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Agriculture, Natural Resources and Food Security

Lessons from Nepal

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Foreword by John Dixon

Nepal is a land-locked country of immense diversity, ecologically and ethnographically. The hills and mountains of the Himalayas dominate the landscape, so that average altitude exceeds all countries in the world except nearby Bhutan. A narrow east-west strip of lowland Terai divides the Nepalese Hills from the Ganges floodplains of India. The dissected landscape and limited infrastructure are major constraints to, but simultaneously opportunities for, sustainable development. The remoteness, diversity, dynamics, and integration of many of the farming and food systems of Nepal have been a severe challenge to researchers and policy makers for many decades. The livelihoods of Nepalese farm families are in transition and depend on four evolving pillars: available natural resources; the management of interdependent crops, livestock, and forests; linkages to value chains; and off-farm income from local, regional, or international work. Cereals, especially rice, wheat, maize, millet, and barley, underpin dietary energy consumption for farmers and city-dwellers alike, increasingly supplemented by vegetables, milk products, eggs, and meat. Today, livestock—cattle, sheep, goats, and yaks—plays important roles in human nutrition and cash income. Their traditional functions as sources of manure for plant nutrition and draft power for ground preparation, threshing, and transportation are being replaced by mechanization. Forests provide fuelwood, timber, fodder, leaf litter, and ecosystem services. The use of external inputs such as seed, fertilizer, feed, and seedlings is low by Asian standards, yet growing as infrastructure and market systems develop. Farming system productivity is also lower than many Asian countries, and slow growth is a challenge for household and national food security. In fact, the national food system has increasing dependence on cereal imports.

Planners often distinguish three broad farming and food systems in Nepal —the lowland Terai, the mid-Hills, and the high Mountain systems. Typically, the lowland Terai systems have larger average farm sizes (although still small), more irrigation, and better access to input and produce markets, including the mega-markets of neighboring India—and good potential for crop intensification and diversification. The Hill farming and food system features strong crop–livestock–forest linkages and strong social capital which are both weakening as population pressure grows and market access improves, especially in districts close to cities or with well-organized value chains for milk or horticultural produce, e.g., orange. Off-farm income has grown in importance for rural livelihoods and farm investment. The

mountain farming system features even stronger population pressure on limited cultivated land and features a variety of minor food crops, potatoes, and grazing yaks, cattle, and their crosses. Tourism is an important source of local income. Both the hill and mountain systems have experienced strong temporary out-migration in search of remittance income as well as permanent relocation to urban centers and the Terai—and growing evidence of abandonment of marginal cropland.

Due to the confluence of ecological and economic characteristics, Nepal has a unique rural development experience from which lessons can be drawn for other small land-locked and mountainous countries around the world. This book, *Agriculture, Natural Resources and Food Security: Lessons from Nepal* is a valuable compendium of rural development knowledge for South Asia and other developing regions of the world. Each of the 24 chapters takes a deep dive on one or another component of the farming and food systems of Nepal. Related to crops, the well-experienced authors document urban agriculture, agro-biodiversity, soil health, pest and disease management, food safety, food production, fruits and vegetables, post-harvest management, citrus production, seed systems, and emerging approaches of conservation agriculture and regenerative agriculture. In relation to animal production, the book analyses livestock development, livestock (and land) ownership, fisheries, and the emerging one-health approach. The role of forestry is examined through the drivers–pressures–states–impacts–responses (DPSIR) framework and the success of community forestry (for which Nepal is famous) leading to emerging thinking on ecosystem services and selective logging policies. The pillars of crops, animals, and forests are tied together through the crosscutting themes of the water–energy–food nexus (as a planning framework), climate-related crop simulation modeling (as a decision support system tool), and a final chapter on gender and adaptation to climate variability. Many of these chapters present analyses of relevant sector and sub-sector trends which point to a mixture of challenges and successes. As in other countries, these agricultural dynamics arise from seven drivers and trends associated with demography, natural resources and climate, knowledge systems and gender, science and technology, markets and infrastructure, and institutions and policies. Overall, the book signals an optimistic view of farming and food systems development in Nepal. In fact, with a recently updated constitution and governance institutions, Nepal looks forward to a vision of achieving the sustainable development goals by 2030 and graduating from the least developed country status to a middle-income developing country soon to create a prosperous and happy Nepal.

Each chapter and the whole book contain development insights in relation to highly constrained smallholder agriculture which are of immense value to researchers and policy makers in Nepal and in other countries with similar situations and farming systems. For example, the successes and challenges of the Nepalese Hill diversified farming system (termed the South Asian Highland Farming System by FAO and the World Bank) are directly relevant to 65 million ha across the South Asian Himalayas from Afghanistan to Myanmar, as well as similar farming systems in east and southeast Asia, Africa, and Latin America. The great potential for integrated farming systems

with effective market access, such as agroforestry systems incorporating trees, crop, and livestock, is emphasized. In a similar fashion, the insights from interlinked agricultural and tourism development in the Nepalese Mountain farming system (termed the South Asian Sparse Farming System) are valuable for 34 million ha across the South Asia region, as well as the high mountains of Africa and Latin America. Of course, these highland and mountain farming systems constitute the water towers which underpin energy and food production for hundreds of millions of lowland populations in South Asia and the rest of the world. In conclusion, the analyses of the rural development experiences in Nepal will be valuable reading for many researchers and policy makers in emerging economies around the world.

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Foreword by Bimala Rai Paudyal

Nepal is one of the richest countries in the world in terms of its incredibly diverse ecology, ecosystems, and biological resources. Human diversity further makes the country rich in knowledge, skills, and capacities. The country is strategically located between two large and rapidly growing economies, namely China and India. However, despite its richness in geographic, environmental, and socio-cultural diversity, the country remains economically poor where poverty, food insecurity, and malnutrition have persisted through time. Agriculture, engaging two-third of labor force, is virtually stagnated with growth rate remaining less than 3% for the past three decades. Its share to the economy is constantly decreasing from 66% in 1970 to 33% in 2010 and 23% in 2020. While food security in Nepal has improved in recent years, the improvement is linked, not to the agriculture production but, to the rapidly growing remittances from overseas migration. About 4.6 million people are still food-insecure, and nearly, half of all children below the age of five are malnourished in the country. Why is there such a wide gap between the potentials and realities?

With the growing realization that food security is intrinsically linked to human and national security, especially in the context of climate crises and geo-political dimensions, recent years have witnessed increasing interest and investment in Nepal from all corners, especially toward innovations, modernization, and expansion of domestic markets in agriculture. The rising demand for homegrown staple food and high-value commodities in domestic and international markets already provides tremendous opportunities for an increased and diversified agricultural production and income. This is an opportune moment to assess and compile good practices, challenges, and opportunities in terms of policies, technologies, extension, and service modalities in such a way that this momentum is capitalized sustainably and equitably.

Although there has been some research and learning documentation on macro- as well as micro-level initiatives to address the policy and knowledge gaps in the sector, the initiatives are scattered and very few come to the notice of dominant policy makers, practitioners, and academics to make an impact. A systematic and comprehensive documentation with professional scrutiny would provide a solid basis for policy makers and practitioners for much-needed improvement needed in the sector. This book, *Agriculture, Natural Resources, and Food Security: Lessons from Nepal* is a product of an enquiry from experts, scientists, academic, researchers, and practitioners that

are multidisciplinary in nature and are interrelated in many ways. The book not only explains the current gaps and explores the potentials in the sectors within the rapidly changing sociopolitical and environmental contexts in Nepal but also showcases practices that can be scaled up throughout the country and beyond. It also provides a useful reference to many other countries in the world that are rich in natural and human resources yet challenged in achieving food security.

Divided into four major parts of interrelated themes, the book provides 24 chapters, and each chapter is rich in content and methodological rigor. Part I —"Agriculture, Horticulture, and Post-harvest management"—highlights a wide range of issues and good practices related to agricultural production and services. Authors outline the potentials of urban agriculture as a model of well-being; advocate for conservation and the use of agro-biodiversity and for improving soil health and security for food security; introduce the concept of plant clinics for better access to crop health services; assess the food production and productivity gap; highlight the need for increased investment for production and post-harvest management of fruits and vegetables; importance of strengthening national seed system and the conservation of agriculture technology. Furthermore, they caution the readers on the growing risks of toxins, contaminants, and adulterants in food and recommend the solution.

In Part II—"Livestock and Fisheries"—authors highlight the contribution of livestock and importance of land and livestock ownership for food security in Nepal and point out constraints, gaps, and opportunities for livestock development; explore the contribution of fishery in the economy; emphasize the interconnectedness of animal–human–environmental health in the context of the COVID-19 pandemic and introduce the "One Health" approach for more collaborative, multidisciplinary, and multi-sectoral solution. Furthermore, the authors introduce a comprehensive framework (DPSIR) to analyze the socio-ecological impacts of transhumance system. Part III—"Forestry, Community Forestry, and Agroforestry"—provides insightful reflections on the potentials of agroforestry becoming an alternative to crop-focused farming and assesses the implications of logging policies and practices on livelihoods. Drawing on lessons from community forestry management, they further assess the potential of an ecosystem-centered approach for local livelihoods and suggest a way forward for a wide and sustainable impact.

In the final part—"Cross Cutting Topics"—authors introduce the W-E-F nexus approach to policy planning and development for sustainable and equitable water, energy, and food security. The potential of crop simulation models to increase food security is explored in the context of changing climate. The final chapter acknowledges the importance of gender roles and relations and examines the interplay between gender equity and adaptation in the Nepalese Himalayas. Increasing feminization of agricultural works on the one hand and widening gender disparities in access to and control over information, technologies, and services on the other requires more dedicated investigation on gender barriers, opportunities, and implications. More importantly, because of direct exposure to nature and greater dependency to perform gender roles, women hold vast knowledge, skills, and capacity for

conservation and sustainable management of natural resources. Such assets need to be valued, protected, enhanced, and promoted for replication/adoption at a wider scale. I believe that the next volume of the book or similar work would shed more light on this often neglected, yet critically important aspect.

I am truly honored to have been one of the first-round readers of such a rich book and for having an opportunity to introduce the book to other readers. I congratulate the authors and the editors for this successful endeavor. I believe the book meets the thirst and hunger of those looking for knowledge, evidence, and sectoral analysis to improve agriculture production and food security in Nepal and beyond.

Thank you.

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Preface

We, in this editorial team, have spent 20–40 years researching on Nepal's agriculture, natural resources, and environment, which form the backbone of Nepalese economy, local livelihoods, and sustainable development. While people and environment have lived together over the millennia in this Himalayan nation, every time we plan our new research, we notice issues of concerns in these sectors. The past decade has been particularly unprecedented, leaving us intrigued and perplexed, as we see the country become a net food importer from a food exporter. The country remains food-insecure, with more than 15% (4.6 million) people experiencing food access problem. Immediate causes are obvious: limited agricultural productivity, low-value addition, and increasing conversion of fertile agricultural land into settlements and other non-agricultural uses, and so on, but there are also deeper level dynamics which are behind these issues. Productive agricultural lands are being abandoned, while food demand is growing. Land, forest, and natural resources are underutilized while a large proportion of youths migrate to other countries for menial jobs to send money back home so families can buy imported food. Forest area has increased while harvests are restricted, despite known sustainable harvesting technologies. Some technological advances in agriculture are emerging, but social and environmental costs of modernization have been ignored. Research and development work is highly fragmented across sectors ignoring the system-wide dynamics.

These concerns have been the seedbed for the germination of this book. While these concerns animated our collective work, our rich experience and research network provided the confidence to embark on this project. We have had the opportunity to analyze various facets of Nepal's problems and opportunities from various disciplinary angles, from Nepal as well as from Australia, where four of us have been living and working for years. We have worked from within Nepal as well as from outside and have active research projects during the production of this book. Over 60 researchers and experts who joined us as contributors to this volume bring unparallel insights into why Nepal is facing such challenges and how these can be tackled. All this experience put us in the unique position to explain Nepal's agriculture and environment sector and identify emerging and potential solutions to make Nepal food secure and environmentally sustainable.

This book emerged out of our collaborative work at the Nepalese Association of Agriculture, Forestry and Environment in Australia (NEPAFE), which was set up in early 2019 with a goal to advance scientific cooperation between Nepal and Australia in the agriculture and environmental sectors. NEPAFE provided an excellent platform for us to come together and share our concerns and visions. As members of NEPAFE, we decided that compiling cutting-edge research in the form of an edited volume could be an important contribution to policy and practice. The idea was endorsed and supported by the NEPAFE community, and the editorial group was formed to take the project forward. We then approached Springer with a proposal and book outline which was accepted.

The book takes and integrated and cross-sectoral approach to diagnose problems and identify opportunities. It takes interdisciplinary approach in presenting the research and practice-based knowledge. We focus on presenting the realities of Nepal while also connecting to wider literature on the diverse topics. This way, our aim has been to identify lessons for Nepal as well as similar developing and mountainous countries in South Asia and the Global South. We believe this book is particularly unique on two counts. First, it covers multiple sectors. Second, it taps into the knowledge of those researchers who have good understanding of the local practical contexts.

Overall, this book showcases recent studies and experimental insights of authors who are actively engaged in Nepal's agriculture and natural resources management policy and practice. Chapters in the book demonstrate how various components of the food systems based on agriculture, livestock, and forestry systems have been researched and managed providing foundations for food systems innovations and how they contribute to achieving various United Nations Sustainable Development Goals (SDGs). Some crosscutting chapters explore gender and climate adaptation, nexus approach to research, development and policy, and application of crop simulation models in research and policy practices and decisions. The book features some of the internationally acclaimed practices with a potential to make significant contributions to food, nutrition, and livelihood security. Overall, the book has investigated why Nepal is facing an increasing level of food insecurity, despite having rich natural resources and explored opportunities for improvement.

The whole work of writing and editing of this book happened at a challenging time. Like with many other things, the COVID-19 pandemic made it difficult to have face-to-face interactions, but also enabled us to see the effects of such crises in Nepal's food system. The cooperation of the chapter authors has been extraordinary, making it possible for us to deliver the manuscript on time to Springer. We thank authors for their willingness to contribute and commitment to revise the paper multiple times in response to the reviewer feedbacks. We have been greatly benefitted by the work of over 40 reviewers who provided critical and constructive comments on the drafts, in some cases needing reviews of multiple versions. We are equally grateful to the publisher

for a timely publication and providing useful feedback on the initial proposal. We hope this book will contribute to scientific and policy debate around effectively managing agriculture, natural resources, and environment in Nepal as well as similar countries around the world.

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About the Editors

Dr. Jagadish Timsina (Editor-in-Chief) is a systems agronomist specialising on sustainable crop, soil, nutrient and water management; conservation agriculture; sustainable land management and land restoration practices; participatory farming systems research and extension; climate change in agriculture and forestry systems; agriculture-aquaculture systems and crop and systems modelling. He has diverse experience in agronomic, economic, and environmental management of agro-ecologies ranging from flat lands in Australia to hills and mountains in South and Southeast Asia. He has published more than 200 papers and book chapters with co-authors from more than thirty countries in various peer-reviewed international journals and books, with Google Scholar based h-index of 43 and total citations of 6850. He has worked with University of Melbourne and Commonwealth Scientific and Industrial Research Organization (Australia), International Rice Research Institute (IRRI) and International Maize and Wheat Research Centre (CIMMYT) in Bangladesh and the Philippines, and the Institute of Agriculture and Animal Sciences (Tribhuvan University) and Agricultural and Forestry University in Nepal for over forty years. Currently, he is associated with the Melbourne-based Global Evergreening Alliance and Sydney-based Institute for Study and Development Worldwide (Australia), and works as a consultant with CIMMYT in Bangladesh, WorldFish Center in East Timor and Asian Development Bank Institute in Japan. In the past, he served as an editorial board member of *Field Crops Research Journal* and *Journal of Farming Systems Research and Extension* and as a guest editor of *MDPI's Agronomy Journal*. Currently, he is an editor of the *Agricultural Systems journal* and *Global Journal of Agriculture and Allied Sciences*.

Prof. Tek Maraseni (Editor) earned a double B.Sc. (Science and Forestry) in Nepal, an M.Sc. (NRM) in Thailand, where he was awarded a gold medal (GPA 4/4), and a Ph.D. (Environmental Science and Management) in Australia. He has over 26 years of research experience in identifying and adopting management practices that improve productivity, profitability and the sustainability of agriculture and forestry systems whilst reducing greenhouse gas emissions. Over the past 6 years, he has successfully completed multiple research projects in 16 countries. He has co-authored with

researchers from 31 countries and published 4 books, 32 book chapters, one submission to UNFCCC, 5 policy briefs, 25 technical reports, and 174 journal papers. He has supervised 16 Ph.D. students to completion, served as an editorial member for two international journals, and reviewed Ph.D. theses and proposals for granting bodies. His research work has been recognised through several national and international awards and fellowships: (1) US National Science Foundation (NSF) Fellowship in 2009; (2) "Queensland-China Climate Change Fellowship" in 2009; (3) US State Department "Climate Change Professional Fellows" award in 2011; (4) "Visiting Professor for Senior International Scientist" award from the Chinese Academy of Sciences in China (2013-2019); (5) First runner-up award from Elsevier Journal "Environmental Development" in 2015; and (6) University of Southern Queensland (USQ) Research Excellence Award, three times (2009, 2014 and 2021).

Dr. Devendra Gauchan (Editor) is an Agricultural Economist with expertise in agrobiodiversity, seed system and food security. He has Ph.D. degree from the University of Birmingham, United Kingdom and has worked as a consultant and expert in various national and international organizations over the past 25 years. He is currently the Honorary Research Fellow at the Alliance of Bioversity International and International Centre for Tropical Agriculture (CIAT), and serves as the Regional Officer South Asia and Research Advisor in Agricultural Economics at Platform for Agrobiodiversity Research (PAR), Rome, Italy. He is an Adjunct Professor at the Institute of Agriculture and Animal Sciences (IAAS), Tribhuvan University, Kathmandu. He was the National Project Manager of Bioversity International led projects in Nepal from 2015–2020. Previously, he was the Head of Socioeconomics and Agricultural Research Policy Division at Nepal Agricultural Research Council (NARC) Kathmandu. During his tenure at NARC, he played instrumental role in bringing social sciences dimension in agricultural research by establishing and leading Socioeconomic and Policy Research Division. He has also worked as a Post-Doctoral Fellow at the International Rice Research Institute, Philippines carrying out rice socioeconomic research activities in South Asia from 2008–2011. He has published several research papers on agriculture and natural resource management in many journals and books.

Dr. Jagannath Adhikari (Editor) is a human geographer. He has over 20 years research, teaching and consultancy experiences in various areas of international development—sustainable livelihood; climate change and food security; sustainable agriculture; participatory natural resources management; land management and land reform; agrarian change and livelihoods; globalization, migration, remittances, and development. He worked as a Visiting Professor in Kyoto University (Japan) and as a Visiting Scholar and Research Fellow in Heidelberg University (Germany), The Australian National University (Canberra), University of Sussex (UK), and Worcester Poly-Technique Institute—WPI (USA). Presently, he is affiliated with Curtin University of Technology, Perth, Australia as an adjunct faculty and with

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Dr. Hemant Ojha (Editor) works partly as an Associate Professor for University of Canberra and partly as a Principal Advisor for the Institute for Study and Development Worldwide (IFSD). His work focusses on understanding and catalysing multi-scalar environmental governance in a way that supports community empowerment and climate resilience, and he pursues this goal by combining political economy and critical policy analysis with action research. From his early career work in the Himalayan South Asia, his work has expanded to Asia and the Pacific as well as parts of Africa. His critical policy analysis and action research has greatly influenced the development of Nepal's community forestry system, which is seen as one of the few global successes in community based environmental management. From Australia, his past 10 years of work in Asia and the Pacific has focussed on exploring policy and action-oriented solutions for climate resilience and inclusive environmental governance. He has also served as a lead author for several international environmental assessments, including a recent Himalayan regional assessment of environmental governance, supported by multiple OECD members. In his current action research, he is testing methodologies for fostering co-production of science, policy and practice in water and agri-food sectors for various contexts. He has published widely on climate change, environmental policy, and international development, and sits on the editorial boards of several international journals.

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Introduction and Overview

1

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Abstract

This chapter provides an overview of 23 chapters included in the book. The book aims to present recent knowledge on issues and topics related to agriculture, livestock, and forestry systems across the three agroecological regions of Nepal. Chapters in the book are grouped into four themes: (a) Agriculture, horticulture, and post-harvest management; (b) livestock and fisheries; (c) forest ecosystems, community forestry, and agroforestry, and (d) crosscutting topics. Chapters demonstrate how various components of the food systems—including agronomy, horticulture, agrobiodiversity, soil science, plant health, food toxins and food safety, seed innovation systems, post-harvest management, livestock production, ownership and health, aquaculture and fisheries production, urban agriculture, transhumance systems, and socioeconomics—have been researched and managed to provide foundations for food systems innovations in Nepal. The book also catalogues a wide range of solutions: need of increased investment in R&D to develop new climate resilient technologies and practices and promotion of locally adapted species and varieties for increased and sustained productivity of cereals, fruits, and vegetables, and aquaculture and livestock; development of market linkages with China, India, and other countries; development of robust national seed system; conservation and multiplication of native and neglected species and landraces; effective soil fertility management and soil health improvement; use of plant clinics for pest management; promotion of conservation agriculture and regenerative agriculture practices; promotion of urban agriculture; correcting infective institutional arrangements to minimize food toxins and post-harvest losses; adoption of multisectoral and collaborative one-health

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approach for integrated animal–human–environmental health; protecting transhumance systems in mountains; integrating ecosystem services in forest and agrobiodiversity management; active harvesting of trees and forest products; promotion of integrated agroforestry systems; managing water–energy–food nexus for research and policy planning and implementation; applications of simulation modelling in closing yield gaps and in climate change studies; and gender and socially inclusive technology development. Whilst these solutions are not entirely new, this book has unravelled why these solutions have not gained traction or how these can be taken forward in more contextually grounded way, not only in Nepal but generally in other countries with similar farming systems and terrestrial environmental issues.

Keywords

Agrobiodiversity · Agroforestry and community forestry · Conservation and regenerative agriculture · Ecosystems services · Livestock and fishery · Simulation modelling · W–E–F nexus

1.1 Background and Rationale

A landlocked country sandwiched between India and China, Nepal is divided into three east–west running agroecological regions or zones. These include: (i) the Terai and Inner Terai in the southern plains that run from the south-east to south-west at elevations typically below 800 m; (ii) the low-, mid- and high-hills in north of Terai and Inner Terai and south of the Himalayan range typically between 800 and 4000 m, and (iii) Himalayan range above 4000 m. Within each of the first two regions, a variety of crops, vegetables and fruits, and tree species are grown, and a range of livestock, poultry and fish species are raised, within an integrated crop-livestock-tree-based system. In the Himalayan region, however, farming (highland crops and livestock grazing) is limited due to extremely low temperatures (Dixon et al. 2001; Krupnik et al. 2021). These agricultural practices are supported by agroecosystems and natural resources which include rich biodiversity, forested landscapes, and abundant water resources.

The agriculture sector in Nepal contributes to about 26% of the national GDP and provides employment to about 60% of the labour force (MoF 2021). Most of the farmers in Nepal are smallholders and poor, and the food they produce is insufficient even for themselves. Nepal remains one of the food insecure countries, with more than 15% (4.6 million) people experiencing food insecurity (USAID 2019). Malnutrition and micronutrient deficiencies amongst children, pregnant, and lactating women are still prevalent, especially in mountainous areas. With current trends of increasing population, decreasing arable land, and low yearly increment in the rate of cereal productivity, Nepal has an annual deficit of >1.3 million tons of edible rice, wheat, and maize (Devkota et al. 2022). Fruits, vegetables, livestock, and fish are also insufficient to meet the demand of ever-increasing population (Neopane et al. 2022; Pandey et al. 2022; Shrestha et al. 2022). Moreover, the agriculture sector in Nepal contributes approximately 50% of the national greenhouse gas (GHG) emissions, rising to 60–70% if multiple points in the food value chains are considered (MOFE 2021). Clearly, increasing productivity and sustainability of agriculture is a major challenge, which is further escalated by increasing GHG emissions from agriculture and global climate change.

Forest and trees are important contributors to the local livelihoods and national economy. Trees grown in the forest or farmlands contribute about 15% of the national GDP and 9.23% of total national employment (World Bank 2016). Forests can protect the environment, provide various kinds of ecosystems services, sequester carbon in soil and biomass, provide timber and non-timber forest products for domestic use and export to other countries, and improve the livelihoods of people living around the forests (Ojha et al. 2022; Poudyal et al. 2022). Agroforestry systems integrating crops, livestock, and trees practised in farmlands in all agroecologies have significant potential to provide all these

benefits to farmers to improve their livelihoods (Dhakal et al. 2022). Whilst technological advancements in agriculture and forestry are important for increasing food productivity and meeting nutritional requirements, there are large socio-economic variations including gender differences, which call for a need to have gender and socially inclusive technology development and farming systems in the country (Bhattarai 2022). These all need to be operated under the nexus approach in policy at the ministerial level and the farming systems approach in research and development at the field level and in the context of global climate change. Application of digital predictive tools such as simulation models for crop yield prediction and decision support systems (DSSs) for crop, nutrient and water management and crop yield prediction and climate forecasting, and adoption of water–energy–food–land nexus as the dominant planning framework would play an important role in future (Amgain et al. 2022; Devkota et al. 2022; Maraseni et al. 2021; Uprety et al. 2022). Hence, the book showcases recent studies and experimental insights of issues on various components of agriculture, forestry and natural resources management and provides concrete research and policy implications and recommendations on the above topics.

1.2 Book Structure and Chapter Overview

Chapters in this book are grouped into four themes: Theme 1–Agriculture, horticulture, and post-harvest management (12 chapters); Theme 2–Livestock and fisheries (5 chapters); Theme 3–Forest ecosystems, community forestry, and agroforestry (3 chapters); and Theme 4–Cross-cutting topics (3 chapters). Each theme includes several chapters which highlight recent advances in research and development practices happening in Nepal. Chapters also draw on wider literature, discuss implications for policy and development and provide detailed recommendations for research and policy in Nepal as well as more broadly for South Asia. In this chapter, we offer theme-wise overview of chapters integrating the knowledge from individual components of agricultural and food systems and provide key research and policy recommendations.

1.2.1 Theme 1: Agriculture, Horticulture, and Post-harvest Management

Cereals are a major source of food security, income, livelihood, and employment in Nepal. Gauchan et al. (2022) used compound growth rates and instability index techniques to assess the growth patterns and dynamics of cereal yields, production and import growth, and food demand and self-sufficiency in Nepal. They estimated the cereal production and demand growth and self-sufficiency ratios for 2050 using different scenarios and Auto Regressive regression model to analyse the relationship between domestic production and income growth with import. They found that the current cereal production is low to meet the current and future food demands of the increasing population. They concluded that the country cannot achieve cereal self-sufficiency by 2030 as envisioned by UN's SDGs and even by 2050. Thus, Nepal will continue to import a large quantity of cereals, particularly rice and maize in the foreseeable future.

Fruits and vegetables are rich sources of dietary fibre, vitamins, minerals, electrolytes, phytochemicals, and antioxidants, with high potential for improving food and nutritional security and peoples' livelihoods. Pandey et al. (2022) documented the status of fruits and vegetables research and varieties developed and recommended, and analysed their area, production, and yield growth rates and import and export situation in Nepal. Their findings showed that the development and release of hybrids and open-pollinated varieties using locally adapted genetic resources are limited in fruits and vegetables. They showed that despite the increase in area growth, the production has not increased resulting in rapid imports of fruits and vegetables in recent years to meet the increasing demands.

Citrus production is important for improving the rural economy in the mid-hill areas of Nepal. The citrus industry and citrus export have the potential to eliminate poverty, reduce hunger, and increase economic growth. The industry is however characterized by poor citrus quality resulting in a low profit. Aryal et al. (2022a) obtained information from actors in the current citrus value chain to explore its prospect for export from Nepal to the Tibet Autonomous Region of China. They described a potential supply chain in terms of actors and pathways, production areas, transport corridors, disease and pest management, cold treatment disinfestation, and other phytosanitary protocols. Khatiwada et al. (2022) discussed the current post-harvest practices and constraints and potentials for improved post-harvest management and quality regulations of fresh agricultural produce in Nepal. They found that the post-harvest loss of fresh produce of fruit and vegetables in the country ranges from 20 to 50% due to improper harvesting methods, inappropriate sorting and grading practices, delay in transport, and poor post-harvest storage and processing facilities. They suggested that the post-harvest management of horticultural crops requires systematic interventions to implement policies under general food safety and quality framework to meet the quality needs of the domestic consumers and for export to other countries.

The use of quality seed is important for increasing crop yield. In Nepal, seed production of most crops is done informally by individual farmers or in groups by farmers' communities, or formally by the government or the private sector. In on-farm situations, seed storage methods are improper, and, in most situations, there is a lack of both dry chain (e.g., hermetic storage bags) and cold chain (e.g., cold storage) facilities for storing seeds (Bradford et al. 2018; Ghimire et al. 2022). Ghimire et al. analysed the strengths and weaknesses of seed policies, programs and strategies and their implementation and found that seed replacement rates of most crops in Nepal are low. They suggested that the production and distribution of good quality seed is possible through a robust national seed system by public and private sectors working together. Since the seed is produced and distributed both formally and informally, strong coordination amongst various partners is important.

Nepal has a long history of managing agrobiodiversity as a source of livelihood mostly in hills and mountainous areas. Such practice has withstood multiple forms of climatic, social, and ecological risks but also adapted in varying degrees to those risks. Joshi and Gauchan (2022) highlighted the importance of conservation and sustainable use of agrobiodiverse species and varieties of crops, animals, and forest emphasizing on native, neglected, and underutilized species (NUS) and landraces for reducing poverty and meeting the food and nutrition security of people, mostly in remote hills and mountains. They concluded that poor investment in research, education, and extension, and weak seed regulatory framework are the key 'policy' constraints for the promotion of NUS and landraces.

Healthy soil is fundamental to crop, livestock, and tree production and for survival of any living being. It is also important for carbon sequestration, reduce methane and nitrous oxide emissions, and mitigate climate change. Hence, soil health improvement is necessary to increase food production and meet food and nutrition security of the increasing population (Usman et al. 2018). Tripathi et al. (2022) reviewed the soil fertility status across various agroecological regions of Nepal, soil-related constraints to crop production, factors affecting soil fertility decline, farmers' current soil management practices and strategies for developing improved soil management practices, soil-related policies including the need for digital technologies for soil mapping and fertilizer recommendations, and contribution of soil to food and nutrition security in the country. Their findings revealed that soil fertility across the agroecological regions is in declining trend due to soil nutrient mining, depletion of soil organic matter, soil erosion, and inefficient or low use of chemical fertilizers.

Poor crop health is one of the main constraints for achieving high yields. In developing countries, extension agencies and agro-vets (agri-input dealers) provide agricultural services to

farmers based on visual symptoms in sick plants which could result in incorrect plant diagnosis. Farmers are then advised to use high doses of chemicals which result in high production costs and can also impact environment, food safety, and human and animal health. G.C. et al. (2022) discussed the use of Plant Clinics originally developed and piloted by Centre for Agriculture and Bioscience International, Netherlands, and now expanded to 34 countries including Nepal. In such clinics, farmers visit and meet with extension workers who are trained as plant doctors. Such doctors then diagnose the farmer's crop health problems and provide appropriate crop health management related advice to farmers.

Nepal is experiencing various issues related to fraud, adulteration, chemical contaminants, and toxins in food. Thus, the Government of Nepal has developed food safety policy and various Acts, Regulations and Standards related to food safety and quality. However, implementation of such legislation is often constrained due to poor governance, limited financial resources allocated to human resources development and laboratory facilities required for chemical and microbiological analysis. Chaulagain et al. (2022) discussed current policies and practices of food safety and quality and provided insights on major drivers for food safety regulations along with the initiatives that the local governments can take in formulating and strengthening such policies and regulations in the country. They concluded that a system for proactive governance system in developing and implementing comprehensive food safety and quality management rules and regulations is instrumental to minimize the toxins and contaminants and assure high quality food.

There are increasing concerns that conventional farming may not be profitable, and sustainable due to increased use of intensive tillage and farm inputs, resulting in high production cost, loss of soil organic matter, and increased GHGs emissions. Regenerative agriculture and conservation agriculture practices are found to be alternative and sustainable practices to conventional agriculture (Dixon et al. 2020; Elevitch et al. 2018; White 2020). Adhikari and Timsina (2022) examined Nepal's agricultural policies considering the inadequate performance of Nepal's agricultural sector and then suggested a planning framework for 'regenerative agriculture', a nature-based farming with optimum use of local resources and reduced or no use of chemicals. They also presented a multiscalar policy and planning framework for the development of regenerative agriculture that has potential to eliminate poverty, reduce hunger, and tackle climate change effects. They suggested that such a nature-friendly farming leads not only to sustainable agriculture through conservation of resources, but also to higher production and availability of diversified, safe, and nutritious foods, and helps generate more income and employment, ultimately leading to improved livelihoods of the farmers. Such a system also contributes to building resiliency to emerging environmental, climate change, and trade problems.

Conservation agriculture (CA) follows three principles in farming: minimum soil disturbance, residue retention on field, and diversified and sustainable crop rotations. CA and resource-conserving technologies (RCTs) have potential to sequester carbon and reduce CH_4 and N_2O emissions, improve productivity, reduce production costs, and increase farmer's income through reduced use of labour, energy, and other farm inputs (Dixon et al. 2020). Amgain et al. (2022) reviewed the application of CA and RCTs (e.g., dry direct-seeded rice, unpuddled transplanted rice, and zero-tillage maize, wheat, and legumes with the retention of crop residues) for improving productivity, profitability, and the sustainability of cereal-based cropping systems in Nepal. Their review demonstrated that the CA and RCTs can increase grain yield and profits and save labour and water use compared to conventional practices. No or minimum tillage along with residue retention can suppress weeds, increase crop diversification, improve soil physico-chemical and micro-biological properties, enhance nutrient- and energy-use efficiencies, reduce soil erosion in sloping hilly areas and undulating land with narrow terraces, and reduce GHGs emissions. They emphasized that there is

an urgent need to institutionalize the CA and RCTs to achieve the food, nutrition, and livelihood security of the growing population in Nepal.

Urban Agriculture (UA)—a system of producing foods within and around the cities—has potential to provide healthy, fresh, and quality food and achieve food and nutrition of increasing urban population in the developing countries (Bryld 2003). Kafle et al. (2022) discussed about the social, economic, and environmental well-being outcomes of the UA with broader policy implications for sustainable urban development, particularly focusing on the policy agenda for Nepal. They concluded that urban agriculture can end hunger, promote food and nutrition security, and can help develop sustainable agriculture.

1.2.2 Theme 2: Livestock and Fisheries

The livestock sector is one of the mainstays of Nepalese economy contributing to 11.5% of national GDP. Though majority of the livestock production system in Nepal is still subsistence-oriented with low production, trends in transition towards semi-commercial or commercial systems are occurring in some areas. Neopane et al. (2022) assessed the current and projected domestic production and availability of livestock products for future and identified key production constraints and issues for making the country self-reliant in livestock products and reducing their import. Using government reported livestock data from 1961 to 2019 and an Autoregressive Integrated Moving Average (ARIMA) model, they predicted livestock population and primary livestock products for 2029/2030. They showed that the projected growths of livestock population and products were likely to increase in 2029/2030 but were unlikely to meet the nutritional needs of people. Low productivity, higher production cost, marketing hurdles, climate change impacts, and inefficient institutions and policies are major issues in livestock production and marketing in Nepal.

Bhandari (2022) investigated the associations between land and livestock ownerships and food security at households using a sustainable livelihood (SL) framework and the nationally representative 2016 Nepal Demographic Health Survey (NDHS) data in Nepal. Based on the results from the multilevel regression (binary logistic and OLS regressions), he showed that the ownership of both land and livestock and farmer's education are significantly and positively associated with household level food security. He also suggested that whilst agriculture is important in addressing the food insecurity challenge, it's not sufficient and a household's access to other capital assets is equally important for solving the multifarious problems.

Though the livestock production system in Nepal is moving towards commercialization there are also concerns of emerging infectious diseases which are posing a severe impact on the sustainable development of this sector. Dhakal and Karki (2022) reviewed the current trend of livestock production and its contribution to achieving SDGs, zoonotic diseases of importance, and the impact of COVID-19 pandemic on livestock sector in Nepal. They found that the pandemic has negatively impacted all aspects of livestock sector including production, processing, transport, sales, and consumption, especially in commercial livestock production systems in Terai, and taught about the importance of the interconnectedness of animal–human–environmental health. They suggested that such interconnectedness requires a One Health approach, which combines the efforts of multisectoral professionals including human health, animal health, and environmental health to reach a common goal of health for all (Mackenzie and Jeggo 2019). They suggested that to prevent future epidemics or pandemics such as COVID-19 and to safeguard veterinary and public health from emerging pathogens, institutionalization and implementation of the collaborative, multidisciplinary and multisectoral One Health approach is necessary for Nepal.

Transhumance systems can play an important role in improving the food security, livelihoods, and overall well-being of rural households and

maintaining ecosystem services in the remote Himalayas and mountains of Nepal. There is however a limited understanding of the nature and extent of its existence and how this is contributing to household level food and nutrition security in the country. Aryal et al. (2022b) analysed the current states, drivers of change, and socio-ecological impacts from the current and emerging trends of transhumance system in Nepal using a Driver-Pressure-State-Impact-Response (DPSIR) framework. The drivers of changes to the transhumance systems come from global, national, and local scales, mainly resulting in labour shortage due to outmigration and reduced flexibility. The study showed a declining trend in transhumance systems in Nepalese mountains resulting in decreased crop production, increased food insecurity and livelihood vulnerability, and reduced biodiversity or ecosystem services. They provided a comprehensive knowledge and understanding for making important policy decisions on transhumance and discussed how the sustainability of long-standing transhumance systems could contribute to achieving different SDGs.

Aquaculture and fishery sector employs 0.6 million people and contributes about 4.25% of the agricultural GDP and 1.33% of the national GDP (Rijal and Jha 2020). Fish is the third most important animal protein source, contributing about 20% of the total animal protein intake in Nepal (MoALD 2020). Shrestha et al. (2022) assessed the status, trend and future scope of aquaculture and fisheries, and made policy recommendations for improved fisheries management and aquaculture development in Nepal. Due to illegal fishing practices and river water diversion, wild catch of fish has been declining whilst aquaculture has been growing annually in recent decades. Though the traditional carp polyculture in ponds accounts for almost 90% of the aquaculture production, commercial cultures of rainbow trout, tilapia, pangasius, and other catfishes are also spreading rapidly due to their high productivity. They found that shortages of fish seed and quality feed are the major constraints, but the sector has great potential to help solve poverty, reduce hunger and malnutrition, improve health and well-being, maintain gender equality, and increase employment opportunities.

1.2.3 Theme 3: Forest Ecosystems, Community Forestry, and Agroforestry

In Nepal, national forests are protected and managed by the central or provincial government. On the other hand, the community forests, though owned by the government, are managed by the local communities with users' rights and benefits shared by them. In either case, conserving forests with optimum tree density and appropriate logging and regenerative practices are necessary for protecting environment and increasing revenues from forest. Also, integration of trees with crops and livestock in private and farm families' lands (i.e., agroforestry systems) is necessary for increasing farmers' income and livelihoods. Yet, very little research and scaling of agroforestry systems have been carried out in Nepal due to the lack of appropriate policies and commitments required for implementations.

Nepal's community forestry has improved the livelihoods of local communities to some extent, but the success of community forestry is not fully explored in terms of ecosystem services that such forests can provide. Ojha et al. (2022) assessed the potential of community forests for providing various kinds of ecosystems services (ES) and improving the livelihoods of the local communities managing those forests. Their analysis based on 14 cases of community forestry across the country showed that most of the cases have clearly sought to promote and develop new ES beyond the traditional products like timber and fuelwood, depending on ecological and economic contexts. They identified several emerging initiatives towards ecosystems-based management of community forestry, and a shift away from the subsistence-oriented to more holistic management of community forests. They concluded that increasing market value of ES has the potential to contribute further to poverty reduction if communities are granted secure tenure

rights over forests and if there is an enabling environment for networking, innovation, and learning amongst community groups.

The efficient use of forest goods and services is crucial for sustainable forest management. Selective logging is a dominant forest harvesting practice, contributing nearly 15% of global timber needs. However, due to increased global awareness and emphasis on need to conserve forests for climate change mitigation, there are contrasting views and opinions about the importance of selective logging in terms of environmental and economic impacts. Poudyal et al. (2022) assessed the policies and practices of selective logging in community forests and the implications of such practice on environmental, economic, and local livelihoods using primary data from a Terai district in central Nepal. They quantified the environmental impact of selective logging on timber production and carbon emissions along the production value chains from timber harvest to its processing. They found higher forest products recovery rates from the harvested trees and lower carbon emissions in logging processes as compared to other countries, which offer lessons even to the highly mechanized and countries of Asia and the Pacific for REDD+ (carbon payment in forestry sector) initiatives.

In recent years, the importance of integrating trees with crops and livestock has been increasingly recognized due to their potential in mitigation of and adaptation to climate change and carbon trading. Dhakal et al. (2022) provided several examples of agroforestry systems in Nepal in terms of improving farmers' livelihoods and food security, halting land degradation, agrobiodiversity conservation, utilizing the ecosystems services, and thereby positively contributing to poverty alleviation and climate change mitigation and adaptation. They concluded that integrated agroforestry systems could be an alternative to sole crop- or livestock-based farming systems in Nepal, though small landholding, lack of institutional setups and access to credit and markets for agroforestry, and farmers' indifference attitude towards environmental benefits accrued from agroforestry could be the constraining factors for its adoption. Nevertheless, the adoption of less labour-intensive agroforestry practices could be an opportunity for farmers who are forced to leave their farmlands fallow due to labour scarcity resulting from youth outmigration for jobs.

1.2.4 Theme 4: Cross-Cutting Topics

Nepal has abundant sources of water required not only for irrigation of its agricultural lands, hydropower development, energy needs, and for industry and household requirements of its own people but also for sale of water and energy to neighbouring countries. Unfortunately, due to lack of political will and geo-political and transboundary situation, water resources in Nepal are not fully utilized, and Nepalese agriculture remains mostly rainfed. Moreover, the country follows a 'sectoral or silo' approach to development rather than an integrated multisectoral approach. An improved understanding and implementation of the relationship and linkages of water, energy, and food (W–E–F) nexus (Rasul 2016) from local to national level would be required to develop hydropower and generate energy, develop irrigation infrastructure, increase agricultural production, and protect environment. Uprety et al. (2022) identified problems and causes of low agricultural productivity and demonstrated that abundant water is available for irrigation of existing rainfed lands to increase agricultural productivity and meet multisectoral energy requirements of the country. They presented three case studies on the application of the W–E–F nexus framework: two studies (Sunkoshi Marin Diversion Multipurpose Project and Bheri Babai Diversion Multipurpose Project) pertain to multipurpose development projects of national importance whilst the third study (Conventional tillage vs. zero tillage in rice-based cropping systems in the eastern Gangetic plains) provides an example of CA-based sustainable intensification practice integrating water, energy, and food in two eastern Terai districts of Nepal. They provide a perspective on the importance of W–E–F nexus and suggest adopting such nexus

approach as the dominant planning framework by the National Planning Commission by replacing the existing sectoral framework. They emphasized that the nexus approach is critically important for Nepal because water is the only abundant resource available and must be utilized effectively integrating the development of hydro-energy, irrigation infrastructures, and human and industrial consumptions.

Global research has shown that crop simulation models can generate various recommendations related to biophysical factors such as crop, water, tillage, nutrient, and pest management, crop yield and weather forecasting, predict yield trends and yield declines in cropping systems, and predict the impacts of climate change on crop productivity (Timsina et al. 1995; Timsina and Humphreys 2006a, 2006b). Devkota et al. (2022) reviewed the development and application of crop simulation models for major cereal crops in South Asia, focusing on Nepal. Their analysis revealed that the average gaps between potential yields and farmers' yields of rice, wheat, and maize in Nepal are high (10–12, 5–8, and 11–15 t ha^{-1}, respectively), suggesting the large scope for yield improvement by research or by developing improved management practices. They demonstrated that for achieving self-sufficiency in cereal grains by 2030, the average national yield of rice, wheat, and maize needs to be increased to 5.7, 3.9, and 4.9 t ha^{-1} by 2030 from the current low national average yields of 3.76, 2.85, and 2.82 t ha^{-1}, respectively. They concluded that the simulation models can be useful DSS tools for policy planning and implementation, determining the impact of climate change in crop yield, increasing efficiency in research, prioritizing research and extension interventions for increasing yields, helping achieve food and nutritional security, and addressing the effects of, and developing adaptation strategies to, climate change.

Asian women farmers play an important role in all aspects of farming. In the hills and mountainous areas of Nepal, women farmers are actively engaged in decision-making as well as participating in various on-farm activities related to crop, livestock, and forestry. Combining a social-ecological systems approach with feminist political ecology lens, Bhattarai (2022) examined the interplay between gender equity and adaptation in the Nepalese Himalayas. From a case study of farm-level practices with a focus on rice cultivation in a mountain village, she showed how gender roles and relations were influenced by wider socio-economic changes and discussed how they could shape adaptation practices, as households adopt high-yielding lowland rice varieties and abandon upland rice cultivation practices. She concluded that agricultural modernization has exacerbated gender inequality and made the farming communities, particularly women, more vulnerable to climate change. She suggested for a more holistic approach to agricultural research and development, with gender-based differentiations in knowledge, management, and policy for agriculture to withstand the impact of climate change and adapt to the socio-economic changes.

1.2.5 Implications for Sustainable Development Goals

Various chapters included in this book have explored opportunities for enhancing contributions to several SDGs, especially goal (1) eliminating poverty, (2) ending hunger, (3) ensuring healthy lives and promote well-being, (5) achieving gender equality and empower all women and girls, (7) ensuring access to affordable, reliable, sustainable, and modern energy for all; (8) promoting sustained, inclusive, and sustainable economic growth, (11) making cities inclusive, safe, resilient, and sustainable, (12) ensuring sustainable consumption and production patterns, (13) combating climate change and its impacts, and (15) protecting, restoring, and managing terrestrial ecosystems, combating desertification, and halting reverse land degradation and biodiversity loss (United Nations 2015,2016). Contributions of various chapters to achieve various goals are summarized in Table 1.1.

Table 1.1 Chapters contributing to different sustainable development goals (SDGs)

SDGs	Chapters	Description
1	Agrobiodiversity; Agroforestry systems; Aquaculture and fisheries; Cereal supply and demand projections; Citrus production and export; Conservation agriculture; Ecosystems services from community forestry; Fruit and vegetables production; Gender; One health approach; Regenerative agriculture; Robust seed systems; Simulation modelling; Water-Energy-Food nexus	Reducing poverty and promoting food and nutritional security
2	Agrobiodiversity; Agroforestry systems; Aquaculture and fisheries; Cereal supply and demand projections; Citrus production and export; Ecosystems services from community forestry; Food toxins; Fruit and vegetables production; Gender; Livestock production; Livestock ownership; One health approach; Plant clinics; Post-harvest losses of fruits and vegetables; Regenerative agriculture; Robust seed systems; Simulation modelling; Soil health and soil security; Transhumance systems; Urban agriculture; Water–Energy–Food nexus	Ending hunger and promoting food and nutritional security
3	Agrobiodiversity; Aquaculture, and fisheries; Food toxins; Fruit and vegetables production; Livestock production; Livestock ownership; One health approach; Post-harvest losses of fruits and vegetables; Regenerative agriculture; Transhumance systems;	Good health and well-being and promoting nutrition security
5	Aquaculture and fisheries; Gender	Gender equality and empowering women and girls
6	Agroforestry systems; Selective logging practices; Soil health and soil security; Water–Energy–Food nexus	Ensuring availability of safe water and improving water quality
7	Selective logging practices; Water–Energy–Food nexus	Ensuring access to affordable, reliable, and sustainable energy for all
8	Agrobiodiversity; Aquaculture and fisheries; Ecosystems services from community forestry; Gender	Decent work and economic growth
11	Urban agriculture; Water–Energy–Food nexus	Making cities inclusive, safe, resilient, and sustainable
12	Agrobiodiversity; Fruit and vegetables production; Plant clinics; Post-harvest losses of fruits and vegetables	Responsible consumption and production
13	Agrobiodiversity; Agroforestry systems; Conservation agriculture; Ecosystems services from community forestry; Fruit and vegetables production; Gender; Livestock production; One health approach; Regenerative agriculture; Selective logging practices; Simulation modelling; Soil health and soil security; Transhumance systems; Water–Energy–Food nexus	Climate change mitigation and adaptation; environmental conservation; Reducing GHG emissions
14	Aquaculture and fisheries; Plant clinics;	Improving life below water
15	Agroforestry systems; Regenerative agriculture; Conservation agriculture; Ecosystems services from community forestry; Fruit and vegetables production; Robust seed systems; Selective logging practices; Soil health and soil security; Plant clinics; Water–Energy–Food nexus	Sustaining life on land

1.2.6 Conclusions, Research Gaps, and Research and Policy Recommendations

Three agroecological/farming system zones (Terai, mid- and high-hills, and mountains) are well-known and clear characteristics of Nepalese agriculture. This chapter emphasizes that farming systems approach to research and development integrating crops, livestock (including fisheries and poultry) and forestry should be the major overarching, and achievable, research and policy recommendation for the country. Major research gaps and research and policy recommendations provided in each chapter are summarized below, which would be useful for researchers and policymakers in agriculture, forestry, and natural resources management sectors in Nepal and South Asia as a whole.

1.2.6.1 Theme 1: Agriculture, Horticulture, and Post-Harvest Management

- Government should increase investment in crops, fruits, and vegetables research and development to generate high-yielding technologies and production practices and facilitate their marketing. To materialize these, adequate policy support and services are required to ensure household and national level food and nutrition security, reducing import, and make the country self-reliant.
- There is a need to develop post-harvest handling guidelines, set 'basic' quality standards, and develop post-harvest storage and processing facilities that could pave the path for further development of horticulture sector.
- There is a need to sensitize consumers and create market to produce safe and healthy and nutritious food.
- Policy should encourage the small-holder farmers to participate in citrus value chains including their export potential to achieve high profit and improve their livelihood security.
- There is a need to promote use of dry and cold chains technologies to safeguard the seed quality, especially during harvesting and storage. Such technologies (e.g., hermetic storage bags and cold storage) should be upscaled to improve food and nutrition security, biodiversity, and disaster resiliency.
- Clear guidelines are needed to produce hybrid seeds and maintain their standards.
- Implementation of the seed sector policies and laws is essential through public and private sector partnership to fulfil the gap between seed demand and supply, improve the capacity of private sector stakeholders, and speed up the seed industry development.
- Digitization of the seed information system is required for efficient data sharing and information management.
- Local landraces and their genetic enhancement should be strengthened by using both conventional and molecular techniques and building human resource capacity.
- There is a need to develop site-specific staple, nutritious, and climate-resilient varieties and diversified products by utilizing rich agro-biodiversity of diverse neglected and underutilized species (NUS) of crops, livestock, and trees to achieve the long-term food, nutrition, and livelihood security.
- There is a need to develop policy and programs for mapping the farming systems zones of NUS species to develop site-specific species or landraces of staple crops, vegetables, spices, fruits, livestock, fish, and trees.
- Policy formulation is necessary to enhance and support household- to province-specific products focusing on neglected, underutilized, understudied, and unexploited crops and other neglected plant and animal species with high potential to raise the country's economy.
- Research should focus on developing improved practices using integrated plant and soil nutrient management, growing food legumes or green manure crops in rotations, growing cover crops and mulching, practising in-situ manuring, strip-cropping, or agro-forestry systems with hedgerow/alley-cropping, and with reduced or minimum tillage.

- Integrated nutrient management with combined use of organic and inorganic fertilizers is necessary to maintain soil nutrient balance and improve soil health, and enhance productivity, profitability, and sustainability of cropping systems.
- There is a continuing need for development of improved soil information systems using digital technologies such as digital soil maps, mobile soil testing labs, and DSS-based site-specific nutrient or fertilizer recommendations.
- Local government authorities need better integration of plant clinics services with the enhanced coordination of private and non-government sectors.
- There is a need to develop strong and well-developed farmers' institutions (farmers' groups and agriculture cooperatives) that can implement plant clinics at the local level. For this, systematic introduction and integration of plant clinics into the existing agricultural programs and their operation in cooperation with farmers' institutions is needed. This will help develop effective, fast, and reliable diagnostic tools for crop health issues.
- Development of online database for pest monitoring and surveillance and the integrated management of crop health problems should be the policy priority.
- Establishing, strengthening, and technology-based quality monitoring and surveillance system at the quarantine check points in airports and land borders should be strictly enforced to regulate the import of substandard or adulterated food stuffs.
- Effective implementation of food regulations locally and at the quarantine check points, formulation of legislative and policy measures, development of technical human resources, well-equipped laboratory facilities for food toxins testing, and allocation of financial resources from three tiers of government are necessary for food toxins minimization.
- Government needs to create a policy environment to enable and use the regenerative agriculture framework at different scales and planning agencies and people need to be trained to improve skills in this framework implementation.
- There is a need to create policy environment that enables communities of a landscape to come together to integrate their plans for regenerative agriculture. The federal structure and the devolution of power and resources to the sub-national levels can provide such an enabling environment.
- Government support in research and development and protecting farmers and their interest in promoting regenerative agriculture through incentives is required for quick adoption of this framework.
- Various CA and RCTs practices need to be tested, verified, and scaled-out across the mid-hills and Terai regions to increase productivity, profitability, and sustainability cropping systems.
- A concrete plan to initiate/establish machinery production units/industries and their value chains should be devised and implemented to facilitate the adoption of CA.
- There is a need to develop a joint plan of action by the federal and provincial line ministries and associated research and extension bodies to scale-out the currently available CA and RCTs and make the local government a prime implementer of the plan.
- CA and RCTs need to be mainstreamed in agricultural educational institutions, agriculture ministry's planning and implementation units, and in climate change-related policies, planning, and management mechanisms.
- There is a need to select and implement proper well-being indicators and formulate robust policies and programs for promotion of urban agriculture.

1.2.6.2 Theme 2: Livestock and Fisheries

- There is a need to strengthen market infrastructure and support services, technology development and dissemination, building capacity of institutions and stakeholders, and

enable policy environments for livestock and poultry breed improvements and development.
- There is a need to prioritize conservation and improvement of local livestock and poultry breeds.
- Effective policies on breeding, feeding, and animal health need to be formulated for sustainable livestock and poultry production.
- There is an urgent need for revising conservation policies in higher Himalayas due to ongoing adverse ecological impacts of grazing and declining trends of transhumance systems.
- DPSIR framework needs to be recognized as an important methodological tool in the study of social ecology of the transhumance systems in Himalayan ecosystems.
- There is a need to develop policies to provide the ownership of land and animals to the households to help lessen food insecurity problem.
- Aquaculture and fisheries need to be integrated in education, research, and development institutions.
- Aquaculture and fisheries management policies need to be fully developed and implemented.
- An institutional set up for effective implementation of multisectoral one health policy needs to be established.
- To prepare for next generation of experts and facilities to tackle future disease outbreaks, biosafety laboratories and animal health services in different provinces need to be established and veterinary and public health curricula need to be updated with inclusion of zoonotic diseases, epidemics and pandemics, and their preventive measures.
- Veterinary laboratories should be equipped with molecular diagnostic facilities for timely and precise surveillance of pathogens and effective regular treatments.
- Livestock insurance policy needs to be developed to reduce the risk of diseases and natural disasters.
- Investment in infrastructure such as cold chains and powder milk plants in public–private partnership in strategic locations needs to be made to preserve perishable livestock products.

1.2.6.3 Theme 3: Forest Ecosystems, Community Forestry, and Agroforestry

- Policy and action plans should prioritize the timely harvesting of mature trees and minimal damage to neighbouring plants.
- Improvement of natural forest harvesting guidelines should be the first important step in improving the recovery of forest products and to minimize harvesting damage to the forest undergrowth.
- Reducing bureaucratic burden and minimizing involvement of the state forest agency in day-to-day harvesting activities should be ensured to ease forest harvesting operations.
- Provisioning of single long-term periodic permits for tree harvesting should be made to reduce transaction costs compared to the current multistage tender process in Nepal's forest harvesting system.
- Occupational health and safety codes of conduct and forest harvesting code of practice specifying technical requirements and compliance mechanisms in natural forests are urgently needed.
- Legislation and regulations that contradict the Agroforestry Policy 2019 should be amended.
- Agroforestry practices need to be mainstreamed in agriculture, livestock, and forest and environment ministries.
- Forest user groups of community forests and leasehold forests should be motivated to adopt location-specific and economically viable agroforestry systems.
- Environmental and ecosystems services from agroforestry systems should be quantified, monetized, and paid to the farmers for adopting the agroforestry systems and involving them in the carbon credit mechanisms.
- Mapping agricultural lands suitable for growing trees under agroforestry systems should be prioritized to scale-out agroforestry practices across the country.

- Policy should prioritize collective farming and providing land use rights for crop-tree-based farming in the abandoned farmland.
- There is a need of holistic management of forest ecosystem for maintenance of ecological integrity, poverty reduction, and livelihoods improvements.

1.2.6.4 Theme 4: Cross-Cutting Topics

- Government should apply the W–E–F nexus framework for planning at the Ministerial level and integrated farming systems approach in research and development activities at field level to meet the growing needs of water, energy, and food, and to maintain the sustainability of the natural resource base for the current and future generations.
- There is a need to calibrate, validate, and apply crop simulation models to increase crop productivity, profitability, and achieve food and nutrition security under current and future climate change conditions.
- There is a need to apply crop models for breeding climate resilient varieties, improving resistance against biotic and abiotic stresses, and in agronomic research for improving crop's resilience against stresses.
- Agricultural research and development need to integrate the socio-economic (including gender) and biophysical issues to develop integrated farming systems strategies to address food and nutrition security under varying socio-economic environments.
- There is a need to consider the dynamic links between social, ecological, and agrobiodiversity management to achieve gender equitable adaptation in agrobiodiversity management.
- Agriculture and rural development need to be supported by a nuanced view of the interplay between gendered forms of knowledge, power, and decision-making practices in specific social, political, and environmental contexts.
- There is a policy need to address gender inequity through the analysis of intersectionality based on caste, ethnicity, and class.

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Part I

Agriculture, Horticulture, and Post-harvest Management

2 Cereal Demand and Production Projections for 2050: Opportunities for Achieving Food Self-Sufficiency in Nepal

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Abstract

Cereals are a major source of food security, income, livelihood, and employment in Nepal. However, there is a lack of time-series data for cereals to have a full understanding of the level of production, productivity, and self-reliance in food production in the country. The objectives of this chapter are to assess patterns and dynamics of cereal production, productivity, and import growth, and analyze food demand and self-sufficiency in Nepal. The major data sources for the chapter came from the national statistics, published and unpublished research papers, and policy documents. We used a compound growth rate estimation, coefficient of variation, and instability index techniques for analyzing dynamics and variability of the growth of food production and productivity over time. In addition, production and demand growth of cereals and self-sufficiency ratios were estimated for the next three decades until 2050 using different scenarios of production, population, demand growth, and the effect of climate change. Autoregressive regression model was used to analyze the relation between domestic production and income growth with import. The findings revealed that present production and productivity of cereals are low to meet current and future food demands of increasing population. Moreover, limited marketable surplus available at household level is the fundamental reason for steady increase in food imports. As a result, the country will continue to import a large quantity of cereals, particularly rice and maize in the future too. The country cannot achieve cereal self-sufficiency until 2030 under current growth rate of production, population, and negative effects of climate change. We suggest that government increase investment in agricultural research and development (R&D) to generate new and higher-level technologies

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and production practices for sustainable intensification of cereals with adequate policy support and services for ensuring national and household-level food and nutrition security to meet SDGs 1 and 2 by 2030.

Keywords

Cereal production · Food security · Food import · Productivity growth · Self-sufficiency

2.1 Introduction

Cereal crops are major food staples that play a significant role in food systems transformation and poverty reduction in developing countries. They are vital for human diets and livelihoods of a large proportion of smallholder farmers as well as crucial to meeting increasing food demand of growing populations throughout the world. To meet the food demand of the projected global population of about 10 billion people by 2050, food production should be increased by 50% above the current level without damaging the environment and by reducing greenhouse gas emissions (FAO 2017; WRI 2018). Estimates show that about 60% of the global dietary energy is currently supplied by three major cereals-rice, wheat, and maize (FAO 2017).

Six cereal crops-rice, maize, wheat, millet, barley, and buckwheat-currently account for about 80% of the total cultivated area and grain produced in Nepal, supporting livelihoods of about half of the population and are vital for food security and livelihoods of the smallholder farmers and urban poor (MoALD 2020). Cereals are major food sources in Nepal, where per capita cereal consumption is about 187 kg/year (NRB 2016); they also provide about 70% of the dietary energy supply (MoAD/FAO 2016; MoF 2020). Of all cereals, rice is vital in terms of meeting calorie needs as well as protein intake (Fig. 2.1). Rice alone meets 67% of the cereal requirement and 23% of the total protein intake from different food sources consumed by the people (CBS 2016). The three major cereals (rice, wheat, and maize) alone meet 52% of the total protein needs of the people. The cereal consumption in the country is projected to grow further as a large section of population is still food insecure suggesting for the need for intensification of the sustainable cereal production. Compared to other agricultural commodities, the production of cereals has relatively lower environmental impact (Lancet Commission 2019).

The situation of food security and nutrition of the people in Nepal is extremely poor as the country ranks 79th position out of 113 countries in Food Security Index (Economic Intelligence Unit 2019) and 73rd position out of 135 countries in Global Hunger Index (GHI) in 2019 (von Grebmer et al. 2020). Currently, about 37% of the population is malnourished with high incidence of stunting of children under 5 years of age (NPC 2016). With increasing trends of population and income growth and urbanization, the country has been importing large volumes of foods from foreign countries, mainly India, in recent decades to meet the country's escalating food demand. Recent statistics show that Nepal imported food grains amounting of NPR 52 billion (US$ 450 million) in 2018/19 out of which share of rice alone was 63% of the actual value (DoI 2020; TEPC 2019). This has serious implications for socio-economic development of the country.

Nepal, a net exporter of rice until early 1980s, has now become a net importer as the country's rice productivity is lowest in South Asia (Tripathi et al. 2018). Similarly, sluggish productivity growth of other cereals is also posing great challenge for feeding the country's growing population. With rising imports of food staples, there is a huge challenge for Nepal to meeting national food security and reducing vulnerability through timely availability of food with affordable prices. Unstable cereal productivity is another characteristic feature of Nepalese agriculture. This is because the farmers are yet to use improved technologies in cereals farming and weather extremes largely affect cereals performance over seasons. It is ironic that, even in the favorable year for crop production such as 2020, the country was still deficient in food grains with import requirement

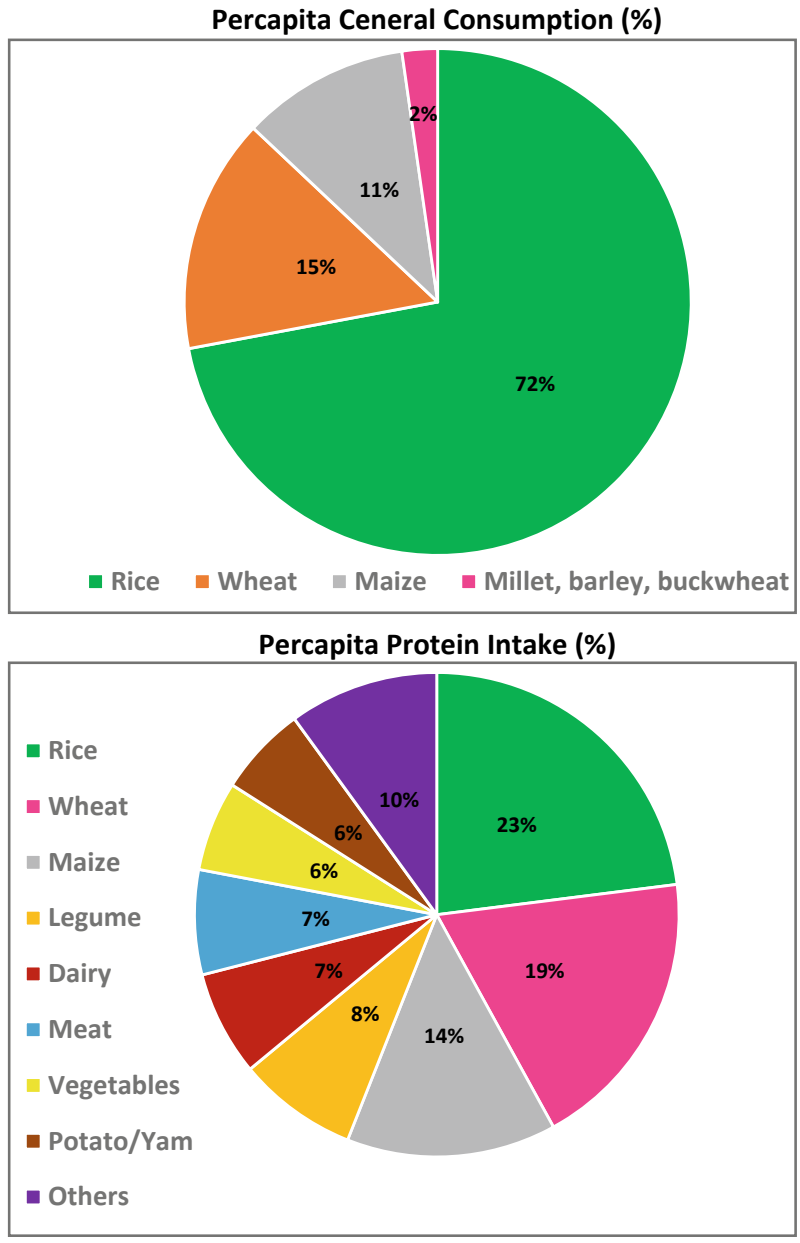

Fig. 2.1 Contribution of major cereals to per capita food consumption and protein intake in Nepal. *Source* CBS (2016)

of 1.2 million tons, mainly rice, to meet the domestic demand (FAO 2020). The country's ability to increase cereal productivity at a reduced cost and to produce enough food for achieving food and nutrition security and better livelihoods of smallholder farmers is largely constrained by lack of rightly focused cereal production programs and activities integrating science, technology, and business models. High production cost, small farm sizes, insufficient support to farmers in terms of access to new and climate-resilient technologies, low input use and low or no new skills, and technical know-how (Adhikari et al. 2020) collectively contribute to low crop productivity in the country. Total factor productivity (TFP) growth, which is a measure of collective contribution of