail chain

stores dealing with fresh vegetables, spices, and other high-value agricultural commodities could be incentivized through tax remissions or subsidies. The government can also support the establishment of retail stores for selling certified produce and encourage the existing marketplace to allocate special counters. Similarly, policies can mandate clear labeling and informative displays among retailers that educate consumers about the benefits and transparency of the certified products, increasing local consumers' trust and awareness of them.

3.3.2 Enhancing International Market Reach

Organization and participation in international trade exhibitions can significantly enhance the visibility and market outreach of certified Nepalese products. A potential connection with global importers and buyers can be established with this approach, and insightful ideas on international trends can be understood by Nepalese HVAP producers. Government support and coordination in organizing such events or facilitating the participation of certified HVAP can expand the outreach of Nepalese products and assist in building long-term business relationships with international buyers, encouraging other producers within the country to register for certification schemes in the future.

3.4 Capacity Building for Farmers and Producer's Groups

3.4.1 Training and Education Programs

Nepal's agriculture growth has been very slow, primarily due to inadequate research and extension linkage and coordination among public and private partners, as well as due to technology generation, transfer, and services to farmers and agro-based industries (USAID/MEANS, 2012). In this regard, training farmers on sustainable production practices and the benefits of production system certification becomes essential for promoting sustainable agricultural practices and the HVAP. Incorporating certification training into policy frameworks can significantly boost the effectiveness and outreach of these programs among HVAP-associated producers. Policies can allocate certain funds and resources for the initiation and development of such comprehensive training programs. The training and education programs will ensure widespread awareness and adoption of certification standards to promote their HVAP, and meet the standards set out by national bodies or international organizations, ultimately creating a resilient and sustainable high-value agriculture production system in Nepal.

3.4.2 Cooperatives and Association Development

Supporting the development of cooperatives and producer groups is pivotal for advocating the interests of certified farmers, providing technical assistance, and facilitating market accessibility of the products. According to Banjara and Poudel (2016), the cooperative can collectively certify products as organic and provide technical training and education on pest management, crop protection, and enhancing overall productivity and crop yield. Likewise, a similar cohesion of farmers can be formed in the case of other voluntary certifications such as NepalGAP, mountain labels, and fair trade to sustain farming. Meanwhile, Geographical Indication (GI) cannot be endorsed until a producer's group is formed and a collective decision on the standards is laid down because of meetings. Policies can promote collaboration between producer associations, government agencies, and other stakeholders such as development actors to ensure a cohesive approach to addressing farmers' challenges and opportunities in developing and marketing certified agro-food products.

3.5 Monitoring and Evaluation

The Government of Nepal should enact specific legislation mandating regular audits and inspections for certified agricultural products. This legislation should outline the frequency, scope, and procedures for these audits to ensure consistency and transparency. Similarly, the national standards for all these certification schemes should be based on the best international practices to govern compliance checks. Subnational authorities, including local governments and district-level agricultural offices, must play an essential role in supporting the implementation of these regulations by providing local expertise, conducting initial inspections, and ensuring that farmers and producers comply with certification criteria. They can also act as a bridge to facilitate communication between national bodies and local stakeholders, ensuring that regional challenges and feedback are considered in policy adjustments. The legislation should delegate most of the authority to the certification bodies and equip them with all the resources needed to complete regular audits and inspections. A regular feedback mechanism also needs to be drawn from the relevant stakeholders and inform policy label adjustments to improve the overall certification system.

4 Policy Recommendations/Implications

The successful implementation of certification and labeling mechanisms for the marketing and promotion of HVAP requires a conducive policy framework that is not effectively met by existing policies related to overall agricultural market development and regulations specific to different existing certification and labeling schemes.

- **Fiscal incentives:** The provision of tax incentives, subsidies, or credit facilities should be made available for farmers and producers who are willing to take up certification and labeling to promote their HVAP. This financial assistance will reduce the burden associated with the certification process, encouraging more farmers and producers to comply and promote sustainable agricultural practices.
- **Regulatory simplification and alignment:** The certification standards currently in place, or those to be developed for other certification schemes, are generally aligned with existing international standards. However, they need to be more comprehensive to effectively promote the export of these products and reduce any hurdles impelling more farmers to participate in certification schemes.
- **Export promotion:** Certified HVAP from Nepal needs to be promoted in the country's short-term and long-term export promotion strategies. Support can be provided by conducting trade shows, market research, and financing and simplification on export to facilitate enhanced market access of HVAP in the international market.
- **Public-private partnership:** Fostering long-term strategic partnerships between the government, the private sector, and the development sector is critical to sharing resources and experience in the implementation of certification and labeling programs.
- **Infrastructure and capacity building:** Government policies need to earmark investments in essential infrastructure such as laboratories, certification and auditing organizations, and traceability systems to increase the adoption of certification and labeling of HVAP in Nepal.
- **Consumer protection:** Clear and enforceable regulations should govern the certification and labeling of certified HVAP. A clear guideline and information displayed on the label must be mandated while developing respective certification standards to ensure that consumers are not deceived. Additionally, a strict penalty system needs to be introduced through the enactment of regulations to deter any misleading labels and build consumer trust in the certification schemes.

Some policy recommendations tailored to each certification in the case of Nepal are (Table 3).

5 Conclusions

Nepal's agricultural sector, which is endowed with diverse agroecological zones, biodiversity, and enormous growth potential, can reap economic rewards through the development of high-value agricultural products (HVAP). High-value agriculture products such as medicinal aromatic plants; honey; mountain-based subsistence products such as millets, buckwheat, and barley; superfoods such as drumsticks and nettles; as well as fruits and vegetables are promising candidates for certification and labels with increased market access both domestically and locally. In this regard, the certification and labeling mechanism—which is still in its nascent stage in the context

Table 3 Policy recommendations for formalization of different certification schemes in Nepal for promotion of HVAP

Certification scheme	Policies required
Organic Certification	• National standards for organic farming that align with IFOFAM should be made comprehensive to receive equivalence • The assistance of organic-certified HVAP to the export market • Facilitating training programs to increase adoption among farmers • Promotion of products in the Nepalese domestic market
Geographical Indications (GI)	• Expedite laws and regulations related to GI • Streamline the product registration process • Strengthen GI protection legally by penalizing fraudulent activities • Raise awareness and promote GI products nationally and internationally
Nepal GAP	• Provide technical and financial assistance for certification and renewals • Invest in capacity enhancement of certification bodies and testing facilities • Launch nationwide marketing campaigns for Nepal GAP-certified products • Implement nationwide training programs on Nepal GAP certification and its principles in coordination with subnational authorities
Mountain Label Certification	• Establish criteria for mountain areas and mountain products within the country • Provide subsidies and technical support to producers aiming to certify mountain products to promote their products • Promote mountain label products nationally and internationally with communication of benefits
Rainforest Alliance and Fair-Trade Certification	• Assistance with the certification process, training, and resources to meet this international voluntary certification scheme • Facilitate national and international markets for this certified product
ISO 22000	• Harmonize national food safety standards with ISO 22000 • Provide training, strengthening, and monitoring of ISO 22000 standards and food safety management systems • Investment in testing facilities and safety inspection

of Nepal's marketing achievements—can emerge as a productive tool to unfurl the potential of Nepalese HVAP by enhancing product value, expanding market access to the domestic and international market, helping producers to fetch premium prices in terms of financial value also as highlighted from the existing research and cases presented, and build long-term consumer trust in products' origin, sustainability, ethical and safety claims.

Despite initial strides in organic and other certification schemes through national standards, ISO2200, and Nepal GAP, Nepal still has a long way to go in leveraging the existing and globally reputed certification schemes to boost products' marketing outreach. A comprehensive certification and labeling system has yet to be fully established, where producers or farmers producing HVAP can display one or a combination of existing certification schemes to market and build trust for their products in diverse markets. As identified in this chapter, the absence of robust infrastructure, limited awareness, adoption, and inadequate policy support pose significant challenges. To successfully eliminate this gap and realize the potential of certification and labeling in marketing HVAP, Nepal should emphasize developing and enhancing the capacity of certification bodies, gain the trust of producers through financial and market-related support to increase certification uptake among farmers, harmonize standards and policies per international regulations to increase market accessibility of products, and launch campaigns to educate and apprise consumers on national labels, signifying the meaning of the certification involved and protecting the rights of certified producers through stringent regulatory policy work.

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