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Editorial

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Agricultural Policies and Practices: Pathways for Transformation

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Agriculture has been a cornerstone of human civilization for thousands of years, providing food and other essential resources to sustain our societies. However, as we enter the 21st century, we face unprecedented challenges that threaten the very foundations of our agricultural systems. Climate change, resource depletion, and population growth are just a few of the issues that demand urgent attention from policymakers and practitioners alike. Further, the growing population, climate change, the recent COVID-19 pandemic, the Ukraine-Russia war, and the depreciation of national currencies have disrupted the global food supply chain and increased food prices and food insecurity in many countries, including Nepal.

The Nepalese agriculture sector alone contributed employment opportunities for more than 60 % of the population with a 23.9% share in total value added of the national economy (Ministry of Finance, 2022). Though the majority of farmers in Nepal are engaged in the agriculture sector, there is still a dominance of traditional and subsistence agriculture and the country's agricultural production is not enough to feed its population. The continued rise in import bills and volume of food products in recent years has been a major challenge for the country. Addressing these constraints warrants consortia of efforts from the government, nonprofits, and private sectors to

Keywords: Special issue, Editorial, Collaboration, Agricultural Policies

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promote sustainable and regenerative agricultural concepts and practices that align with local farm attributes and the agroecological environment.

Thereof, a two-day (January 6-7, 2023) virtual symposium on "Agricultural Policies and Practices in Nepal: Pathways for Transformation" was jointly organized by the Policy Research Institute (PRI) and Association of Nepalese Agricultural Professionals of Americas (NAPA) with the aim to discuss and synthesize structural, policy intervention-related procedural, and local barriers and issues inherent to inadequate agricultural growth in Nepal and recommend transformative and pragmatic policies, programs, and practices feasible at local, regional, and national levels.

The other symposium collaborators were the Ministry of Agriculture and Livestock Development (MoALD), Nepal Agricultural Research Council (NARC), Agriculture and Forestry University (AFU), Institute of Agriculture and Animal Sciences (IAAS, Tribhuvan University), Nepal Agricultural Cooperative Central Federation Ltd. (NACCFL), and Society of Agricultural Scientists-Nepal (SAS-Nepal). The 38 papers presented at the symposium brought together over 500 researchers, policymakers, and practitioners from around the world. The symposium highlighted the importance of innovative policies and practices that can help transform agriculture and ensure its sustainability for future generations.

The symposium was organized and facilitated in four thematic areas. The Agriculture Policy theme highlighted an analysis of current agricultural policies, laws, and regulations that have hindered the production and marketing of farm products, land use policies, transformative agriculture for the viable and circular economy, promoting cooperative farming, farm diversity, and sustainability including internationally successful policy practices suitable for Nepal. The Agricultural Research, Education, and Extension theme included diverse subject matters. These were genetic improvement of crops and livestock for diverse agro-climatic zones; technology innovations and dissemination; science-based knowledge and extension practices; climate-smart and organic agriculture; agri-business and entrepreneurship; commercial agriculture; and integration of the agricultural research, education, and extension. Similarly, the Technology and Infrastructure Development theme focused on varied avenues of innovative technology (such as UAV, GIS, and Remote Sensing), farm mechanization, and smart and efficient irrigation practices to optimize costs of production, labor, fertilizer shortages, and monitoring of plant and soil health Finally, the Governance theme underpinned coherence and discordance between the policy frameworks and governing structures/mechanisms of three levels of government and opportunities for realignment for agricultural transformation as well as a local governance framework for agricultural service delivery at a municipality level.

Finally, the symposium highlighted the importance of partnerships and collaborations in driving transformational change. The papers discussed the potential of public-private partnerships, multi-stakeholder platforms, and other forms of collaboration to leverage resources, share knowledge, and scale up innovative solutions.

This special issue received 20 papers for publication consideration, however, after the review process, it is able to manage 12 papers for publication. These papers provide a rich and diverse set of insights into the pathways for transforming agriculture. They offer both practical guidance and theoretical frameworks for policymakers and practitioners seeking to navigate the complex challenges facing agriculture today. We hope this special issue will inspire further research and action towards a more sustainable and equitable agricultural future.

We thank all the authors who contributed to this special issue and the reviewers who provided their valuable feedback. We also extend our appreciation to the symposium organizers and collaborators. Finally, we encourage additional authors/presenters to submit their papers in the NPPR's Regular Issue, which will be published in September 2023.

Special Issue Editors

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Research Article

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Water, Energy, Food, and Ecosystem (W-E-F-E) Nexus River Basin Policy Paradigm for Agriculture Transformation and Multisector Infrastructure Development of Nepal

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Abstract

Water is Nepal's most abundant resource, and its development and utilization are essential for driving the development of multisector infrastructures (agriculture, energy, industry, urban development, etc.). Nepal has hitherto adopted an isolated and sectoral silo policy approach to development planning that has remained the dominant mode of planning across many countries in the world with few exceptions until recently when inadequacies of sectoral planning became apparent. The search for alternatively more integrative approaches came into the forefront of development discourse in the backdrop of shrinking natural resources, climate change, inexorable demand of a rapidly growing urban population, and other needs and requirements at a global scale.

The river basin-wide W-E-F-E nexus development policy strategy offers significant potential for optimum water resource utilization driving development of all sectors, including agriculture. The fundamental aspect of the W-E-F-E nexus policy framework entails the understanding of interdependencies and interactions amidst its components (water, energy, food, and ecosystem) and assessing their synergistic impacts on food, energy, water, and environmental securities in the basin. The W-E-F-E nexus policy framework aims to harness the synergy created from the interaction of interlinked components to achieve sustainable development goals (SDGs). This paper argues that Nepal government must carefully weigh the pros and cons of designing singular run-of-river mega hydro-project visa-vis multipurpose water reservoir projects with provisions of integrating irrigation, drinking water, inland waterways, and flood control infrastructures besides hydro-energy leveraging W-E-F-E nexus relationship.

Keywords: Integrated River Basin Development, Multipurpose Development Projects, Sustainable Development Goals (SDGs), TBM Technology, WEFE Nexus Policy Paradigm

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1. Introduction

This paper emphasizes the importance of the Water-Energy-Food-Ecosystem (W-E-F-E) nexus as an integrated planning policy framework for natural resource development in achieving water, energy, food, and ecosystem security that ensures sustainable development goals (SDGs). The paper argues that the W–E–F-E nexus as an integrated river basin development policy framework is highly imperative to address the need for integrated development of developing countries whose economies are primarily dependent on natural resources (water, land, forest, and agriculture). Unless the W-E-F-E nexus becomes the dominant planning framework that replaces the existing sectoral planning framework in general and the sectoral water resource development in particular, economic prosperity and sustainable development goals (SDGs) cannot be realized. Developing countries cannot ignore the W-E-F-E nexus planning framework to meet the growing needs of water, energy, food, and ecosystem service security of their people as well as the sustainability of the natural resource base for future generations (Pandey, 2017; Upreti et al., 2022; Upreti, 2021). The W-E-F-E nexus policy framework is critically important for Nepal because water is the most precious resource available that must be utilized judiciously, with the integration of the development of hydropower, irrigation, drinking water, inland waterways, flood mitigation infrastructures, and human and industrial consumptions.

Agriculture transformation in Nepal can be achieved by developing adequate irrigation infrastructures and utilizing water and energy judiciously. This will increase food production by many folds, and subsequently enhance the ability of the farming communities to safeguard and manage the natural resource base (Shrestha et al., 2018; Upreti et al., 2022). The crucial question is which approach to adopt for developing water resources in Nepal that can integrate, connect, and drive the development of other sectors, such as energy, agriculture, urban centre (drinking water), tourism and industrial development. Specifically, what planning policy and development strategy can prioritize water as the central element and drive the interconnected development of sectors intertwined with water resources? This paper argues that multipurpose water reservoir development projects conceptualized within the W-E-F-E nexus framework, can contribute significantly to yield better results due to the synergy and resource use efficiency created by the W-E-F-E nexus and, thus, needs to be adopted as a national development planning paradigm.

2. State of Agriculture

Despite its tremendous development potential, Nepal is still considered one of the world's poorest. Agriculture currently contributes only about 26 % to the GDP,

despite employing 60 % of the population. Ideally, this should have been the opposite, with agriculture employing 20-25 % population and contributing 50-55 % to the GDP. Nepal used to export grains four decades ago, but now it is importing grains and agricultural products worth more than 1200 million USD annually from neighbouring countries (Upreti, 2022; Bhattarai et al., 2020).

The productivity of agricultural labour in Nepal is significantly low, estimated at only one-fourth of the productivity of the overall economy. The major cause of low agricultural labour productivity is the subsistence type of agriculture and the fact that the most productive labour force (those in the 20 to 40 age group) seek employment abroad or in other sectors within the country. Another critical factor hindering agriculture growth is the virtual absence of the agro-based business sector which is directly connected to the productivity and growth of agriculture in neighbouring countries like India and Bangladesh. Small and medium-sized farmers in these countries have benefited from agro-industries, and agriculture has become a profitable enterprise for them.

Given Nepal's limited per capita arable land, the promotion of agro-based business sectors increased agricultural productivity through the development of irrigation, energy, input (fertilizers, improved seeds, cold storage etc.), and market infrastructures is essential for making agriculture economically and sustainably profitable. Shortage of farm workforce and climate change and its adverse impact effect is also posing serious threats. Climate change will have serious impacts on water bodies, particularly mountain glaciers, river waters, and surface and subsurface water quantity and balance in the river basins.

Year-round irrigation is the most important determinant for the transformation of subsistence agriculture into commercial one. Without adequate irrigation water, the potential of other essential inputs, such as fertilizers, improved seeds etc. cannot fully be realized, and the productivity of agriculture remains stagnant. National agriculture development policy must prioritize the commercialization of agriculture in Terai, as Terai has the largest chunk of prime arable agriculture land (1.6 million hectares). Table 1 exhibits, out of 1.6 million hectares, not even 50 % (.6 million hectares) of the land has accessible year-round irrigation infrastructure. Most of these lands are partially irrigated and heavily dependent on the monsoon water causing low productivity. Another 50 % of irrigable arable land (.8 million hectares) is completely devoid of irrigation water and a hundred percent dependent on the monsoon. Even if 50 % of Terai arable agriculture land is brought under year-round irrigation, this will not only increase the agriculture productivity by 2.5 to 3 times but also lays the foundation for the commercialization of agriculture in Terai (Upreti et al., 2022).

Table 1. Irrigated and potentially irrigable land in Nepal

Category	Terai		Hills		Mountains		Total, ha ('000)
	ha ('000)	%	ha ('000)	%	ha ('000)	%	
Cultivated agricultural land	1,594	44.8	1,566	44.0	401	11.3	3,561
Potentially irrigable land	1,480	65.3	627	27.7	159	7	2,265
Present area irrigated							
Surface water	434		170		41		654
Conjunctive use	207		–		–		207
Groundwater	226		8				234
Total	866	79.8	178	16.4	41	3.8	1085
Remaining potentially irrigable land	613	51.4	448	38.5	118	10.1	1180

Source Adapted from Irrigation Master Plan (2019)

There is an ample amount of sub-surface water available in Terai for year-round irrigation of 0.6 million hectares of irrigable arable land through electricity-powered tube wells. The total electricity required for the year-round irrigation of nearly 0.6 million hectares has been estimated to be about 300 MW (Shrestha, 2018). If the required electricity is made available to the farmers at subsidized rates, the increased agriculture productivity will not only ensures food security but also generates nearly $2.5 billion in revenue (Upreti et al., 2022; Shrestha, 2018).

Water constitutes a pivotal resource element for a diverse range of activities including but not limited to irrigation, hydropower, and human and industrial consumptive uses. Nepal must judiciously plan water utilization and development prudently, avoiding a singular focus on hydro-energy generation that compromises its multifaceted benefits.

3. Water Resource Development Policy Review

Let us briefly revisit the current water resource development approach in Nepal and the development policies and strategies guiding it. In reality, there is no well-conceived national policy or strategy for water resource development. Instead, it is based on

adhocism motivated by political interest, bureaucrats, and special interest groups to control and exploit the country's critical rivers for the sole purpose of generating hydropower. The current water resource development policy has completely disregarded the holistic approach of integrating energy, irrigation, drinking water, industrial, and other varied consumptive uses. In Nepal, there is virtually no inter-ministerial involvement, coordination or interaction when it comes to water resource development. The Irrigation Department has been moved back and forth between the Ministry of Agriculture and the Ministry of Energy and Water Resources depending upon the government's interest and convenience rather than professional and functional requirements. Consequently, there is virtually no coordinated involvement and efforts among these stakeholders, departments, and ministries in the development and implementation of energy, irrigation, drinking water, and other water-related projects, often leading to a lack of understanding of each other's work.

Development of irrigation and drinking water infrastructures in the hydropower reservoir development project can irrigate thousands of hectares of agricultural lands and supply water to urban centers with relatively less capital investment, significantly increasing the food production in the country and meeting drinking water and other consumptive and industrial uses. This will undoubtedly encourage the farming community to participate in watershed and environmental management. The adverse climate change impacts reinforce the need for an integrated, holistic development policy paradigm in the development of Nepal. The Water, Energy, Food, and Ecosystem (W-E-F-E) nexus policy strategy offers the greatest potential for the integrated development of water, energy, food, and the maintenance of ecosystem processes in the river basins to achieve Nepal's economic prosperity and sustainable development goals (SDGs).

4. Water–Energy–Food–Ecosystem (W-E-F-E) Nexus Policy Paradigm

There is no universally agreed definition of the nexus approach among development professionals. However, they seem to agree to concur on the nexus as a concept that describes the linking of these components (W-E-F-E) and serves to understand the interdependent relationship among them. Hoff (2011) was the first development professional to describe the water-energy-food nexus approach, which focuses on achieving water, energy, and food security in an emerging green economy of the world and aims to leverage higher resource use efficiency of the nexus. The nexus, thus conceived, reduces tradeoffs, builds synergies, and increases water, energy, and food security, which ultimately results in securing access for all people. The nexus concept was founded upon the principle of sustainability and was adopted by all participating states at the first UN Conference on Sustainable Development in Rio.

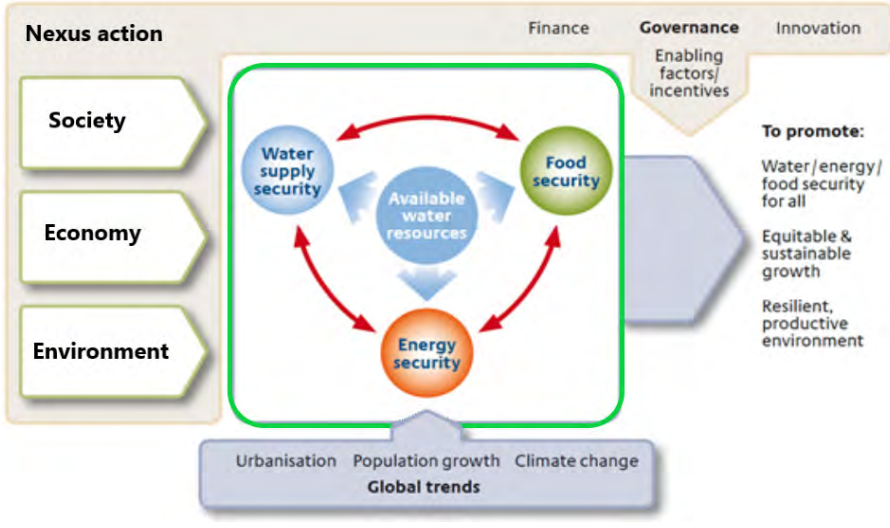

Fig 1: Water, Energy and Food Nexus (Source: Hoff (2011))

Thus, the W-E-F nexus concept serves as a framework for analyzing the dynamic interdependent relationship among water, energy, food, and ecosystem to achieve equitable distribution of these services. Recently, the ecosystem component has emerged as an integral part of the nexus due to the dynamic impact of the ecosystem on other components of the nexus. Moreover, under certain conditions, ecosystem services can hold even greater importance. Hence, ecosystem services have been added to the nexus framework to account for their interdependent relationship with other components. (ICIMOD, 2021; Upreti, 2022). Environmental thinkers, and now international communities have long recognized the interconnection and interdependence of the water, energy, food, and ecosystem components and require an integrated policy planning approach to address the escalating global challenges of securing water, energy, and food security while maintaining the ecosystem health and achieving SDGs (Goodland, 1988; Costanza, 1991; Upreti, 1994; Upreti, 2022). W-E-F-E nexus components are interconnected and deeply intertwined, and their mutually enabling interactions form the basis of sustainable development. It is in this context, the W-E-F-E nexus policy approach becomes paramount in addressing the adverse effects of climate change and maintaining the productive capacities and resilience of interlinked nexus components (water, energy, food, and ecosystem health). The policy decisions inferred from the W-E-F-E nexus paradigm provide optimism for mitigating the adverse effect of climate change, human adaptation, and economic, environmental, and social sustainability ultimately achieving water, energy, food, and ecosystem security for human well-being.

5. Water Resource Development Beyond Hydropower

Water is a precious resource that is essential for sustaining life, ecosystem processes, and human social and economic infrastructures, including energy, agriculture, and industrial systems. Its numerous uses, including irrigation and food production, energy generation, domestic consumption and sanitation, transportation, industry, ecosystem processes, and recreation, have a significant impact on the need for integrated development of this resource, especially given its growing scarcity worldwide. The development and management of water resource projects for integrated multiple uses undoubtedly yield multifold benefits compared to development for a singular purpose like hydropower or irrigation.

Furthermore, the complex interaction among different elements, such as water, energy, food, and ecosystem in a nexus relation, makes it critical to evolve an integrated approach to water resource development that can harness the synergies from the positive interactions among them. Water is the central component in this interconnected network of W-E-F-E elements, essential for irrigation for food production, hydropower generation, direct human consumption and industrial uses, ecosystem functioning, etc. As the world's population grows, urbanizes and demands more food and energy production, water for human and industrial consumption, and maintenance of ecosystem processes, it is necessary to understand the intricate relationships among these intertwined components and develop policy strategies and approaches that leverage the synergy created by their interactions to yield multiple benefits.

A multipurpose hydropower reservoir project that leverages the W-E-F-E nexus framework is the most rational approach to developing Nepal's water resources, agriculture, energy, and maintaining ecosystem processes. However, a major challenge in such projects is sharing the benefits among stakeholders and competing users. The SHARE concept and the principles as outlined by Branche (2017) provide essential guidelines for sustainable development and management of multipurpose hydropower reservoirs involving the participation of all stakeholders in river basins, ensuring more sustainable and equitable outcomes. Endo et al. (2017) note that simulation and optimization management models can provide valuable insights into the tradeoffs inherent in the W-E-F-E nexus relationship, and guide scarce resource allocation over time to maximize the overall welfare of the societies.

6. Why River Basin W-E-F-E Nexus Planning Policy for Nepal?

Nepal is primarily a country of three major river basins:, Koshi, Narayani and Karnali. with many sub-basins within each primary river basin. Table 3 shows the relative

distribution of land and population between the basins, with Koshi having about one-third of the land area and 50% of the population, mainly due to the Kathmandu Valley being located within the basin. The Narayani basin is about 25% of the land area and population, and the Karnali Basin is about 42% of the land area and 23% of the population. Therefore, the river basins and their sub-basins play a vital role in Nepal's socio-economic development.

Table 2: Major River Basins

Basin	Area(km2)	Population(M)	Districts(#)	Sub-basins(#)
Karnali	62,299	6.10	25	4
Narayani	38,749	6.58	22	2
Koshi	46,742	13.81	30	5
Total	147,790	26.49	77	11

Source: Irrigation Master Plan 2019

According to MoEWRI (2020), more than 225 billion cubic meters (BCM) of surface water is available every year in Nepal that can be used for the generation of much-needed hydropower and the development of irrigation, drinking water, and other infrastructures for multisector development including agriculture transformation. However, due to the non-uniform temporal and spatial distribution of the water resources, less than 10% of available water has been utilized in the country for irrigating agricultural lands (MoEWRI, 2020). The generation of hydro-energy in the river basin and the development of irrigation infrastructures to leverage the abundant available water resources provides the foundation not only for agricultural revolution but also the multisector development for achieving the economic and social prosperity of the country. Moreover, agriculture's contribution to Nepal's gross domestic product (GDP) can be increased by many folds, making agriculture a game changer in the country's development.

The W-E-F-E nexus framework is a fundamental aspect of understanding the interdependencies and interactions among the components and how their interactions impact food, water, energy and environmental securities. Increased availability of water causes the corresponding abundance of hydro-energy and vice versa because energy can extract water from the sub-surface and move water bodies from one river basin to another across landscapes (using TBM technology), and can be used for a vast number of operations such as inland waterways and transportation, flood control, fisheries, human consumption (drinking), and agriculture-related heating

and cooling systems, etc. This intricate nexus relationship among these resources did not come to the surface in the development planning framework of most countries in the past. Very recently, the W-E-F-E nexus evolved to its prominence in policy and development discourses in the light of global environmental problems exacerbated by climate change and rapidly increased demand for human consumption (Upreti et al., 2022; Scott et al., 2015; Simpson & Jewitt, 2019).

The hydrology of Nepal's river systems is driven by monsoons during which the water volume in the major river systems increases by manyfold and is drastically reduced during the dry season. The collection of monsoon water by designing multipurpose water storage reservoirs is the most promising and rewarding act of water resource development in Nepal from the perspective of multiple uses of water for generating hydro-energy, irrigating arable lands during the dry season, water supply to urban centres, mitigating floods and developing inland waterways, fisheries, and tourism development. Multipurpose integrated water reservoir hydropower projects in river basins can generate many additional and even better benefits, enhancing water, energy, food, and ecosystem security against climate risks, drought, floods, and increased connectivity with inland waterways and navigation (Biswas & Tortajada, 2001; Tortajada, 2014). Nepal's river systems contribute half of the annual flow of the Ganges and 75 % during the lean, dry season of March to May (Pun, 2004). Jeuland et al. (2013) report that Nepal stores less than 1 % of the total annual runoff since there are no water reservoirs in the major river basins of Nepal. However, more than 30 sites have been identified as suitable for building multipurpose water reservoirs with a capacity of 121 KM3, which is equivalent to 18 % of the total annual flow of the Ganges (Biswas, 2008). Nepal occupies the central position in the Hindu-Kush Himalayan (HKH) range. Water, energy, food, and environmental security are inseparably connected to the rivers originating from the Himalayas, which provide huge potential for the development of water resources for hydropower, irrigation, fisheries, flood mitigation, inland waterways, navigation, and tourism (de Fraiture et al., 2010; Rahaman, 2009; World Bank, 2014).

Currently, many hydropower projects are under construction in Nepal to meet increasing energy demand within the country and export surplus energy to neighbouring countries to reduce the trade deficit Nepal is facing with India. These projects are designed to exclusively generate electricity compromising many potential benefits for both upstream and downstream riparian populations within major river basins of Nepal. Such run-of-the-river hydropower projects cannot meet electricity demand due to the drastically reduced quantity of water during the dry season when more energy is needed and have virtually no other benefits for people living in the

river basins. This approach to water resource development cannot meet the growing demand for water, energy, food, and other competing uses and also compromises the development of other potential better benefits.

6.1 W-E-F-E - and multipurpose hydropower reservoirs

Hydro energy is the largest renewable energy source in the world and currently has more than a million MW (1085 GW) installed, producing 3200 TWh/year energy. This is only 16 % of the total electricity generated worldwide, of which 76 % of electricity is renewable (ICOLD, 2017). Dams store water for different uses and requirements. About 56 % of the world's dams are built for a single purpose, and irrigation is the most common use, and about 44 % of world dams are built for multipurpose, including hydropower generation (ICOLD, 2017). Most of the dams built for irrigation purposes have the possibility for additional energy generation. The potential appeal of such solutions is demonstrated by the case of the USA where more than 80,000 non-powered dams have been detected with a total potential of an additional 12 GW (Hadjerioua et al., 2012).

Multipurpose hydropower reservoir projects can be designed in Nepal's major river basins integrating irrigation and drinking water infrastructures from which water can be transported from one place to another within and across river basins to irrigate thousands of hectares of arable agriculture lands. Hydro-energy generated can be used to establish fertilizer manufacturing plants, post-harvest cold storage facilities, and agro-based industries. Water can be used to recharge and maintain surface and sub-surface water balance and maintain ecosystem services of the landscapes. The circular movement of the water, energy, food, and ecosystem services can maintain and enhance each other's productivity, and water remains the central component of this circularity.

If hydropower projects are designed with a singular objective of generating hydro-energy, this will critically constrain Nepal's development opportunity because it would be impossible to convert such projects into multiple-use projects and the multiple benefits that could have been generated would be forgone. Nepal government's current foreign direct investment (FDI) scheme encourages foreign companies to invest in hydro-energy generation, which is faulty and suicidal for Nepal's long-term water resource development because such a scheme will not have the provision for the development of multiple-use infrastructures and gives the total control of the river water to the investor companies exclusively for a hydro-energy generation. From the perspective of private investors, a single-purpose hydropower project naturally, financially, and operationally becomes more attractive, but the such

scheme does not allow the full realization of the multiple benefits and synergies obtained from designing the multipurpose hydropower reservoir infrastructures. It is possible to develop an investment scheme with public-private partnerships for the development of multipurpose hydropower infrastructure projects and make it attractive from the inception of the design phase with the involvement of the government to resolve issues arising from conflict of interests among different uses.

6.2 Monsson water and multipurpose water reservoirs

As table 3 indicates, six South Asian countries have a total hydropower potential of around 388 GW of which only 16 % of this potential has been utilized. For the realization of this potential, South Asian countries, in general, and Nepal, in particular, require building multipurpose water storage reservoirs infrastructures to capture monsoon water to generate hydropower, irrigate arable lands, supply water to varied consumptive uses, develop inland waterways, mitigate flood, develop fisheries, and tourism infrastructures. The collection of the monsoon water is extremely important because the distribution of the water is highly skewed as 80 % of the total rainfall occurs in four months from June to September and quickly flows to the sea, drastically reducing hydro-energy generation from the run-of-the-river hydropower projects in the dry season (January to May). With multipurpose water reservoirs, water can be released in the dry-lean season, ensuring the full potential of hydropower generation, and generating multiple co-benefits including irrigation for food production, water supply to urban and industrial sectors, mitigation of drought, fisheries development etc.

Table 3: Hydropower Potential in South Asia

Potential	Afghanistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Total
Theoretical potential (MW)	23,000	755	30,000	184,700	80,000	100,000	388,006
Feasible potential (MW)	23,000	755	24,000	84,004	43,000	59,000	236,350
Installed (MW)	442	230	1615	51,756	867	7,320	62,230
Current utilization (%)	1.9	30.4	5.3	28	1.1	7.3	16

Source: Bergner (2013) and International Hydropower Association (2017).

The rivers originated from HKH range in general, and Nepal's rivers, in particular, are highly susceptible to the strong seasonality resulting in low dry-seasonal flow in the river basins. The dynamics of Nepal's river systems are driven by the monsoon,

which dramatically increases the risk of climatic and hydrological drought in the dry season. This calls for the necessity of designing and building multipurpose hydropower reservoirs to harvest monsoon water and supply water during the dry season, ensuring the generation of a constant higher quantity of hydro-energy and water supply for various consumptive uses, including irrigation, substantially mitigating the hydrological drought and climate risk during the dry season. The water released in the dry season from multipurpose hydropower reservoirs can meet many essential needs apart from hydro-energy and irrigation, drinking water in urban centres and industrial uses, etc. Studies suggest that multipurpose hydropower reservoirs can be built upstream to capture monsoon water and augment river flow during the dry season, mitigating water stress and meeting many essential needs (World Bank, 2014; Wu et al., 2013; Rahaman, 2009).

Nepal's hydropower projects are run-of-the-river projects from which electricity generated is drastically reduced in the dry season, during which more energy is needed for domestic, industrial and irrigation purposes. Such projects cannot harness the potential multiple benefits and undermine the realization of such benefits with negative effects on public goods and services. From multipurpose projects designed leveraging the W-E-F-E nexus, water used for generating hydropower can be utilized for irrigating agricultural land downstream, developing navigation, fisheries, tourism, mitigating floods, and improving connectivity. The multipurpose function of the water reservoir dams should first be considered in the design phase so that potential multiple benefits from such reservoirs can be harvested and are not foregone forever. Nepal cannot afford to continue the current sectoral approach to water resource development and must adopt the holistic, integrated W-E-F-E nexus policy framework as a development policy planning paradigm. If Nepal continues its water resource development with the singular objective of generating electricity, such an approach precludes the opportunity of receiving multiple benefits and the optimum uses of natural resources sustainably to achieve SDGs in the context of the ever-increasing shrinking of natural resources (water, energy, biodiversity, and ecosystem services).

7. W-E-F-E Nexus and Agriculture Infrastructure

The availability of more than 225 billion cubic meters of surface water is something that can rarely be found elsewhere in the world given the physical size of the country. This huge amount of water can be used to generate much-needed hydro-energy and irrigation infrastructures and increase agricultural productivity. Multipurpose water reservoir projects (MWRP) designed from the W-E-F-E policy paradigm can have many direct and indirect circular impacts and implications on the construction and creation of agriculture-related infrastructures in the country. These infrastructures

constitute the very basis for the rapid transformation and commercialization of agriculture. Some of these infrastructures are briefly described below.

7.1 Irrigation infrastructures

It is apparent that Nepal's agriculture suffers miserably from inadequate irrigation throughout the year despite having abundant water resources in the country. Perhaps, there is no other country in the world that faces such an unfortunate predicament. One of the most important benefits of MWRP, apart from hydro-energy generation, is the construction of irrigation and water transport infrastructure from the reservoir site to the area where it is needed for agriculture, drinking purpose, and other consumptive uses within and across the river basin. The use of modern Tunnel Boring Machine (TBM) technology in Nepal has already proved that it is feasible to transport water from an area of water abundance to an area of water scarcity in a mountainous country like Nepal (Upreti, 2022). Hydropower energy generated from MWRP can be utilized to transport water from low land to upland (lift irrigation) for meeting irrigation and drinking water requirements of the communities living in the mountains and valleys. Likewise, hydro-energy can be made available to the farmers in Terai Madesh at a subsidized rate to irrigate about eight hundred thousand hectares of highly irrigable but unirrigated agriculture lands through the tube wells utilizing available sub-surface water. Nepal's agriculture is predominantly monsoon dependent (approx. 75% of arable land), which can only partially irrigate the limited arable lands annually. Until we find an alternative for monsoon-dependent agriculture and food production systems in Nepal with the development of adequate year-round irrigation infrastructures, the future of Nepal's agriculture, food production, and food security will always remain an enigma. Furthermore, Nepal's development depends on agricultural development due to its multiplier effects on other sectors, including agro-based industries, cottage industries, tourism, and energy development (Upreti, 2022).

The government of Nepal (GON) recently intensified the much-awaited Kaligandaki Tinau Diversion Multipurpose Project (KTDMP). The KTDMP project will divert 90.6 cubic feet of Kaligandaki waters per second from Ramdighat in Syanja district to the Tinau River in Rupandehi district through a 9-meter wide and 30 km-long tunnel (myRepublica, 2021). The multipurpose project envisages irrigating 107,000 hectares of land (54,000 in Kapilvastu and 53,000 in Rupandehi) and producing 126 MW of electricity (Gautam 2021). Nepal cannot achieve prosperity without an environmentally sustainable Green Revolution which is possible only through a water-energy-food nexus development strategy that can integrate water resources, hydro-energy, irrigation infrastructures, and drinking water.

7.2 Fertilizer manufacturing infrastructures

The farmers of Nepal have been chronically suffering from the government's utter neglect and lack of political commitment to make essential agriculture inputs, particularly fertilizers and improved seeds, available to the farmers at a critical time when they need them. The availability of major chemical fertilizers (N-P-K) at a critical time of the farming season has been an ongoing saga for the last 30-35 years, even after the advent of democracy and the dissolution of the Panchayat system. According to MOA, the annual need for chemical fertilizers has been reported to be around 0.8 million metric tons at a far less recommended dose for three major food grains (rice, wheat, and maize). With increased year-round irrigation and commercialization, the fertilizer requirements will increase at least by 2.5 to 3 times (2 to 2.5 million tons).

It makes no sense to talk about the commercialization of agriculture without the timely availability of agricultural inputs, particularly fertilizers and improved seeds. Voices and concerns have been raised in the past and the present for the establishment of a fertilizer manufacturing plant, and political parties have been parroting their commitments for a long time but always ended up with the entanglement of commission scandals. A well-equipped fertilizer manufacturing plant requires around 500 MW of electricity which is huge by any standard, but now the situation has changed. In the next 3-4 years, Nepal will have 2500–3000 MW of hydro-energy and allocation of 500 MW to the establishment of a fertilizer plant should not be a problem.

7.3 Post-harvest cold storage infrastructures

There is not even a single cold storage infrastructure in the country. Perishable agriculture products, particularly vegetables, fruits, dairy products, meats, and other commodities, can be kept intact and preserved in cold storage warehouse facility for 3-4 months from the time of harvest. This is considerably significant length of time during which high-value perishable agricultural products can be safely stored and translocated to regional, national, and international markets through the development of an efficient supply chain marketing network. With cold storage facilities, and well-planned commercial production of vegetables and fruits in temperate, subtropical, and tropical regions, dairy products and meat production and their supply to the appropriate regional and international markets can become a reality.

Nepal needs at least three well-equipped cold storage facilities, one in each major river basin. Such storage facilities are needed in regional market centres also. The establishment of such cold storage infrastructure facilities may require 600-800 MW of electricity if Nepal is seriously committed to the transformation of its subsistence

agriculture to commercial agriculture. It is possible through the commercialization of high-value agriculture commodities that have distinct comparative advantages leveraging the regional markets in South Asia and China.

7.4 Market and supply-chain infrastructures

The market supply chain infrastructures provide agricultural commodities, including food, energy, medicine, and other products on which depends our way of life. Many different entities are responsible for the functioning of the market supply chain, including collection, transportation, and distribution from production centres, public-sector buyers, private-sector businesses, and other foreign and domestic partners. The supply-chain infrastructure system relies upon an interconnected web of transportation infrastructure and pathways, information technology, and energy networks connected to the local, regional, and international markets. While these interdependencies promote economic activities, they also serve to propagate risk across a wide geographic area or industry that arises from a local or regional disruption. Nepal's government, in collaboration with regional and private sector stakeholders, should undertake efforts to strengthen the supply chain mechanism.

Nepal should be able to capitalize on the regional and global supply chain system that supports and promotes trade in the region. Government should focus on the development of a national supply chain strategy that integrates a network of collection, transportation, and distribution infrastructures by which goods are moved from the point of production until they reach an end consumer. Such a strategy may include the promotion of efficient and secure movements of goods while protecting and securing the supply chain from exploitation and reducing its vulnerability to disruption. Another important aspect of such a strategy is to foster a national resilient supply chain system that is prepared for and can withstand evolving threats and hazards (as in the case of the Indian embargo in the past) and can recover rapidly from disruptions.

8. Conclusions

Despite abundant water resources, Nepal has not been able to utilize even 2 % of its water resource. It is the only resource whose appropriate development drives the development of infrastructures for all sectors. The sectoral development policy approach of water resource development needs to be replaced by a holistic, integrated approach of W-E-F-E nexus policy framework leveraging the synergistic interactions of the nexus elements. The W-E-F-E nexus policy framework offers the best opportunity for Nepal's development and prosperity. In view of the growing threat of climate

change and its cascading impacts on Nepal's Himalayas, monsoon and seasonality driving the hydrological dynamics of Nepal's river systems, the adoption of the W-E-F-E nexus policy paradigm is not an option but a necessity for the integrated development of energy, irrigation, inland waterways, drought and flood mitigation, fisheries, and tourism infrastructures on which Nepal's development and prosperity invariably and decisively depends.

Multipurpose hydropower reservoir projects conceived from the WEFE nexus policy framework generate much-needed hydropower and provide much-needed irrigation and water supply infrastructures for food security and other consumptive uses critical for the integrated development of all sectors driving economic transformation and the prosperity of the country. If water resource development is driven exclusively with the singular objective of generating electricity and Nepal's rivers are handed over to the control of foreign companies like GMR and others, such an approach to water resource development would be suicidal to Nepal.

9. Policy recommendations

- Adopt and apply the W-E-F-E nexus policy framework to develop integrated and comprehensive water, energy, irrigation, inland waterways, flood mitigation, fisheries, and tourism cross-sectoral development analysis and navigation plans based on the baseline information in three major river basins.
- Identify potential upstream sites for the development of multipurpose hydropower reservoirs projects with the provisions of energy, irrigation, drinking water, inland waterways, and ecosystem services in each river basin and mark these project sites as the national high-priority projects that should not be compromised for the single purpose hydro-energy generation. Once such potential multipurpose water reservoir projects are compromised, the enormous multiple benefits that can be harvested will be forgone forever.
- Develop a well-equipped database of natural resources (water, lands, agriculture, forests, biodiversity, etc.) and river hydrology in each basin to assess cross-sectoral interactions, possible synergies and tradeoffs, and positive and negative externalities.
- Use the nexus approach to examine and identify potential synergies and tradeoffs across multiple sectors and scales to evolve harmonious policy and incentive structures across the water, energy, food, and ecosystem that can promote integration and synergy.
- Adopt a participatory approach to involve and engage all stakeholders (upstream

and downstream) within and across river basins to develop mechanisms for sharing costs and benefits and resolving conflicts and disputes.

- Engage policymakers, provincial and local government representatives, key stakeholders and the private sectors, civil society, and research institutions in the interactive sessions to better understand the challenges of water, energy, food, and ecosystem security within and across river basins and evolve policy instruments to ensure equitable sharing of the benefits and the costs.
- Establish cold storage and market-related infrastructures in each river basin for the collection and storage of agricultural produces (fruits, vegetables, food grains and animal products etc.).
- Establish fertilizer manufacturing plants in the appropriate location (perhaps the central region) of the country taking into consideration of supply-chain transportation network across the country.
- Develop inland waterways navigation, transportation, flood control, tourism, and regional and national market infrastructures.

Confilct of Interest

The author declares no conflict of interest.

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Policy Provisions and Implementation of Seed Technology Research, and Innovation in Nepal

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Abstract

Favorable policy provisions and their effective implementation are critical in promoting agricultural research innovation and technology development for ensuring food security and livelihood improvement of the farmers. This paper aims to (i) review current policy provisions made for research and innovations in the seed sector; (ii) assess its implementation status as envisaged in the policies and (iii) identify issues and gaps to make recommendations for potential policy solutions. The study employed a three-step process which included listing and review of the policies, followed by an assessment of their implementation status by developing a policy framework. The study showed that most policy documents have emphasized increasing production and productivity in agriculture, but have undermined the importance of research and technology to enhance agricultural productivity. In addition, current challenges such as nutritional security, natural resource management, and climate change have not been given adequate space in policy design. Very few policy documents have focused to develop climate-resilient varieties, breeds and technologies. Policy provisions for investment in agriculture research and innovation are inadequate and fragmented, despite their significant role in achieving a high rate of return in agriculture development. Analysis showed that investment, human resource development and institutional frameworks are weak, but the policy framework sounds relatively good. Therefore, it is urgent to manage human resources and investment as well as develop new provincial and local government agricultural policies and institutional frameworks aligned with federal policy considering the issues and challenges being faced in the present and what may happen in future. Increased investment and capacity development in plant breeding, modern technology, and seed system; facilitating public-private partnership and private sector to attract research investment; participatory and decentralized variety selection, release and recommendation; coordination mechanism for policy formulations and implementation; and provide incentives for research, release and promotion of domestically developed varieties are recommended to strengthen the variety and seed system innovations in Nepal.

Keywords: Agricultural research & innovation, institutional set-up, investment, productivity enhancement, policy gaps, policy implementation.

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1. Introduction

Numerous agriculture and related policies, acts, strategies, visions, directives, procedures, and regulations have already been formulated and implemented to support agricultural development in Nepal. The nation has prioritized agriculture since the first periodic plan (1956-61) (NPC, 1956) and the agriculture sector was emphasized in the fifth five-year plan (1975-80), with the year 1975 being celebrated as agriculture year (NPC, 1975). Nepal adopted liberal economic policies with the advent of multiparty democracy in 1992, which are reflected in the five-year economic development plans formulated since then, including a long-term 20 years Agricultural Perspective Plan in 1995 (GoN, 1994; Gauchan et al. 2002). The main objective of APP was to improve productivity to accelerate the agriculture's growth rate. Agricultural inputs such as irrigation, fertilizer, technology, roads and power were prioritized to achieve the desired goal of agricultural growth that leads to poverty reduction and employment generation. Following the APP objectives Agriculture Policy 2004 was introduced and the Agriculture Development Strategy (2015-35) was formulated post APP, with a major aim of improving production and productivity, increasing commercialization and enhancing the competitiveness of agricultural produce (GoN, 2015). Despite these efforts, the agriculture sector has not been able to improve productivity, ensure food security and enhance the livelihood of people as expected.

Most of the policy documents have focused on increasing production and productivity in agriculture, however, they have undermined the importance of the seed sector. Nepal's formal seed sector development began with the release of short-duration, temperature resilient and nutrient-responsive wheat varieties in the 1960s. The Seed Act 1988 and the National Seed Policy (1999) were developed and implemented, followed by the National Seed Vision (2013-2025). These policies provide the framework to guide or design government programs and projects and influence the investment areas for investors, including the private sector. The policy should be periodically updated to facilitate and strengthen the sector while considering the user's needs.

Developed nations adopt progressive policies to increase productivity and economic growth, emphasizing research and technological innovation (Karasev et al. 2018; Raghupathi & Raghupathi 2019). Different models have been adopted for agricultural development in different periods, such as frontier, conservation, urban-industrial impact (locational), diffusion and the high payoff input have been adopted for agricultural development in different periods (Udemezue & Osegbue, 2018). The frontier model focused on area expansion to increase agricultural production, the

conservation model believed in sustainable intensification of the cropping system, the urban-industrial model aimed to increase production by linking to urban and industrial growth whereas the high pay-off input model emphasized the research investment to make modern high payoff inputs available to farmers. Among them, the high pay-off input model emphasizes research investment to enhance the capacity of research institutions to produce new technological knowledge (Ruttan, 1977). Since research and development are critical aspects of every policy, it has to be reviewed and updated periodically. Evidence shows that planned and organized investment in scientific research and technological innovations gives a higher rate of return (Alston et al., 2000). A strong linkage between research investments, innovation and agriculture productivity growth has been reported (Fuglie & Heisey, 2007). The role of policy provisions and their effective implementation are critical to bringing desired changes in research investments, and innovations and increasing agricultural productivity. However, there is a lack of adequate studies and information bases for this. Available information indicates that targets and provisions made in the existing policies are undermined while designing and implementing the related projects and programs in Nepal. This necessitates the need of identifying the gaps in the policies (e.g., agricultural research and technology innovation), in absence of these, the agriculture sector has not been able to bring desired changes despite the highest priority given to the nation. This research answers the following questions: What are the key agricultural policy documents and their provisions related to variety and seed system research and innovations? Are different agricultural policies sufficiently addressing the priority needs and targeted goals of variety and seed system innovation? and Have seed sector policies been formulated and implemented effectively in Nepal?

2. Research Methodology

The study employed a three-step process to the list, review, analze and assess the implementation of agricultural policies through the interpretation of the research outcomes. The first step involved an exhaustive listing of available related policies/strategies/visions (150), and legislations (360). Policies were collected from the official websites of the respective line ministries. Laws were collected from the official website of the Nepal Law Commission. Regulations, directives, and procedures were collected from the official website of the Ministry of Agriculture and Livestock Development (MOALD). Further details are provided in Annex 1.

In the second step, policies, strategies and visions; acts; regulations and directives related to seed system innovations were selected for review and assessment through an interactive discussion of authors with policy experts . Further details are provided in Annex 2 and Annex 3. The objectives of the policies (policies, laws, regulations,

directives, and procedures) reviewed were based on their relevance to the study from the author's perspective. A total of five indicators as provided in Annex 4 were identified from the expert consultation to determine policy provisions regarding variety and seed system research and technology innovations.

In the third step, the effectiveness of the implementation, considering different aspects comprising legal, human resource, organizational and investment were analyzed. International experience, standards and expert consultation were employed to identify the issues and gaps for policy feedback. The conceptual framework of the study is provided in Figure 1.

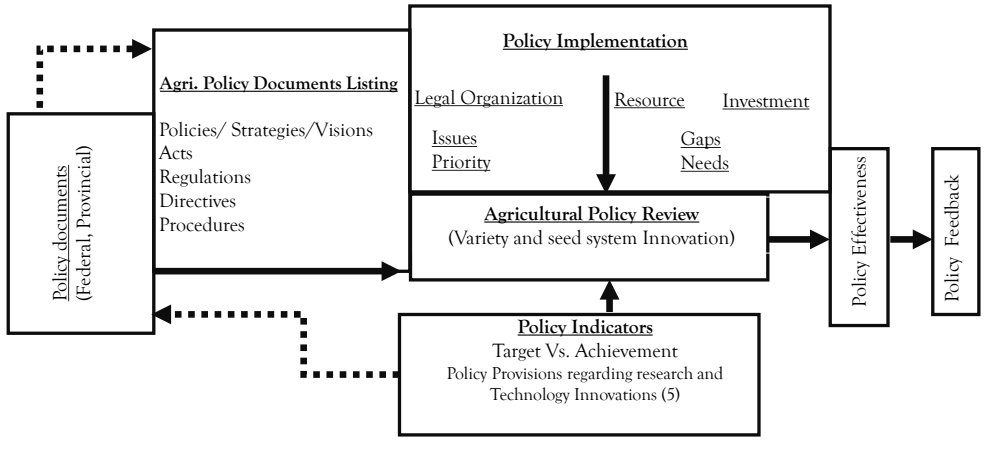

Figure 1: Conceptual framework for Policy Listing, Review and Assessment

3. Results and Discussion

3.1 Policy provisions regarding variety and seed system research and technology innovations

A total of 55 agriculture and related policies, 28 acts, 5 strategies, 2 visions, 39 directives, 44 procedures, and 11 regulations have been already formulated and implemented to support agricultural development in Nepal. In our study, we have reviewed 55 federal and 90 Provincial policies and analyzed the provisions made in these policies for variety and seed system innovations based on their level of explanation (refer to Table 1). Results showed that about 30% of documents have made provisions for variety and seed system innovations but only National Seed Vision (NSV) 2013-2025 was explained clearly with indicators.

Table 1: Detail analysis of variety and seed system innovations in different policy documents

Number of policies Reviewed	Overall provisions of policies on seed system innovation		
	Excellent	Good	Fair
Federal: (55)	1	2	13
Provincial: (90)	0	3	0

Note: 1= Excellent: clearly explained with indicators;2= Good: specifically explained; 3= Fair: broadly explained

Most of the policy documents highlighted increasing the production and productivity in agriculture in a broader perspective but undermined the importance of nutritional security, natural resource management, and the consequences of climate change that have been creating challenges in recent years. Very few policy documents have focused to develop climate-resilient varieties and breeds and technologies, and innovations for modern high-tech agriculture. The key provisions made for variety and seed system innovations are provided in Annex 5.

3.2 Effectiveness of policy implementation

3.2.1 Seed Policy Framework

Several seed policy-related documents such as seed vision (1), seed policy (1), seed act (1), regulation (1) and directives (11) with respect to variety and seed system innovations have been developed and updated. NSV 2013, and Seed Policy (1999) are formulated and implemented. The seed act was developed in 1988 and has already been amended first in 2008 to update the latest provisions and then second in 2022 considering the federal context. The latest second amended act has made key provisions for improving the seed sector through the establishment of a seed board at three tiers of government, encouraging the private sector to invest in the seed business, and providing authority to the Province level to give licenses for producing hybrid seed. Moreover, it has provisions for ownership rights of community-based organizations (groups) for local seed. The documents provided priority for the involvement of private sectors in seed business including hybrid seed production, however, they have to meet the standards (human resource, infrastructure, inbred lines, varietal development plan etc.) as per the provisions. Until now, three private seed companies (SEAN seed, Lumbini seed and Gorkha seed) have taken the license for hybrid seed production in Nepal. Other drafted policies such as National Agriculture Policy (2004-first amendment), agribusiness Promotion and commercialization act (2022) have also given higher priority to variety and seed system innovations. However, there is still missing the

provisions of pre-release seed multiplication in the policy documents. Cooperation and coordination between key stakeholders are required in the formulation and effective implementation of policies with adequate legislative and institutional provisions (Khanal et al., 2020). Article 231 (2) of the Constitution of Nepal (2015), provisioned the inter-governmental relationship among three tiers, between federal-provincial and provincial-local. Accordingly, the provincial government can formulate the agriculture policies, rules, guidelines and norms in agriculture and allied sector for the entire or part of the province. So far, 90 provincial agriculture policies, rules and regulations are formulated by the seven provincial governments. Among them, three policy documents are found related to seed research and innovations. To date, Bagmati province only formulated the provincial seed act in 2019 and other provinces have yet to develop such seed-related policies.

3.2.2 Human Resources Development

The status of human resources available to contribute to variety and seed system innovation seems very weak. About 293 seed specialists envisioned in NSV 2013-2025 to get engaged in seed quality control, inspect the seed production farms, and shall also be the legal and authorized person for monitoring. But the number of specialists is found 18 until December 2022 as 72 specialists were not renewed. Further, the seed quality control center (SQCC) announced its application on 14th November 2022 to provide a license and received 445 applicants. Of them, 184 got selected. Out of 184, around 40% were from the government system which might create the environment to function effectively. But still, there are questions about the expertise and engagement of all seed specialists to maintain the quality of seed. So, there is a need for provisions for the capacity enhancement of the specialist as well as their engagement plan. Similarly, about 71 breeders are expected to increase by 2020 but only 49 breeders (31 from NARC, 6 from the private sector, and 12 from Universities) are working in breeding. Out of which, only 50% of breeders are actively involved in a real breeding program. Few of the senior breeders (5) will be retired within a year. Likewise, in the last five years, about 49% of scientific positions are vacant in NARC, more specifically 75% of the crop breeding positions related to seed research and innovation are vacant. This shows the critical situation to generate sufficient innovations in variety and seed system innovations. Ghimire et al. (2020) reported the decreasing number of breeders and seed technologists working in the research system in Nepal which are required for variety and seed system innovations. Furthermore, the private sector in Nepal is small, weak and constrained by a lack of qualified scientific manpower and infrastructure facilities, although recently it is evolving and emerging as an important factor in seed sector development (Gauchan, 2019). Therefore, engagement of both public and private sectors and positive research

culture need to be established to get innovations in science and technology which can be achieved through regular support and motivation to the researchers (Sherab & Schuelka, 2019)

Table 2: Details of human resource provisions

Provisions	Targets	Achievements
Seed Specialist	293	202 (72*)
Number of breeders	71	49
Scientific positions approved in NARC	423	216

*Source: Seed act 2022; NSV 2013-2025; NARC, 2022; * indicates not renewed*

3.2.3 Infrastructure and Institutional Framework

The policy review showed that NSV 2013-2025 focused on strengthening the existing institutions for the development of the seed sector in Nepal. The development of a hybrid research program/unit was suggested in the NSV, but this has not yet been established and institutionalized. The institutional framework for plant breeding and seed research activities is weak for horticultural, forage and underutilized crops (Gauchan, 2019). After federalization, the seed act (second amendment 2022) envisioned the seed board at the central and provincial levels and the seed management board at the local level. There is also made provision for the involvement of three tiers of govt. for assurance of quality control for seed production, processing, storage, packaging and distribution; establishment of gene bank at central and community seed bank at the provincial level for indigenous seed; establishment of seed laboratory by the Ministry, local govt and private sector/person after meeting the standard set by the Ministry. Until December 2022, SQCC is established only at the federal level except in Bagmati province by making their seed act. DNA (Deoxyribonucleic Acid) fingerprint and agro morphological characterization study for DUS (Distinctness, Uniformity and Stability) testing have been made mandatory by SQCC before releasing crop varieties. Currently, National Seed Research Centre (NSRC) under NARC has done this for mid-hill, and respective commodity programs are doing it for specific commodities. The provincial govt. has also provided authority for variety release and registration, but who will do the trial and other mandatory tasks (DNA fingerprint, DUS test) before registering/releasing of variety at the province level is not clear. Similarly, clear coordination and linkages mechanisms among federal and provincial governments are not spelt out, which creates the possibility of duplication/overlapping while releasing and registering the varieties at the federal and provincial levels. The government of Nepal (GoN) and the Food and Agriculture Organization

(FAO) (2013) reported that the institutional capacity for implementing the plans and policies is very limited in Nepal. The adoption of a supply-driven approach without the active participation of concerned stakeholders for policy formulation hinders the effective implementation of policy (Khanal et al., 2020). While revising the seed regulation, consideration of the above fact is important. There is a provision for the establishment of a standard seed testing laboratory in the seed act 2022, for which the guidelines for maintaining minimum standards of the lab are also drafted and under discussion.

3.2.4 Investment in Seed Research and Innovation

Review and assessment showed that 30% of NARC annual budget allocation for varietal breeding and maintenance was envisioned in NSV 2013-2025, but the allocation is less than 15%. Similarly, its major share goes to source seed production. In 2020, NARC has allocated 6% of the total budget to source seed production which increased to 9% in 2022. The policy provides for the investment in agriculture research and innovation have been inadequate and fragmented, despite its significant role in achieving a high rate of return in agriculture development. Currently, 0.30 % of Agriculture's Gross Domestic Product (AGDP) is invested in agri-research which needs to increase more. Over the last two decades (2001-2020), the total surplus of rice, maize and wheat was found NRs (Million) 2773, 3390 and 3840 respectively with the internal rate of return (IRR) of 82,87 and 91 per cent for each crop. A higher IRR of more than 80% indicates a higher economic return from investment in major cereals in Nepal (Timsina, 2021). The limited investment in the seed sector is reported by Ghimire et al. (2020). It is also necessary to activate National Agriculture Research Fund (NARF) as envisioned in ADS (2015-2035) to initiate the competitive grant system for quality research and increase resource use efficiency. Provincial allocation in agriculture research and innovations is rare/negligible. The average share of investment in agriculture to the total budget of local government is less than 5% and none of the investment for agriculture research and innovations is found. Therefore, it demands the assurance of the necessary investment in research and innovation and implementation requirements for its successful implementation.

3.2.5 Technology Development and Dissemination

Technology development and dissemination on seed research, technology development and dissemination require the development and dissemination of specific components of innovation on seed systems, germplasm, hybrid technologies, private sector participation and biotechnological approaches which are briefly outlined below.

Seed system

It is seen that the breeder and foundation seeds of major cereals are more than sufficient but improved seed is inadequate. If the proper seed cycle is maintained, the current production of breeder seed of major cereals and lentil are more than enough to use in the total area that has been allocated for major cereals in Nepal (Gairhe et al., 2023a; Timsina, 2021). Prasai (2022) reported that the seed system is heavily dominated by the informal system (78%) even though more than 325 community-based organizations are working on seed multiplication in Nepal (Ghimire et al., 2020). Weak or limited monitoring to maintain the quality of seed is another issue in the field. Farmers and entrepreneurs have poor incentives to produce and market quality seeds due to the unregulated flow of exotic hybrids and spurious quality of open-pollinated variety (OPV) seeds in the urban markets (Gauchan, 2019). The demand for foundation seed is lower than the supply and the demand for breeder seed is more than the requirement, which showed ineffective seed cycle maintenance. Different studies showed the ineffectiveness in the maintenance of the seed cycle in Nepal (Gairhe et al., 2021; 2023a, b). The source seed production of minor cereals is far below than targeted in the NSV which is linked with the limited investment, research, and innovations in minor crops. Ghimire et al. (2020) reported very poor source seed production for millet, barley and legumes in Nepal. The achievement in open-pollinated varieties released is also far below (285) the target set (423) in NSV. The farm-level adoption of crop varieties is an indicator of dissemination of new seed technology but the finding from a rice survey in 2012-13 revealed that only 61% of the market share of the varieties adopted at the farm level was from national release system with an older generation having an average age of 15 years indicating the poor state of dissemination of new varieties (Gauchan, 2017).

Germplasm

Out of 275 released crop varieties (excluding registered ones), 66 varieties are from local origin, 150 are the introduced germplasm, and 59 are from an unknown source (Joshi 2017). Among the introduced lines, those from India, International Rice Research Institute (IRRI), International Maize and Wheat Improvement Center (CIMMYT) etc. are among the significant ones. There is more than 40 lakh of accessions that is accessible to Nepal, however, only 150 accessions are yet to be used in Nepal. Likewise, in addition to introduced germplasms, local germplasm also is an important gene pool. Out of 1000 (Joshi et al 2020), crop genetic resources only 66 are yet being used. Thus, there is still ample opportunity to utilize both those introduced and landraces yet to be explored. A study from rice research and farm-level adoption in 30 districts of Nepal showed that only 5% of the farm-level adopted rice varieties were derived from genes from domestic sources in Nepal (3 % using full

domestic genes and 2% of the varieties had genes from both domestic and exotic sources such as Khumal-4) indicating the poor state of use of domestic agrobiodiversity in agricultural research innovation in Nepal (Gauchan, 2017).

Hybrid seed technology

The target of 40 hybrids (20 vegetables, 12 maize and 8 rice) from the public and 20 hybrids (10 vegetables, 5 maize and 5 rice) from the private sector) was set in NSV. However, only 15 hybrids (10 maize, 3 vegetables and 2 rice) were released, and that was only from the public sector. None of the hybrid varieties has been developed and released by the private sector so far even though there are more than 25 seed companies in Nepal (Ghimire et al., 2020). Hybrid varietal choices and availability are low in Nepal (Prasai, 2022). Ghimire et al. (2020) reported the limited progress on varietal research and development, the market development of new varieties, and the low capacity of public and private sectors on hybrid variety development.

Seed Replacement Rate: The average varietal age of NARC-released varieties of major cereals was found to be more than 20 years for rice and maize whereas it is nearly 15 years for wheat (Timsina, 2021). The seed replacement rate is increasing gradually but is not achieved in the case of maize which requires strong intervention to disseminate certified seeds of newly released varieties. The introduction of an innovative marketing strategy that can promote newly released domestic varieties is important.

Private Sector Participation

The limited participation of the private sector in varietal and technological development and their involvement mainly in the trade of foreign seed create gaps to meet the target set for the private sector. Participation in the private sector is currently weak due to a lack of adequate incentives and a favourable environment to invest in Research & Development (R& D). The legal incentives that promote private sector investment in R&D such as Plant Variety Protection and Biosafety laws are not in place yet (Gauchan, 2019). Private sectors also lack adequate incentives in subsidies, tax breaks and technical support in developing seed enterprises. As a result, the NSV targets of establishing 4 mega seed companies in four developmental regions to meet the domestic seed needs of the country through private sector participation proposed in four regions of Nepal are not yet initiated. Thus, there should be policy provisions and incentive mechanisms to attract the private sector for variety release, maintenance and source seed production.

Biotechnology

It is important to strengthen biotechnology, prepare our human and technical strengths to not be left behind on international scenarios of developing modern technologies such as marker-assisted selection, transgenics, gene editing etc, and introduce nuclear technology emphasizing modern fast-track breeding to release farmers preferred high yield varieties is urgent. Moreover, our policy document (seed policy 1988) has also provided an avenue to initiate research on GMOs which could be an important area in future. Despite, the use of biotechnology, is almost none in varietal development. The details of the policy indicator targets and their achievements are given in Table 3.

Table 3: Other indicators set in different policy documents regarding variety and seed innovations

Indicators and Source	Target (2020)	Achievement (2020)
Cereals Breeder Seeds- Mt	58 (88)	95.5
Minor Cereals Breeder Seeds- Mt	0.908 (1.63)	0.61
Cereals Foundation Seeds- Mt	1186	1034
Minor Cereals Foundation Seeds- Mt	12.85 (22.74)	3.14
Hybrid by Public Sector-Number	(40)	15
Hybrid by Private Sector-Number	(20)	0
Total OP –Number	(423)	285
Cereals SRR (%)	18 (25)	19

Note: Figures in parentheses are the targets by 2025 proposed in National Seed Vision (2013-25)

These above indicators indicate that except for breeder seed production in cereals, all of the targets proposed in the National Seed Vision (2013-2025) are not achieved. The most important target of hybrid variety development from the private sector is nil so far which indicates that especially incentives and enabling environment need to be created for private sector investment in hybrid R&D.

4. Conclusions and Policy Recommendations

A large number of agriculture and related policies, legislations and regulations, have already been formulated and implemented to support agricultural research and development in Nepal. However, the agriculture sector has not been able to improve its productivity, provide food security and enhance the livelihood of the people. From the

analysis of different policies, appropriate investment, institutional framework, and human resource development aspects look weak. But the policy framework related to seed sector development sounds favourable and updated recently even in the federal context (such as the Seed Act amended in 2022). However, most of the required institutional set-up and legal requirements have also not yet been developed at the provincial and local levels to implement the policy effectively. There is an absence of policy documents regarding agriculture research and innovation formulated in the context of the current three-tier federal governance system, though recent some initiatives are made in this aspect. In this context, it is urgent to revise policy documents in the federal context as well as develop new provincial and local government agricultural policies and institutional frameworks aligned with federal policy considering the issues and challenges being faced in the present and what may happen in future. A further study considering other policy provisions like provisions of crop management technologies; post-harvest, value addition and market research innovations; and institutions and governance are suggested as this study could not assess during the study period. Moreover, it is further suggested to assess empirically the diverse perception and knowledge of different policy stakeholders in different agro-ecologies as well as at the provincial and local level based representative sample surveys on the specific provisions, gaps and issues related to agricultural policies and suggests possible policy measures for improving agricultural productivity and prosperity of the country. However, from the findings of this study following recommendations are made.

- Increased investment and capacity development in plant breeding, modern technology and seed system through strengthening NARS and NARF (as per ADS provision) to reduce dependency and promote minor crops.
- Facilitating private sector participation in hybrid seed research and innovation (eg. Providing licenses, intellectual property rights and other incentives etc.) by attracting them to research & development investment, hybrid development and large-scale marketing (hybrid seed production) through ensuring proper regulation mechanisms from public sector
- Participatory and decentralized variety selection, release and recommendation for the specific domain through adopting fast-track breeding and variety release and registration procedures
- Coordination mechanism for policy formulations and implementation on variety registration, release, and promotion including seed quality regulation and monitoring at three tiers of government.
- Incentives for research, release and promotion of domestically developed varieties utilizing own genetic resources and agrobiodiversity.

Author Contribution Statement

Krishna Prasad Timsina: Conceiving ideas; formulation of overarching research goals and aims; design of methodology; application of study framework; conducting a research and investigation process, drafting and finalization of manuscript.

Devendra Gauchan: Conceiving ideas; formulation of overarching research goals and aims; design of methodology; application of study framework; conducting a research and investigation process, drafting and finalization of manuscript.

Sabin Basi: Design of methodology; application of study framework; conducting a research and investigation process, drafting and finalization of manuscript.

Mahesh Jaishi: Design of methodology; application of study framework; conducting a research and investigation process, finalization of manuscript.

Sunita Pandey: formulation of overarching research goals and aims; design of methodology; application of study framework; conducting a research and investigation process, finalization of manuscript.

Confilct of Interest

The authors declare no conflict of interest.

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Annex 1: Sources of Policy documents

Ministries	Website
Ministry of Agriculture and Livestock Development	MOALD
Ministry of Home Affairs	MOHA
Ministry of Federal Affairs & General Administration	MOFAGA
Ministry of Education, Science and Technology	MOE
Ministry of Energy, Water Resources, and Irrigation	MOEWRI
Ministry of Health and Population	MOHP
Ministry of Industry, Commerce and Supplies	MOICS
Ministry of Culture, Tourism and Civil Aviation	MOCTCA
Ministry of Forests and Environment	MOFE
Ministry of Labor, Employment and Social Security	MOLESS
Ministry of Finance	MOF
Ministry of Communications and Information Technology	MOCIT
Ministry of Youth and Sports	MOYS
Ministry of Land Management, Cooperatives and Poverty Alleviation	MOLCPA
Ministry of Urban Development	MOUD
Ministry of Women, Children and Senior Citizen	MOWCSC
Nepal Law Commission	NLC

Note: Authors compilation

Annex 2: Reviewed agricultural policies, strategies and visions

SN	Policies	Date	SN	Policies	Date
1.	Foreign Investment and one-window policy	1992	29.	Agricultural Mechanization Policy	2014
2.	National Seed Policy	1999	30.	National Employment Policy	2014
3.	National Tea Policy	2000	31.	Foreign Investment Policy	2014
4.	National Fertilizer Policy	2002	32.	Agriculture Development Strategy	2015-2035
5.	Foreign Aid Policy	2002	33.	Constitution of Nepal	2015

SN	Policies	Date	SN	Policies	Date
6.	National coffee Policy	2003	34.	Land Use Policy	2015
7.	Rural Water Supply and Sanitation National Strategy	2004	35.	National Youth Policy	2015
8.	Rural Water Supply and Sanitation National Policy	2004	36.	Commercial Policy	2015
9.	Irrigation Policy	2004	37.	Public Private Partnership Policy	2015
10.	National Nutrition Policy and Strategy	2004	38.	Rural Energy Policy	2016
11.	National Agricultural Policy	2004	39.	Bee-keeping Promotion policy	2016
12.	Herbs and non-timber forest products development policy	2004	40.	National Intellectual Property Policy	2017
13.	Labor and Employment Policy	2005	41.	National Food Security Policy	2018
14.	Agro-Biodiversity Policy	2006	42.	National Food Safety Policy	2018
15.	Agricultural Genetic Policy	2006	43.	National Food Hygiene Policy	2018
16.	Biotechnology Policy	2006	44.	National Land Policy	2019
17.	Agribusiness Promotion Policy	2006	45.	International Development Cooperation Policy	2019
18.	Dairy Development Policy	2007	46.	National Environment Policy	2019
19.	Tourism Policy	2008	47.	Poverty Alleviation policy	2019
20.	International Development Assistance Operational Policy	2011	48.	National Agro-Forestry Policy	2019
21.	Industrial Policy	2011	49.	The Fifteenth Plan	2019-2024
22.	Poultry Policy	2011	50.	National Science, Technology, and Innovation Policy	2019

SN	Policies	Date	SN	Policies	Date
23.	NARC Vision (yet to be approved)	2011-2030	51.	Climate change Policy	2019
24.	Rangeland Policy	2012	52.	Monetary Policy	2021
25.	Supply Policy	2012	53.	National Livestock Breeding Policy	2021
26.	National Cooperative Policy	2013	54.	National Animal Health Policy	2021
27.	Floriculture Promotion Policy	2013	55.	National Fisheries Development Policy	2022
28.	Seed Vision	2013-2025			

Annex 3: Summary of policy documents regarding seed in Nepal

Act (1)	Regulation (1)	Directives (11)
Seed Act 2045 (1988), second amend-ment 2022	Seed Regulation 2069 (2013)	Registration, genetic improvement and source seed production of Indigenous and local varieties 2079 (2022) drafted
		Seed Production, supply and management directory, 2078 (2021)
		Technical test guide for seed production, 2075 (2018)
		Seed Business and monitoring directory 2075 (2018)
		Seed certification 2074 (2017)
		Seed Entrepreneurs' Registration and Monitoring 2073 (2016)
		Appointment of Seed inspector, seed sample collector and analyst, provisions of licensing and monitoring 2073 (2016)
		Compensation due to seed use 2073 (2016)
		Seed monitoring and destruction of confiscated Seed 2073 (2016)
		Seed sample selection 2073 (2016)

Act (1)	Regulation (1)	Directives (11)
		Private sector seed Production and Management 2073 (2016)

Annex 4: Variety and seed system innovations related indicators used in the analysis

Policy provisions /indicators
Technology development (Variety development, release, registration, and variety maintenance)
Climate resilience/adaptation and nutrition enhancement research and innovations
Production of source seeds, breeds and other planting materials
Application of biotechnology/nano-technology in breeding research
Conservation and utilization of indigenous/local resources/materials through both participatory and conventional breeding

Annex 5: Policy provisions regarding variety and seed system innovations in different agri. policy documents

S.N	Policies+++	Variety and seed system innovations related provisions
1.	National Seed Policy 1999	• The system of producing nucleus, breeder, and foundation, certified and improved seeds will be continued. • The institutional capacity of Government agencies, involved in seed research and seed production will be strengthened. • The involvement of non-governmental organizations (NGOs) and the private sector to perform the varietal development and maintenance work will be carried forward. • Study and research will be carried out on biotechnology or genetic engineering for the genetically modified organism (GMO), transgenic plants, and tissue culture. • Private sector participation in the seed business and quality declared seed system adopted to control the quality of seeds. • The involvement of agencies engaged in varietal development shall be ensured only after providing the details of infrastructure and needs.

S.N	Policies+++	Variety and seed system innovations related provisions
2.	National Agricultural Policy 2004	• Increase agricultural production and productivity. • The production and use of hybrid seeds and improved breeds shall be encouraged. • The local production, sale, and distribution of improved agricultural inputs (seeds, plants, saplings, breeds, fingerlings etc.) shall be regulated, and quality shall be maintained in their supply. • The use of genetically modified organisms shall be regulated. • Priority to Indigenous varieties while releasing new varieties+ • Provide a subsidy to seed buyers (farmers) after developing standard guidelines+ • Regulation of the seed sector for quality control+ • Source seed production priority based on national demand+ • Restructuring of research and extension organization for effective delivery of agri. inputs including seed considering federal system+ • Establishment of the laboratory at three tiers of govt and ensure manpower to provide quality services+
3.	Agro-Biodiversity Policy 2006	• Traditional seeds distribution between farmers will be strengthened. • Equitable distribution of agriculture genetic materials/ resources and traditional knowledge • Emphasis shall be given to surveying, research, investment, technology development and transfer for Ex-situ conservation of agriculture genetic resources
4.	Agricultural Genetic Policy 2006	• Climate resilient variety will be developed. • Traditional ways of production and distribution of seeds will be preserved and improved.
5.	Biotechnology Policy 2006	• Research to use biotechnology in tissue culture, forest, agriculture and food grains, herbs, mushroom production, and processing system including animal and human health systems will be encouraged.

S.N	Policies+++	Variety and seed system innovations related provisions
		• Promote participation of the private sector and give high priority to research, development, and expansion of biotechnology. • The infrastructure of existing biotechnology-based research shall gradually be strengthened. • Technologies relating to genetic engineering or cell culture, microbiology, biochemistry, molecular biology, and tissue culture will be used.
6.	Agribusiness Promotion Policy 2006	• Enhance import and export of seeds and crops along with the agricultural item.
7.	Industrial Policy 2011	• Encouragement shall be given to engaging in research and development in the areas of industrial information and communication, appropriate technology, and biotechnology.
8.	NARC Vision 2011-2030 (yet to be approved)	• Development of suitable high-yielding varieties of major food crops such as rice, wheat, and maize and minor crops such as millets, barley, and buckwheat through selection and hybridization to ensure food security. • Variety improvement of cash crops such as tea, coffee, cardamom, sugarcane, ginger, and jute through selection and hybridization for enhancing quality production and productivity • Development of suitable high-yielding varieties to raise the productivity of irrigated and rainfed rice • Development of high-yielding rice varieties for warm and cool temperate zones with a major emphasis on tolerance to drought and cold based on the need of each domain • Development of high-yielding wheat varieties for improving wheat productivity and sustainability in terai, inner terai, and foothills of Nepal • Development of high-yielding finger millet, barley, and buckwheat varieties with early maturity and other desirable traits for different production environments in the mid and high hills.

S.N	Policies+++	Variety and seed system innovations related provisions
		• Development of high-yielding desirable winter and summer legumes for different production environments with an emphasis on tolerance to drought and other stresses. • Develop new varieties of fruits (citrus, apple, and mango) and vegetables (tomato, cauliflower, cabbage, beans, cucumber, and chilly) through conventional and modern breeding techniques to address climate change and food crises. • Improve and strengthen the tea sector by developing Nepalese tea varieties suitable to different production environments. • Development of crop varieties/hybrids to address biotic and abiotic stress as well as quality. • Supply of source seed including livestock and fish and technical backstopping to private seed producers to ensure quality seed to end users. • Variety improvement of sugarcane, coffee, ginger, and jute crops through selection and hybridization for enhancing quality production and productivity • Characterize crop species/varieties at a molecular level for better utilization in a breeding program. • Marker Assisted Selection (MAS) in crop improvement for resistance to biotic and abiotic stresses. • Application of molecular markers toward the improvement of maize varieties for hybrid vigour • Construction and facilitation of biotechnology laboratories with the installation of modern biotechnological equipment
9.	Rangeland Policy 2012	• The awareness of stakeholders, including producers and consumers, will be increased about the production, collection, and processing of grass seeds, animal products, herbs, and non-timber forest products. • Arrangements shall be made for grass seed production, conservation, collection, storage, and distribution.

S.N	Policies+++	Variety and seed system innovations related provisions
10.	Supply Policy 2012	• Centralizing food sovereignty jurisdiction: Ensured quality, and weight of seeds and seedlings. • Ensure to provide seed to farmers before cropping seasons++ • Provide cash back to farmers if they brought quality to improve seed from licensed suppliers++
11.	Floriculture Promotion Policy 2013	• Markets with modern equipment will be developed and expanded in major places in the country to manage the purchase and sale of flower seeds and produced products.
12.	Seed Vision 2013-2025	• Improve the system for source seed production and seed multiplication with active participation from the private sector and government collaboration. • Support in implementing a devolved seed production system including quality assurance. • Strengthen commodity research programs in a variety of development and maintenance breeding both in the public and private sectors. • Enhance access to new seeds and information to households and individuals through participatory breeding and the use of local genetic resources. • Develop and strengthen seed networks, seed dealers, and seed supply channels in the public and private sectors. • Strengthen varietal development, release, and maintenance breeding, using a diverse gene pool both from local and exotic sources at different agroecological zones. • Support public, community, and private enterprises in source seed production, seed multiplication, processing, and conditioning through efficient seed quality services. • Facilitate the development of local plans and policies in breeding better and climate-resilient varieties. • Support regional and local governments and private institutions in the development, maintenance, and release of location-specific crop varieties.

S.N	Policies+++	Variety and seed system innovations related provisions
		• Develop policies, mechanisms and procedures for a prompt popularization of seeds of new varieties to farmers. • Increase the number of breeders (71), seed specialists (293), cereals breeder seeds production (88mt), minor cereals foundation seeds production (23 mt), hybrid variety release (60) etc
13.	Agriculture Development Strategy 2015-2035	• Promote the production of hybrids and establish an information system on seed demand and supply. • Promote open-pollinated, improved, and local seed production systems to address seed sovereignty. • Promote private and cooperative sector and community-based seed production; Promote partnerships with relevant public, private, and cooperative organizations, farms, and nurseries to produce quality planting materials. • Promoting public and private sectors to produce breeder, foundation, and hybrid seeds. • Encouraging local hybrid seed production within Government organizations, private and cooperative sectors, and in partnership with foreign companies. • Implement integrated water resource management. • Build resilience for farmers to climate change, disasters, price volatility, and idiosyncratic shocks through the adoption of the stress-tolerant crop. • Research on stress-tolerant varieties and breeds.
14.	The Fifteenth Plan 2019-2024	• Given the legal basis for food sovereignty, arrangements shall be made for the supply of seeds and fertilizers adhering to agreed standards, quality, and weight. • Production of seeds will be oriented towards self-reliance by developing improved and hybrid varieties through strengthening research as well as capacity building of the private sector, and farmers • Resilient technologies will be developed and expanded to mitigate the effects of climate change in coordination and collaboration with education, research, and communication agencies.

S.N	Policies+++	Variety and seed system innovations related provisions
		• The development and utilization of bio-fortified crops and other products will be expanded.
15.	National Science, Technology, and Innovation Policy 2019	• Assistance shall be provided for the development and utilization of bio, nano, and nuclear technology for agricultural sector development.
16.	Climate Change Policy 2019	• Crops suitable for dry and water-logged areas will be identified and promoted.
17	Seed Act 1988, second amendment 2022	• Seed board at three tiers of government • Encourage the private sector to invest in the seed business. • Producing source seed and hybrid by taking a license at the Province level • Patent rights of community-based organizations (groups) for local seed • Giving license to produce hybrid from Provincial government. • Involvement of three tiers of govt. for assurance of quality control for seed production, processing, storage, packaging and distribution • Establishment of gene banks at central and community seed banks at the Provincial level for indigenous seed • Establishment of seed laboratory by the ministry, local govt, private sector/person following a standard set by the ministry
18	Seed Regulation 2012	• Variety release, registration and approval sub-committee led by the Director General (DG) of the Department of Agriculture (DoA) • Quality standards and management sub-committee led by the Executive Director (ED) of the Nepal Agricultural Research Council (NARC) • Training will be provided to seed entrepreneurs, seed inspectors and other private sectors by SQCC.

S.N	Policies+++	Variety and seed system innovations related provisions
		• Seed type by truthful (breeder, source seed, labelled seed and improved seed) is made compulsory. • Seed type by certification (Breeder, foundation, certified and improved) is made voluntary. • Six months' time for quality seed after inspection if stored safely can be extended 6 months more after inspection by seed analyst.
19	Private sector seed production and management directive 2016	• Provision of getting licensing of variety development and maintenance (R&D sites with MSc breeder, BSc agronomist, crop wise agronomist; infrastructure and processing facilities; assurance of inbreed line acquisition and variety development plan • Provision of getting license hybrid seed production (production sites with MSc breeder, BSc agronomist, crop wise agronomist; infrastructure and processing facilities; inbreed line acquisition mechanism and training) • Provision of getting a license to be a producer of foundation seed (B.Sc. (agronomist) and JTs with infrastructure and processing facilities) • Provision of getting a license to be a producer of improved seed (training with infrastructure and processing facilities)
20	Agribusiness Promotion and Commercialization Act 2022 (drafted, yet to be finalized)	• Guaranteed to provide agri. inputs (including seeds) to farmers. • Provide a subsidy to farmers based on farmers' identity cards. • Develop standards/protocols for agri. inputs delivery including seeds and laboratory services. • Provide incentives to private sectors for delivering quality agri. inputs to users. • Involvement of private sectors in agri. research and technology development after developing legal standards (licensing to the private sector)

Note: + provisions made in drafted (first amendment of 2004) National Agriculture Policy 2020; ++ provisions made in drafted (first amendment of 2012) Supply Policy 2022; +++ seed related act, legislation, directives are also included; Authors compilation 2023.

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Agroecological Approach to Agricultural Sustainability, Food Sovereignty And Endogenous Circular Economy

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Abstract

The resource over-exploitative, waste-burdening, linear developmental model has transgressed the planetary safe operating limits of the earth systems engendering climatic emergencies and also exacerbated socioeconomic imbalances. The only way of mitigating these planetary and social crises is to formulate and strictly enact ecofriendly, resource recycling, circular economic, equitable, decentralized and peoples´ participatory developmental policies and practices. The objective of this review is to contribute to the discourse on transformative agriculture-centred, circular economic policies and practices that foster nature-based solutions and prudent extraction, use, re-use, and recycling of resources while minimizing waste and environmental externalities. The review highlights Nepal's geophysical, agroecological and socioeconomic realities, their manifestations and policy implications. It also explores how past development policies have been mismatched with these realities, eroding the indigenous resource bases and knowledge systems, and thereby, disrupting the agriculture-based, self-reliant, and food sovereign livelihoods systems. The article argues that agroecology, as a science, practice and movement envisions a nature-based, circular economic and socially just transformative pathway towards sustainable agri-food systems embracing food sufficiency, safety and sovereignty. This pathway contributes to healthy people, healthy animals and healthy ecosystems, hence strengthening the vision of One Health. Building on the agroecological perspectives, this article presents the resynthesized eight operational elements referred to as "8-S-elements" for agroecological transformation. These elements pertain to the prudent management of space (S1), species (S2), seeds (S3), soils (S4), seasonality (S5) and stress factors (S6) through the synergistic integration of agroecosystems and livelihood systems components (S7) with socioeconomic rationality (S8). In the Nepalese context, as an agriculture-based economy, agri-food and livelihoods are viewed as complementary facets. This study recommends the transformative policy options based on the principles of ecological stewardship and socioeconomic objectivity.

Keywords: "8-S"-elements, agroecology, ecosystem services, nature-based solutions, Nepal, Policy

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1. Introduction

The predominant model of economic development and industrial agriculture led to myriads of ecological and climatic externalities while magnifying socioeconomic disparity and social insecurity. Industrial agriculture is one of the culprits for the loss of biodiversity (Brühl & Zaller, 2019; Dirzo et al., 2022), land degradation (Baude et al., 2019; Hossain et al., 2020; Prăvălie et al., 2021), reduction in soil carbon stock (X. Chen et al., 2020; Lal, 2018), greenhouse gas emission (Garnier et al., 2019; Laborde et al., 2021), environmental pollution (Glibert, 2020; Özkara et al., 2016; Tudi et al., 2021), evolution of resistance of pests against pesticides (Bras et al., 2022; Gould et al., 2018; Hawkins et al., 2019; Karlsson Green et al., 2020), loss of ecosystems resiliency, and increasing costs and risks in production systems (Crews et al., 2018). The greenhouse gas emission driving the climate change will further perturb the agriculture and food systems (Ma et al., 2021; Malhi et al., 2021; Mora et al., 2018). At the same time, the overemphasis on capital-centered development, economic efficiency and growth neglecting the environmental and social costs has also exerted adverse impacts on the human social system (Crews et al., 2018)

Six of the nine processes that regulate the stability and resilience of the Earth system have transgressed beyond the safe operating limit (Jaramillo & Destouni, 2015; Persson et al., 2022; Wang-Erlandsson et al., 2022). The anthropogenic factors that have exceeded the safe operating limit include environmental pollutants and other "novel entities" including plastics (Persson et al., 2022), loss of biodiversity (Cowie et al., 2022), climate change (McLaughlin, 2011), land system change (Winkler et al., 2021) and biogeochemical flows of nitrogen (N) and phosphorus (P) (Jaramillo & Destouni, 2015). More recently green water functions (terrestrial precipitation, evaporation and soil moisture) have also been shown to be transgressed (Wang-Erlandsson et al., 2022). Agriculture is attributed to be a driver of overshooting the planetary safe operating limits (Campbell et al., 2017). Alarmed with the finding that exceeding 1.5°C global warming could trigger multiple climate tipping points in the earth system (McKay et al., 2022), scientific communities have declared ecological and climatic emergencies and have urged for advocacy and collective activism for mitigating the negative trends by promoting eco-friendly practices (Gardner et al., 2021).

Since the start of developmental planning, Nepal's economic development strategies evolved from a neo-classical to a neoliberal framework. The ideologies and perspectives did not reflect the ground reality of Nepal's geophysical specificities, agroecological diversities and agrarian complexities (Sugden, 2009) in designing agricultural research, development and education systems. The challenges to economic development

persisted and endogenous self-reliance on basic needs worsened over time despite various political changes in the country (Guthman, 1997; Khadka, 1998; N. R. Khanal et al., 2020; Metz, 1995). Those policies and practices emphasized a simplified intensification and commercialization approach to farming with heavy reliance on external synthetic inputs, and adoption of a few externally-bred cultivars at the expense of local landraces and under-utilized crops (N. R. Khanal et al., 2020; Uprety & Shivakoti, 2019) while making the food system increasingly reliant on the import of food, agricultural products, fertilizers and pesticides (Adhikari, Shrestha, et al., 2021). This severely undermined the indigenous knowledge and finely-tuned nutrient recycling, circular-economic practices (Willett, 1993), food and nutritional security (Rasul et al., 2018), and at the same time, eroded the seed sovereignty and dignity of agriculture-based livelihood systems (Adhikari, Shrestha, et al., 2021; Ghale, 2010). Climate change has aggravated various risks to Nepal's agroecosystems including the naturalization of invasive plant species (B. B. Shrestha & Shrestha, 2021; U. B. Shrestha & Shrestha, 2019) and a decrease in carbon storage (Ge et al., 2022; S. Rijal et al., 2021). The interplay of mismatching policies straining the people's livelihood strategies, Nepal is also undergoing varied manifestations of global socioecological issues (Givens et al., 2019).

Nepal has progressively declined from a food surplus to an importer country over time. Import dependency is also colossal for various agricultural products and synthetic inputs (Adhikari, Shrestha, et al., 2021). However, Nepal has ample potential to transform the agriculture and agri-food system to a sustainable agroecological model to replace imports and develop surplus, sovereign, localized, diversity-based healthy food systems. The objective of this review is to contribute to the discourse for transformative agriculture-centred, circular economic policies and practices fostering nature-based solutions and prudent extraction, use, re-use, and recycling of resources while minimizing waste and environmental externalities. This review proposes ecology-guided management of space (S1), species (S2), seeds (S3), soils (S4), seasonality (S5) and stress factors (S6) through the synergistic integration of agroecosystems and livelihood systems components (S7) with socioeconomic rationality (S8). It also highlights the salient geophysical and socio-economic realities of Nepal and their implications for generic and agricultural development strategies.

2. Research Methodology

The research approach involved a narrative review with the incorporation of the authors' experiences from Nepal, Canada, and the USA. Literature was searched with various words and phrases such as agroecology, agricultural systems, agricultural sustainability, food security, permaculture, conservation agriculture, climate-smart

agriculture, biodynamic agriculture, sustainable intensification, regenerative agriculture, food sovereignty, landscape engineering, bioengineering, biodiversity, planetary boundary/safe operating limit, climate change, landlocked fragile geography, tourism, seed sovereignty, agroecosystems services, UN sustainable development goals, nature-based solutions with and without the words "agriculture" and "Nepal". Relevant examples of agroecological initiatives from other developing or low-income countries are extracted as case studies.

3. Results and Discussion

3.1 Nepal's geophysical and socioeconomic realities and their policy implications

Salient geophysical and socioeconomic realities of Nepal include landlocked, geo-tectonically active fragile geography, an abundance of ecological diversity, a heterogeneous cultural landscape embedded with agroecosystems, a treasure trove of natural beauty, and copious water resources. These specificities call for varied policy imperatives (Table 1). The landlocked situation presents high transaction costs and volatility in international trade (Grechyna, 2021; Vindegg, 2022), hence implicating a diversified endogenous circular economy and food-sufficiency approach to development (Corral et al., 2022; Papangelou & Mathijs, 2021; Schröder et al., 2020). The COVID-19 pandemic situation proved the fragility of the industrial corporate food systems (Montenegro de Wit, 2021), and the resilience and vitality of the localized, short-chain, diversified and sovereign approach to food systems (Adhikari, Timsina, et al., 2021; Menconi et al., 2022; Nemes et al., 2021; Turnšek et al., 2022; Zollet et al., 2021). Landlocked boundary and fragile geography dictate emphasis on contextual integration of cleaner locally available renewal energy options such as animal draft power, biogas, solar and wind energy, and micro-hydroelectrical power systems (Khatri & Paija, 2021; Koirala & Acharya, 2022; Malla, 2022; Neupane et al., 2022; Raihan & Tuspekova, 2022; K. Rijal et al., 1991; Suman, 2021) for residential use and agricultural and rural/agro-industrial mechanization to replace import of fossil fuel while reducing wastes and hazards.

The geo-tectonically active, fragile mountainous landscape and rainfall extremes under changing climates engenderer slope instability, excessive runoff, soil erosion, landslides, and destructive scouring, flooding, and sedimentation in the valleys and plain areas damaging roads and constraining transportation (N. Chen et al., 2023; Dahal, 2022; Li et al., 2022; Tiwari, 2000). This implicates eco-engineering policies and practices for infrastructure development and land use system (Gobinath et al., 2022; Y. Zhang et al., 2020) with minimal disturbance to land and natural drainage systems such as ropeways (Magar, 2016), micro-hydropower (Hussain et al., 2019), and

eco-cultural conservation-based development (Baral et al., 2007; ICOMOS, 2021; Schröder et al., 2020; Stronza et al., 2022) and localized, sovereign food systems (Béné, 2020; Canfield et al., 2021) to minimize risky transports and food in security.

The treasure trove of natural beauty and cultural diversity holds bountiful leisure and recreation potentials for eco-tourism, cultural tourism and agro-tourism (Dhakal, 2022). This calls for policies ensuring Nepal as a haven for tourism while promoting indigenous cuisines and preserving cultural integrity and natural trove. With visionary management strategies, the colossal water resources suffice for residential and agricultural usage, and for hydro-electricity generation for fueling industries, ropeways and agricultural mechanization (Nepal et al., 2021; Upadhyay & Gaudel, 2018).

The abundance of ecological diversity offers diverse natural food, medicines, bio-pesticides, fodder and pasture, animal bedding materials, handicraft materials, pasture and timber resources for ecologically adaptive livelihood systems (Fonzen & Oberholzer, 1985; Rajbhandari, 2017; RHOADES & THOMPSON, 1975). It requires strong policy measures incentivizing community-based conservation and sustainable utilization of the resources. Diversity of agroecosystems and cultures implicates policy support for diversity-based integrated agriculture embedded in indigenous food culture, preserving and promoting indigenous knowledge (Perfecto et al., 2019; Willett, 1993).

Table 1: Salient geophysical and socioeconomic realities of Nepal and their policy implications

Realities	Manifestations	Policy implications	References
Landlocked boundary	High transaction costs and volatility in international trade	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	(Corral et al., 2022; Grechyna, 2021; Khatri & Paija, 2021; Malla, 2022; Neupane et al., 2022; Papangelou & Mathijs, 2021; Raihan & Tuspekova, 2022; K. Rijal et al., 1991; Schröder et al., 2020; Suman, 2021; Vindegg, 2022)

Realities	Manifestations	Policy implications	References
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 eco-engineering in infrastructure development with minimal disturbance to land and natural drainage systems; eco-cultural conservation-based development; and localized, sovereign food systems to minimize risky transports	(Baral et al., 2007; Béné, 2020; Canfield et al., 2021; N. Chen et al., 2023; Dahal, 2022; Gobinath et al., 2022; Hussain et al., 2019; ICOMOS, 2021; Li et al., 2022; Magar, 2016; Schröder et al., 2020; Stronza et al., 2022; Tiwari, 2000; Y. Zhang et al., 2020)
The abundance of ecological diversity	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 incentivising community-based conservation and sustainable utilization of the resources	(Fonzen & Oberholzer, 1985; Perfecto et al., 2019; Rajbhandari, 2017; Rhoades & Thompson, 1975; Willett, 1993)
Cultural and agroecosystems diversity	Differential combination of crop and animal species and land races, seasonality, land use patterns, non-farm activities, feast and festivals, food ingredients and preparations	Diversity-based integrated agriculture embedded in indigenous food culture, preserving and promoting indigenous knowledge	(Fonzen & Oberholzer, 1985; Perfecto et al., 2019; Rajbhandari, 2017; Rhoades & Thompson, 1975)

Realities	Manifestations	Policy implications	References
The treasure trove of natural beauty	Bountiful leisure and recreation potential for eco-tourism, cultural tourism and agro-tourism	Strong policy measures for making Nepal a haven for tourism while promoting indigenous cuisines and preserving cultural integrity and a natural trove	(Dhakal, 2022; Nepal et al., 2021; Upadhyay & Gaudel, 2018)

3.2 Agrocological pathway to the agri-food system

Various contesting terminologies and perspectives have emerged in the agricultural sustainability discourse. Some of them to name are permaculture (Hirschfeld & Van Acker, 2021), conservation agriculture (Palm et al., 2014), climate-smart agriculture (Lipper et al., 2014), biodynamic agriculture (Soltani et al., 2016), sustainable intensification (Rockström et al., 2017), regenerative agriculture (Gordon et al., 2022) and agroecology (Wezel et al., 2020). Agroecology takes a more holistic discourse covering both ecological and socioeconomic perspectives embracing the science, practice and movement for agricultural transformation. The agro-ecological model comprises two phases of incremental and transformational strategies. The incremental phase involves three simultaneous schemes: (i) enhance resource use efficiency based on comparative advantage, appropriate regenerative technology and renewal energy-based mechanization; (ii) substitute harmful inputs and practices with ecofriendly alternatives; and (iii) redesign diversified agricultural production systems to enhance nutrient recycling and synergize the agroecosystem processes through functional diversification of production systems components. The transformational phase involves the integration of food and livelihood systems components from the local to regional and national levels. The model emphasizes the co-creation of innovation and practices through the blend of indigenous wisdom and scientific knowledge (Anderson et al., 2021; Wezel et al., 2020). This requires a radical shift in paradigm in the education, research, extension and development system. Selected examples of agroecological initiatives and outcomes in developing countries are given in the box below:

Case study I: Switching to low external input systems in Ethiopia - After the severe droughts in the 1980s, Ethiopia started adopting intensive external input-oriented agriculture, including chemical fertilizers. Besides increased food production, this approach increased dependency on costly chemical fertilizers,

the price of which was continuously increasing putting many farmers in debt. Experts found a close interrelationship between the use of external inputs, degraded farmland, poverty, and food insecurity. In 1996, a low external input approach was promoted in the area focusing on organic composting, soil erosion control, rainwater harvesting, cover cropping, reintroduction of indigenous grass species, agroforestry, etc. Farmers reported several agro-ecological benefits, including improved soil fertility and moisture retention, higher local water tables due to conservation, increased temporal as well as spatial crop diversity, and production stability.

Case study II: Promotion of bio-intensive farming in Kenya - Kenya's agricultural policies traditionally emphasized producing cash crops for export, thereby neglecting smallholder farmers that make up most producers. A three-year drought in the early 1980s created severe food insecurity and hunger in far-western Kenya. Following the drought, cereal imports increased by 245 percent in a few years, which affected smallholder farmers. In the following years, some private agencies helped farmers to practice the "Grow Biointensive" method. The project aimed to help smallholders grow the most food needs on the least land using locally available inputs and resources such as compost, open-pollinated seeds, botanical pesticides, and natural pest-predators. The average yields for crops under bio-intensive agriculture were 2-4 times higher than in conventional farming, soil fertility has improved, and water supplies and retention have stabilized. After the program, farmers and their families not only produced enough food for themselves, but they also generated an average income of $30 per month from selling excess produce in the local market. Most households in the area can now afford school fees by selling extra produce.

Case study III: Community seed bank/seed fair approach in Zimbabwe and Uganda - Traditionally, the Zimbabwe government and private agencies have promoted the use of hybrid seeds and chemical fertilizers to increase maize production. Such hybrid seeds and chemical fertilizers made farmers solely dependent on private suppliers. The use of hybrid seeds has also promoted monocropping. Regardless of its price, the timely availability of seed and fertilizer became the major issue. Consequently, low yield and hunger are commonplace during the 1990s and early 2000s. After 2006, with support from various organizations, farmers started practicing conservation farming (CF) based on minimal tillage and locally available open-pollinated maize seeds conserved at community seed banks. Organic manure was used to boost soil fertility and mulch was used to conserve soil moisture. Community seed banks were established in every 4-5 villages. Chemical fertilizers were fully replaced by organic manure starting the second year of the project, which

enhanced yields and was a lot cheaper and readily available to farmers. The participating farmers were also less vulnerable to drought and more likely to have a good harvest even if there was less rainfall because of the improvement in soil quality and the use of locally adapted crop varieties. See fair program with hands-on training was also successful in Uganda.

Case study IV: Promotion of locally adapted crops in Zambia and Malawi - Traditionally, both Zambia and Malawi's governments have promoted maize cultivation through massive subsidies and price support to farmers. As a result, maize replaced traditional crops like cassava, millet, and sorghum, which were e more drought-tolerant. In the early 1980s, a series of droughts seriously affected maize, because it is one of the high-water demanding crops. Further, the financial constraints forced governments to reduce maize subsidies and support systems. Following the drought years, both Zambia and Malawi's governments decided to promote cassava that can be harvested throughout the year, demands little labor, and doesn't require chemical inputs (fertilizers, pesticides). Research and breeding programs focused on the identification of the best local varieties of cassava and the distribution of clean planting material to avoid pest contamination. In the 1990s, they explicitly discouraged maize production in drier areas to provide space for more drought-resistant crops, cassava, and sweet potato. By 2009, there were over 397,000 cassava farmers each in Zambia and Malawi. In both countries, improved cassava varieties produced more output with the same labor and land and without purchased external inputs (pesticides and fertilizers).

Note: These case studies were compiled and published by the Oakland Institute and the Alliance for Food Sovereignty in Africa (AFSA) at different periods. A full set of case studies can be found at www.oaklandinstitute.org and www.afsafrica.org.

3.3 The 8-S Operational Elements For Agroecological Pathways

Building on the concept of agro-ecological pathways, Khanal (2023) has developed a framework of eight operational elements, which are referred to as the '8-S elements'. These elements aim to enhance the sustainable functioning of agroecosystems and livelihood systems. The framework integrates the management of space (S1), species (S2), seeds (S3), soils (S4), season (S5) and stressors (S6) through a systems approach, integrating synergistic components for balancing the ecological and economic trade-offs (S7) with socioeconomic objectivity (S8). The framework provides an operational guideline for policies and practices. Readers are encouraged to refer to Khanal (2023) for a global review and examples. For readers' convenience, a brief excerpt of the review, additional contextual findings, and opinions are presented below:

3.3.1 Spatial bioengineering

Agricultural systems evolve through efforts to accommodate socio-economic needs while considering the prevailing natural environment and agrarian policies. Spatial bioengineering is consciously designed systems that achieve desired socioeconomic outcomes while sustaining the carrying capacity of the natural environments. Various terminologies are found in the literature to describe the design of watershed management and land use systems, such as ecoengineering (Gobinath et al., 2022), climate-smart landscapes (Scherr et al., 2012), agroecological engineering (Dollinger et al., 2015) and soil and water bioengineering (Rey et al., 2019). Khanal (2023) uses the term spatial bioengineering to refer to the adaptive modification of physical and vegetal landscape tailored to the constraints presented by climatic, geographic, and soil conditions. It can be scaled up from field to community and/or watershed level or scaled down from the watershed to field scale depending on the pre-existing development and landscape complexity. Land sharing and land sparing perspectives can be contextually adapted to balance the ecosystem's functions for food production, biodiversity conservation and environmental protection (Phalan et al., 2011). Prudently planned spatial bioengineering can serve multiple productive, protective and micro-climatic modulating functions. These functions range from the stabilization of agricultural and peripheral landscapes and regulation of water resources (Scherr et al., 2012; Y. Zhang et al., 2020), the provision of operational and conservation features (such as homesteads, barns, farm ponds, and structures for grain and feed storage, composting, water-harvesting and drainage) (Liu et al., 2013; H. Zhang et al., 2022), the diversification of physical landscape terracing and diking (Baryła & Pierzgalski, 2008; D. Chen et al., 2017; Giráldez et al., 1988), and the integration of production system components with varied annual and perennial crops, economic plantations, natural vegetation and livestock vegetation (Paul et al., 2017; Quandt et al., 2019). The assorted landscape and vegetal features condition the local micro-climate, providing a comfortable setting for humans and animals, and a favorable environment for crop production (Schmidt et al., 2017). The micro-environmental setting enhances resiliency in the production and social system (Freeman et al., 2021) through mosaics of habitats for beneficial biodiversity (D'Acunto et al., 2016; Gallé et al., 2020; A. E. Martin et al., 2020; E. A. Martin et al., 2019), nutrient recycling and carbon sequestration (D'Acunto et al., 2014; Schoeneberger, 2009), and thereby synergizing the agroecosystem components. Thus, the emergent multi-functional landscape system lays the foundation for transformative livelihoods and food systems that prioritize sustainability and resilience.. Nepal's traditional agriculture and land use systems exhibit strategic spatial bioengineering characteristics that support a range of community needs and services..

Community or watershed level spatial bioengineering might include zoning for settlement, arable land, support infrastructures, location for irrigation channels, water harvesting reservoir, ponds etc. for water supply and recharge, and small-hydroelectricity system, schools/vocational training centres (demos of best practices, cultivating science), biodiversity sanctuaries, land stabilizing vegetation, market place, local processing/manufacturing, recycling, waste disposal, biogas/biofuel generation plants, stable roadways, community-based tourism support structures.

3.3.2 Species diversification

Spatial bioengineering can create niches that are diversified with various crop species and peripheral vegetation in spatial and temporal patterns. This enhances the landscape's carrying capacity, while also providing shelter for productive and supportive ecosystem services such as pollinators and natural enemies of pests, through the land-sharing approach (Phalan et al., 2011). The crop diversification strategies with the mosaics of cropping systems and peripheral vegetation engender a multi-functional environment optimizing yield and ecosystem services such as soil formation, nutrient retention, organic matter storage, pest suppression, and abundance of natural enemies and pollinators (Crews et al., 2018; Gallé et al., 2020; Isbell et al., 2017; A. E. Martin et al., 2020; Vasseur C., Joannon A., Burel F., Goffi C., Meynard J.M., 2008; Vasseur et al., 2013), thereby reducing the need of conventional inputs.

3.3.3 Seed sovereignty

Agricultural systems evolved with the farmer's selection of desirable plants and seeds for subsequent cropping creating an abundance of agrobiodiversity. The crop landraces have gone through the guided evolution on-farm towards increasing fitness and adaptability to management regimes in the given agro-climatic environment. The crop landraces associate with a wealth of farmers' knowledge about their biology, agronomy, adaptation and uses. The landraces thus evolved have remained as freely accessible common pool resources with indefinite evolutionary potentials. However, modern plant breeding and genetic modification not only truncate the evolutionary continuum but also come with different governance policies and more recently with private ownership, which threatens agrobiodiversity and seed sovereignty (Mueller & Flachs, 2022). The industrial agricultural development policies favouring modern commercial cultivars and externally governed seed systems cause genetic erosion, lowering the future potential for feeding the variability into the breeding programs (Cowling, 2013; Khoury et al., 2022). It is paramount to fosterer the guided evolution of agrobiodiversity in on-farm niches for diversified and health food systems (Marone et al., 2021; Mir et al., 2020). Tremendous variability among landraces and wild

relatives preserves the genetic potential for crop improvement in the future (Halewood et al., 2018; Khoury et al., 2019). On-farm agrobiodiversity conservation measures offer dynamic management of population evolution, adaptation, and diversity (Enjalbert et al., 2011; Thomas et al., 2012). On-farm seed selection, seed saving, and community-level seed exchange networks existed in the traditional agricultural systems (Altieri, 1993; Delêtre et al., 2011) and policy measures should incentivize such practices while protecting seed sovereignty. Participatory decentralized evolutionary plant breeding approaches have evolved to be a potential tool for improving crop landraces and developing cultivars with desired traits and local adaption, while conserving agrobiodiversity and seed sovereignty (Ceccarelli & Grando, 2019, 2022; Colley et al., 2022; Joshi et al., 2020).

3.3.4 Seasonal synchrony and satiation

Choice of crops or cultivars with climate-adaptive phenology, shifting seeding time and tailoring cropping sequences in response to changing weather patterns, and harnessing efficient irrigation at critical stages are some of the seasonal adaptations of farming. Global climate change is bringing about more frequent erratic and extreme weather patterns. In arid unirrigated environments, crop performance depends on soil moisture during seeding for proper crop establishment. This imposes more stresses and perturbations on the agricultural production systems (Beillouin et al., 2020; Sun et al., 2019). Adjusting seeding time and seeding rate in response to changing weather patterns can become a low-cost eco-friendly approach to minimize production risks. In production systems prone to terminal drought and temperature stresses, early seeding may allow crops to escape the stresses resulting in higher yields. Timely seeding and sequencing of crops along with conservation agricultural practices in the rice-wheat cropping system in South Asia helped mitigate terminal moisture and temperature stresses on wheat, which led to an increase in wheat yield and overall systems productivity (Devkota et al., 2019; Somasundaram et al., 2020). Spatial bioengineering and supplemental irrigation enhance local microclimate enabling smooth systems functioning and resiliency measures (Soltani et al., 2016). Readers are referred to Khanal (2023) for the global examples of seasonality adaptation of cropping systems.

3.3.5 Soil health management

Soil health management embraces the integration of diverse practices that conserve soil, maximize nitrogen fixation, enhance nutrient recycling and enrich the soil properties for sustaining crop productivity while optimizing the agro-ecological and economic trade-offs. It may include various tillage systems such as conservation tillage, strategic or occasional tillage, bio-tillage, cover cropping, residue management, green manuring, organic amendments, biochar, biofertilizers and supplemental

nutrient applications in the right forms, at right time, at the right rates and with right methods. Under favourable environmental conditions, annual legume crops can fix up to 260 kg atmospheric nitrogen per ha (equivalent to 565 kg Urea fertilizer) (Herridge et al., 2022), and preceding legumes crops can meet full nitrogen requirement for the immediate succeeding crop and up to 50% nitrogen requirement for the second succeeding crop (N. Khanal, 2022; N. Khanal et al., 2021). In his review article, Khanal (2023) has extracted global examples of diverse soil management practices and their tradeoffs. The policy measures should incentivize sustainable soil management practices that generate ecosystem services to the benefit of society and the environment.

3.3.6 Stressors management

The spatial bioengineering, species diversification, seed sovereignty, seasonal synchrony and soil health management impart high resiliency and nature-based solution to the production systems against various abiotic and biotic stresses such as drought, heatwaves, floods, crop weeds, diseases, and insect pests. The supplementary stressors management strategies involve contextual integration of the above-noted elements and adopt nature-based solutions to alleviate abiotic and biotic stresses and perturbations. Integrated pest and disease management (IPDM) helps to keep the pest population below the economic threshold level while minimizing the potential loss from insects/pests. Crop and livestock insurance and disaster preparedness would help either to transfer or minimize the risk associated with biotic and abiotic factors.

3.3.7 Systems integration

Eight of the UN Sustainable Goals (SDGs) relate to agriculture and food systems. Agriculture development policy must embrace all those SGDs as an integrated package for the effective realization of the impact indicators (Barrett et al., 2022). A systems approach to integrating synergistic components helps optimize the ecological and economic trade-offs from field to landscape scale. To this end, it is important to revitalize, incentivize and advance the integrated systems such as agro-forestry, crop-livestock integration, integrated multi-trophic aquaculture, and biogas/biofuel-integrated farm mechanization and agro-processing plants (Kitaoka, 2019), agro-tourism (Huber et al., 2020), and local food and marketing networks. The multi-sectoral and interdisciplinary approaches enable income diversification and drive a circular economy. It may include value addition through the establishment of household/community-based small agri-food processing industries powered with renewable energy such as bio-gas and small hydro-units; launch of community-based agro-tourism and agri-fairs (homestay, local/organic food fairs etc.); regulated fair marketing

through community-based cooperatives, local haat-bazaar, and provisioning of micro-financing and insurance systems; development of support infrastructures (storage, irrigation, marketing stalls, collection centres, energy and power systems etc.), and re-connecting producers and consumers through short-chain local food networks, supported with publicly funded infrastructures and institutional networks to scale-up food networks through the governance structure. The country's agricultural research, education, and extension system should integrate both sustainable agriculture and food systems innovations. The innovations should encompass crop production, land use, distribution and their environmental footprints, dietary improvements and waste management for circular economy and OneHealth. It requires stakeholders' engagement for the charting of transition pathways and development of appropriate incentives, regulations and social licence measures.

3.3.8 Socioeconomic objectivity

Strong policy measures are required to abolish policy-bias, power-asymmetry and enact subsidy measures to promote the practices that produce public goods and services and boost the dignity of farmers and agri-entrepreneurs. The policy should visualize outmigration and labor shortage; promote renewal energy-based mechanization and land consolidation measures (such as waiver of land title transfer fees for land consolidation to make single-parcel operations units), to enhance time efficiency amidst labor shortage; need bottom-up scaling of policy from community groups to Wards through municipalities to national level. Small, fragmented landholding limits mechanization, implicating region-specific selective mechanization based on animal, biofuel and hydro-electric power. It is a shame to exchange human resources with fossil fuels by exporting the youth labour force abroad and importing the fossil fuel for inapt mechanization. The transformative policy must provide an incentive for public goods and services; subsidize investment in community-based resource conservation and development; restructure education, extension and developmental systems; provide vocational training and investment supports to youths and landless tenants to the reclamation and use of arable barren land. Accordingly, the policy measures should subsidize only those practices that produce public goods such as biodiversity conservation including indigenous minor food crops, integration of agro-ecosystems components, environmental protection, maintenance of aesthetic landscape, and building social capitals.

4. Conclusions and Policy Recommendations

Nepal's geophysical and socioeconomic realities call for an endogenous, self-reliant, regenerative, and holistic model of development. Past and current agricultural

development policies and practices have emphasized the synthetic chemical-dependent, modern cultivar-based, simplified agricultural practices leading to resource degradation, environmental pollution, and eroded indigenous agro-biodiversity and knowledge systems. This trend has further disrupted the agriculture-based, self-reliant livelihood systems, and weakened food sovereignty. It must be reversed, and it is both possible and urgent. It requires a paradigm shift to balance the tradeoffs between economic growth and socio-ecological health. The policy orientation must transform from sectoral silos to multi-disciplinary, multi-sectoral and integrative bottom-up approaches. It should focus on developing nature-based solutions and devise strong measures to diversify and circularize local economies. Drawing on the aforementioned discussions, the policy recommendations are summarized below:

- Emphasize the co-creation of innovation and farming practices through the blend of indigenous wisdom and scientific knowledge.
- Incentivize the gradual substitution of external synthetic inputs (fertilizers, pesticides) with locally available and ecofriendly alternatives.
- Focus research and extension efforts on redesigning diversified agricultural production systems to enhance nutrient recycling and synergize the agroecosystem processes through functional diversification of components such as integration of crops, livestock, annuals, perennials, pollinators, aquaculture, and peripheral biodiversity components.
- Subsidize biodiversity-based agriculture and food systems, and promote indigenous or underutilized food crops, resource conservation and cooperative initiatives.
- Incentivize components integration rather than a specialized or single practice that does not synergize outputs or does not produce ecosystem services.
- Provide support to diversify local economies through value addition (household/community-based small agri-food processing industries powered with bio-gas and small hydro-units), community-based agro-tourism (homestay, local/organic food fairs etc.), fair marketing (community-based cooperative marketing, micro-financing, local haat-bazaar etc.), and local food networks (re-connect producers and consumers through short-chain markets) underpinned with publicly funded infrastructures (storage, irrigation, marketing, collection centers) and institutional services.

Authors Contribution Statement

Nityananda Khanal: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and

investigation process, specifically performing the experiments, or data/ evidence collection; Report initial draft/review/ final draft polishing;

Sushil Thapa: Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/final draft polishing;

Conflict of Interest

The authors declare no conflict of interest. Views expressed in the article are solely of the authors, which do not represent the views of their respective organizations.

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Public Private Cooperative Partnerships for Scaling Commercial Maize Production in Nepal: Linking Innovations With Policy

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Abstract

The Agriculture Development Strategy of the Government of Nepal (2015-2035) has identified maize as one of the key commodities for commercialization. Maize constitutes at least 50% of the total ingredients in poultry feed, with approximately 3,000 tons of poultry feed consumed daily in Nepal. However, while the demand for feed is increasing at about 10.0% per annum, maize production is only growing at 2.5% per annum. The low productivity with inferior grain quality and a lack of value chain coordination mechanisms starting from inputs (seeds) to output (grains) have hindered the commercialization of the domestic maize sector. Because of the inefficient market mechanism and competitive market structure, farmers are not able to pursue commercial maize production.

To address this issue, action research on the value chain was conducted by the International Maize and Wheat Improvement Centre (CIMMYT), focusing mainly on Sudurpaschim and Lumbini provinces, to implement the maize commercialization model (MCM) between 2020 and 2022. Results demonstrate that public-private partnership approach can increase maize production, improve farm gate prices and farmers' incomes, improve value chain coordination; improve access to services to farmers and enhance information flow among stakeholders.

The study recommends that policies aimed to streamline commercial maize production should adopt a value chain approach, with a focus on chain upgrading and governance and promote coordination among actors to scale up commercial maize production throughout the maize-growing areas of Nepal.

Keywords: Maize, Commercialization, Value Chain, Partnership, Policy

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1. Introduction

Maize is the leading cereal in terms of production, with 1,210 million tons produced on 205 million hectares (M ha) globally, with a productivity of 5.8t/ha (FAOSTAT, 2021). It is one of the three main types of cereal that feed the world (Shiferaw *et al.*, 2011). Beside its staple food use, maize makes a significant contribution to animal feed (especially poultry), as well as biofuel and industrial uses (Hellin & Erenstein, 2009). Population growth, changing diets and a rapidly growing poultry sector are contributing to a sharp increase in maize demand (Erenstein, 2010). In Nepal, maize is the second most important crop after rice in terms of area, production and yield (Subedi *et al.*, 2017; MOAD, 2020). Maize occupies 43% of cereal's area and contributes 53% of its production. The total area, production and yield of improved maize in Nepal have been reported at 0.98 M ha, 2.99 million tons, and 3t/ha, respectively (FAOSTAT, 2021). Mid-hill represent more than 70% of the area and production, whereas high hills occupy 20% of the area and 10% of the total production. The Terai occupies 10% area, contributing 20% to national maize production (Gurung *et al.*, 2011). In Nepal, maize is grown in three seasons: summer, spring and winter with 74% (mainly in mid-hills), 14% and 12% coverage respectively (Gurung *et al.*, 2011). In 2019/20, Nepal produced 2.99 million tons of maize, against a national requirement estimated to be 3.59 million tons (21% food, 60% household managed livestock, 19% industrial livestock), with the deficit being fulfilled by imports of about 0.6 million tons worth of US$ 138.97 million) (MoALD, 2020; TEPC, 2023). While about 86% of maize production in the hills is used for human consumption, about 80% of the production in terai is used for poultry and animal feed (Gurung *et al.*, 2011).

The Agriculture Development Strategy (ADS), which is the flagship policy of the GoN aims to commercialize the agriculture sector in Nepal to move from subsistence to commercial production. The GoN and the Prime Minister Agriculture Modernization Project (PMAMP) had launched various programs such as the maize mission program, mega maize program, and maize block program etc., to support production, mechanization, irrigation, subsidised loan, crop insurance, etc., in the country to promote maize production. Under PMAMP, zones (500ha) and super zones (1000ha) are administered by the federal government whereas blocks (50ha) and pockets (10ha) are managed by the provincial government and local level, respectively. The Provincial governments have set up Agriculture Knowledge Centres (AKCs) and Integrated Agriculture and Livestock Development Offices (IALDO) to provide agriculture extension and business development services in the agriculture sector, including maize, in their command area. However, these structural units face challenges in designing and implementing activities due to limited human resources, unclear communication strategies with the Local Levels and the federal government,

lack of institutional memory/data developed before federalism, and poor linkages with the private sector. Although various research and development organizations are working in the maize sub-sector, there is a huge yield gap between research stations and farmers' fields, and the value chain remains poorly organized. These challenges demand an approach to maize sector promotion and competitiveness that acknowledges the vital role of the private, public and cooperative sectors and better implementation of the policy priorities.

1.1 Rationale-Policy challenges in Maize Production

The commercialization of the domestic maize sector in Nepal faces several policy challenges, including low productivity with inferior grain quality and a lack of value chain coordination mechanisms starting from inputs (seeds) to output grains (grains). The generic maize VC map is depicted in Fig 1. However, there is a lack of estimation of the amount of maize used in household and unorganized feed industries.

According to CIMMYT (2018), only 14% of households in Nepal sold maize. This is primarily due to small size and fragmented farms, which make it difficult for farmers to realize economies of scale and forces them to sell produce in local markets where prices are low. Furthermore, the maize yield of 1.96 t/ha in Nepal is lower than the national average yield of maize in 2016, which was of 2.43 t/ha (CIMMYT, 2018). The total annual demand for maize seed in Nepal is 19,552t, but the seed replacement rate (SRR) is only 15.3% (SQCC, 2021).

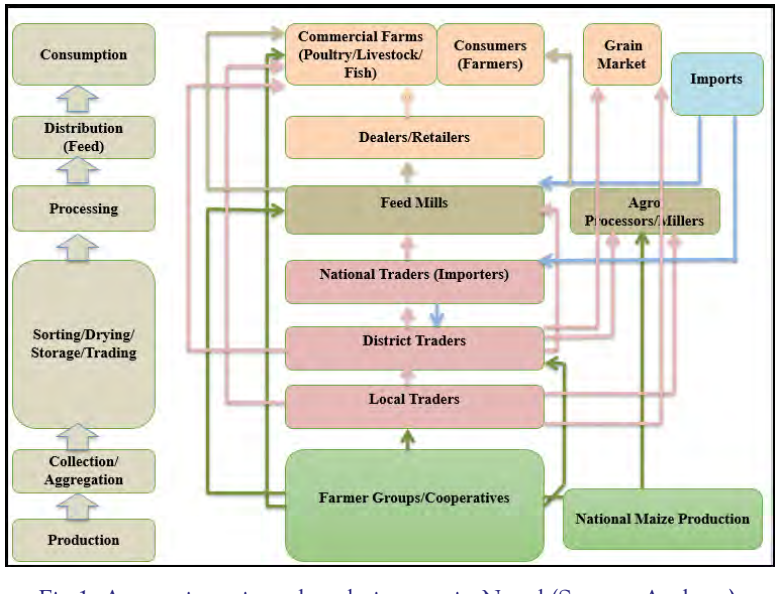

Fig 1: A generic maize value chain map in Nepal (Source: Authors)

The unavailability of competitive hybrid cultivars within the country and underdeveloped seed industries has resulted in a dependency on imported hybrid maize seeds every year (Gurung et al., 2011). Farmers and agro-dealers have limited access to information on new varieties and their traits. Only 24% of the farmers in Nepal are reached by formal extension services (ADS, 2014) and private-sector agricultural inputs and service providers are almost non-existent in remote rural areas (Gurung *et al.,* 2011). Producers also face major problems with postharvest handling for drying maize as maize must be dried to at least 14% in order to be stored safely for any period of time (Ransom, 2001). Additionally, the annual requirement of maize for formal sector poultry feed is 0.54 million tons and in 2021/22, the annual value of maize import for feed was estimated at US$ 126 million (TEPC, 2023). Due to the lack of an efficient market mechanism and competitive market structure, farmers are not in a position to benefit from increased production (Koirala, 2002). Small producers are unable to market their produce individually due to small volumes and long distances, resulting in selling produce in local markets where the prices are low.

1.2 Objectives of the paper

The feed sector is driving commercial maize markets in Nepal, and there is tremendous scope to link smallholder farmers to commercial feed markets. The objective of this paper is to share the results obtained from action research on public-private-cooperative partnerships for commercial spring maize production at three levels : value chain coordination, production and post-harvest, and market linkages.

2. Research Methodology

The assessment started with a literature review (Brown & Ashman,1996; Bouwen & Taillieu, 2004; Warner, 2006; Schut et al., 2017; Choudary et al., 2018) and key informant interviews with stakeholders within the United States Agency for International Development (USAID) delineated Zones of Influence (ZOI) covering the terai areas of Sudurpaschim, Karnali, Bagmati and Lumbini province. These included interviews with key personnel from seed companies, feed mills, provincial ministries of Agriculture, AKCs and IALDO, farmers cooperatives, and traders to assess the potential of spring maize in the ZoI in March 2021. It was found that the rice- wheat cropping pattern was the dominant cropping system in the study districts covering about 30% of the total rice production land. Maize was only cultivated at a small scale mainly for household consumption. In addition to wheat, farmers grew cash crops such as lentil, potato and rapeseed after rice. Thereafter, >80% the land remained fallow for about 70 days (after wheat) to 130 days (after potato & rapeseed). The commercial maize production program harnessed the potential of spring maize

in this fallow land estimated at 0.2 million ha in the western Terai region of Nepal (MoALD, 2021) and selected Banke, Bardiya, and Kailali for the action research. Thereafter using a framework for action research on value chains following Riisgard et al., (2010), the study assessed the structure, functioning and governance of maize value chains in Banke, Bardiya and Kailali and identified major challenges related to value chain coordination, production and post-harvest and marketing and key policy issues and risks in the maize value chain. To share these findings and to initiate action research to upgrade the maize value chains a multi stakeholder platform approach was adopted following the methodology suggested by Schut et al. (2017).

Three maize commercial networks (MCN) comprising the above-mentioned stakeholders were formed in the three identified districts between April – June 2021. All of these networks were coordinated by leaders from local farmers cooperatives and government agencies played the advisory roles and USAIDs Nepal Seed and Fertilizer (NSAF) project provided technical support. The VC assessment findings were compiled and shared with the stakeholders by organizing 4 MCN meetings in each district and actions and strategies to promote commercial maize production and improve domestic maize value chains in the three districts through the maize commercialization model (MCM) was co-created (Table A1, annex 1). A cropping calendar for maize was developed and activities were planned with roles of respective MCN members. These activities were focused on production, marketing and coordination of public sector programmes. A national level workshop was organized in March 2022 together with the Department of Agriculture (DoA) to share the learnings from the action research from 2021 and to review key policy and technical support required for scaling MCM to all potential spring and winter maize growing regions of Nepal.

Data on yield, prices, incomes, value chain coordination and learnings were collected through semi-structured interviews (30 farmers), crop cuts (56), focused group discussions with farmers groups, key informant interviews with traders (15) and feed mills (4) and GoN officials (5) between August 2021-2022. Data was analyzed using descriptive statistics and the process, functional and market upgrading of the maize value chains were assessed based on field observations and information received from stakeholders. Key policy issues were identified based on consultations with federal, provincial and local level departments and units.

3. Results and Discussion

This section provides the results obtained from the action research for improving the maize VC at three levels viz., value chain coordination, production and post-harvest and marketing.

3.1 Policies on value chain coordination:

The MCN meetings revealed several challenges for maize commercialization. These include a) limited knowledge about seed varieties, b) lack of seed market promotion, c) poor extension services to promote improved crop management practices; soil fertility management, irrigation and pest (fall armyworm) management, d) lack of efficient mechanism or framework to align central, provincial and local governments' efforts for maize commercialization, e) lack of suitable models to facilitate access to finance and insurance to small holder farmers, f) slow and inefficient service delivery and insufficient private sector engagement in extension. The MCN provided the platform for all the maize value chain actors and stakeholders to address these challenges and streamline their role and delivery of services to support commercial maize production. Realizing the potential, 15 Local Levels (Bardiya- Badhaiyatal, Bansgadhi, Guleriya, Madhuwan; Banke- Raptisonari, Dudhuwa; Kailali- Gauriganga, Lamkichuha, Kailari) including AKC Banke and Kailali and IALDO, Bardiya invested US$ 2.37 million for maize commercialization in 2022 (Authors own calculations from provincial and local governments funding to MCM).These streamlined GON investments in the MCM sites for improved seeds, mechanization, fall armyworm control, and irrigation boosted large scale maize production in spring season which became a new cropping window in the research sites. Moreover, Lumbini province government announced area-based incentive @ NPR 6,000/ha for farmers and NPR 300,000 per 50ha for cooperatives. The MCM mobilized government technicians and lead farmers through training of the trainer's program to provide extension services on crop and soil management. USAID's NSAF co-financing supported producers, traders and processors to acquire new tools, equipment and facilities for post-harvest management. Traders and feed mills shared market standards and prices and were able to procure locally produced maize in bulk thus reducing imports. Moreover, the Government agencies such as the Local Level (Palika)s, AKCs and IALDO) found the maize commercial network useful for implementing their programs in a fast-track, focused and coherent manner.

3.2 Production & Post Harvest

A total of 2,260 households (HH) associated with 65 cooperatives from 19 Local Level (Palika)s of Banke, Bardiya and Kailali districts received information on best management practices of maize crops and marketing. These HHs planted maize in 547.8ha and produced 3,232t maize grain. Due to improved connection with farmers seed companies were able to sell newly developed Nepali hybrid variety maize seed (Rampur Hybrid-10) in the MCM areas. Seed companies tested and demonstrated varietal performance of existing and pipeline varieties in farmers fields and increased

investment in hybrid maize seed production. Farmers also got information and purchased new varieties of hybrid maize such as Kanchan (early variety, single cross sold by Kanchenjunga Seed Company), Rajkumar (medium duration variety, single cross sold by Bioseed Company), and Subarna (medium duration variety, single cross sold by Bioseed company).

Due to training provided farmers practiced line sowing across the MCM sites. Farmers applied a full dose of DAP and MOP during planting as basal application. For urea, 37% of farmers did single top dressing and 63% did two top dressing in equal splits. Weeding, irrigation, and disease and pest management were performed by the farmers as per the recommendations. The average maize yield recorded in farmer's fields was 5.1 t/ha in 2021 and 5.7 t/ha in 2022. This is much higher than the national average of 2.5t/ha.

Table 1. Comparative assessment of MCM activities in 2021 and 2022.

Parameters	2021	2022
Districts	Banke and Bardiya	Banke, Bardiya and Kailali
Local Level (Palika)	5	19
Maize cooperatives	9	65
Maize growers	872	2260
Maize area	278	547.8
Crop yield	5.5	5.9
Total production (t)	1,390	3,232
Production value (US$)	290,039	890,708
Directly sales to feed mill (t)	30	521
Farm gate maize price (Rs/kg)	26.5 (20 to 29)	35 (33 to 37)
Household income (US$)	333	367

Note: 1 US $ = Rs. 127

Based on the potential of spring maize, a farmer's cooperative and a trader, built storage centers with the capacity of 3100t. The provincial Government provided 75% cost (NPR 2.6 million) for the first storage to the cooperative. A grain trader in Bardiya built a new storage facility with the capacity of 3,000t with a total cost of NPR 15 million that was fully funded by the proprietor.

Comparative assessment of MCM activities (maize grower farmers, yield, total production, maize grain price and household income etc.) is presented in Table 1. In 2022, the total commercial maize transaction in the MCM site was US$ 0.9 million, and average household income from maize farming was US$ 367 which is 10.2% higher than in 2021 (US$ 333).

3.3 Marketing and Access to Services

Maize farmers realized increased yield, higher output price, less price variation and higher income while participating in the MCM. In 2022 households received NPR 35/kg for maize which was Rs 3 to 4/kg more than previous season. Traders opined that they benefited from the gained knowledge about post-harvest management of maize grain, increased network with farmers cooperatives, and increased availability of grain with better quality. Feed mills remarked that locally produced maize grain was as per international standard (<14% moisture) and they were optimistic about potential to produce maize for feed in Nepal.

New forms of market coordination emerged as a result of the action research that also linked farmers with end markets. In 2021, a feed mill purchased 30t maize grain directly from two maize producing cooperatives which increased to 521t by three feed mills in 2022. By selling to feed mills, maize grower farmers received Rs. 2 to 3/kg higher price than from selling to the local traders while cooperatives were also able to earn Rs. 2 to 3/kg from maize trading. To encourage procurement from cooperatives, feed mills sent vehicles to collect maize grain if there was a guarantee of 5t maize availability in a location. Several bundled services such as reduced payment time of 15 days for cooperatives, setting up small scale weighing machines for smaller farmers (up to 50kg) and free of cost veterinary advisory services to maize cooperatives farmers for livestock and poultry care, were provided by feed mills. Local traders also launched new services such as collecting grains from farms, advance payments and provision of sacks for packaging. The results show that market coordination has the power to change often discriminatory market practices with a win-win situation for all actors. Previous studies (Brown & Ashman,1996; Bouwen & Taillieu, 2004; Warner, 2006) have also shown the benefits of multi-stakeholders' platform in trust building and technology dissemination.

4. Conclusions and Policy Recommendations

Based on the findings of this action research, it can be concluded that the Maize Commercial Model (MCM) has resulted in higher maize production, increased maize prices, improved maize quality, and enhanced networks and knowledge among

the actors and stakeholders, leading to better farmer-market linkages. New forms of market engagement by farmers' cooperatives and local traders have emerged, promoting transparency and mutual benefits from transactions. The MCM has the potential to increase the coverage of maize areas, indicating its potential for scaling to other maize production regions. Some of the main policy recommendations include:

- **Coordination**: The GON should utilize and expand the MCM platform to channel its maize development programs and funds to reach the target farmers. The ADS envisions commercial maize production in Nepal, and the MCM is a model that can be replicated to achieve this vision.
- **Seed Development**: Develop and launch new and competitive hybrids suitable for various agroecological regions of Nepal. Nepal needs early-maturity maize hybrids that can fit in the fallow period between wheat, rapeseed and potato and rice.
- **Extension and services**: Commercial maize production requires access to inputs and services. This entails mobilizing all service providers such as agro-dealers, machinery hiring centres, fertilizer distribution agencies, farm equipment and post-harvest technologies in the commercial zones, and facilitate the delivery of their services to farmers. There is a need to design suitable digital approaches to strengthen horizontal coordination and information exchange among maize farmers.
- **PHT and Drying**: Increase access to post-harvest processing equipment and technologies through custom hiring facilities, rural enterprises and cooperatives. Develop a maize storage directive which could facilitate to implementation of insurance while storing maize.
- **Markets**: Facilitate purchase agreements between farmer groups and feed mills. Develop maize market yards with large storage facilities to maintain grain quality. Develop maize quality grades and corresponding prices for transparency. Educate local traders on maize quality management and make available finance for access to capital for procuring maize.
- **Scaling Commercial Maize Production**: Follow a public-private partnership approach through multi-stakeholder platforms such as the Maize Commercial Networks to scale commercial maize production for meeting domestic demand.

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Authors Contribution

Dyutiman Choudhary: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Report initial draft/review/ final draft polishing;

Narayan Khanal: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Report initial draft/review/ final draft polishing

Naba Raj Pandit: Development or design of methodology; Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Report initial draft/review/ final draft polishing;

Dilli K.C: Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/ final draft polishing;

Krishna Prasad Timsina: Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/ final draft polishing;

Conflict of Interest

The authors declare no conflict of interest.

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Annex

Table A1. Issues, potential solution measures and stakeholders for strengthening maize value chain.

SN	Issues	Potential solution measures	Key stakeholders
1	Lack/limited seeds of farmers' preferred maize seed in the communities	Support local seed companies for developing suitable hybrids/ increased access to registered hybrid maize seed	Seed companies, importers, SEAN members, development partners
2	Land fragmentation-difficult in using machinery and irrigate crop fields	Land consolidation, implement land bank concept	Central, province and local government
3	Limited human resource (limited number of trained human resource at Local Level (Palika), poor service delivery from extension agencies	Use of ICT, development of district level maize commercial network	Local Level (Palika), AKC, PMAMP, development partners
4	Limited irrigation facility/dried water sources, no water release from irrigation project during the spring season	Mapping of irrigated area, strengthen linkage between maize grower cooperatives with linking with irrigation projects, establish additional irrigation facilities/ structures in PPP mode	AKC, Local Level (Palika), irrigation projects, development projects
5	Lack/Limited availability of chemical fertilizers	Promotion of community-based compost production and utilization schemes, use of digital soil map for rational distribution/ utilization of available chemical fertilizer, increase awareness on 4R principles to promote integrated soil fertility management	Cooperatives, Local Level (Palika), AKC, development projects

SN	Issues	Potential solution measures	Key stakeholders
6	Limited technical know-how on machinery calibration and use	Custom hiring center established by PMAMP, expertise of NARC and private actor (e.g. NAMEA, DKAM, agri-solution) could be utilised	PMAMP, NAMEA, AKC/ IALDO, development partners
7	Limited aggregation/ storage facility at farers level and lack of storage directive	Cooperative could utilize partial grants provisioned by national planning commission, PMAMP, AKC/IALDO, Local Level (Palika); feed mills could be motivated to build up/hire storage facility at maize production pockets	PMAMP, AKC/ IALDO, Local Level (Palika)
8	Limited knowledge and facilities of post-harvest and drying	Local innovations in drying (use of fan, plastic tunnel), testing and promotion of maize dryers	PMAMP, NARC, AKC, IALDO, Local Level (Palika)
9	Difficulty in accessing subsidized/ concessional loan to farmers due to collateral and complex and long documentation process	Possibility to access loan in 2 to 3% interest rate from province government; crop insurance available in free of cost to farmers; ICT could support on fast-track service delivery	MOLMAC/ MoALM, Bank, AKC/IALDO, Local Level (Palika), development partners
10	Crop damage by wild animals (wild boar, monkey)	Fencing of the maize production fields, siren, community mobilization	Local Level (Palika), National Park, development partners

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Government Framework for Agriculture Service Delivery at the Local Level in Nepal

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Abstract

This paper examines the policy, institutional and legal aspects of agriculture service delivery (ASD) of local government in federal Nepal. The aim of this study is to recommend an appropriate framework for improving ASD unit efficiency in delivering agricultural services to citizens. The paper seeks to answer the question of whether the ASD unit of municipalities facilitates a local government framework while discharging their agriculture services to the citizens. To achieve this, both primary and secondary data were used. Primary data were collected through structured interviews of agriculture service takers using stratified random sampling and were accompanied by participant observations, FGDs and KIIs. Secondary data were obtained from government documents. A convergent parallel mix method research design was adopted, which implied abductive reasoning with pragmatist research philosophy.

The study found that despite poor facilities and structures at the local level, the client experienced extended agricultural service delivery. Local governments are undergoing a transition in harmonizing institutional and legal policies, as evidenced by the differences in service delivery and expertise. The study identified three areas of demand from people with local authorities viz; infrastructure for basic services, quality extension from professional experts, and prioritization of the agriculture sector. Based on the findings, an enhanced ASD framework at the local level is recommended to meet the quality service needs of diversified clients. In this regard, enhanced municipal capacity is crucial.

Keywords: Agriculture service delivery, Clients, Local government framework, Municipality

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1. Introduction

Nepal has a long history of participatory development but a short experience with a fully devolved local government system (Subedi, 2014). The first attempt at decentralization in Nepal started in 1954 through the creation of a panchayat (Dhungel, 2011). Decentralization as the policy was started in the 3rd planning period (1965-70). Decentralization Act, 1982 and Decentralization Regulation (1984) were the first legal bases that institutionalized the decentralization process and practice in Nepal (Subedi, 2014)). In 1999, the Government of Nepal (GoN) enacted Local Self-Government Act, 1999 to empower the local bodies and consolidate the decentralization in policy but in practice, it continued to follow a centralized governance system so the spirit of LSGA was partially implemented (TAF, 2017; DRCN, 2019). After the second people's movement in 2006, the constitution of Nepal 2015 mandated three tiers of governance structures: Federal, provincial and local. Local government now has the authority to have their laws, and fiscal jurisdiction, devise plans and policies, prepare annual budgets and implement them. The devolution in Nepal provided a strong basis for grassroots democracy because it ensured the devolution of power, participatory planning processes, community and private sector involvement, accountability, and public service delivery (TAF, 2017, Dahal et al., 2020). The Constitution of Nepal (2015) embraced the federal structures through exclusive judicial and executive powers and authority. Local governments are responsible for provisions of service delivery including agriculture service delivery (ASD) to the farmers (Acharya, 2018; Chaudhary 2018; Dahal et al., 2020).

According to Kyle and Resnick (2018) low state capacity particularly human resources, budget and infrastructures is frequently blamed for poor service delivery in developing countries. Dahal et al. (2020) argued the number of issues of service provided by LGs: Poor implementation of policies and plans, low investment, weak governance, and lack of effective service delivery mechanism. Bishwakarma (2022) showed that service delivery extensively increased with moderate satisfaction after federalization with limited state capacity. Bhattarai, (2022) and Jaishi et al. (2022 a) argued for huge potentiality in agriculture service delivery through the community and suggested improving fundamental infrastructures to strengthen integrated linkage mechanisms among Agriculture Research Extension and Education (AREE) institutions. It is essential to portray the agriculture service delivery framework so that local representatives and authorities may consider it while they are implementing agriculture service delivery activities (Hagman et al 2002; Balckmore et al. 2015).

2. Research Gap and Rationale of the Study

Nepal is in the early stage of institutionalizing local government (Dhungel et al 2011; Kyle and Resnick, 2018; Adhikari, 2021, Shahi and Sthapit, 2022). As per the constitutional provisions, the agriculture organization underwent massive restructuring for the devolution of agriculture extension to the local level (Shrestha, 2022). As a result, the agriculture and livestock section was created over the entire Local government (LG) level responsible for agriculture service delivery. This restructuring and paradigm shift in ASD offered an opportunity for access to agriculture extension services at the local level on one hand and posed challenges to the quality and mechanism of services on other hand. The challenges further emerged from limited human resources and their capacity, reduced institutional mechanisms, low priority and lack of clarity of working modality. Very limited studies have explored ASD in a changed context to conceptualize it (TAF, 2017; Kyle and Resnick 2018; Dahal et al., 2020; Bishwakarma, 2022).

The paper focuses on the institutional arrangement under federal transformation that enable and empower local government to address ASD as per the spirit of the Constitution of Nepal and the Local Government Operation Act, 2017. This paper aims to answer the following specific research questions:

a. Does the current institutional, legal, and political policy framework enable local governments to fulfil their mandates in ASD?
b. What components should local government authorities consider strengthening ASD?
c. What are farmers' preferences for ASD features to meet their needs and aspiration, as per LGOA 2017?

3. Governance, government and local government: Meaning and concept

"Government" and "Governance" are often used interchangeably in dictionaries, referring to the exercise of authority in an organization, institution or state (UNDP, 1997) Government is the name given to the entity exercising that authority. Authority can be most simply defined as legitimate power (Legaspi, 2005). Scholars from various countries have proposed five major propositions of governance as a theory (keeping, 2017). Local government is the doorstep government to the local people and is responsible for undertaking and performing public activities, and possesses a defined area, a population, an organization and also the authority. The main roles of the government include the executive, judicial and legislative functions

(Kharel and Kharel, 2020). According to the service delivery approach, the local government provides an opportunity for political participation, helps to ensure efficient service delivery and expresses a tradition of opposition to an overly centralized government (Asaju, 2010). In this sense, a local government is a relatively autonomous, multi-purpose institution providing a range of services, with a tax-raising capacity, and is controlled through the election of representatives to oversee the work of full-time officials. From the sovereignty perspective, local governments exist as infra-sovereign geographic units found within sovereign nations or quasi-sovereign states.

Dahal et al. (2020) argued that a poor understanding of federalism and weak political commitment of local authorities to accountability and responsibility pose a challenge to effective governance. Kyle and Resnick (2020) identified a gap between farmers' expectations and the authorities' actions related to devolved ASD practices in municipalities. Paudyal (2021) argued that good governance has yet to yield development results and further explored that implementing governance challenges include weak delivery agency capacity, structured deficiencies, poor management systems, corruption, weak fiscal discipline and legal ambiguities.

4. Research Methodology

This research utilized convergent parallel mix methods research design to enable an in-depth exploration of how government framework can work for effective service delivery. Mix methods offer flexibility in designing and combining different types of tools to distil the most informative results for a comprehensive analysis of research problems. Cresswell (2009) believes that the use of mixed methods provides the opportunity for contextualization and generalization from the insight of qualitative and quantitative data, and ease to generalize the valid insights as demonstrated in the three parts of this study. Bhattarai (2015) argued that no single point of view could explain the nature of facts and accepted the multiple realities of agriculture service delivery options. Abductive reasoning was applied as a research approach. Both quantitative and qualitative data were collected simultaneously during the research process and analyzed independently and interpreted the finding together as synthesis as explained by Cresswell and Pablo-Clark (2011). The three parts of the study included:

a. A total of 21 local governments (ten municipalities and 11 rural municipalities) three each from seven provinces representing Hills and Terai were purposively selected.

b. Four events of focus group discussions (FGDs) and ten KIIs formed the qualitative results
c. Two events of participant observation of service delivery units of local government were conducted to witness the service delivery by the researcher.

Primary and secondary information was collected from August-November, 2022 and analysis was conducted simultaneously. Local Government Operation Act 2017, Agriculture Development Strategy (2015-2035) and Schedules 6, 7, 8 and 9 of the Constitution of Nepal, and associated policies and documents were reviewed to contextualize the agriculture service delivery framework.

5. Results and Discussion

5.1 Nepalese Agriculture Research, Extension and Education System & Service Delivery

Agriculture service delivery refers to the institutional arrangement established by local governments, whether public or private, to provide a range of goods & services, advice, training, education, policies and plans to their citizen (Dahal et al, 2020). The responsible local government is accountable for providing effective and efficient agriculture services to its citizens. In Nepal, the agriculture research, extension and education institutions are the three responsible stakeholders for the agriculture service delivery. The agriculture research function is still in the domain of the central government operated by the NARC. The NARC operates its research function through 12 disciplinary divisions, six cross-cutting divisions, seven directorates, 4 RARS, 13 ARS and 110 outreach sites (NARC, 2010; Gauchan and Paudel, 2012; Timsina et al., 2018; Bhattarai, 2022). The Provincial Government is responsible for the technical backstopping and resource management function which it operates through directorates, laboratories, farms and agriculture business promotion & training centres. The livestock sector has similar functions and functionaries. The functions and functionaries of local government, especially in the agriculture and allied sectors, are operated through the agriculture and livestock sections separately. Approximately 3500 graduates are working in private and public agencies throughout the country (Chaudhary and Pasa, 2015).

Agriculture education in Nepal began in 1957 at the School of Agriculture under the Ministry of Agriculture. It was upgraded in 1968 to the College of Agriculture and was further upgraded again to the Institute of Agriculture and Animal Science (IAAS) which was moved from Kathmandu to Rampur Chitwan. Now, agriculture education operates through 30 affiliated and constituents Agricultures Academic Institutions

(AAIs) scattered across all seven provinces under six universities throughout the country. The total intake capacity of these universities is over 2500 per year. Additionally, more than 13000 mid-level students peruse agriculture education under poly techniques and technical school of CTEVT with three categories: diploma level, TSLC and short training courses. The Ministry of Education also operates technical schools in different streams in grades 9-10 and 11-12 under one municipality on the technical school concept throughout the country. Currently, 450 schools are operating their programs with the support of municipalities, with an intake capacity of 11,250 high school students.

Shrestha (2022) argued that the public extension system is under scrutiny worldwide for its relatively poor performance, and Nepal is no exception. The coverage of extension services is rather poor in terms of geography, with an average of one-fourth of HHs receiving irregular, scattered and trickled extension services (Shrestha and Sanjel, 2018). The number and competencies of front-line extension workers are generally inadequate. This is proven by having a gazette officer in only 12 among 21 municipalities. Blanket approaches to service delivery, supply-driven rather than demand-driven, are mostly adopted and have more production-oriented goals. The agriculture and livestock sections of respective municipalities are responsible for the planning, execution, monitoring & evaluation of agriculture projects and programs, particularly the ASD after the devolution of agriculture to the local government (LGOA, 2017, section 3 & 6).

5.2 Legal framework, power and functions of three tiers of government

Nepal's has historically emphasized local participation and empowerment in its approach to local government rather than creating institutions for service delivery (World Bank, 2014). Over sixty years of sub-national governance reforms have resulted in an administrative framework of local bodies (LGs) consisting of 77 District Coordination Committees (DCCs), 6 metropolitan cities, 11 sub-metropolises city 276 municipalities and 460 rural municipalities. However, the legal framework itself is not advanced unless it is supported by an effective institutional mechanism for service decentralization (Subedi, 2014).

According to Paudyal (2021), Nepal exercises polycentric power where power is to be understood as the basis of interaction for socio-political norms, rules, procedures, accountability and authorities among governing institutions. Yalmanov (2021) considers that the main characteristics of political decisions are the presence of power and a specific purpose.

Since the last sub-national government reform in 2015, the LGs' names indicate that their primary role is 'service delivery', understood as carrying local governments ensuring a mix of inputs for the effective delivery of public services. Twenty-two devolved powers are mentioned as functions of local governments, mostly related to agriculture and allied sector transformation. However, it is also apparent that the authority of the governments is helpless without sufficient agro-technicians, basic infrastructures, facilities, funds and good plans and motivation.

Table 1: Types of power with three tiers of government in Nepal Constitution, 2015

SN	Types of power	Level of government		
		Federal	Provincial	Local
1	Executive powers[1]	35 (Schedule 5)[2]	21 (Schedule 6)	22 (Schedule 8)
2	Concurrent powers[3]	2 (Schedule 9)		
3	Residual powers[4]	Article 58		

According to the Constitution, the legislative power of the local level is vested in the Village Assembly and Municipal Assembly (Jaishi et al. 2022c). Local bodies in Nepal have become more empowered than ever (TAF, 2017; Kharel and Kharel, 2020), with 22 absolute powers, and 15 shared with the province and federal government, enabling them to plan their development activities according to the needs and demands of the people (Kharel and Kharel, 2020). The Nepalese agriculture extension system underwent a structural shift with the top-down to bottom-up plan. However administrative issues resulting from the political shift are yet to be tackled institutionally based on the principle of functional coordination, cooperation and collaboration (Jaishi, et al., 2022c). To make local government-led community-owned initiatives and mechanisms functional and sustainable, functional coordination and collaboration between the various levels of government are necessary.

From the KII, it is found that the local authorities have limited and inadequate knowledge of the powers, functions, duties and responsibilities given in the LGOA

1 Executive power is part of government which enforces the laws and has overall responsibilities for the governance of the state.
2 Schedule is an appendix to a formal document especially a list, table or inventory in the constitution.
3 Concurrent power is the power exercised by the federal or provincial government in the same area among the same group of citizens.
4 Residual power is only parliament having the authority to make the law on the subject

2017, and in the Schedules of Nepal's Constitution 2015. Most of them have very generic knowledge and idea in relation to roles responsibilities, functions and duties. The service delivery framework is to be seen from a system perspective and it requires policy to conform with the obligation of the state defined in the policy documents. Paudyal (2021) suggest that local authorities are to be entrusted with the responsibility of agriculture service delivery to the people. So it is suggested to ascertain the capacity of local authorities for all of those matters and issues described in the constitution and LGOA, 2017.

Participants of FGDs were blamed for their lower consultation and interaction during the annual planning process. Paudyal (2021) raises the concern that people's participation and interaction with the concerned stakeholders are essential to make it more accountable, owned, and inclusive governance. Public consultation should be made substantive rather than procedural because public consultation is the key feature of policy-making and implementation (OECD, 2001).

5.3 National and provincial policy framework for agriculture development

Nepal's experiences in the implementation of multiple policies related to agricultural reform suggest that patience and perseverance with uninterrupted commitment over a long period are essential (Uprety and Shivakoti, 2019; Khanal et al., 2020). Agriculture Perspective Plan (APP), Agriculture Development Strategy (ADS), and National Agriculture Policy 2061 (NAP, 2004) remain the main policy documents to date (Upreti and Shivakoti, 2021). All these policies are judged to be sound in design but have suffered greatly in implementation. In many cases, they lacked the supporting legislation and resources for implementation (Chaudhary, 2018). The APP (1995-2015), ADS (2015-2035), and The National Agriculture Policy (2004) is umbrella policy for Nepal, however, require updates and modification in context to the new constitution and LGOA (2017). Some fundamental policies of the agriculture sector requiring further refinement are Agri-business Promotion Policy (2006), Argo-diversity Policy (2007), Agriculture Mechanization Policy (2014), Land Use Policy (2015), and Land Policy 2018. The policies also consider the Gender Equity and Social Inclusion (GESI) mainstreaming strategies (NPC, 2018).

The provincial and local governments shall have mutual coordination for necessary arrangements considering the sharing of available resources through policy instruments as specified in Annex 7 & 9 of the Constitution of Nepal 2015. Further, local authorities and representatives also believed that national, provincial and national policy harmonization is a must with the new policy agenda for ASD reform

in the local context. However, the existing organizational structures, human resources and municipal capacity are neither adequate nor capable to accomplish the task. Some of the authorities of the province and federal department and ministry put their views that federal and provincial government should not involve in the project sanctions and implementation rather than should concentrate on guiding, facilitating, monitoring, and evaluating the agriculture projects and programs at the municipal level. Further structural support to the current mechanism with state capacities is, therefore, required.

Khanal et al. (2020) stated that legislative provisions have been made to achieve agriculture transformation through four kinds of policies in Nepal: Land tenure-distribution; agriculture service infrastructures; agriculture production and food quality standard. Article 231 (2) of the Constitution of Nepal, provisioned the inter-governmental relationship among three tiers, between federal-provincial and provincial-local. At the national level, there are a large number of general and sector-specific public policies have been formulated (55 policies, 5 strategies, 28 acts, 11 regulations, 39 directives, 3 guidelines, and 44 procedural documents) and their implementation. Accordingly, the provincial government can have endorsed the agriculture policies, rules, guidelines and norms in the execution of agriculture and allied sector in the entire or part of the province. So far, 90 provincial agriculture policies, rules and regulations formulated by the seven provincial governments are listed below.

Table 2: Number of agriculture policies documents endorsed by province level

Province	Koshi	Madhesh	Bagmati	Gandaki	Lumbini	Karnali	Sudur Paschim
Number	12	11	12	4	12	28	11

Source: Alliance for Agriculture and Food, 2022

Rijal and Upreti (2022) opined that multilevel policy-making and implementation have been the constitutional mandate of three levels of government. To respond to the specific needs, situation and context maintaining coherence and smooth implementation, customized policy-making capacity requires to be developed particularly at the province and local levels. Accordingly, several institutional changes in pluralistic agricultural extension approaches need to be adopted to improve the adequacy and efficiency of agriculture and extension policies (Uprety and Shivakoti, 2019). Emerging private sector including financial institutions,

development agencies, cooperatives, entrepreneurs, and agro-traders' engagement in the sector is imperative.

5.4 Agriculture service delivery framework at the municipality level

In generic terms, public service delivery is the main state responsibility (Paudyal, 2021). According to Shah (2005), the legitimacy of the government can be established when the state is capable of delivering the fundamental services by the free or paid government that can express its legal presence. According to Hagman et al. (2002), the meaning of any service system has to be understood within and across the three sub-systems of demand and supply. These three components are an integral part of the service delivery framework: Organizing and facilitating the demand, responding to the demand and supporting the response. All three components need to function effectively to create a service delivery system. The basis of the agriculture service delivery framework is the simple fact the service providers need to follow the supply and demand chain (Blackmore, et al., 2015; Bishwakarma, 2022).

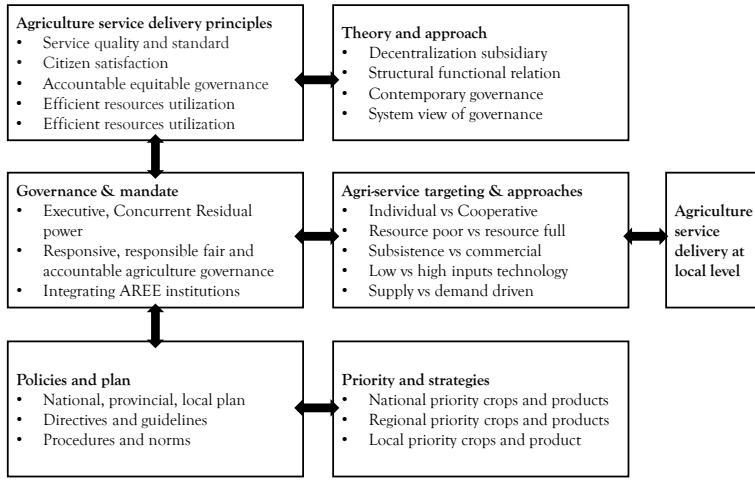

Figure 1: Agriculture service delivery (ASD) framework at local level

The study framework support to study of the subject under study, which will attempt to ensure an appropriate, complete, rigorous, fair, and unbiased analysis (Shahi and Sthapit, 2022). Each category of components is split into further sub categories to characterize service delivery. It supports the evaluation of the ASD guidelines, funds & budget, and human resources.

Following Figure (1) ASD framework is characterized by six components: Theory and principles, agriculture service delivery principles, governance & constitutional power & mandate, targeting & approaches, policies & plan, and priority &

strategies. The Framework captures most aspects of governance outcomes ie improving the ASD framework to be developed in their respective municipality. In any event, there can be little disagreement that one cannot get on measuring ASD quality without first defining and defending an appropriate framework that measures ASD. These aspects are also emphasized by ADS 2015-2035 and many of the policies of Nepal.

5.5 Basic facilities and infrastructure of the service delivery at the municipality

From participants' observation conducted in study municipalities, it is found that the Agriculture Development Section have limited physical facilities and infrastructures. Almost all municipalities are lacking lab equipment for basic laboratory services, well-spaced laboratory rooms, equipped training halls, ICT equipment, advisory kits, demonstration models, specimen, demonstration sites and library facilities. Most of the service delivery units were found congested office space, lacking advisory & counselling rooms, and audio-visual devices. Similar kinds of observations (Dahal et al., 2020; Bishwakarma, 2022). Kharel and Kharel (2020) argued that the local government have the problem of appropriate size budget, administrative capacity and visionary leadership.

The trend of budget allocation to local government is increasing trend (Kharel and Kharel, 2020) still the volume of budget in the agriculture sector is under priority. During the KII, local authorities also agreed with these facts and municipal publications verified the budget trends that, the economic sectorial budget to the other three sectors found lower. Comparative budget allocation data of sampled municipalities in four sectors, viz. economic, infrastructures, social, governance and administration showed that only 6.17 percent of the total budget has been dispersed in agriculture and the allied sector as compared to 44.53 percent in infrastructure, 29.72 percent in social services, 8.25 percent in governance and 11.13 percent in the administration sector. The average budget of studied municipalities for three years (FY 2019/20-22/23) was found 10.14 M/year. This proved that still the agriculture sector is an under-investment priority and this is the possible reason behind the lacking all the facilities and infrastructures of ASD in the municipality.

Farmers' perceptions towards ASD were analyzed from 12 statements using a Likert-type scale (structured interview, n=210). The mean score below and higher than 2.5 were split to map the positive and negative perceptions of the constructs. The mean score value showed that 6 statements indicated a positive response and 6 statements showed a negative response towards ASD.

Table 3: People's Perception of the Basic Infrastructures and Process of Agriculture Service Delivery in the Municipalities

SN	Construct	Mean score
1	The LG has addressed the farmer's needs and demands at the local level	2.03
2	The agriculture section in our municipality has a well-structured agriculture service delivery unit	2.00
3	Basic laboratories services of the agriculture section are satisfactory	1.00
4	The LG have well-equipped training services and resources	2.00
5	Basic laboratory services are regular and as per the demand of local people	1.24
6	The agriculture sectorial plan has been prepared and implemented as per the strategic plan	1.06

Source: Field Survey, 2022

The average mean score (1.55) of the constructs related to basic services provision, infrastructures and sectorial plan indicated a negative perception. Side by side (Mean score 3.35) people also felt the agriculture service has been increased after the devolution of agriculture to the municipalities. Particularly, the incentives, equipment support and farm subsidies have been motivating the farmers. Similar kinds of results were also found in the research conducted by (Bishwakarma, 2022).

Table 4: People's Perception of the Agriculture Service Delivery at the Municipalities

SN	Construct	Mean score
1	There is a positive relationship between local government service and the adoption of agricultural technology	3.01
2	The local government has programmes in place to promote and ensure agriculture development in the municipal area	3.06
3	The local government has tried for extended agriculture service delivery	3.36
4	The agriculture section fully engages in the agriculture program implementation in local government	3.20

SN	Construct	Mean score
5	There is a positive relationship between local government/ extension activities and the prosperity of farmers	4.01
6	Advisory services provided by LG units are satisfactory and effective	3.56

Source: Field Survey, 2022

5.6 People's Expectations and key features of Agriculture Service Delivery

The features of ASD were discussed in the FGDs session keeping in mind what people are expecting from their local authorities. Each of the respondents was asked to state features and indicators of successful ASD they are expecting in the coming five years to come. These features of agriculture service delivery are the components stated in the service delivery framework (Figure 1). The participants of FGDs raised their expectations and concerns in seven dimensions: Targeting the clients, service accessibility, consistency of service, service quality, service delivery approach, service delivery models and service providers (Table 5). The participants also suggested desired service delivery features. Most of the participants blamed scattered and trickled service, low quality per se, non-consistence, irregular, limited and blank approached services. Respondents also showed their concerns to have community-owned, farmers group-focused, sector-wide, transparent and demand-driven, integrated, output-based agriculture service in days to come.

Table 5: Previous and expected agriculture service delivery features at the local level

Indicators	Previous service delivery features	Expected service delivery features
Target identification	Blanket approach, biased, uneven	Performance-based, sector-wide
Accessibility of services	Limited & scattered, irregular	Supply meets demand
Consistency of service	Nonexistent among providers	Existent with alternatives
Service quality	Low and not monitored	High and transparent
Delivery approach	Top-down, supply-driven	Demand-driven, transparent

Indicators	Previous service delivery features	Expected service delivery features
Delivery model	Scattered and trickled services	Integrated and bundled services
Service providers	Service center, project, program	Community own, private sectors

Source: (FGD, 2022)

5.7 Improving agriculture governance: Participatory strategy setting

In the FGD, the pairwise ranking was deployed to rank the issues related to agriculture governance. It was found that poor practice of participatory strategy setting is the most important aspect of governance to be improved in the municipality. FGD was focused to answer what are the issues to be improved agriculture governance in the municipalities. Most of the respondents felt that the poor practice of participatory strategy setting, poor territorial listening with rural proofing practice, inadequate capacity of local authorities, mismatched targeting, and ideology-based issues are the five major issues of agriculture service delivery and agriculture governance.

Table 6: Issues of agriculture governance in municipalities by rank

Particular	PSS	TLRPP	MMT	IBI	ICLA	Total score	Issues by rank
PSS	–	1	1	1	1	4	1st
TLRPP	0	–	1	1	1	3	2nd
MMT	0	0	–	0	1	1	4th
ICLA	0	0	1	–	1	2	3rd
IBI	0	0	0	0	–	0	4th

PSS= Participatory strategy setting. TLRPP= Territorial listening & rural proofing practice, MMT= Mismatched targeting, ICLA=Inadequate capacity of local authorities, IBI=Ideology -based issues

Similar kinds of observations were also found by Bishwakarma (2022); Dahal (2020); Paudyal (2021). In the words of Chaudhary (2018), municipalities and their structural mechanism entail the devolution of power and the service delivery can only be effective and sustainable only when agriculture governance is improved and it is possible through truthful interaction among the people, authorities and representatives.

Governance, is one of the four components of ADS framework of the ADS (2015-35), without strengthening governance, ASD is impossible to improve (MoAD, 2014). ADS identified four elements of governance: Accountability, participation, forecasting ability and transparency.

The importance of integration at the institution at the local level is highlighted in the word of Shah (2006) because municipalities represent the multi-centre, multi-level and multi-order of the system. Strengthening horizontal and vertical linkage among the AREE institutions as strategic actions suggested in ADS to improve agriculture governance (MoAD, 2014). From the KII, it is found that the integration among the AREE institution is very poor even not in priority. Possible reasons behind this may be that staff are concentrated on their already heavy load of mandated annual activities.

One of the surprising facts found from a structured interview is that none of the studied municipalities has their strategic and action plan prepared with participatory farmers' consultation. However, in the public forum and interaction the authorities do talk much more than they give priority to the sectorial plan, allocating the budget accordingly and have identified the priority crops and products. In reality, neither the agriculture sectorial plan nor the long-term plan of the agriculture sector found endorsed by the municipality council. The local authorities also agreed that still they have to work on prioritization of crops, products, strategy and so on.

KII with local authorities confirmed that the reasons behind these scenarios are because of the agriculture section running its program with staff inadequacy and insufficient capacity. One example to support the fact is, 9 among 21 municipalities operating their agriculture program with under-gazetted level officials.

6. Conclusion and policy recommendations

In recent years, the responsibilities of service delivery have shifted strategically from the federal to the sub-national government, with the most localized public service providing agriculture and the allied sector. People expect a strengthened ASD based on the principles of self-government and subsidiary governance. Seven policy agendas were found for ASD reform in local government, including performance-based targeting, community-owned public-private providers, output-based support system, demand is driven, integrated and consistent agriculture service.

The paper concludes that ASD at the local level should consider three fundamental strategies: Strengthening agriculture governance, building basic service-providing infrastructures, and managing qualified & sufficient human resources. The most

important output of this paper is the ASD framework. The framework encompasses a broader scope of theory and principles, constitutional power, national and sub-national policy documents, varied service delivery approaches, national provincial and local priorities and targets, modalities, and strategic action priorities.

The ASD framework is based on the simple fact that ASD should follow the supply and demand chain between the service seekers and service providers. Three tiers of agencies must focus on three fundamental roles and responsibilities: Organizing and facilitating the demand, responding to the demand and supporting the demand. To achieve this, harmonized policy instruments and close integration among AREE stakeholders are essential. The following policies and strategies are strongly recommended to improve the agriculture service delivery: Authorities and representatives requires a clear understanding of the components and their dynamic relationships among various components, beneficiaries, service providers, implementer and stakeholders of the ASD framework. Sensitization and capacity-building interventions may be necessary.

- Governance is one of the four components of the ADS (2015-35) framework and is equally significant in local government. Policy instrument for promoting and strengthening agriculture governance is needed.
- To harness these governance efficiencies, vertical as well as a horizontal linkage among various AREE institutions (government, civil society, development partners, private sector) need to be strengthened. AREE integration must be harmonized with policy instruments.
- Agriculture sectors have to be prioritized equally with other sectors of investment with policy instruments, identifying the priority crops and products, and implanting a long-term agriculture plan. Sensitization of the authorities and representatives could help achieve this.
- Three tiers of AREE agencies of three tiers of government must coordinate their efforts to three subsystems of ASD: organizing, facilitating and responding to the supply and demand from a system perspective.

Authors Contribution

Mahesh Jaishi: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/ evidence collection; Report initial draft/review/ final draft polishing

Govinda Prasad Sharma: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/ evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources

Purna Bahadur Nepali: Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/ final draft polishing

Devendra Gauchan: Conceiving ideas; formulation of overarching research goals and aims; Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/ final draft polishing

Ram Krishna Shrestha: Conceiving ideas; formulation of overarching research goals and aims; Application of statistical, mathematical, computational, or other formal; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/ final draft polishing

Krishna Prasad Timsina: Conceiving ideas; formulation of overarching research goals and aims; Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/ final draft polishing

Huma Neupane: Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/ final draft polishing

Conflict of Interest

The authors declare no conflict of interest.

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Policy Gaps and Practices on Genetic Diversity, The Heterogenous and Localized Evolutionary Population as well as Native Landraces in Agriculture of Nepal

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Abstract

Formal breeding strategies and processes focus on developing uniform and non-evolutionary populations. However, many farmers continue to cultivate heterogenous cultivars and populations. To understand the recognition of genetic diversity (heterogenous cultivars and populations) in policies and the fields, a literature survey along with field survey, interaction and field action research were carried out in 15 districts of Nepal. Existing policies demand varieties to go through DUS (distinctness, uniformity, stability) testing and be registered in National Seed Board (NSB) for commercial production and sale. This means all native landraces and other broad genetic-based genotypes cannot be marketed without registration. A formal agriculture system accelerates the cultivation of a single genotype in a large area, leading to a lack of pollinators and the loss of many genetic diversities.

Legal agricultural systems have focused mainly on modernizing agriculture through exotic resources, giving less priority to making native landraces and technologies globally competitive. In contrast, the informal seed system deals with polymorphic and evolutionary populations. Therefore, policies should consider the strategies that favor and increase genetic diversity, evolutionary population, site-specific genotypes and staple food, self-seed production system, ecological services, insects/birds/ microorganism-friendly systems, etc. Native agricultural genetic resources (AGRs) with broad genetic bases are essential for food, nutrition, health, environment, and business security. Therefore, native landraces of all six components of agrobiodiversity (namely crops, forages, livestock, aquatic genetic resources, insects, and microorganisms) should receive priority in research, development, extension, and education. Additionally, a favorable policy for the commercialization of such native landraces and/ or their products without registration should be established. Alternatively, a registration system should be developed for broad genetic base genotypes and heterogenous and evolutionary populations.

Keywords: Commercialization, Genetic Diversity, Monogenotype, Registration, Site-Specific Variety, Uniform

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1. Introduction

The agricultural industry has long been focused on yield increment through controlled practices, such as the use of chemical fertilizers, pesticides, plastic tunnels and the promotion of monogenotype cultivation., etc. (MoAD, 2014). These practices have been necessary to feed growing human and livestock populations. Chemical and uniform genotype-based agriculture (also called modern agriculture) had proved to increase the yield significantly in major crops and livestock. Therefore, all policies developed so far in many countries have provisions for accelerating modern agriculture (MoAD, 2013, 2014; SQCC, 2013). Under modern agriculture, a few technologies and genotypes have been disseminated around the world. In Nepal, few uniform genotypes have been given due attention to increasing their areas of farming, resulting in the loss of localized and high genetic diversity from the fields (Chaudhary et al., 2006). The values of genetic diversity and heterogenous evolutionary populations are ignored by policy, agriculturists, researchers and consumers (Gauchan et al., 2004). The risk-bearing and buffering capacity of native landraces to the natural and farmers' practices are being replaced by modern varieties which in some cases, completely failed to produce (Gauchan, Joshi, Ghimire, et al., 2018; Thapa Magar et al., 2020)

In the past, circular agriculture (Figure 1) had been practised by farmers and was self-dependent and sustainable. In circular agriculture, genetic diversities at all five hierarchical levels (Figure 2) are valued and utilized. Later linear agriculture was given due focus targeting to increase very few traits e.g., grain in cereals through developing uniform and homogenotypic varieties. Farmers started using almost all inputs brought from outside the system and dependency on other agents therefore farming keeps going increasing. In Nepal, all released and registered varieties are uniform, monogenotype and non-evolutionary (Joshi et al., 2020). The policy has established a formal seed system where farmers are not eligible to produce seeds of different classes. Native and genetically diverse landraces could not be marketed, and incentives are not applicable to traditional practices and landraces, and so on (MoAD, 2013; Gauchan, Joshi, & Bhandari, 2018). In the contexts of climate change, unstable production practices and degradation of environmental and human health, many farmers, consumers, researchers and policymakers are seeking and practising alternatives such as natural farming, evolutionary population (EP) farming, organic agriculture, permaculture, ecological agriculture, integrating farming, cultivar mixture, sustainable agriculture, circular agriculture, etc. These practices consider genetic diversity at species, varietal and genotype levels for expecting sustainable and healthy production systems. EPs are successful in maize, barley, bread, durum wheat,

common bean, tomato and summer squash in Jordan, Ethiopia, Iran, and Italy (Ceccarelli, 2017). European Union's organic Guidelines, (EU, 2018) have also recognized the importance of evolutionary plant breeding. EP is being registered in Italy, the UK, Canada and Spain.

Policy provisions and field practices might differ on using and maintaining the genetic diversity of agrobiodiversity which includes six components (crops, forages, livestock, insects, microorganisms, and aquatic genetic resources) and four subcomponents (domesticated, semi-domesticated, wild relatives and wild edibles) of agrobiodiversity (MoAD, 2016). This paper, therefore, highlights the provisions and gaps in sectoral policies and field practices along with policy options in line with genetic diversity, heterogenous and localized evolutionary populations and native landraces.

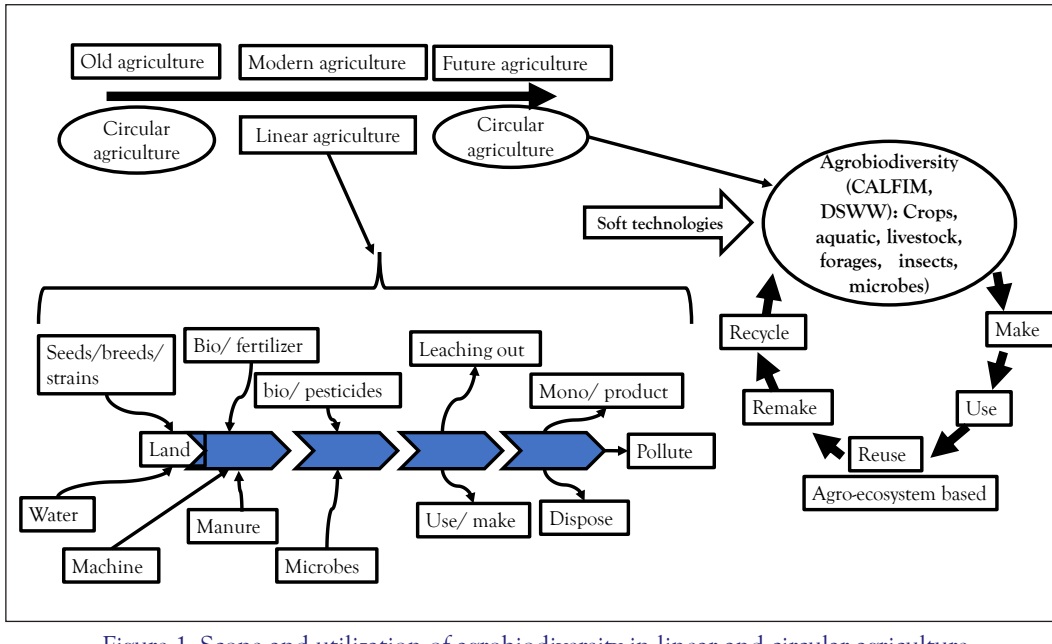

Figure 1. Scope and utilization of agrobiodiversity in linear and circular agriculture

DSWW, domesticated, semi-domesticated, wild relative, wild edible

2. Methodologies

National Genebank has been carrying out on-farm research on native AGRs for the last two decades in Nepal. Publications of six projects namely 1. Evolutionary plant breeding project (Use of Genetic Diversity and Evolutionary Plant Breeding for Enhanced Farmer Resilience to Climate Change, Sustainable Crop Productivity and Nutrition under Rainfed Conditions), 2. In-situ global project (Strengthening the

scientific basis of *in situ* conservation of agrobiodiversity on the farm in Nepal), 3. CUAPGR project (conservation and utilization of agricultural plant genetic resources), 4. Rebuilding local seed system project (Rebuilding local seed system: Collection, conservation and repatriation of native crop seeds in earthquake affected areas in Nepal), 5. Local crop project (Integrating traditional crop genetic diversity into technology: Using a biodiversity portfolio approach to buffer against unpredictable environmental change in the Nepal Himalayas), 6. IMPGR project (Morphological and Molecular Characterization of Selected Rice and Buckwheat Collections to Promote Use), which were implemented by the National Genebank, were reviewed along with other relevant literature. Twelve policy documents (Table 1) related to agriculture, nutrition, environment and climate change were analyzed. Focus group discussions and key informant surveys were carried out in more than 15 districts and 50 key persons respectively to document the localized important cultivars and products (Table 2) and field practices (Table 3). Issues and concerns along with practices in the fields were collected from workshops, travelling seminars, and field visits. Interactions with farmers, policymakers and breeders were the additional approaches to collecting the information along with the authors' field works and experiences.

3. Finindings and Discussion

3.1 Genetic diversity and heterogenous agricultural genetic resources

Genetic diversity refers to different inherited traits within a species, cultivar and individual. Landraces and populations having different types, colors, sizes, shapes, heights, structures, textures, scents and forms are called heterogenous. Such populations have different traits over generations and possess the potential to adjust the changes in climatic and growing conditions. Genetic diversity is crucial for genetic improvement, adapting to changing environments, giving birth to new genotypes, etc. The importance of agrobiodiversity in ecologically resilient agriculture is understood by the relationship, "*Genetic diversity at inter/intra population (varieties, breeds, genotypes)* $\propto$ *Resilient (climate changes, stresses) population (adaptability)*".

In modern agriculture, genetic diversity is mostly talked about and utilized in breeding stations. Such diversity is very crucial in the field as there is huge diversity in different aspects e.g., soil type, climate, biotic and abiotic stresses, etc. (Mcguire & Sperling, 2016; Sthapit et al., 2019; Thapa Magar et al., 2020). Diversity at all five hierarchical levels and types (Figure 2) should be increased as much as possible to make the agricultural business profitable, sustainable and self-dependent.

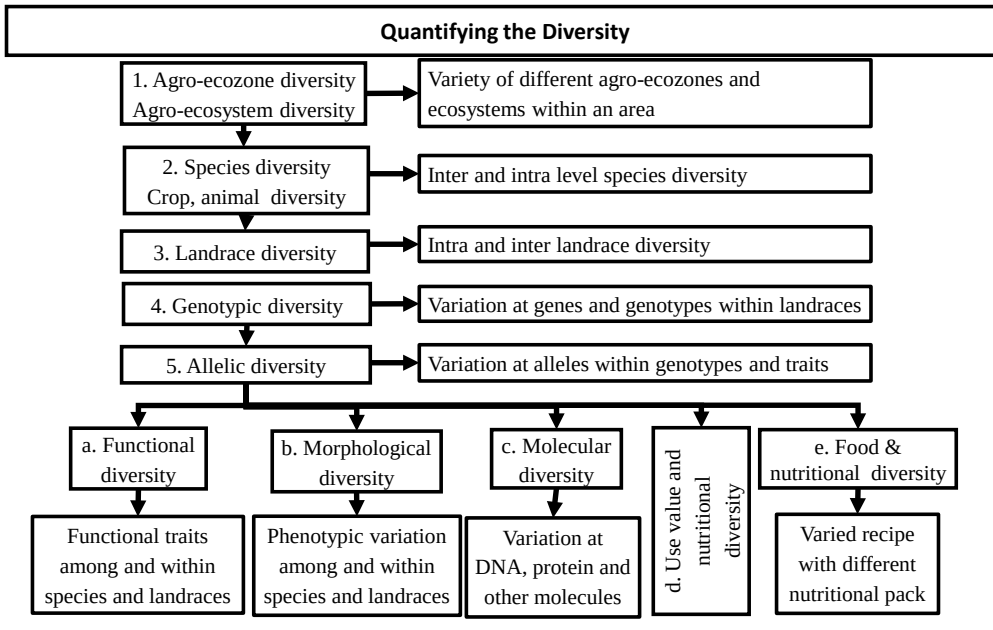

Figure 2. Hierarchical levels (number levels) and types (horizontal box levelled by letters) of agrobiodiversity

3.2 Policy provisions and gaps

Provisions and gaps in policies related to agriculture, agrobiodiversity, environment, nutrition and climate changes are given in Table 1. The majority of the policies have considered the importance of native agricultural genetic resources, but they are poorly implemented. Informal seed systems, informal agricultural practices and neglected and underutilized AGRs have been poorly recognized in these policies. Due to the favourable policies for exotic and uniform mono genotypes (of crops, forages, livestock, fish, bees, mushroom, etc.), more than 90% of total germplasm in the formal system are exotic. Major gaps in these policies are restrictions on formally handling and promoting genetic diversity, cultivar mixture, heterogenous and localized evolutionary populations, native landraces and wild relatives and edible species (MoAD, 2013). The guiding philosophy in the policy formulation was that economic benefits can only be derived from the promotion of modern uniform varieties (Gauchan et al., 2004). Moreover, despite some positive policy provisions vis-à-vis interlinkages among agrobiodiversity, nutrition and climate change, many provisions have hardly been translated into action. The majority of the farmers are unaware of policy provisions (Khanal et al., 2022). Lacking a policy framework on farmers' rights also limits the promotion of conservation and use of heterogenous landraces (Gauchan, Joshi, Ghimire, et al., 2018).

Table 1. Provisions and gaps in selected policies related to agriculture, agrobiodiversity, nutrition and climate changes

SN	Policy	Provisions	Gaps
1	Agriculture Development Strategy 2015	• Promote and use local genetic resources • Developing regulation for genetically modified organisms (GMOs) • Promoting community-based seed production • Research on climate-resilient varieties • Reorientation of investment in public research towards biosafety, mitigating effect of climate change, environment and biodiversity conservation	• Complementary interlinkages among native agrobiodiversity, agriculture, nutrition, health and climate change • Promotion of localized genetic diversity for food, nutrition, health, business and environment
2	Agrobiodiversity Policy 2007 (Amendment 2014)	• Manage, conserve and sustainable use of agrobiodiversity and traditional knowledge • Protection of farmers and traditional knowledge • Arrangements for equitable sharing of benefits • Incentives for the conservation of native AGRs • Ex-situ, on-farm and in-situ conservation strategies	• Conservation and marketing of native AGRs through uses • Evolutionary system of agrobiodiversity conservation • Role of agrobiodiversity for nutrition and health security, and climate changes
3	Environment Protection Act 2019	• Periodic study on adverse impacts of climate change on eco-system and biodiversity • Implementation of adaptation	• Agrobiodiversity for balanced agro-ecosystems and enhancing ecological services
4	ITPGRFA-MLS Implementation Strategy and Action Plan	• Documentation system of agricultural plant genetic resources (APGRs) at local, regional and national levels	• Utilizing the native agrobiodiversity for nutrition and climate change mitigation and

SN	Policy	Provisions	Gaps
	(IMISAP) 2017	• All relevant national policies act, and regulations are to be integrated to implement the IMISAP. • One-window system for export of PGR and multiple-window system for import	adaptation • Focus only on crop sectors not integrated farming
5	National Agriculture Policy 2004	• Provision of genebank and biodiversity park • Promotion of in-situ conservation	• Roles of native AGRs on climate change and nutrition and health improvement • Agro-park, agro-garden, agro gene sanctuary for the conservation • Marketing and promotion of native AGRs
6	National Climate Change Policy 2019	• Agriculture and food security-related issues • Crop diversification, protection of agricultural biodiversity and organic farming	• Linkage with nutrition, resilient system using niche-specific agrobiodiversity
7	National Environment Policy 2019	• Mainstreaming environment issues in development plans and policies • Pollution control, waste management, nature/ environment-friendly sustainable development	• Good practices of agrobiodiversity conservation and utilization, circular agriculture • The role of agrobiodiversity in carbon sequestration, climate change mitigation, and developing an evolutionary production system

SN	Policy	Provisions	Gaps
8	National Seed Policy 1999	• Conservation of local crop varieties and agrobiodiversity • Protecting the rights of the local community • Regulation of GMOs	• Good practices for dynamic conservation of native AGRs • IPR mechanisms for AGRs and associated knowledge
9	National Seed Vision 2013-2025	• Use of local landraces and their wild relatives for developing climate-resilient and nutrient-rich varieties • Local seed security and promote community-level conservation works • Promote the exchange of germplasm among national, international genebanks and community seed banks	• A specific mechanism for the use of native agrobiodiversity for food, nutrition, health, business and environment • Informal and non-formal seed system • Seed production by farmers
10	Seed Act 1988 (Amendment 2008)	• Promotion and regulation of quality seeds and exotic seeds • Ownership rights to local varieties	• Values of agrobiodiversity, in the context of climate change and nutrition • Marketing of seeds not linked with ownership rights • Informal seed system • Native crop landraces in the formal seed business • Genetic variation within cultivars
11	Zero Hunger Challenge National Action Plan 2016-25	• Five pillars-based actions for creating hunger and malnutrition free society • Actions for promotion of climate-smart crops	• Complementary interlinkage among agrobiodiversity, nutrition and climate change • Site-specific stable food items and genetic resources

Although modern varieties produce relatively high yields, the risk of harvest loss is comparatively more than the landraces. Landraces are polymorphic and keep evolving as directed by nature, therefore, they are resilient to climate change and other factors. Even with minimum care and inputs, landraces produce a good amount of grains and biomass. This is mainly because of a higher degree of genetic diversity in landraces as compared to modern varieties (Joshi et al., 2018). Because of these merits, registration of landraces is now started in some countries e.g. Bolivia, Laos, Nepal, Zimbabwe, India, Mexico, China, Peru, Ethiopia, Turkey, and Spain (De Jonge et al., 2021). The impact due to gaps in policies along with mitigation is given in Figure 3. The major impact is the loss of genetic diversity and an unstable production system mainly due to the wide expansion of monoculture. Such monoculture also contributes to creating an unhealthy environment, unhealthy people and an imbalanced agroecosystem. Site-specific genetic diversity of all six components of agrobiodiversity should be maximally utilized for food, health, nutrition and environment security and to cope with climate changes.

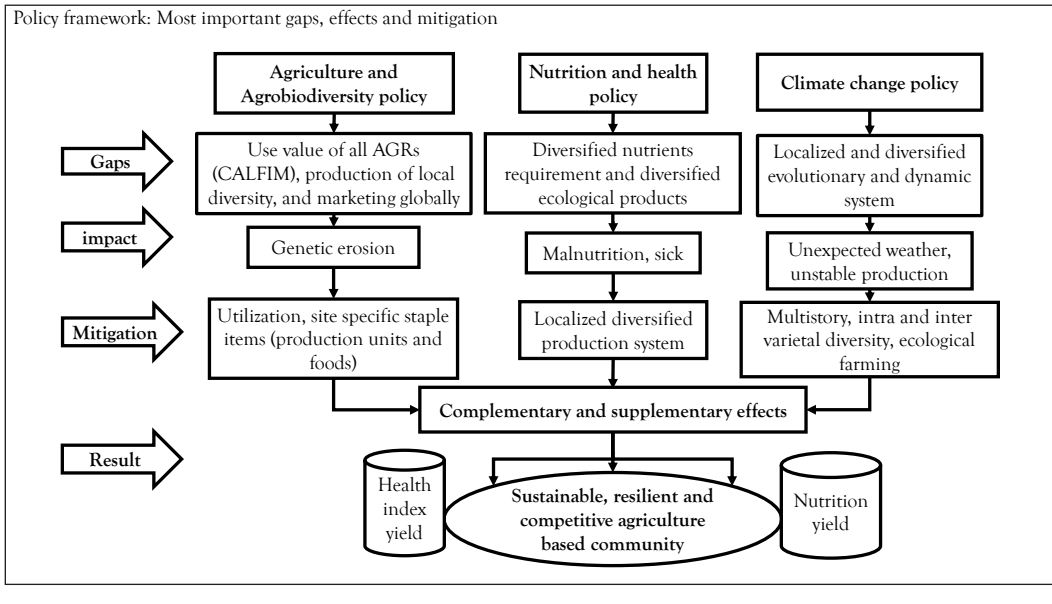

Figure 3. Most important gaps, effects and mitigation in three policy sectors

AGRs: agricultural genetic resources; CALFIM: crop, aquatic, livestock, forage, insect and microorganism *Source: (NABS & LI-BIRD, 2021)*

3.3 Localized evolutionary population and native landraces

Nepal has three agroecozones and 15 agroecosystems. Due to varied climates and landforms, a large number of unique and localized agricultural genetic resources are being evolved, maintained and used by farmers. Farmers keep handling such landraces

by imposing less selection pressure which means giving nature to decide for survival and production. This process is also the same for livestock, forage, agro-insects, agro-microbes, and aquatic genetic resources. Such populations have high genetic variation within and between (Joshi et al., 2018), therefore, keep evolving as per the direction of natural factors. Yield advantages and disease tolerances of the genetically diverse population have been well established in many crops (Mundt, 2002; Rahmanian et al., 2014). Some localized and famous landraces are listed in Table 1. These are very potential for agri-business and getting geographical indication right. But due to the wide scaling of single and uniform varieties, such localized evolutionary populations and landraces are at risk of extinction. In addition, policy support is almost negligible for these resources. If there is a provision of providing a geographical indication tag to such products, landraces or heterogenous populations may not be necessary to register.

Table 2. Major localized and famous agricultural landraces and products

SN	Landrace/ product	Location	Unique traits
1	Ailaa (whiskey)	Kathmandu	Very strong, high market value
2	Akabare Khursaani	Ilam	Very hot but delicious with medicinal properties
3	Apple	Marpha, Dolpa and Jumla	Very delicious, juicy, high demand and market value
4	Bean	Jumla, Mustang, Humla, Rasuwa and Lukla	Very delicious, nutritious, high demand
5	Bhaktapur ko dahi (yogurt)	Bhaktapur	Very good taste, high market demand and value
6	Black gram	Ramechhap	Easy to cook, tasty
7	Cheese	Illam; Langtang, Jiri	Good taste and color
8	Digaam gud (sugarcane jaggery)	Gulmi and Tokha	Sweet, good smell, tasty
9	Hamsaraaj dhaan (rice)	Sudhur Paxchim province	Very soft, aromatic and tasty
10	Jumli maarshi (rice)	Jumla	Adapted to cold areas, tasty, nutritious, *aandilo*

SN	Landrace/ product	Location	Unique traits
11	Kaalo musuro (lentil)	Rasuwa	Delicious
12	Khoku ko suntalaa (mandarin)	Khoku, Dhankuta	Delicious
13	Kulekhaani ko asalaa (fish)	Kulekhaani	Delicious, high market value
14	Maadaale Kaakro	Pelakot, Aaruchaur, Rupakot, Syangja	Good for pickle, disease and insect tolerant
15	Mankamanaa ko suntalaa (mandarin)	Manakamana, Gorkha and Dhankuta	Juicy, tasty
16	Mudeko aalu, Bajhanko aalu, Hemjako aalu (potato)	Mude, Dolakha; Langtang; Hemja, Kaski and Bajhang	Soft, tasty, delicious
17	Naaphal (wheat)	Humla	Winter wheat, a high protein content
18	Oil (mustard)	Khokana	Tasty, good smell
19	Pharping ko naaspati (pear)	Pharping, Kathmandu	Delicious and juicy
20	Pyuthane mulaa (radish)	Pyuthan	Tasty, high-demand, shiny
21	Rumjataar ko suntalaa	Rumjataar, Okhaldunga	Sweet, juicy
22	Sugarcane	Dhunibensi	Soft, juicy
23	Timur	Salyan; Pyuthan	Pungency, good taste, medicinal value, high oil content
24	Trishuli ko maachhaa (fish)	Trishuli	Delicious
25	Tusaa (bamboo shoot)	Pokhara	Tasty and nutritious

3.3.1 Practices in the field

Formal and informal practices are found in the field. Informal practices maintain, promote and use genetic diversity and formal practices promote monogenotype on a wider scale (Table 3). Traditional agriculture values the genetic diversity in farmers' fields and houses, but modern agriculture pushed such genetic diversity either in the room as Genebank or replaced by distributing modern varieties. Almost all breeding methods in modern agriculture target to develop of uniform, and monogenotype with high economic yield in high input conditions. Informal practices are more nature-positive and old age which keeps high diversity at all five hierarchical levels and five types of diversity (Figure 2). These informal practices maintain broad genetic base populations, whose products can also be marketed well (Ceccarelli, 2017). The formal system has focused on very few crops and forage species. In addition, many seed suppliers have emerged for promoting the formal seed system (Sthapit et al., 2019).

Table 3. Current formal and informal practices in agricultural fields

SN	Practice	Features	Type	Policy dimension
1	Agro-eco zone specific genotype and technology	Consider only three agro-ecozones and few genotypes and technologies in large areas	Formal	Favored by policy
2	Chemical (fertilizer and pesticides)-based farming	The immediate impact on cultivars is costly and outside dependency	Formal	Favored by policy
3	Crop mixture	Different species growing together, balance agro-farming system, maintain species richness	Informal	Less favored by public sector agri-policies
4	Cultivar mixture	Production is secured, diversified and nutrition-dense production, diversity is conserved, and the population keeps evolving	Informal	Less favored by public sector agri-policies
5	Formal breeding and seed system	Develop monogenotype using diversity, recommend single variety to large scale, legal to market seeds and restricted seed production	Formal	Policy-based practice

SN	Practice	Features	Type	Policy dimension
6	Haatbazar (open-air market)	Direct connection between primary producers and consumers, even small amount of products can be sold	Informal	This is not policy guided
7	Household-specific landraces and technologies	Private genotypes and knowledge inherited within a family lineage, creation and maintenance of diversity by an individual family	Informal	There is a policy gap
8	Integrated farming	Circular agriculture, the production of all six components of agrobiodiversity (crop, forage, livestock, aquatic, insect, microbe), plays an important role in agrobiodiversity	Formal and informal	Limited policy guidelines and provisions
9	Mechanized farming	Imported machines for commercial and monoculture	Formal	Policy supported
10	Monoculture	Single genotypes over a large area, replace much genetic diversity in the field	Formal	Policy supported
11	Multi traits focused farming	Growing many different types of germplasm for the production of diversified traits (grain, vegetables, forage, etc.)	Informal	The policy does recognize at a limited scale
12	Natural selection and informal seed system	Does not have a separate mechanism for seeds and genetic diversity is handled by nature and utilized by farmers	Informal	The policy does not support
13	Open agriculture	Farming in a normal and open field favors natural factors to play	Informal	A very limited provision in the policy

SN	Practice	Features	Type	Policy dimension
14	Own seeds source	Maintain all planting materials over the years by farmers themselves, inherit the localized diversity	Informal	Less favored by public sector agri-policies
15	Protected agriculture	Farming in controlled condition, with natural factors controlled, need more care and inputs	Formal	Supported by policy
16	Seed business	Seeds for farmers are channelized through profitable businesses, and many different steps involved	Formal and informal	Supported by policy
17	Seed exchange	Farmers exchange seeds freely as gifts, barter system, or through a sale	Informal	Lack of promotional and supportive actions
18	Seeds from the agro vet and registered organization	In linear agriculture, farmers need to purchase seeds each season, creating a mechanism to involve seed merchants to make a profit from farmers	Formal	Policy favors this practice
19	Single trait-focused farming	Only focus on grain yield, ignore all agro-ecological factors to maximize the grain yield	Formal	Policy favors this practice
20	Traditional tools-based farming	Labour-intensive, agro-ecosystems undisturbed	Informal	Less favored by public sector agri-policies

3.3.2 Farmers' Expectations and Rights

Farmers are producing a diverse set of agricultural products in varying amounts. Two major expectations of farmers are market and irrigation assurance. Farmers can manage all types of agricultural inputs except irrigation and market. If there are market guarantees even for a single fruit or seed, farmers can produce a lot which ultimately helps to secure food and nutrition. To promote the marketing of local

products, farmer's households should be considered as a shop and collection centers should be established in many locations. Year-round irrigation facilities on the other hand can boost the farmer's willingness to produce more and more diversified products. They want to ensure that the inputs are timely and available at affordable prices. A system or practice of self-dependent agri-business is always in demand.

Major farmers' practices and their rights are given in Figure 4. Many formal processes have transferred farmers' rights to other institutes and stakeholders. For example, many strategies have focused on increasing the seed replacement rate (SRR) which ultimately restricts on saving of seeds by farmers themselves. This SRR system makes farmers compulsion to buy seeds from the markets. Similarly, among the different seed classes in the formal seed system, farmers are not eligible to produce the seeds of many of these classes. But farmers have maintained landraces from generation to generation and have rich knowledge of seed production and maintenance. And such landraces should be considered private goods. We can observe specific lineages of landraces of many crops being maintained over many years and some farmers have also very unique landraces. Farmers should have, therefore, the right to handle such landraces as private goods.

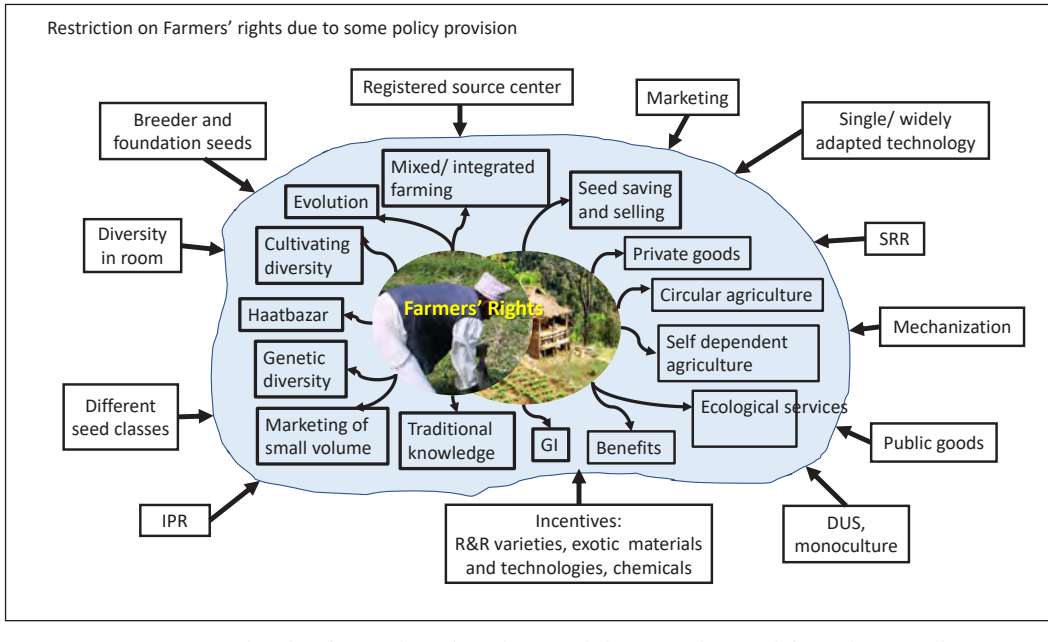

Figure 4. Farmers' rights (central part) endangered due to policy and formal system (outer rectangular boxes) of agriculture

GI, geographical indication; SRR, seed replacement rate; IPR, intellectual property right; DUS, distinctness, uniformity, stability; R&R, released and registered

3.3.3 Policy options for genetic diversity, the heterogenous and localized evolutionary population and native landraces

- Develop the standard protocols and practices for promoting polymorphic and heterogenous cultivars (e.g., landraces, cultivar mixtures and evolutionary populations) through a formal system. Identification keys of any type of all cultivars are necessary and therefore, it is important to identify such keys for handling and maintaining such cultivars. A system should be developed for the release or registration of such broad genetic base populations, native landraces and traditional knowledge. Regulation needs to revise for favouring variations within cultivars considering not only mean value but also minimum and maximum values, and standard deviation of important traits. The provision of an equal (or different) proportion of each variant in a population could be the simple method for maintaining, cultivating and distributing of population. Alternatively in the case of cultivar mixture and EP, either components, mixture, or population as such should be able to register by farmers and researchers. Another option is to create a provision of marketing products of heterogenous cultivars and populations without registration of seeds.
- Seed-related regulatory frameworks should have a provision of rewarding cultivar mixture, evolutionary population and contribution of an individual farmer or researcher in maintaining the landraces. The policy should support farmers to produce seeds themselves for next season's planting and marketing of seeds. Native and local landraces should be treated as private goods, which can be promoted and marketed not only the seeds but also their products.
- Develop and implement mechanisms and strategies to control the drivers of agrobiodiversity. The working principles of red zoning, red listing and germplasm rescue should be mainstreamed. Before the implementation of any project, the policy should have a provision for carrying out the agrobiodiversity impact assessment (AIA). Important native AGRs should be collected or relocated from such project sites as well as from farming areas where modern varieties are planned to be disseminated widely. For the overall conservation of AGRs in dynamic mode, there should be provision for establishing agro gene sanctuary (similar to a national park), agrobio garden (similar to a botanical garden), agrobio park (similar to a city park), agro-zoo (similar to the zoo).
- Recognize the roles of agrobiodiversity in food policy, nutrition and health policy, climate change and environment policy and intellectual property rights. There should be a conservation and utilization-focused agrobiodiversity policy;

a multiple commodities-based food policy; a multi traits-based climate change policy and a nature-positive product-based nutrition policy.

4. Conclusion

The management systems for agriculture and agrobiodiversity in Nepal exhibit significant differences between policy provisions and farmers' practices. The major policy gaps include lack of recognition of genetic diversity, both intra and inter-cultivar diversity, marketing of native agricultural genetic resources, site-specific landrace and food items development, complementary interlinkage among agrobiodiversity, nutrition, food and climate change, etc. Additionally, policies have not prioritized the promotion of localized evolutionary populations, though, evolutionary and heterogenous populations are crucial for ecologically resilient agriculture systems, as agrobiodiversity plays a multi-functional role in food, nutrition, health, business and environmental security. Despite this, the majority of farmers still follow the informal seed system and to meet their diverse needs and maintain agroecosystems, farmers adopt practices that promote and demand more diversity at species and genetic levels. Farmers have partly controlled both abiotic and biotic stresses through increased genetic diversity. Therefore, policies should include the provisions to promote increased genetic diversity and marketing of native AGRs and their products.

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Authors Contribution

Bal Krishna Joshi: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Conducting a research and investigation process, data/evidence collection; Report initial draft and final revision

Subodh Khanal: Conducting a research and investigation process, data/evidence collection; Provision of study materials, materials; Report review

Ram Krishna Shrestha: Formulation of overarching research goals and aims; Development or design of methodology; Conducting a research and

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Conflict of Interest

The authors declared no conflict of interest.

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Dr. Bal Krishna Joshi received PhD in Agricultural Science from Japan. Dr. Joshi has been working on agrobiodiversity conservation and utilization since last 25 years and have developed and identified 101 good practices and approaches. Dr. Joshi has significant scientific contribution on in the field of Plant Genetics and Breeding, Agrobiodiversity and related policy, Biotechnology, Statistics, Conservation Science, Geographical information system, and Climate smart plant breeding. Dr. Joshi has served as an Editor-in-Chief in Journal of Nepal Agricultural Research Council and Nepal Agriculture Research Journal. He has received 12 different awards including National Technology Award, and Science and Technology Youth Award. His major thrust is to make native agricultural genetic resources competent globally.

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Agribusiness and Supply Chain Development Policies in Nepal: A Review from Temporal Dynamics

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Abstract

A critical review of agriculture policies during different plan periods, aligned with political changes, has been conducted out to understand the shift in priorities, technology transfer ,support products, and private sector engagement. Firstly, in the 1950s, the policies were influenced by the first five-year plan and focused on the import and dissemination of technology. During the three decades of the Panchayat era, there was an emphasis on state mechanisms for technology transfer, agribusiness, and research, with limited incentives for the private sector. After 1990, agricultural policy products followed a path of liberalization and focused on defining the state's role and promoting pluralism. This period witnessed the establishment of a wide range of private and cooperative-led agribusinesses, although their growth was hindered by political conflict. Subsequently, policies began to incorporate priorities such as nutrition security, comparative advantage, competitiveness, climate change adaptation, agrobiodiversity conservation, and sustainability. However, with the federalization of the state and establishment of a three-tier governance system in 2015, agriculture policies, priorities and strategies a became fragmented, diversified, and localized, and lack harmonization. This review demonstrates that agriculture policies were largely influenced by domestic political developments and structural changes at the international level. Nonetheless, a consistent focus on increasing production and productivity, as well as achieving food security and self-sufficiency, can be observed.. Throughout all policy periods, supply chain development, a crucial component of agribusiness, received limited prioritization, which remains a major impediment to agricultural transformation. Despite seven decades of policy evolution, Nepal has been unable to create an enabling policy environment to attract significant private and cooperative sector investments that could drive substantial growth in agribusiness. This situation calls for further research in the field of policy formulation capacity among the three tiers of government to foster agribusiness and promote supply chain development for agricultural transformation.

Keywords: Agriculture, Policy, Food Security, Productivity, Commercialization, Development

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1. Introduction

The agricultural sector engages around 50.1 % of the total population (CBS, 2023), and contributes approximately one-quarter (23.9%) of the nation's GDP (MoF, 2022). The total cultivated area is 3,0,91,000 ha out of which 48.93 % (15,12432 ha) is irrigated (MoALD, 2022). Among the total agricultural production, the contribution of agriculture subsectors is as following for the Fiscal Year 2021/22: Food Crops 44.3 %, Vegetables 17.1%, Cash Crops 15.3%, Industrial Crops 13.2%, Fruit Crops 5.8 %, and others 4.3% (MoALD, 2022). In 2018, Nepal imported 1.2 million tons of cereals , which indicates that domestic food production is not sufficient to feed its population (FAO, 2019). Similarly, during FY 2020/21, selected agricultural commodities worth NRs 7,901.04 million were exported from Nepal (DoC, 2022). However, the productivity and competitiveness of the sector are low, the adoption of improved technology is limited, and a significant cultivated area is dedicated to cereals. Since the beginning of the APP (1995/96), the growth of agricultural GDP has been slow (about 3%) and highly variable over the years (MoALD, 2015) indicating a low level of agribusiness development. The average annual Agriculture Gross Domestic Product (AGDP) growth rate for the last eleven years (2011/12 to 2021/22) was only 2.99 %, which is far lower than the Medium Term (10 years) Target (i.e. 5%) of ADS (MoALD, 2022). Several factors such as the decade-long conflict (1996-2006), natural disasters, CoVID-19, poor governance, weak linkages between research, extension, and education agencies; and poor extension service etc. have affected agricultural growth. In addition, some of the gaps and constraints limiting agricultural growth include inappropriate approaches in designing agricultural policies, plans, and programs; inadequate, and in some cases, contradictory legislative provisions; low institutional capacity; and weak coordination between key stakeholders in formulating and implementing the sectoral policies (Khanal et al, 2020).

As about 18.7 % of the population is still living below the absolute poverty line, the agriculture sector is crucial to increase income, alleviating poverty and uplifting the living standard of the people (MoF, 2022).

Agricultural growth is the most powerful mechanism for poverty reduction when an economy is at a low development stage. Realizing this fact, the Ministry of Agriculture and Livestock Development (MOALD) envisaged accelerated growth of agriculture through improved governance, increased productivity, profitable commercialization, and enhanced competitiveness as guided by ADS (MoALD, 2015). The transformation towards a more commercialized agriculture requires a set of measures that focus not only on farmers but, fundamentally on agro enterprises and supply chains for products and services. An agribusiness supply chain includes a number of processes such as

supply management, production management and demand management to ultimate customers through a competitive distribution channel (Chandrasekaran & Raghuram, 2014). Agribusiness and supply chains in Nepal are widely criticized for inefficiency, governance, quality, and sustainability. The complexity of agribusiness supply chains is due to the bulkiness of produce, perishability, and seasonality (Chandrasekaran & Raghuram, 2014), which demand specific policies, programs, and infrastructures. Further, agribusiness and supply chain development are significantly dependent upon enabling a policy environment in the field of infrastructures, land use, information technology, finance, and subsequent efficient policy-implementing institutions. Although the country witnessed five major socio-political changes followed by subsequent agricultural development policies during the last seven decades, the performance of this sector has been inadequate to meet the increasing food demand and livelihood needs of the country's growing population. The Agriculture Perspective Plan-APP (1995/96-2014/15), National Agriculture Policy 2004, Agribusiness Promotion Policy 2006 and Agriculture Development Strategy-ADS (2015-35) are the major guiding policy initiatives of the Government of Nepal for agriculture development. There are over 25 active sectoral and commodity promotion policies, including ADS that have been shaping agribusiness, supply chain development and transforming the agriculture sector from subsistence to commercialization (MoALD, 2020).

The sector is still in a low development stage as highlighted by a number of indicators including labour productivity, productivity gaps, trade and competitiveness, poverty and malnutrition, and infrastructure (MoALD, 2015). In this context, it is important to critically examine government policies, including legislative and institutional provisions, for agricultural development and identify associated gaps and constraints. This paper attempts to critically review the dynamics of agriculture development policies in terms of priorities, technology transfer, support measures, allocation of resources, research-extension-education linkage, and incentives for private sector engagement over the periods. Further, the analysis of this paper aligned with political changes and the evolution of agriculture policies referring to different time horizons since 1950. Therefore, the main objective of this study is to review and analyze the major agriculture policies with respect to their contributions to promoting agribusiness and supply chain development in Nepal.

2. Methodology

This paper is primarily relies on the review of literatures and agriculture policies in different time periods. Specifically, the study covers agriculture policies, programs

and agriculture extension approaches adopted by the Government in various national periodic plans, starting from the first five year plan (1956-61) to the current fifteenth five-year plan (2019-2024). Similarly, the study also includes a critical review and analysis of major agriculture policies and plans implemented by the Government in the past decades, such as Agriculture Perspective Plan-APP (1995/96-2014/15), National Agriculture Policy 2004, Agribusiness Promotion Policy 2006, Agriculture Development Strategy-ADS (2015-35), and other commodity specific agriculture policies. The review focusses on assessing dynamics of policy priorities concerning agriculture commercialization and agribusiness development over the periods. Additionally, specific policies for seeds, land use, irrigation, trade, and other key areas have been reviewed and analyzed. The source of data/information were Ministry of Finanace/ Economic Survey, Central Bureau of Statistics (CBS), FAOSTAT Statistical Information on Nepalese Agriculture, Compilation of Agriculture Policies, and other publications. The statistical tools such as growth rates, trend analysis, percentage analysis, and average have been employed for quantitative analysis. Furthermore, the qualitative information related to the objective has been organized in tabular and descriptive forms and analyzed critically. The study has also adopted qualitative approach to data analysis including a framework for private sector incentives. Focus group discussions (FGD) and key informant consultations were utilized to understand policy dynamics and their impact on agribusiness and supply chain development. The FDG's involved agriculture experts who have served in public ,private, and development practitioners in Nepal. Additionally, individuals currently working in the public,private,development sectors were consulted during the study. The purposive sampling technique (non- probability sampling) was employed for consultations with the respondents.

3. Results and Discussions

3.1 Historical perspectives in agriculture development

3.1.1 Agriculture extension service perspective

The history of agriculture extension in Nepal goes back to Rana regime when they introduced new breeds from outside as part of technology transfer. Since then, the extension service system has undergone a wide range of transformations in institutional mechanism, investment, structure, objectives, and approaches. Initially, the agricultural extension system was a monolithic government-funded technology dissemination service with limited representation and contribution from the private and agribusiness sectors. The source of technology was primarily the public research system, focusing on the uniform needs of farming communities while neglecting

the requirements of agribusiness and supply chain development.Similar to trends in extension system worldwide, the early approaches in Nepal were more top-down, led by technicians or experts. However, in recent decades, efforts have been made to make extension services more participatory, inclusive, democratic, and beneficiary-led (Ghimire et al., 2021). The recent extension approaches in nepal are pluralistic, participatory, market oriented, and commercially focused. The advancement in Information Communication Technology (ICT) have significantly increased access to the modern agriculture technology among the youth agri-entrepreneurs. Nepal has implemented various extension approaches in the past (Table-1) but with little success (Ghimire *et al.*, 2021). The suboptimal success of these approaches can be attributed to weak implementation mechanism, which are directly linked to the competency of employees (Ghimire, 2017). When the Agriculture Perspective Plan (APP) was launched in FY 1995/96, Nepal's agricultural sector was much less developed compared to the present. Since then, there has been relative improvement in living standards of farming communities, and that the overall performance of the agricultural sector has improved. Productivity, infrastructure, food security have improved, and poverty has decreased. However, indicators such as food and agricultural trade deficit have been increasing and per capita agricultural land holdings have been decreasing. With the establishment of federal governance system, the responsibility for agricultural extension functions has been transferred to provincial and local governments. This has created significant challenges in terms of horizontal and vertical coordination for technology transfer. Consequently, the primary role of technicians has shifted from technical support to becoming grant-distributing agents.

Table-1: Agriculture Extension Approaches Adopted in Different Time Periods

SN	Agriculture Policies and Programs	Time Period	Key Features	Contribution to agribusiness and supply chain development
1	Tribhuvan Gram Bikas Yojana	1952	Rural development	Agriculture development considered a major pathway for rural development, wider integrated approach adopted, agribusiness and supply chain thinly focused

SN	Agriculture Policies and Programs	Time Period	Key Features	Contribution to agribusiness and supply chain development
2	4-H (Charpate) Club	1953	Rural youth mobilization for development	Technology dissemination focus
3	First Five-Year Development Plan	1956–61	Human resource development Increasing agriculture production and productivity Zonal and district offices established	Priority was given to transportation, communication and construction, followed by technology transfer focu
4	Integrated Rural Development Project (IRDP)	1970	Rural development by making a simultaneous effort to develop all sectors such as education, health, agriculture, drinking water, etc	The IRDP approach followed in all the 75 districts to provide holistic support from service to production and marketing.
5	Training and Visit (T&V) Program	1975	Transfer of Technology (ToT)	Focused on technology dissemination
6	Tuki extension approach	1977	Assigning extension functions to locally rooted volunteer farmers	Focused on technology dissemination, agribusiness and supply chain development for agriculture inputs
7	Farming System Research and Extension (FSRE)	1989	This concept was initiated to integrate research and extension by generating technology in the	Focused on participatory technology generation and dissemination following system perspective with less focused on agribusiness and supply

SN	Agriculture Policies and Programs	Time Period	Key Features	Contribution to agribusiness and supply chain development
			research outreach sites with the participation of the farmers.	chain development
8	Block Production Program	1982	Intensive use of resources in consolidated way to increase farm productivity. Main focus on Block Production Program was intensive farming.	Focused on increasing cereal productivity with modern technologywith almost no focus on agribusiness supply chain development
9	Farmer Group Approach	1987/88	Put farmers of similar interests together and carry out agricultural development and associated activities on group basis. The group approach has been effective to bring innovation to groups and expand to other farmers in their command area	Successful in technology transfer, agribusiness, and supply chain development. Groups and cooperatives-based supply chains and agribusiness developed in different subsector
10	Pocket Package Program	1982	Production focusing on a particular area (or pocket). This approach is effective to introduce new demand-driven technologies.	Instrumental in commercializing crops, dairy, vegetables, and other crops. Contributed to input output supply chain development in agriculture

SN	Agriculture Policies and Programs	Time Period	Key Features	Contribution to agribusiness and supply chain development
11	Projectization Approach	2000	Commodity-based production programs implemented following project design framework (timeframe, financial planning with expected outputs)	Contributed to promote agribusiness and supply chain development including all required set of interventions on project framework
12	Farmer Field School (FFS)	1997	Based on adult learning, learning by observing, and learning by doing principles	This opened up new avenues for agribusiness as IPM products and supported to develop market infrastructure
13	Public Private Partnership	2004	Private parties also invest their share in the program (in cash or kind) and provide services to needy farmers or groups in collaboration with government agencies.	This specially focused on agribusiness development through complementary investment schemes

Source: Ghimire et al. (2021)

3.1.2 Policy evolution perspective

The history of agriculture policy evolution goes back to 1956 when the first five-year plan was formulated, and continued till now. Currently there are over 2 dozen of policies, , which are provided in Table-2 The main common strategic components of the plans (1952-1995) and policies have been to establish systems on technology, institutions, support and extension, production management, research, education and extension linkage, agribusiness, and trade and linkages. The dynamics of these systems is the core of the agriculture policy evolution. However, technology development and increasing production and productivity have been prioritized during all the policy periods. Commercialization, comparative advantage, competitiveness, private sector engagement, export promotion and trade balance,

regulatory mechanisms and supply chain development are the new axillary branches emerged during the later stage of agriculture policy evolution. Since the APP started in FY1994/95, the agricultural sector in Nepal has made progress in several indicators of well-being and development. For example, income per capita and productivity of agricultural labor have increased, poverty has decreased, and malnutrition has declined (MoALD, 2015). The road network has been considerably expanded and irrigation coverage has increased. Access to infrastructure and services including road, market, banks and agricultural service centers have also improve considerably. In almost all agriculture subsectors (crops, livestock, fishery, and forestry), there has been progress in terms of production or/and productivity. However, there are several indicators where the sector needs to improve that include labor productivity, productivity gaps, trade and competitiveness, poverty and malnutrition, and infrastructure. Some subsectors have progressed, but in overall, the progress are not sufficient to improve conditions of a large number of people engaged in agriculture, reduce malnutrition and assure food security. There are however positive signs and potentials for growth and opportunities.

3.1.3 Policy periods, and agribusiness and supply chain development

Agriculture development policies are largely shaped by changes in international theoretical perspectives on development political economy. These theoretical roots were emerged from one or more of macro-level development theories neoliberalism, modernization, world system, and transformative and micro level elite, group, systems and institutional, incremental, and rational choice. The level of influence of a particular theory or theories in agriculture policy and plan formulation has been different over the periods. In Nepal, agriculture policies and their general outcomes can be broadly categorized into six periods, however there is no distinct boarder line to separate these.

Before 1950 period: The is no evidence of any notable shape for agriculture development until 1950. Around the 1850s, Jung Bahadur Rana imported a Jersey bull, two Jersey cows, and clover grass seeds from the United Kingdom, and initiated a cattle-breeding program. However, some infrastructure such as veterinary hospitals, central research farms, and technical schools (Ghimire et al., 2021) were established before 1950. Eextension services were centralized and top-down, farmers' awareness and ambitions were low, and farming was dominantly subsistence-oriented. There were no sub-sectoral conceptual priority, farmers to farmers technological system and defined state support system, Communities shaped family farming to achieve household food security. However, a few agriculture development programs in small and localized scale assisted rural farmers through educational programs aimed at improving household food security and ood systems.

During 1951 to 1960: The political change in 1951 brought democratic ideological changes in social and political systems and planted the seed for people's participation in development. The theoretical perspective of planned development introduced was through first five-year plan that covered 1956 -1961 (NPC, 2016). This plan put second priority to agriculture development and social services, and agriculture extension workers were considered multi-functional professionals to solve problems of farm families and communities, and lead increased farm production and income. The major focus was to demonstration, distribution of good seeds and improved fertilizers, expand cultivation of vegetables and fruits, raising poultry, and scientifically protecting plant and animals from diseases. In 1957, a school of agriculture was established under the Department of Agriculture (DOA) at Kathmandu, and agriculture extension office were established in 25 districts in 1959 (Ghimire et al., 2021). Development of supply chain and market enterprise were not envisioned during the period. Weak and pro-trader marketing channels were identified as constraint for increasing farmer's income as they were compelled to sell their produce at cheaper price at the time of harvest. However, formation of marketing and purchasing co-operatives, support to farmers to constructstalls, sheds and storage for protection from spoilage, the standardization of weights and measures, and the establishment of standardized grades for agricultural produce were focused in the plan. The state enterprises conceptualized as diary collection centers, central dairy processing units and cheese processing units at different locations. The technological, support and extension system was not clearly conceptualized by the plan.

During 1961 to 1990: This period witnessed political instability, from introduction to abolition of absolute monarchy. Started with the three-year plan (1962-65), this period adopted mixed economy in theoretical perspective and implemented six periodic plans until 1990. The main focus remained on state managed mechanisms for research and technology, education and extension, input supply, regulatory and output marketing systems. Establishment of input supply chains through government farms; research, education training, and financial institutions; state trading enterprises for fertilizer, seed and agricultural machineries. For example: extension offices were established in 50 districts in 1963 (Ghimire et al., 2021). Similarly, to absorb agriculture raw materials, commodity-based state-controlled processing enterprises e.g. jute mill, rice mills, sugar mills, spinning mills, and tobacco factorywere established during 1965 to 1970 through Third to Seventh Plans. (NPC, 2016). For output marketing through forward linkages, state trading enterprises e.g. Food Corporation, Paddy and Rice trading company and Salt Trading Corporation were established. In overall, major commodity value chains were state-led and

controlled. The domestic agriculture research system were linked to international public institutions under CGIAR and other country specific agriculture research system to establish robust agriculture technology dissemination. For example: Nepal Agricultural Research Council (NARC) was established during the seventh five-year plan. The supply chain linkages were largely limited to state trading enterprises in and outside the country. The forward and backward linkages in agribusiness system were largely dominated by state enterprises. The policy and priorities hardly incentivized private sector to investment in agribusiness and supply chain development. There was weak B2B linkages for input supplies, service provision, research, extension, education, value addition, processing, and forward linkages. In summary, during this period, state controlled agribusinesses and supply chains were established, which did not incentivize private sector investment, nurture private innovations and innovate support products to promote private agribusiness and supply chains.

During 1990 to 2008: This period started with restoration of democracy in 1990, globalization, liberalization and structural changes aligning with international development, which shaped domestic economic policies. During the eight plan (1992-97), the government followed liberal economic policies, planned development and wide range of reforms implemented to incentivize private and cooperative sector investment and participation in development. Agriculture policy priorities shifted to promote commercialization, competitiveness, and comparative advantages in the agriculture sector to achieve food security and trade balance. State managed supply chains and agribusiness were dismantled through privatization and subsidy cutoff in agro enterprises to promote private sector. Only research farms and technology centers remained under the government system where there was low incentives for private sector. With structural changes and pro private sector policies, private enterprises were excluded for input supply chains, processing, and value addition, B2B linkages at domestic and international level. Promotion of cooperative movement as a third pillar for economic development cooperative enterprises also flourished during the Ninth (1997-2002) and Tenth (2002-2007) Plans (NPC, 2016). Earlier, public enterprises focused state support system to farming communities and later extended to access private and cooperative sector with introduction of new support products. At later stage of this period, agribusiness policies were largely guided by WTO framework reducing subsidy in several subsectors including credit. Private agribusiness and supply chain enterprises concentrated more on agriculture input supplies; technical services; dairy, poultry, vegetables and seed import and export;, and agro processing. During the same period, private and cooperative sectors emerged as integral and powerful part of technology, research, education,

extension, and service system in agribusiness and supply chain development. However, the pace and coverage of private and cooperative sector investment and participation in agribusiness and supply chain development deeply retarded during ten year armed conflict and remained unable to deliver visible impact of policy reforms (MoALD, 2015). The APP (1995-2014/15), a growth and commercialization focused strategy, was the guiding document for this period. Likewise, other key policy framed to drive agribusiness during the period were National Agriculture Policy, 2004, Agriculture Extension Strategy, 2006, and Agribusiness Promotion Policy 2006 (MoALD, 2021). Fertilizer supplies was opened to private sector and subsidy was removed. Competitive grant system of support was introduced to incentivize private sector investment in agribusiness. Formation of commodity organization and their involvement in agribusiness promotion was also key achievements during the period.

During 2008 to 2015: After initiation of peace process in 2006, the transitional governments continued liberal economic policies to promote agribusiness and supply chain development. Private sand cooperative sectors, supported with enabling policies, matching and startup grants, export incentives, investments in agro products and agribusiness development considerably increased. More than 15 public policies were formed during this period in agriculture sector (MoALD, 2021), which were oriented towards promoting private sector engagement in agribusinesses. National Agriculture Research and Development Fund (NARDF) was established to enhance participation of private sector in research and technology system. National Seed Vision (2013-25), a seed sector development strategy, was formulated in 2013. This is the first official document of its kind, which guides all stakeholders associated with the seed business in Nepal for variety development and maintenance, seed multiplication, seed processing and conditioning, seed marketing, and seed quality control and use (MoAD, 2013). Additionally, there is significant increase in number and volume of private sector and cooperative investments in input supply chains, agro advisory and technical services, research, technology and education system, agro processing, seed business, and export promotion.

2015 onward: Nepal promulgated federal republic constitution (2015) with three tiers of governance system with allocation authorities, resource and accountabilities to subnational level. The Constitution has envisioned building an advanced, self-reliant, and socialism-oriented economy. Subsequent governments followed same kind of liberal economic policies and planned development as theoretical ground for development (Constitution, 2015), with main focus on food and nutrition security, trade balance and agriculture commercialization. The ADS (2015-2035) focuses on

technology innovation, value chain development, food and nutrition security, decentralized education science, and is being implemented accordingly. Additionally, there is a significant increase in the number of educational institutions from public and private sector involved in human resource development required at different level for agriculture development in the country.

The critical analysis of public policies including periodic plans, APP, ADS, National Agriculture Policy 2004, Rural Infrastructure Plan 2004, Agri-Business Promotion Policy 2006, and several others are all emphasizing commercialization, modernization, diversification, and industrialization of agriculture sector to enhance food and nutrition security, import substitution, export promotion, and poverty reduction.. Most policies in Nepal are supportive to agribusiness promotion. Although, the Government has been implementing sound public policies for agriculture development and agri-business promotion over the periods, yet there are some strength and weakness of these policies.

Numerous policies have been left at a draft stage, not implemented, often lack supporting legislation and resources, because of limited implementation capacity, financial resource constraints, poor coordination, lack of supporting legislation, and lack of monitoring and evaluation. For example, the overall performance of APP has been mixed (MoALD, 2015). The APP period saw a dramatic improvement in rural road infrastructure, community forest, and horticulture. Irrigation expanded considerably even though it did not achieve the groundwater targets . Within livestock, subsectors such as dairy processing and poultry performed well. Cereals, in general, did not do well, partly because of deficiency in accessing inputs such as improved seeds, quality, and affordable chemical fertilizer on time, and partly because of higher incentives for farmers to engage in higher value commodity production.

Similarly, the disruptive conflict had negative implications for the implementation of policies, plans, and projects; both local elites and a sizable share of the labor force have abandoned rural areas depriving agriculture from needed capital, resources, and labor; while increasing pressure on infrastructure and peri-urban area of already crowded major cities. Likewise, frequent changes in government have constrained continuity of leadership and senior officer thus making implementation of programs more difficult. Despite existence of numerous policies, often favorable to agriculture, their implementation has been below expectations due to a host of factors such as lack of resources, weak capacity, lack of credibility of policies and absence of supporting legislations. In the present context of federalization, the functional coordination and harmonization of resources for agribusiness promotion among the three tiers of government is a challenging task.

Table 3: Summary of dynamics in agribusiness and supply chain development policies and outcome over last six and half decades

Periods	Strategic focus	REE system	Support system	Output with respect to supply chain and agribusiness development
Before 2051	Technology introduction	Not shaped	Not clearly shaped	
2051 -2061	Production and productivity , subsector defined	State owned system, vocational training, outside technology, -localized focus and deployment of technicians, farmer to farmer technology transfer,	State owned system, Seed distribution, Veterinary services, Small localized markets	Localized supply chains in dairy and vegetables
2061-2090	Diversified strategic focus; state mechanism building to promote subsectors, production, and productivity	State owned REE system: national research network, CGIAR based technology source, government owned resource centers, state owned education and vocational training system, technology as public good, state to state enterprise linkage, state value addition and trading enterprises	State directed support system, service provision to farmers and extension teaching, focused on technology dissemination products, subsidy on seed and fertilizer, dedicated state owned credit institution	State owned agribusiness flourished, state managed supply chains evolved/ established, weak development private agribusinesses, B2B networks

Periods	Strategic focus	REE system	Support system	Output with respect to supply chain and agribusiness development
1990-2008	Strategic focus on commercialization, competitiveness, comparative advantage, privatization, and liberalization to gain efficiency	State owned technology system complemented with market opened for private patented technologies; private educational and training enterprises established; public extension system complemented with pluralistic extension involving private service providers, CBOs and cooperatives, technology source, delivery and demand diversified, private sector involvement opened in research with NARDF establishment	Public sector subsidy and support removed for state enterprises,, subsidy removed for chemical fertilizer; credit and seed, pluralistic support system evolved from NGOs, INGOs, cooperatives; support system guided by WTO rules; private and cooperative sector incentivized	State owned agribusiness and supply chains stunted, private and cooperative agribusiness and supply chains evolved, agro advisory enterprises developed B2B linkages at national and international level established, commodity associations emerged as advocacy group
2008-2015	commercialization, competitiveness, comparative advantage continued, self sufficiency	Weak REE linkage, diversified technology source, pluralism in extension system, diversified precision service demand for technology among farming	Fertilizer subsidy re-introduced and regulated supplies, pluralistic support system evolved from NGOs, INGOs,	Private and cooperative agribusiness and supply chains grown; agro advisory enterprises developed;

Periods	Strategic focus	REE system	Support system	Output with respect to supply chain and agribusiness development
		population, private sector participation in service delivery, competitive grant system wide promoted to promote private investment, cooperatives promoted, private sector involved in research, wider participation of private sector in agri education widely	cooperatives, support system guided by WTO rules, private and cooperative sector incentivized, matching grant support to agro enterprises, crop insurance introduced	B2B linkages at national and international level established; commodity associations emerged as advocacy group
2008 onward	ADS main guiding document, strategic priority value chain development, decentralized education science and technology, food and nutrition security, innovation and agro entrepreneurship, farmers right at federal level	REE linkage fragmented, private evolved in varietal research R and D, diversified educational institutions at provincial and federal level, diverse curricula, no specified public extension system, extension function handed over to local and provincial level, technology source diversified, access to technology increased with digital connection, pluralistic	Fragmented support system, private sector and cooperative support through competitive grant system at all levels, higher investment from private sector agribusiness and supply chain, crop insurance, agriculture credit, electricity tariff for irrigation subsidized, output-based cash	Wider development of private and cooperative sector in agribusiness and supply chain development, regulatory mechanism need to be strengthened to improve the quality of agribusiness and supply chains

Periods	Strategic focus	REE system	Support system	Output with respect to supply chain and agribusiness development
	Fragmented diversified strategic focus among three tiers of government	delivery systems and precision service demand, private sector involvement in technology import	incentive introduced	

Source: Adopted from different periodic development plans of Government of Nepal (NPC, 2016, NPC, 2020)

3.1.4 Public investment perspective

Public investment in agriculture is crucial and have significant effects on public health, nutrition, and poverty reduction in the country. The ADS (2015-35) has mentioned that annual budget for agriculture is expected to be about 10% of total budget expenditure. There has been a gradual increment in budget allocation in agriculture sector (Figure-2) with some ups and downs in some years. However, this is not enough investment in agriculture as it is still less than 2 percent of GDP. Investment in agriculture, agribusiness and rural development by the Government, development partners, and the private sector has increased since 2000, due to global and domestic factors including a more stable business environment. For example, Morang Merchant Association and Chambers of Commerce and Industry reports that NRs 2 billion industrial investment has been made in the Sunsari-Morang corridor between April 2010 and October 2011 (Ghimire, 2011). Investment includes soy processing, rice milling, biscuit manufacture, and plywood, from both domestic and Indian investors. The private sector has investment has been strong in dairy processing and marketing poultry (estimated to be NRs 21 billion). The larger part of the Government's annual budget to agriculture goes for support services, including research and extension; subsidy on fertilizers, seeds and planting materials, insurance, credit; and for infrastructure and information services. Agriculture investments are also aimed at stimulating input market development for commercialization of agriculture by offsetting high initial distribution costs until the market expands, economies of scale are realized, and prices decline (World Bank, 2008). Hence, the overall impact of agricultural investment in its aggregate is at increasing welfare and development in Nepal.

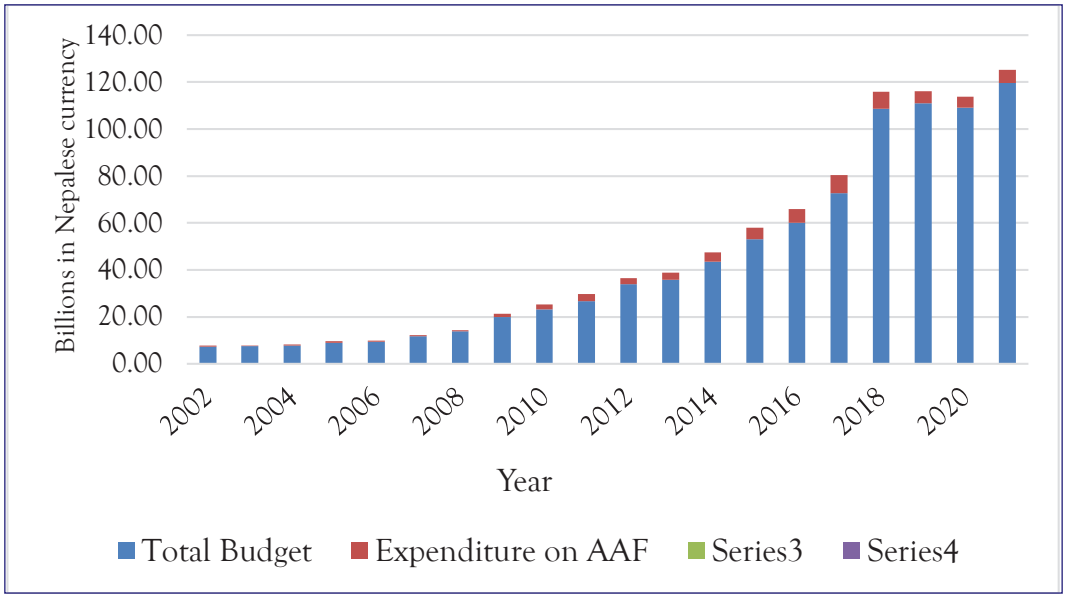

Figure-1: Government Expenditure on agriculture, forestry, and fishing (AFF) in Nepal. *Source: FAOSTAT. https://www.fao.org/faostat/en/#country/149*

3.1.5 Commercialization perspective

Historically, agriculture has been the root of industrial growth worldwide. Nepal, having an agro-based economy, improvement in agricultural productivity will provide an initial spur to industrialization (Gauchan, 2018). Nepal has an estimated 44.7% of agricultural entities commercialized, and 55.3% are subsistence farming entities (MoALD, 2015). Staple commodities such as rice, wheat, potato, and vegetables have higher commercialization rates (30-50%) than maize and fruits (15-25%). Commercialization rates for milk (60%) buffalo meat (80%) and goat meat (85%) are high, reflecting the high value of these products (MOAC and JICA 2010). The low proportion of commercial agriculture in Nepal is highlighted by the low use of mineral/chemical fertilizers, irrigation and mechanization, and limited production of rural surplus for the rest of the economy. Thus, stimulating the process of commercial transformation has been included in past and current policies.

Agriculture and agribusiness investment are constrained by inadequate suitable policies (e.g. contract farming), competition with state enterprises and cooperatives, lack of services and infrastructure to support value chain development (e.g. agribusiness incubators, agro-industrial parks), low coverage of agricultural insurance, and a transparent and stable tax and incentive system to promote innovation and reduce risk. The key issue is how to increase sustainable and profitable investment

in agriculture and agribusiness that could accelerate the growth and modernization of agriculture. Nepal-India Trade Treaty has de facto created free trade between the two countries and resulted in Indian products outcompeting some of the Nepalese agricultural produce in the Nepalese domestic market, particularly in the cereal market. Due to a lack of good farming and manufacturing practices, it has been difficult for Nepalese farm products to comply with international quality standards. As a result, Nepalese products face non-tariff barriers in the form of sanitary and phytosanitary (SPS) and technical standards in the export markets. Pegged exchange regime with India has resulted in the erosion of the competitive edge of Nepalese products in exports to India as well as in domestic markets. One of the issues of agriculture trade is how to use trade policy instruments in securing food security through a self-reliant food economy. Therefore, APP and ADS have viewed agriculture as an engine of growth for triggering commercialization, promoting competitiveness and developing industries in the country.

The transformation towards a more commercialized agriculture requires a set of measures that focus not only on farmers but, fundamentally on agro-enterprises involved in the commercialization of agricultural products and services. These enterprises include input providers, producer companies, marketing cooperatives, storage operators, logistic companies, agro-processors, importers and exporters of agricultural and food products, distributors, traders, and agricultural service providers (including financial service providers, insurance providers, business service providers (Gauchan, 2018). These enterprises may be micro, small, medium, and large. Profitable commercialization requires the combination of several measures such as an enabling investment climate and a number of reforms to strengthen contractual arrangements, taxes, and financial services to promote efficient commercial agriculture.

The registration trend of agro-industries has increased during the past few decades and poultry stands number one among agro-industries (Figures 3 and 4). Similar is the case for agriculture, multipurpose and commodity-specific cooperatives registration. There are altogether 15,217 agriculture-related cooperatives registered in Nepal till FY2016/07 (Figure 5). The reality is different as increased registration of agro-industries and cooperatives does not reflect growth on the ground. The government support policies demand firms or cooperative registration as basic eligibility criteria for this the registration number increased exponentially in recent years. A large number of agro vets established and operate a strong supply chain of seed, breed, agrochemicals and embedded services. In total, 12,066 agro vets have been licensed and they have a strong B2B network at the domestic and international

levels (Figure 6). This is a wide and deep supply chain significantly contributing to agriculture commercialization in the country.

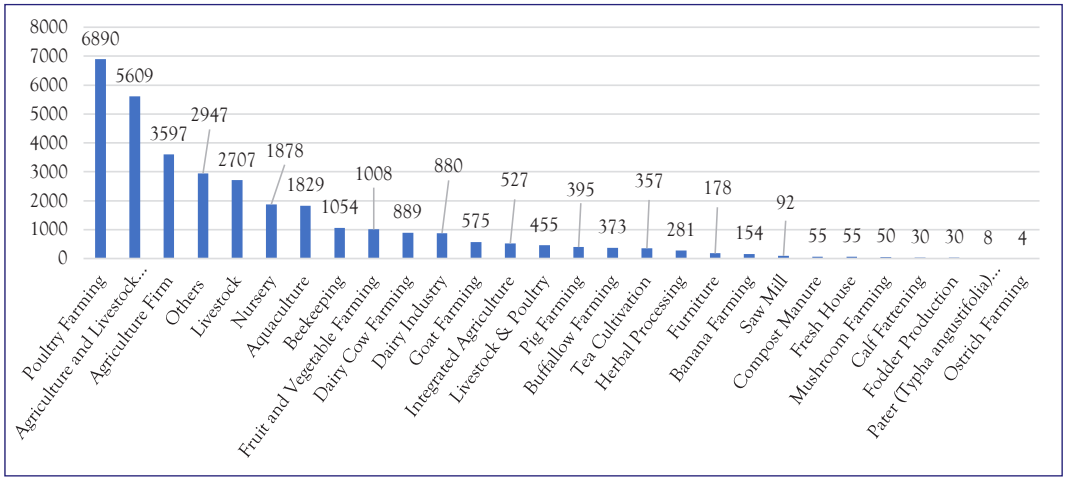

Figure-2: Agribusiness Registered during 1994-2021 in Nepal. *Source: DoI, (2021/022).*

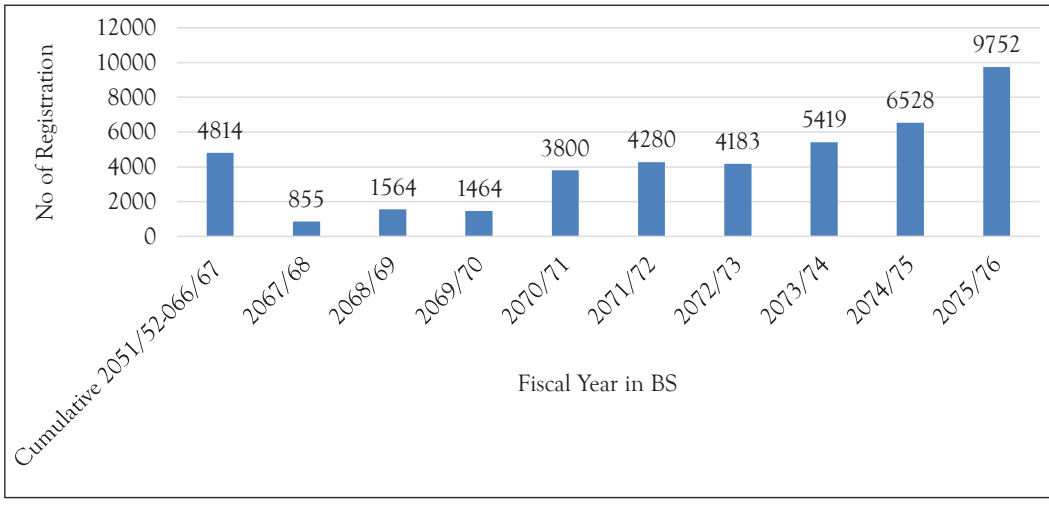

Figure-4: Agro-Enterprise Registration Trend in Nepal. Source: DoI, (2021/022).

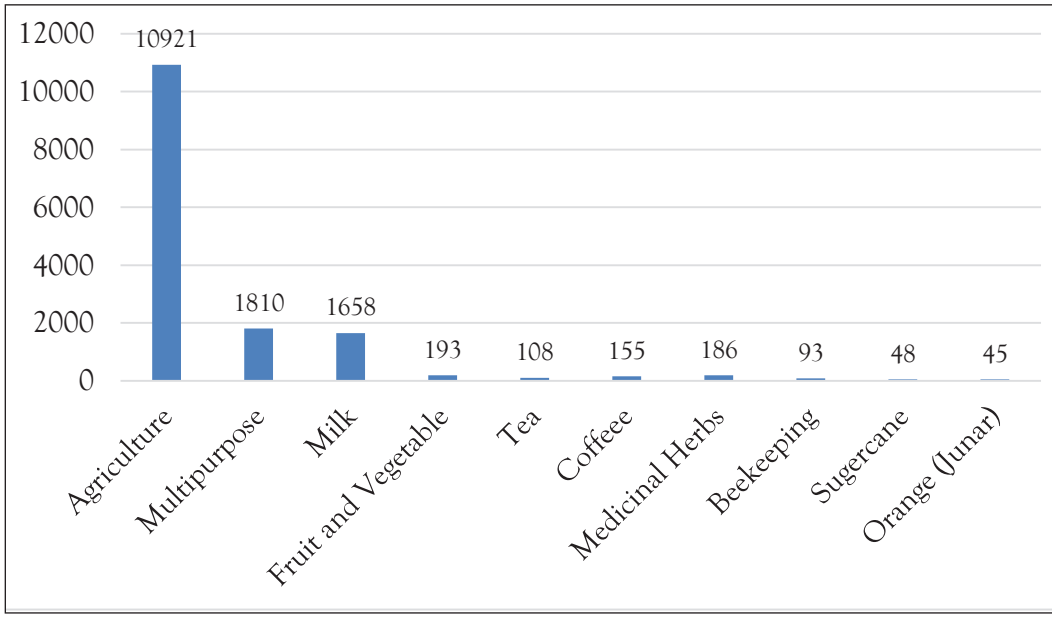

Figure-4: Agricultural Cooperatives Registered till 2016/17 in Nepal. Source: DoC (2017)

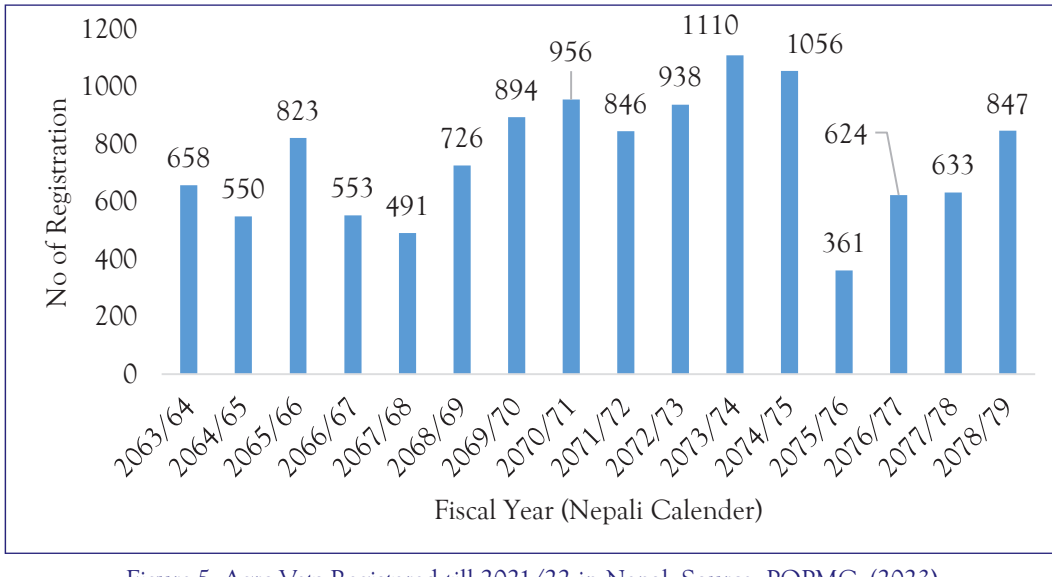

Figure-5: Agro-Vets Registered till 2021/22 in Nepal. Source: PQPMC, (2023).

3.1.6 Production trends perspective

There is considerable potential for the growth of agricultural productivity in Nepal. Since its first five-year plan (1956/57–1960/61), the Nepalese government has

continuously focused on improving food production. However, the agriculture growth rate remains stagnant, with an average rate of less than 3% per annum, which is far below the targeted 5.4 % in the Fifteenth plan (2019/20-2023/24). Currently, the level and the growth of productivity are low due to several factors including an ineffective and underfunded agricultural research and technology transfer system, lack of an effective mechanism for linking research extension and farmers, the low availability of year-round irrigation, the limited availability and affordability of key inputs (fertilizer, seed, breeds, etc.), declining soil fertility, poor integration of research and extension with the agricultural education system, and high incidence of pests and diseases.

Rice, maize, and wheat occupy the maximum share in terms of area and production of Nepalese agriculture and play major roles in the food and nutrition security of the country. Although the Government has been investing in cereal production since the 1960s, there is a slow and steady growth in area, production and yield. Rice, wheat, maize, barley, buckwheat, and millet are the cereal crops that are grown in Nepal, among which the first three occupy 91.31 and 96.67 percent of the total area and production of cereal, respectively (MoALD, 2021). Cereal crop plays a major role in food and nutrition security in Nepal as Nepalese food habits are based on cereal crops. Cereal supplies 65 and 60 percent of the total food energy and proteins to the Nepalese population (Regmi, 2016). Cereal crop shares about 33 and 23 percent of the total food expenditure of rural and urban households, respectively in Nepal.

Despite having importance, Nepal is not able to become self-sufficient in terms of cereal crop production. The cereal import dependency ratio is increasing every year and the food import-to-export ratio is at an all-time high. Import of food has increased fourfold from 2011 to 2018 making the country vulnerable to food insecurity (NPC, 2019). Cereal crop production is heavily input intensive in nature. They require a large amount of investment in terms of fertilizer, irrigation, labor force, and plant protection chemicals. Only 54 percent of the total cultivated land is irrigated, among which only 33 percent of the land has year-round irrigation facilities in Nepal (Dahal et al., 2022). Such a situation makes the Nepalese cereal production system highly monsoon dependent. Paddy production heavily depends upon the timing and amount of the monsoon rainfall, whereas maize and wheat depend on rainfall in other months. Production of these crops varies due to highly variable, unpredictable rainfall as well as lack of other irrigation systems.

The linear regression analysis shows that the production of cereal crops in Nepal has been increasing gradually with yearly rise and fall for the period of 1961 to 2021 (Figure-1). The coefficient of determination ($R^2 = 0.929$) for the cereal crop production

in Nepal shows that there is a strong positive correlation between agriculture policies/programs and the production of cereal crops in Nepal. Similarly, the land area for cereal crops has also been increasing slowly with some ups and down for the same period (Figure-1). Likewise, the productivity of major cereal crops in 2021 is 3.21 Mt/ha which was only 1.85 Mt/ha in 1961(FAOSTAT). Therefore, it can be interpreted that the government policies, programs, and extension approaches that were adopted in the past had significantly contributed to the increase in the area, production, and productivity of cereal crops in Nepal.

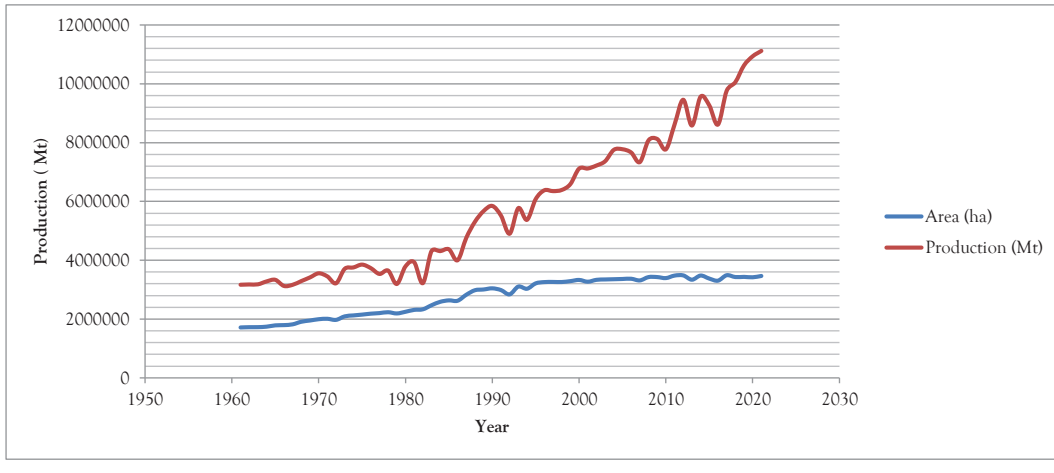

Figure-6: Cereal Crop Area and Production in Nepal. *Source: FAOSTAT. https://www.fao.org/faostat/en/#country/149*

4. Conclusions

The review reveals that there has been an alignment of agriculture and agribusiness policies with the international and domestic political economy during the last seven decades. In the early stage of planned development and throughout the panchayat regime, there was a widespread and deep promotion of state-managed agribusiness and supply chains. These initiatives encompassed various aspects, including technology generation, dissemination, input supplies, finance, collection aggregation and processing. State-managed enterprises were established thrived during this period, while market-based private enterprises remained limited due to the absence of policy and program incentives.

With the restoration of democracy, and adoption of a liberal economy, followed by subsequent structural reforms state managed agribusinesses and supply chains were either privatized or disincentivized, .This led to emergence of private sectors and

other non-state actors such as cooperatives, producer groups, and community-based organizations (CBOs), and non-governmental organizations (NGOs) emerged as key providers of inputs, seeds, exotic varieties, and the technical services. This policy environment was made more friendly to nurture private and community-based actors in agribusiness and supply chains. Currently, the public sector still plays major role in agricultural research (new seed varieties, source seeds, fertilizer), extension service, and provision of support services (subsidies, input supply etc.), while private sectors are emerging in the provision of input supply and agro- advisory services associated with their agricultural inputs, particularly in commercial production systems and market access areas.

Despite the existence of more than 24 agribusiness-enabling policies, there is insufficient investment from the private and cooperative sectors to transform the agriculture sector. An important aspect of agribusiness is the supply chain, which is found to be insufficiently focused on existing policies. Therefore, this review calls for further diagnostic participatory analysis of policy and practice gaps under the current three-tier federal governance system. Such an analysis should encompass overall policy capacity extended from policy formulation, institutions, and resources for implementation.

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Authors Contribution

Rajendra Prasad Mishra: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/ evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/ final draft polishing;

Indra Hari Paudel: formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/ final draft polishing;

Conflict of Interest

The authors declared no conflict of interest.

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Appendix

Table-A1: Recent Agriculture Development Policies in Nepal

National fisheries policy 2079 (2022)	Climate change policy 2067 (2010)
National animal health policy 2078 (2021)	National land use policy 2069 (2012)
National animal breeding policy 2078 (2021)	Forest policy 2071 (2014)
National dairy development policy 2078 (2021)	Agri mechanization promotion policy 2071 (2014)
National agro forestry policy 2076 (2019)	Floriculture promotion policy 2069 (2012)
National food safety policy 2076 (2019)	Bird farming policy 2068 (2013)
National fertilizer policy 2058 (2001)	Range land policy 2068 (2013)
National tea policy 2057 (2000)	Agribusiness promotion policy 2063 (2006)
National coffee policy 2060 (2003)	Gender mainstreaming policy 2063 (2006)
Agro biodiversity policy 2063 (revised 2071) (2014)	National agriculture policy 2061 (2004)
Irrigation policy 2070 (2013)	National seed vision (2013-2025)
Industrial policy 2067 (2010)	Agriculture Development Strategy (2015-35)
Industrial policy 2067 (2010)	NRB soft loan directive 2074 (2017)
Agriculture Perspective Plan (1994/95-2014/15)	

Source: Agriculture Policy Compilation of MoALD (2021)

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Food Safety Awareness, Food Policies, and Gender: A Review and an Empirical Examination from Nepal

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Abstract

Hunger and malnutrition are critical challenges for developing countries. Access to sufficient safe and nutritious food is the key factor in addressing food security, health, and nutritional goals. Food safety and security are vital components of sustainable food systems. However, in developing countries like Nepal, food safety issues have received limited attention within the food systems. This study aims to review the relationship between food safety and food security, sustainable food systems, awareness, and food policies in Nepal, while also discussing the potential roles of women in these areas. Furthermore, the empirical examination presents our findings based on primary survey data from 604 consumer households in five major metropolitan areas of Nepal, Particularly focusing on gender differences in food safety awareness and purchase of fresh produce. Our overall findings suggest that the basic food safety practices and the enforcement of regulations have been overlooked in Nepal. Moreover, the study also underscores the potential roles women could play in enhancing awareness of safer fresh produce systems and safer food consumption. However, the findings also indicate that women in Nepal have lower awareness of food safety compared to men, emphasizing the need to improve education and awareness among women. To fully harness the potential of women as effective initiators, implementers, and promoters of enhancing food safety and sustainable food systems, awareness and training programs on food safety should prioritize the participation of women. It is crucial to encourage their involvement in food-related activities, leadership and management, and entrepreneurship.

Keywords: Safer Food, Fresh Produce, Vegetables and Fruits, Nepal, Metropolitan Households, Women Roles, Gender, Food Safety, Awareness, Consumption, Developing Country

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1. Introduction

Several risk factors for ill health are associated with food and diets (Webb et al., 2018). Access to sufficient, safe and nutritious food is critical for addressing food security, health, and nutritional goals. Unsafe food can create a vicious cycle of disease and malnutrition among children, the elderly, and vulnerable populations. A safer food supply is an instrumental factor in supporting food and nutritional security and sustainable development. The consumption of food plays a direct role in human health and well-being. Food security was traditionally defined as the availability of food that can meet the daily caloric needs of a given population in developing countries. However, by the 1996 World Food Summit, the definition has expanded to "*people having physical and economic access to safe and nutritious food to meet their dietary needs for an active and healthy life*" (WHO, 2019). This internalizes the essence of food safety for food security as well as broadens food security links to food rights and food sovereignty. Food safety encompasses the aspects of handling, preparation, storage, and consumption of food preventing contamination throughout the process and food chains, and reducing foodborne illnesses. Apparently, the inherent linkages between food safety, food security, and nutrition are integral.

Foodborne illness can occur because of our inability to detect risks and hazards in the food that we consume. For the assurance of safer food, we need assurance that the food will not cause harm to consumers when it is prepared and eaten according to its intended use (FAO / WHO, 2014). It is also a way to preserve the quality of food. Unsafe food means that the food might have been exposed to dirt, and germs and most of them have infections caused by bacteria, viruses, and parasites that we cannot detect with our naked eyes. Other than that, harmful toxins and chemicals are also the main reason for foodborne illnesses when food is contaminated (CDC, 2020).

In developing countries like Nepal, food safety issues have received limited attention in the food systems, typically when hunger is the primary constraint to guaranteeing food security. However, Nepal has slowly dropped its score on the Global Hunger Index (19.1) from a serious to moderate level (https://www.globalhungerindex.org/). There is still much work to be done in the broader avenue of addressing food insecurity and ensuring a safer food supply and consumption in Nepal. The efforts on food safety in Nepal are emerging but are at the initial stages. These efforts so far are mainly on identifying the issues and challenges and documenting or drafting some policies and acts (for detail, see our review in a subsection under 3.1) In this stage, along with policy designs, Nepal should work on the premise of speeding the awareness, educational, and dissemination efforts on the importance of food safety to consumers, entrepreneurs, and communities. This probably needs to find the best key initiator

and dissemination on multiple levels: households, communities, and private and public sectors to enhance the understanding of the need for and importance of safer food.

From a gender perspective, women play a central role in the food system and are integral components in the cultivation of food crops, food production, food consumption and related activities (Visser & Wangu, 2021; Njuki et al., 2021). According to the United Nations, women make up at least 43 percent of the agricultural workforce in developing countries – and as much as 70 percent in some countries. Therefore, women could be instrumental in the fight against malnutrition and in making food systems more sustainable. However, gender roles and women's contributions are often not consistently recognized (Njuki et al., 2021). This study aims to address this gap in Nepal by providing a comprehensive discussion and recommendations.

The objective of this study is twofold. Firstly, we review the existing literature related to food safety, food security, and gender roles in food systems focusing in developing country perspectives and Nepalese context. We present our findings based on a comprehensive review into different subsections. Additionally, we conducted empirical examination utilizing primary survey of data from consumer households in Nepal. Specifically, our focus is on food safety awareness regarding fresh produce and gender differences. We examined the awareness level of food safety in fresh produce shopping and consumption, analyzing responses from a primary survey conducted in five major metropolitan areas of Nepal.

2. Methodology

For the first objective, we comprehensively reviewed the previous literature related to food safety, food security, and gender roles in food systems in developing country perspectives. Previous journal articles, information on formal websites, reports, google scholar, and Web of Science searches are the main sources for our review. We have presented review findings under different sub-headings in the result and discussion section. For the second objective, we used empirical survey data generated from a research project implemented[1] in Nepal to understand the baseline and drivers of food safety among consumers and producers of fresh produce systems, in collaboration with academic institutions, NGOs, and local government agencies. Based on the sample survey data of consumer households in five metropolitan areas of Nepal, we

1 The major partner for field activities of the project in Nepal are Agriculture and Forestry University, Nepal, and a national-level NGO, Sahavagi in Nepal; more information on the project: https://rb.gy/mhsoj

have assessed the roles of men and women members of the household in food safety-related practices. Additionally, we examined gender roles in fresh produce shopping and purchase, food preparation, and food decisions. We also investigated the level of awareness and understanding of different dimensions of food safety.

We administered stratified random sampling with randomly selected *wards*, and then *Toles*[2] within the selected metropolitan area. We devised a sample frame in each metropolitan area in collaboration with local government authorities and officials and administered in-person interviews based on a structured questionnaire using survey enumerators. Prior to conducting the survey, the project team constructed a detailed sampling and selection strategy protocol for this field survey. First, from each metropolitan area, 4 *wards* were randomly selected by picking a random number between 1 and the number of total *wards*, without replacement. Second, 3 to 4 *Toles* from each selected *ward* were randomly selected following the same random procedure. The project team ensured the representation of 12 random *Toles* from 4 random *wards* in each metropolitan area. Next, the project team prepared a comprehensive household list of 12 selected *Toles* of each metropolitan area in collaboration with local government authorities and officials. The number of households in the compiled list varied by location but it averaged around 1,000 households per metropolitan area. We randomly selected an average of 120 random households from each metropolitan's sample frame to represent the intended research questions of the project. Then the project team proceeded to conduct in-person interviews with randomly selected households from June to August of 2022. From in-person interviews conducted among households, altogether from 60 *Toles* of 20 *wards* in 5 metropolitan areas, we obtained 604 complete responses representing each metropolitan area. In-person interviews were conducted with one adult representative member of the household. The survey maintains questions to collect information from both the respondent and the household head if the primary respondent is not the household head.

Prior to survey administration and sampling, the data collection procedure and survey instrument (questionnaire) were approved by the Institutional Review Board (IRB) of the lead institution of the project as well as the Nepal partner institution responsible for data collection. Survey interviews were conducted by trained enumerators under monitoring and feedback in the field directly by the project's co-Principal Investigator (Co-PI) from a partner institution in Nepal. Figure 1 shows the

2 *Toles* represent the clusters or neighborhoods within the wards of a municipality. Ward is the smallest unit of local government within a metropolitan area or municipality. In constructing sample frames, the project directly collaborated with members/officials of "*Tole Sudhar Samitee*" that exist in metropolitan areas as the community's unified body to communicate with local government regarding local field-level needs and development.

consumer survey locations representing five large metropolitan areas in Nepal, namely Kathmandu Valley[3] metropolitan area (Kathmandu, Lalitpur, and Bhaktapur districts), Bharatpur metropolitan area (Chitwan district), Butwal metropolitan area (Rupandehi district), Pokhara metropolitan area (Kaski district), and Hetauda metropolitan area (Makawanpur district). We maintained survey questionnaires electronically and recorded responses using Qualtrics[4] software.

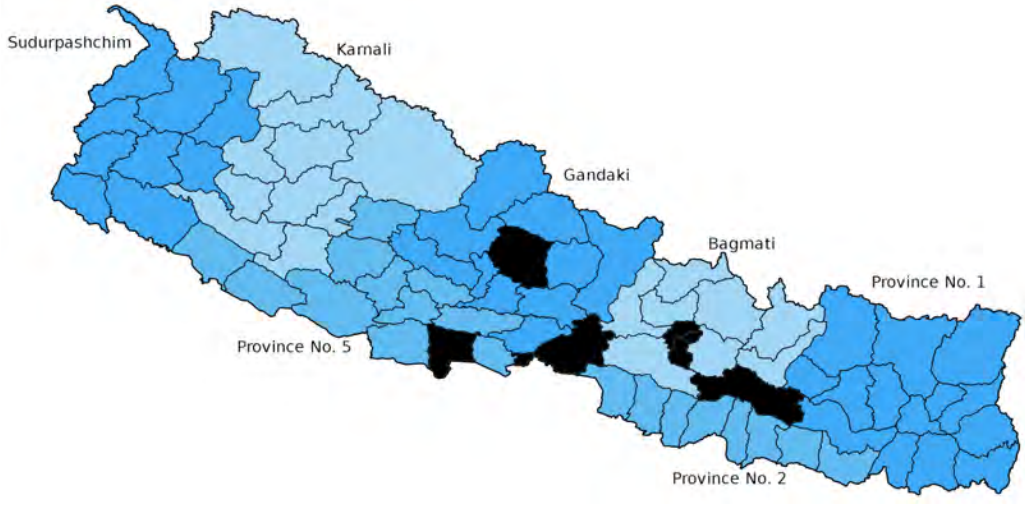

Figure 1: Figure showing the metropolitan area districts used in the consumer household survey (indicated by black dark shades)

3. Results and Discussion

3.1 Food Safety, Sustainable Food Systems, Gender Roles, and Nepal: A Review

3.1.1 Food Safety and Food Security for Sustainable Food Systems

Food safety and security are complementing elements in sustainable food systems. The tools and strategies used to achieve food security must align with food safety and public health as well as sustainability. It is necessary to maintain and ensure food safety in the food supply meeting the hunger reduction goals. However, maintaining food safety and quality assurance can result in some reduction in quantity in the

3 We included Kathmandu valley representing larger metropolitan area concept in this study because of the proximity and close commercial, market, and location ties of three districts within this (the Valley captures metropolitan areas of Kathmandu, Lalitpur, and Bhaktapur districts). Moreover, it is not uncommon to refer "Kathmandu Valley" for common larger metro area in studies and communication.

4 Qualtrics (https://www.qualtrics.com/) is one of the leading platforms in electronic and offline survey questionnaire design and response data collection

short run. However, one should internalize the implications and consequences of food not being safe and its connection to food security. Food is not wholesome if it is not safe—this brings us to the notion of "there is no food security without food safety" (FAO, 2019a), or "food safety is food security" (UNSCN, 2019) in maintaining sustainable food systems.

A sustainable food system should provide food security and deliver nutrition for all in such a way that the economic, social, and environmental bases are not compromised for future generations (FAO, SFS, 2022). United Nations Sustainable Development Goals (SDGs) aim for sustainable food systems. The SDGs, adopted in 2015, call for constructive changes and positive transformations in food and agricultural systems to end hunger, achieve food security, and improve nutrition by 2030. These require the combination of interconnected actions at the local, national, regional, and global levels.

The Food and Agriculture Organization of the United Nations (FAO/UN) estimates in its report – *The State of Food Security and Nutrition in the World 2019* - that 820 million people in the world were still hungry in 2018 (FAO, 2019b). The situation highlights the emphasized needs and importance of the hunger eradication agenda of the United Nations' SDGs. This requires proper approaches to improve the current food systems (El Bilali et al., 2019; Panait et al., 2020). The FAO estimates an average of 600 million cases of foodborne illnesses annually (FAO, 2019a; FAO, 2019b, FAO, 2020) and 420,000 deaths associated with contaminated food (FAO, 2019a). Food safety is an integral part of the SDGs (FAO, 2019a; FAO, 2019b). Particularly, addressing SDG goal 2 of ending hunger with secured food and nutrition in sustainable agricultural systems is only achievable when available food is safe for consumption. Unsafe food represents a global threat to both human health and economies and obstructs the goals of sustainable food systems. However, research in food safety as a part of sustainable food systems has been just emerging in developing countries.

3.1.2 A review of historical development and current policies and efforts on food safety in Nepal

The institutional initiative on regulating food safety in Nepal began after the establishment of the Department of Food in 1961. However, regulation of food safety in Nepal began in 1966 by enforcing the Food Act (Pant, 2007). This is followed by the Food Regulation of 1970 and the formulation of the Food Safety Policy in 2019. Traditionally, food safety regulations were based on inspecting and analyzing end products (FAO, 2009; Singh, 2005). Current efforts are aimed to replace traditional approaches by ensuring total quality management and 'farm to fork' holistic approaches, which focus on all levels of production, processing, transportation, and trading (Singh, 2005). Additionally, the attention to the requirement for international

markets and provisions and thus the initiation of government's regulations on food safety started after Nepal's WTO (World Trade Organization) membership, especially on sanitary and phytosanitary (SPS) requirements (Pant, 2007).

Nepal's five-year periodic plan started to give importance to the agriculture sector in 1956. However, efforts to adopt policies related to food insecurity started mainly from the Agricultural Perspective Plan of 1995 to 2015 (APP, 1995-2015). Likewise, the tenth periodic plan (2002-2007), the first three-year interim plan (2007-2010), and the second three-year interim plan (2010-2013) supported and introduced a long-term vision for food security. The Food and Nutrition Security Plan (FNSP), 2013 supported the government's initiatives in quality and nutritious food.

In the context of Nepal's commitment to zero hunger challenge initiatives introduced by the Rio+20 conference on sustainable development to end hunger, food insecurity, and malnutrition by 2025, Nepal should equally emphasize food safety measures (FAO, 2015). However, the initiatives in Nepal towards food chains have focused less on the quality of the produce. Besides, the Nepal government's long-term Agricultural Development Strategy (2013-2023), and Multi-sector Nutrition Plan (2013-2022) have not emphasized well on the food safety regulations. However, the third three-year interim plan (2013-2016), National Food Safety Policy (2019), and the recent 15th five-year periodic plan have importantly discussed the consideration of food quality and food safety-related issues (MOALD, 2019; NPC, 2019).

The Constitution of Nepal (2015) has enshrined the right to food as a fundamental right for its citizens. Even after the endorsement of regulations like the consumer protection act by the government of Nepal, fresh produce like vegetables and fruits available in the market are unsafe (Prasain, 2020). Adequate implementation of new policies, regulations, and approaches are questionable with the lack of strict monitoring and feedback mechanism. Moreover, there have been repeated incidences of sickness outbreaks from food consumption at formal parties, social events, festivals, and restaurants (Aryal, 2022). Major issues in food safety in Nepal are microbiological and chemical hazards and surveillance of foodborne diseases which are associated with contaminated water with *E. coli* and other pathogens (Koirala & Tamrakar, 2010). Nepal's structural and institutional reforms and initiatives for self-reliance on agricultural produce, and consumer awareness of food hygiene demand for a change in the existing food safety policy. Further, the changing international food safety context also realizes the need for food safety policy reform.

On one hand, organizations involved in the food supply chains lack efforts to establish and implement food safety and quality assurance in Nepal. On the other hand,

government authorities have limitations in monitoring, control, and support mechanisms in implementing food safety assurance in food supply chains (Khanal, 2021). Moreover, food safety policy should also address the awareness needs of consumers on food hygiene and nutrition and appropriate inspection systems from farm to consumers. The new food safety regulations should capture the essence of the Plant Protection Act 1972, the Black Marketing Act 1975, the Competition Act 2007, the Consumer Protection Act 1997 and the Essential Commodities Act 1961 and similar to have provisions for protecting consumers from unhealthy and unsafe foods.

Women's knowledge and preference related to the selection and preparation of food are critical for household-level food safety. This importance of gender roles should be streamlined in agriculture and nutrition programs that address food safety and health risks. The Food Act (GoN, 1967) and the Consumer Protection Act (GoN, 1998) aim for food safety and consumers' rights. However, the Food Act has no specific provision to maintain gender-balanced or gender-inclusive voices or responses. The Consumer Protection Act has provisions for two women representatives nominated for the Consumer Council.

Recently, the House of Representatives of Nepal has endorsed the proposal to consider the bill to revise the Food Purity and Quality Act (Ghimire, 2023). The new Act should address the ambiguities of the role and responsibilities of the three tiers of government for the effective implementation of food safety regulations and should envision addressing the current gaps as mentioned above. Nepal is making efforts on food safety as an emerging need with new safety standards through the amendment of existing policies (Prasain, 2023).

3.1.3 The gender-based decision in the households of developing countries and Nepal

A plethora of literature focused on developing countries supports that women generally play an active role in many aspects of family and households, particularly meeting the family's basic needs for food, water, and fuel; women are also heavily occupied in crucial tasks but often unpaid and under-recognized (World Bank, 2015; Safilios-Rotschild, 1980; Accati, 1983; Safilios-Rotschild, 1983; Waring, 1997).

Women and men support each other at home and community levels in the aspects of household management and different activities involving food and agriculture. However, women have distinctly more significant roles than men in ensuring nutrition, food safety and quality (Gender and Development Plan of Action (fao.org), accessed 2022). In Nepal, women are primarily responsible for preparing and processing food for their households and spend considerable time in marketing activities related to food. Thus women can have vital roles to ensure food safety (Gender and Development Plan of Action (fao.org), accessed 2022).

KC (2021), in his study, reported that women are an integral part of the household activities such as cleaning, washing, preparation of meals, and marketing in Nepal. They have a major role in the food, nutrition, water, hygiene and consumption decision of families and children. Also, women and girls are primarily responsible for water-related work in Nepal (KC, 2021).

Gender roles, reflected in the tasks and responsibilities, is generally referred to how males and females decide, think, and feel according to norms and traditions and sometimes meet expectations and identities associated with being male or female in a certain society (for example, see: GESI, Nepal 2017; ASDP- GESI Strategy, 2021, FAO, 2011).

3.1.4 Potential Roles of Women in sustainable food systems in Nepal

Women are active participants in food systems as they are represented in every step and stage with a significantly important proportion as farmers, producers, workers, processors, distributors, researchers, vendors, food meal planners and makers, as well as consumers. Still, their contributions are often not consistently recognized. Women could be instrumental in the fight against hunger and malnutrition and an efficient contributor to productive and sustainable food systems. Following points discussed in I to III summarize and highlight our review findings in regard to the role of women in sustainable food systems in Nepal.

a. Food safety: Women can play a crucial role in mitigating malnutrition, specifically because they are involved in crop and food production activities and primary decisions on the preparation of food for their families. World Food Conference in 1974, in its resolution VIII, recommended and highlighted "food supporting activities" as important contributors to meeting hunger and nutrition. Women's important roles in childcare and child feeding, and their primary involvement in food preparation for the family, maintaining general cleanliness of stored foods, and marketing of food portray the potential roles women can play directly in maintaining food safety.
b. Agricultural production and food security: FAO (2011) reports that significantly higher percentages of women in Nepal are employed in the agricultural sector than men. Active participation of female labor in agriculture has increased from 36 percent in 1981 to 66.5 percent in 2016 and 57.5 percent in 2018 (CBS, 2014, 2016, 2019)—a higher involvement of females in agriculture than male counterparts. Furthermore, due to the migration of men to urban areas, women are taking on greater responsibilities and tasks in rural areas (FAO, 2010). Rajkarnikar (2020) reported a remarkable foreign labor migration of men from Nepal which has changed the decision-making roles of females. Remarkable male-dominated labor

emigration in Nepal has contributed to increased land abandonment and a decrease in farming (Chaudhary et al., 2020). Additionally, the workload for farms and households has increased for females as farm and household responsibilities are transferred to female members (Pandey, 2021). This phenomenon, also referred to as the "feminization of agriculture" possesses challenges but also creates new opportunities for women in rural areas to lead and contribute. This increased involvement of females as agricultural labour, entrepreneur, or decision-maker in different stages of production and distribution highlights the role that women can play in maintaining safer food systems and contributing to the broader food security goals. However, scholars indicate that the proper documentation of women's major functional roles and contributions to food production and food and nutritional security are underreported (Singh & Ram, 2014).

c. Nutrition of family members: Women's contribution is not only important for the total food supply to the household but also for dietary variation. Discussion and review suggest that women's participation and increased involvement in food chain activities: i) enhances food availability and the type of food entering food chains, ii) enhances family's nutrition as women are likely to give higher priority to the nutritional needs of their families than men, and iii) when women have higher access to the food and related cash, these resources are likely to be used for food consumption in the household and in enhancing nutrition for small children (ACC/SCN, 1989).

3.2 Food Safety Awareness on Fresh Produce Consumption: Gender-based Findings from a Primary Survey

In this section, we present and discuss our empirical findings on gender-related questions from the primary survey of 604 consumer households representing five major metropolitan areas of Nepal. Considering the food safety sensitivity and the focused agricultural commodities of the funding agency in Nepal, we specifically chose fresh produce consumption and purchase in this study. Fresh produce typically includes fresh vegetables and fruits. Fresh produce is sensitive to food safety as they are prone to both microbiological and chemical contamination.

Table 1: Descriptive demographic information of the respondent

Respondent characteristics	Frequency (number)	% sampled household
Gender: Male	285	47.19
Gender: Female	312	51.66
Gender: Other	2	0.33

Respondent characteristics	Frequency (number)	% sampled household
Respondent is the household head: yes	374	61.92
Respondent is the household head: no	230	38.08
Location of the respondent's household		
Kathmandu metro	122	20.36
Bharatpur metro	121	19.54
Butwal metro	121	20.03
Pokhara metro	120	19.70
Hetauda metro	120	19.87

Specifically, the salad vegetables and fruits that are typically consumed raw are more sensitive to food safety standpoint and microbiological contamination. With their higher sensitivity to quality deterioration, unsafe fresh produce can lead to higher foodborne illnesses. Food contamination is among the most common routes for transmission of *Salmonella spp.* and *Campylobacter spp.* (Jorgensen et al., 2002; Goncalves-Tenorio et al., 2018) and fresh produce is a principal source of foodborne illness outbreaks implicating toxin-producing *Escherichia coli*, *Salmonella*, *Listeria*, and human parasites (Callejon et al., 2015). Table 1 presents descriptive selected demographic information of the respondent in our sample. Among 604 complete survey responses, 52% were female respondents and 47% were male respondents representing consumer households sampled in nearly the same proportion from 5 metropolitan areas (around 120 households from each). Table 1 also shows that 62% of these respondents identified themselves as the head of the household.

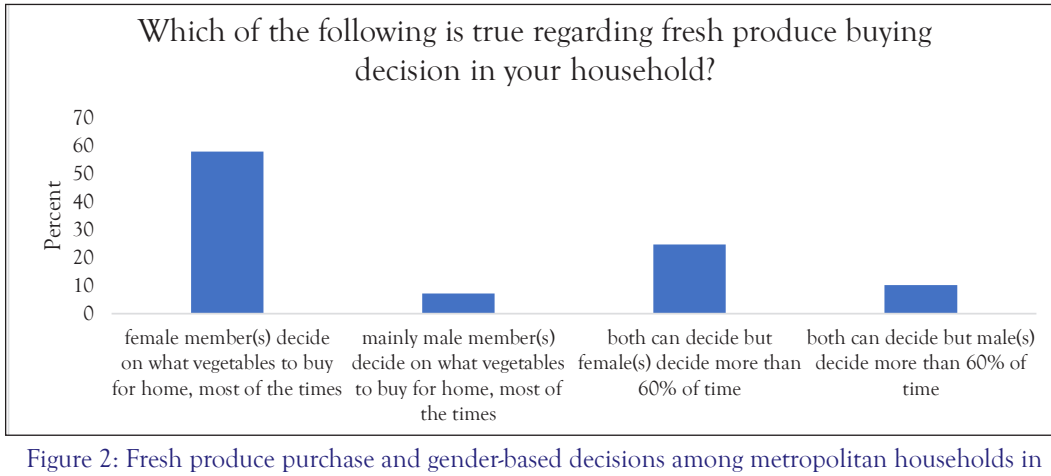

Figure 2: Fresh produce purchase and gender-based decisions among metropolitan households in Nepal, Source: primary survey, 2022

Figure 2 shows the household-level decisions on fresh produce (what and where to buy) by gender, among metropolitan households in Nepal. Our results suggest that females in the household are primarily the decision makers on fresh produce: 58% of the sampled households indicated that females in the household decide on what vegetables to buy for the household, most of the time while only 7% indicated mainly male members decide on what vegetables to buy, most of the time. It is also interesting to see the response to the other two options to affirm the mix or extent of decision-making on this. Note that 25% of the sampled households indicated "both can decide but female(s) decide more than 60% of the time" while only 10% indicated "both can decide but male(s) decide more than 60% of the time." Together, we see that female member of the household is dominantly the decision maker in fresh produce purchase decisions in 83% of the households in metropolitan areas. A male member of the household is the primary decision maker in fresh produce purchase only in 17% of the households.

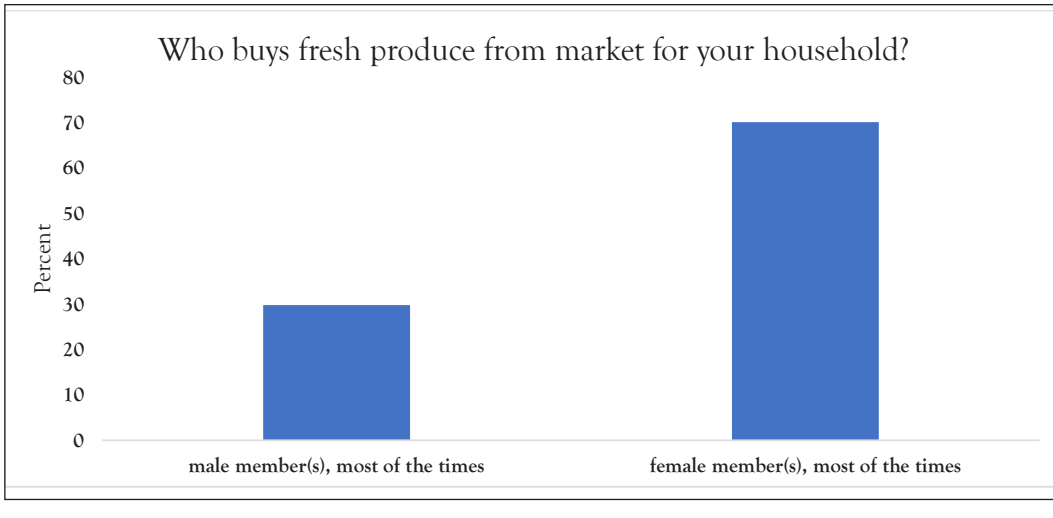

Figure 3: Gender roles in fresh produce purchase from the market, Source: primary survey, 2022

Figure 3 shows the gender roles in fresh produce purchases from the market. This question is related to the actual purchase or buy activity from the market or marketplace. It intends to capture the selection and choice, which typically involves the buyer's consideration or judgment based on a set of attributes of a commodity and/or market. Our result (figure 3) shows that female members are involved in purchasing fresh produce from the market for the vast majority of households. Female members are involved in fresh produce buying activity in 70 percent of the sampled

households while male members are involved in the same activity in 30 percent of sampled households.

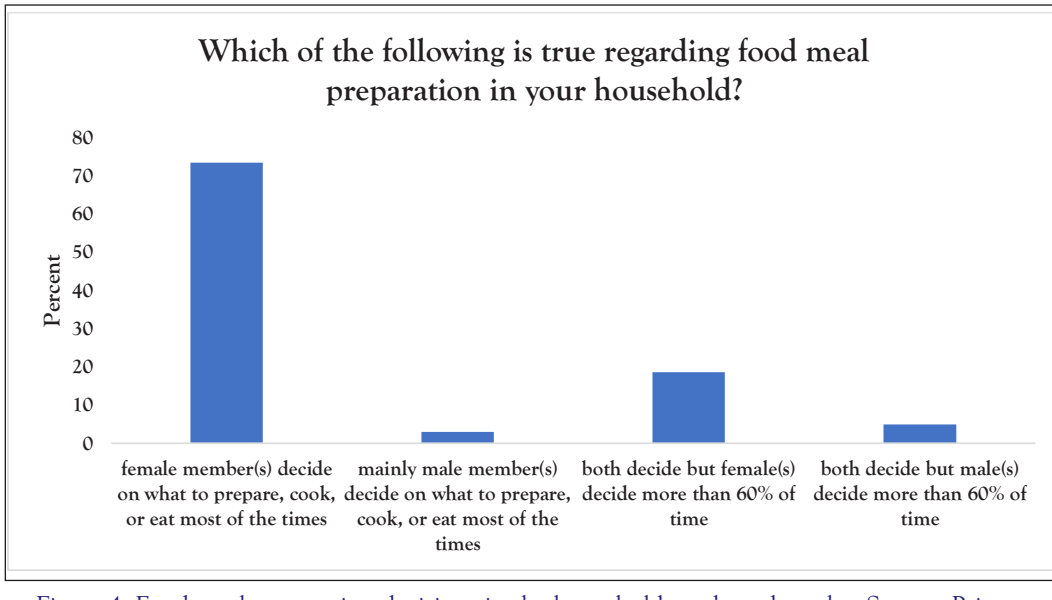

Figure 4: Food meal preparation decisions in the households and gender roles, Source: Primary Survey, 2022

Figure 4 shows the gender roles in food meal preparation, intending to capture the decision and access related to food meal preparation in the households. Our results show that a remarkably higher proportion of the sampled households, 73 percent, indicate that "female members decide on what to prepare, cook, or eat most of the time" and 19 percent indicate "both decide but female(s) decide more than 60% of the time." This suggests that females have strong and dominant roles in decisions related to food meal choice, preparation, and cooking in households.

Clearly, the findings shown in Figures 2, 3, and 4 suggest that women are dominantly the decision maker in fresh produce purchase, shopping, and food meal preparation in households. This also indicates that the women's choice decisions in the fresh produce market as well as their decisions in food meals, guided by awareness, could potentially drive the food safety and nutrition-related aspects in the household and communities. Next, we present our findings on awareness levels of different attributes and the differences by gender.

Table 2: Level of perceived importance on food safety and other attributes in fresh produce by male and female primary buyers, metropolitan households (HHs) in Nepal

Attributes	Primary buyer of Fresh produce in the HH	Level of perceived importance (numbers indicate frequency, expressed as proportionate (%) of the total of that gender)				
	(Male: 180 HHs Female: 424 HHs)	not important (1)	slightly important (2)	moderately important (3)	important (4)	very important (5)
Low price	Primary buyer: Male	20.99	27.07	30.94	14.36	6.63
	Primary buyer: Female	19.01	24.41	28.64	19.01	8.92
Easy shopping access	Primary buyer: Male	7.73	14.92	25.97	32.04	19.34
	Primary buyer: Female	5.40	13.62	23.24	32.16	25.59
Organic product[5]	Primary buyer: Male	1.65	7.69	7.14	13.74	69.78
	Primary buyer: Female	1.41	9.39	10.09	19.01	60.09
Graded and sorted	Primary buyer: Male	20.44	29.28	20.44	19.89	9.94
	Primary buyer: Female	22.82	33.88	19.76	15.76	7.76
Labelled for safely produced	Primary buyer: Male	20.99	16.57	10.50	20.99	30.94
	Primary buyer: Female	32.55	15.93	10.07	15.46	26.00
Labelled pesticide residual free	Primary buyer: Male	18.78	16.02	9.94	12.71	42.54
	Primary buyer: Female	31.22	15.73	8.45	9.62	34.98

Table 2 presents the level of importance expressed by the consumer households on the main attributes of fresh produce. We present frequency results in each attribute and the importance level differentiated by male primary buyer households and female primary buyer households. Note that, consistent with Figure 3, female primary buyer households are those that indicated that a female member of the household is the primary buyer/ shopper of the fresh produce for the household. In our sample, 424 households (70 percent of sampled households) indicated that a female member is a primary buyer in their household. The level of perceived

5 We did not specifically describe word or definition of organic during the survey interviews and let consumers interpret and respond as is by this term.

importance of the attribute is expressed on a scale of 1 to 5: from 'not important' (1) to 'very important" (5). The frequency count numbers presented in Table 1 are proportionate to the total number of responses of that gender. In that, this is weighted by the number of responses on each. We used six important attributes: 'low price', 'easy shopping access', 'organic product', 'graded and sorted', 'labelled for safely produced', and 'labelled pesticide residual free' and were asked to rate each on a scale of 1 to 5.

The proportionate numbers on different importance levels on 'low price' are comparable across male and female primary buyers. For example, 9% of female primary buyers considered low prices a very important factor while only 6% of male primary buyers considered low prices very important. On the other hand, a higher proportion of male primary buyers (70%) consider organic produce a very important factor, as compared to the proportion of female primary buyers (60%). However, easy shopping access is a very important factor for a considerably higher proportion of female primary buyers than it is for male primary buyers—26% of female primary buyers considered it 'very important' while only 19% of male primary buyers considered it 'very important.' Findings presented in Table 2 show that in the case of directly observable attributes like graded and sorted, both male and female primary buyers are consistent in considering it as a 'slightly important factor. Around 34% of female primary buyers and 29% of male primary buyers considered it as a 'slightly important factor. Finally, we considered two factors with direct implications for food safety: the indication of safely produced (labelled for safely produced) and the indication of chemical toxicity free (tested and labelled pesticide residual free). We found interesting results. In both cases, higher proportions of male primary buyers put these factors as 'very important' than their female counterparts. 31% of male primary buyers as compared to 26% of female primary buyers consider safely produced attributes as a very important factor. On another spectrum, 31% of female primary buyers considered safely produced attributes as 'not important' as compared to 21% of male primary buyers. The results on the attribute pesticide residual free have a similar and even higher extent of difference between male and female buyer proportions. Around 31% of female primary buyers consider pesticide residual free as a 'not important' attribute in fresh produce while only 19% of male primary buyers considered it as not important. On the other hand, the proportion of female and male primary buyers considering pesticide residual free attribute 'very important' is 35% *versus* 43% (Table 2).

Table 3: Food safety-related considerations on fresh produce purchase by male and female primary buyers in metropolitan households (HHs) of Nepal

Signs/ indicators	Primary buyers of Fresh produce in the HH	Extent (numbers indicate frequency expressed as proportionate (%) of the total of that gender)				
	(Male: 180 Female: 424)	Never	Rarely	Sometimes	Very often	Always
Mold growth	Primary buyer: Male	0.55	0.55	0.55	2.20	96.15
	Primary buyer: Female	0.00	0.47	0.00	3.53	96.00
Sign of pesticide residues	Primary buyer: Male	12.71	26.52	14.92	19.89	25.97
	Primary buyer: Female	15.73	30.05	15.73	17.14	21.36
Bug damage, rots	Primary buyer: Male	0.00	2.22	3.33	8.33	86.11
	Primary buyer: Female	0.47	1.88	1.88	6.59	89.18
Potential for microbial contamination	Primary buyer: Male	15.38	32.97	12.09	22.53	17.03
	Primary buyer: Female	18.27	34.19	11.24	20.61	15.69

Table 3 presents the results of how often male and female primary buyers look for important food safety-related factors when buying fresh produce. We included common signs and indicators such as mould growth, a sign of pesticide residues, bug damage and rots, and indicators that are potential for microbial contamination. We asked each respondent on the extent of frequency on a 5-level scale from 'rarely' to' always.' Our findings suggest that most of the buyers (both male and female) consistently 'always' look for mould growth—around 96% of male primary buyers as well as female primary buyers. Higher proportions of male buyers look for whether there are signs of pesticide residuals than female buyers. Around 30% of female buyers, and 26% of male buyers, rarely look for signs of pesticide residuals. However, the highest proportions of both male and female buyers (89% and 86%, respectively) always look for bug damage and rots— which are directly observable factors in fresh produce. Finally, our results in Table 2 show that a seemingly subtle but highly important consideration for indicators of potential microbial contamination is often neglected by both male and female buyers as nearly 33 to 34% of both male and female buyers rarely look for this consideration.

Overall, our results suggest that consumers have limited awareness about the needs and considerations of food safety in fresh produce, specifically on unobservable

potential microbial contamination risks. Additionally, females are relatively less aware of this than males and chemical/pesticide contamination risk is considered slightly more frequently in fresh produce decisions by Nepalese consumers than the microbial safety risk. The limited awareness and the associated limited regulations and monitoring can be considered probable reasons for higher food safety risks in Nepal. Outbreaks originating from the consumption of unsafe food and fresh produce have shown implications of higher degrees and magnitude for the public health risks in Nepal (Bhandari et al., 2019; Sharma, 2015; Prasain, 2020; Poudel, 2021).

4. Conclusion and Recommendation

In this paper, we present our findings derived from a comprehensive literature review and analysis of empirical data. The literature review encompasses three main aspects. First, we discuss the relationship between food safety and its inherent connection to addressing food security and promoting sustainable food systems, specifically focusing on developing countries and Nepal. Second, we examine the historical development and current perspectives on food safety and food security-related policies, highlighting the various efforts and challenges encountered in Nepal. Third, we delve into gender-related discussions, exploring the potential roles and importance of women in food systems, as well as their contributions to food safety and related aspects in Nepal. Using our empirical data based on the primary survey of consumer households and their decisions, we examined food safety awareness, gender roles, and gender differences in the choice of fresh produce attributes in consumption and purchase.

There have been efforts from Nepal's government and other stakeholders on food safety, even though food safety issues still need to be emphasized more as primary concerns in the food system. Our review findings on existing policies and mechanisms suggest that even existing policies and regulations in documents are lacking adequate implementation. These also face limitations in monitoring and feedback systems. We recommend that food system sustainability targets should be ensured with compatible food safety policy fitting it well with the current structural changes in Nepal's government system and maintaining feedback-based revisions from multiple stakeholders. Recently, the House of Representatives of Nepal endorsed the proposal to consider the bill to revise the Food Purity and Quality Act. The new Act should clarify the ambiguities of the role and responsibilities of the three tiers of government for the effective implementation of food safety regulations and should envision addressing the current gaps discussed.

Nepali food culture, food servings, food access and related activities hold women's roles as important risk managers in food consumption, preparation, and processing.

Thus investigating women's knowledge and preference related to the selection and preparation of food is critical for household-level food safety. This emphasizes the importance of gender-sensitive policies in the development of food safety interventions. Our review suggests that women play crucial roles in the food systems in Nepal. Our empirical findings support women's vital roles in fresh produce purchase, food meal preparation, and food-related decisions in households in Nepal. Further, feminization in Nepal's food production system also emphasizes women's vital role in augmenting food safety practices.

Moreover, our empirical findings also suggest that, in the current context, women are less aware than men of food safety-related issues and their importance in Nepal. Considering the roles women could play in food safety but their limited awareness, our study suggests the involvement of women in food safety and sustainable food programs. Therefore, awareness and training programs on food safety, which threaten public health, should emphasize women's participation.

Women's involvement should be emphasized and encouraged in food-related critical management, and decision-making activities, as well as in leadership and entrepreneurship. Formulation of food safety policy considering multiple stakeholders and gender sensitivity should encourage women to be effective implementers and promoters of food safety in sustainable food systems. Overall, in the interface of food safety, sustainable food systems, and women's roles, we recommend four important aspects: a) women's empowerment to emphasize the importance of food safety and roles they could play in food-related activities and decisions, b) awareness of food safety through training and outreach ensuring women participation, c) women-focused programs, enterprise development, leadership, and entrepreneurship in food systems, and d) gender-sensitive policy design, dynamic policy changes with changing government structure and multi-stakeholder feedbacks.

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Authors Contribution

Aditya R. Khanal: Khanal conceptualized and developed the idea and construct research goals, arranged resources and fundings; developed initial methodological framework and survey instruments, verified data, prepared plan and procedure for review process and method applications, prepared the first draft of the empirical analysis, and revised, edited, and finalized the manuscript in multiple levels and rounds.

Rita K. Gurung: Gurung applied the review procedure, assisted in formulation of overarching research goals of the study, undertook comprehensive literature review of main sections and initial draft write-up of the review section.

Ram Hari Timilsina: Timilsina contributed in outlining the research goals and aims, assisted in design of review methodology, assisted and supervised the data collection process and field level management in data collection, and contributed in revising the manuscript during multiple rounds.

Saroj Poudel: Poudel contributed in formulating overarching research goals, assisted in method and process designs, led the data collection process in the field, hired and supervised enumerators to collect data, and contributed in data compilation.

Conflict of Interest

The authors declared no conflict of interest.

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Assessing Food Security Scenario at the Ward Level in Nepal: An Analysis of Caloric Needs from Diverse Crops Based on Location-Specific Factors and Policy Implications

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Abstract

Food security means access to food along with food production and availability to every individual at a reasonable cost according to the calorific needs of people. To assure food safety to 30 million Nepali people, it is essential to utilize every piece of available farmable land in each geographic region of seven provinces. We analyzed individual household food intake, dietary energy adequacy, and nutritional status and needs at the ward level of Nepal. We used a decadal (2010-2020) average food production of different crops per unit of farmable area, and food needs for people living in that ward based on their gender and nutritional requirements to perform various activities in different geographic regions of seven provinces. We assumed three food consumption scenarios: a) traditional practices of meeting dietary needs only from major crops; b) consuming major and minor crops; and c) consuming major and minor crops and meat and fruit products. Our analysis revealed that it is essential for Nepal to implement policies that will encourage crop diversification comprising both major and minor crops and inform the public about the nutritional values of various crops that can be grown utilizing location-specific environments in different geographic regions of seven provinces. Our findings assist in policy instrumentation that will pursue farming communities to supplement their dietary needs with diverse crop products and suggest government set aside some matching funds to encourage remitters, who return to Nepal with knowledge and financial resources, to engage in agriculture. We also argue that crop diversification is needed to assure farm productivity if certain crops fail due to unforeseen environmental calamities.

Keywords: Food security, Nepal, policies, provinces, physiographic regions, major and minor crops

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1. Introduction

Once an exporter of agricultural products till late 1985 (Rai, 2019), Nepal has already faced shortages of food products and imports 20.95 per cent of food needs each year (Bhattarai, 2023). ChartsBin (2023) states that the average energy needs per person globally is 2,780 kcal/person/day. The calorie need per person is not consistent across the world. For example, people in developed countries consume 3,420 kcal/person/day whereas the consumption in developing countries is 2,630 kcal/person/day. Subsaharan African people consume 2,240 kcal/person/day and Central Africans limit their consumption to 1,820 kcal/person/day. Within Nepal, there are disparities in calorific consumption. People performing arduous work need high calorific values as compared to those who perform only white-collar jobs. However, some people must survive on poor-quality food either due to unavailability or due to unaffordability. Simply put, there are disparities in food consumption in Nepal.

The World Bank suggests that an adult with a normal health condition requires an intake of 2,200 calories each day for an active life. The calorie consumption as required depends on the availability of food. Thus, this paper takes an average of all the categories listed in ChartsBin (2023) for the purpose to calculate the average calorific need of Nepali per day and categorizes the food consumption under three scenarios for Mountains, Mid Hills and Tarai regions. The people who live in the Mountain region, in difficult terrains and poorly developed alpine conditions, almost in arctic conditions, and engage in arduous activities, are assumed to need 2,700 kcals/day/person for males and 2,500 kcals/day/person for females. In general, living conditions in the Mid Hills are not as arduous as in the Mountainous regions. However, due to the lack of developmental infrastructure, people still need to do menial jobs. Thus, the energy needs are assumed to be at 2,400 kcal/person/day for males and 2,200 kcal/person/day for females. For the Tarai region, the climatic conditions being sub-tropical and developmental infrastructure being relatively better, the calorific need for males is assumed to be at 2,200 kcal/person/day and 2,000 kcal/person/day (health.gov, 2015-2020) for females (Bhattarai and Conway, 2021; USDA, 2023).

In Nepal, 7.8 per cent of the Nepali population is at risk of a severe food crisis (Khabarhub, 2023; RSS,2023). There have been inequalities in food accessibility in different geographic regions of Nepal (Bhattarai and Conway, 2021). Nepal's 15th five-year plan states that 21 per cent population in Nepal still has no access to sufficient food (NPC, 2023). It states that only 48.2 per cent of households are basically food secure. Many lack quality food. In addition to the natural disasters and climate change impacts, artificial food shortages especially during the COVID-19 period and resulting fluctuations of food prices in the national and international markets have posed

uncertainty in the domestic food supply chain (Bhattarai, 2023). Likewise, the shortage of working human labour due to an exodus of the youth force needed for agricultural activities has also contributed to food security in Nepal (Bhattarai et al., 2020). According to World Food Summit 1996, food security exists when all people always have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. The World Bank defines the situation when the calorie intake remains under 1,800 per day per person as severe food insecurity. Nepal government's data shows that during 2020 (2078-2079 BS), the food production in the country was 369 kilos per person and it was estimated to be 257 kilos after deducting seeds, preservation for animal feed and the loss during the post-harvest stage (RSS, 2022). In the 2020 fiscal year (2078-79 BS), the annual food production in the country was 10 million 772 thousand metric tons and it was around 7,530,000 metric tons by deducing the seeds, livestock preservation and post-harvest stage losses. A recent study suggests that Nepal needs "around 5 million 867 thousand metric tons of processed food to meet the food requirements of its people" (Khabarhub, 2023; RSS, 2022).

Nepal imports a large quantity of food to address its daily demand. The consumption of fine-grain rice is on increasing trend, but there is a shortage of rice to meet the growing demand (FAO, 2022; Bhattarai and Conway, 2021). In some cases, the consumption of crops like millet, buckwheat and potato have been ignored despite their contributions to food and nutritional shortage as well as their importance to meet various micronutrients needed for humankind. Recently, however, some successful examples have been observed in some communities in Nepal and India to diversify crop production through the provision of matching funds to farmers (Gurung, 2016; Jain 2023) for growing minor crops to meet the demand for food.

There has been a growing trend of food demand with specific dietary cases – for instance, plant-based food for vegetarians (Malla, 2019) and also for those who try to avoid the meat base product despite the increasing trend of meat consumption with an increase in purchasing parity (Sitaula, 2021). We have assessed food security conditions based on both plant-based, mixed plant-based, and meat-based scenarios (USDA, 2023a; USDA, 2023b). Nepal's government claims that the country is self-sufficient in fish, meat, and egg while it is close to meeting the need for milk and meat. Improved irrigation facilities, availability of improved varieties of seeds and breeds and modernization in farming have helped improve productivity and the commercialization of agro-based products (The World Bank, 2019). However, the mass exodus of about 1,500 -2,000 working-age people each day has marred different agricultural activities in Nepal (Bhattarai et al., 2020). Since the issue of food security is not only linked to human security but also overall development, it is essential to

improve agricultural production and retain Nepal's working-age people within Nepal (Bohara, 2023). To retain the working age people within the country, "food becomes the basic requirement because it helps in maintaining a balance in quantity, price, and supply chain assuring every person to have physical and economic access to healthy and nutritious food as per individuals' needs" (UNHR & FAO, 2010).

The contribution of Nepali agriculture to its total GDP has decreased to 25 per cent in 2021 from 32 per cent in 2011/2012 (Dhakal, 2022). Almost "4.6 million Nepali people are food-insecure, with 20 per cent of households mildly food-insecure, 22 per cent moderately food-insecure, and 10 per cent severely food-insecure" (USAID, 2019). The situation is much more severe in rural areas of Nepal in general and Karnali Province in particular (Bhattarai and Conway, 2021). As a result, over "40 per cent of Nepalese children younger than five years of age are stunted and 10 per cent suffer from wasting due to acute malnutrition. Pregnant and lactating women (PLW) also suffer from malnutrition, as well as micronutrient deficiencies. Approximately 1.4 million PLW are malnourished, and 48 per cent suffer from anaemia" (USAID, 2019).

The COVID-19 global pandemic and the Russia-Ukraine war have impacted the food grain supply chain in Nepal. Even though the Nepali Constitution Section 3 Article 36 and Section 4 Article 51 rhetorically stress the food guarantee to every Nepali individual, food insecurity still affects more than half of Nepal's people. As a result, many people suffer from nutrition and micronutrient deficiencies. Over a quarter of children are underweight, and more than a third are stunted (Bhattarai and Thapa, 2022; Diao et al., 2022; WHO, 2021). The contrasts, however, are that several people suffer from anaemia, especially, women and children under five years old, while some suffer from increasing obesity and overweight in urban areas, especially, due to the consumption of fatty food (Timsina and Chowhan, 2023). Despite the fact that domestic production falls short of the population's dietary needs, the use of some cereal crops such as buckwheat, millet, barley, and potato are not considered as important as rice, wheat, and maize are, and therefore food imports have increased (Subedi et al. 2020). The low productivity of sloppy lands and inadequate infrastructure to improve land productivity have compelled many people to consume foods having low nutritional values. Even if many exuding people desire to live in Nepal, the lack of irrigation and infrastructure facilities, changing climate with erratic rainfall, long droughts period, and loss of soil fertility have further undermined food production (Liu et al., 2023) challenging the demand for adequate food.

Though food needs vary for different age cohorts and genders in different geographic regions based on their engagements in various types of activities, the scope of this article, however, is limited to the analysis of food security estimation based on gender for

different geographic conditions. Nevertheless, the database can also be used to estimate food requirements for different age groups in different geographic regions. In this paper, we assess the food sufficiency/deficiency at each ward of municipalities of various districts in different geographic regions of seven provinces. Moreover, this paper is mainly on food security based on the secondary data available from the Census Bureau of Statistics (CBS) and focused on the policy instrumentation based on the consumptive scenarios. Since the consumptive scenarios cannot be addressed without considering the land availability, we have focused on location-specific issues such as the types of crops grown and produced at the individual ward level of each village and municipal unit.

The paper first briefly presents the theory of food security, followed by the materials and methods. Then it analyzes food security scenarios using three models.

a. **Model A** food security scenario with the consumption of major crops such as maize, wheat, pulses, rice, milk, and fruit.
b. **Model B** consumption of major and minor crops such as millet, buckwheat, pulses, fruit, potato, and milk consumption.
c. **Model C** consumption of major, minor, milk, pulse, potato, fruit, egg, and meat.

Finally, this paper presents a discussion focusing on policy instrumentation for agricultural transformation in Nepal followed by a conclusion and recommendation.

2. Theory of food security:

The theory on food security emphasizes the need for guaranteeing the quality of food at every place on the earth to every individual at all times in all geographic regions that is economically affordable irrespective of race, socioeconomic conditions, ideological, religious, and political affiliations. To be more specific, Neo-Malthusian analyzes food insecurity from the perspective of food production; the techno-ecology theory sees food insecurity as being caused by improper and inadequate technology and human power; the modernization theory sees food insecurity as being the result of the lack of will of countries to use the most advance technology to enhance food production system; the dependency and the world system theory views food insecurity as a byproduct of world trade imbalance and politicization in the distribution of food resources; the urbanization theory assumes the root cause of food insecurity is due to rural and urban divide weakening the functional relationships between them; the social stratification theory argues food insecurity results due to social stratum; and the militarization theory states that food insecurity results when food is used as a weapon of war.

Though several superfood stores have been established in many places in many countries to help improve the food supply chains, none have guaranteed the supply chain. Climate change and environmental problems and the war in Ukraine have

created a shortage of food causing various health problems on one hand and increasing obesity on the other. In such environments, traditional agriculture practices will not be able to feed the growing population. It is time to switch to sustainable farming practices by engaging every individual to utilize the available land resources to grow new food sources while blending both indigenous and modern knowledge to improve the global food chain. In the case of Nepal, it is high time to think about the neglected micro crops such as barley, millet, potato, quinoa, grams, chickpeas, and others that contain micronutrients that are not available in major crop products such as rice, maize, and wheat and fulfil nutrient needs of people in different geographic regions. Barley, buckwheat, quinoa, and millet are considered pseudo-grains in Nepali society. Food products from these pseudo-grains have occupied precious positions in food items/chains in many five-star hotels after knowing their values that contain high micro-nutrients. Since these pseudo-grains require fewer fertilizers and can grow on inferior lands, Nepal can capitalize on their products to meet food needs.

Blending modern technology with traditional/indigenous knowledge helps to grow food on locally available land areas. Growing food locally helps in saving energy and emissions by avoiding long-distance hauling. It also makes farmers self-sufficient. The pseudo-grains like Kauno, millet, and buckwheat can be grown in different parts of Nepal that can grow in location-specific soil and microclimatic conditions. The positive aspects are that these crops grow even under climatic change conditions with the minimum amount of water and can supplement the food need with micronutrients. They are more resilient and better suited to new climate conditions. After all, farming is thinking about new generations. White revolution (increasing the production of milk through modern breeding) and increasing meat production not only will help in the circular economy but also will help in reducing trade deficits by reducing the import of packed food such as milk and meat products in rapidly urbanizing Nepal.

3. Materials and Methods

This paper assesses food security scenarios at the 6,618-ward level of 753 local political units of Nepal. It takes the population base of 2021 at each ward level. Agricultural lands were computed from 2021 Sentinel-2 at 10 x 10 m land use data available on the Esri website (https://www.arcgis.com/). Linking the population from the census record of 2021 to each ward level, we calculate the calorific needs of the population at each ward level based on their gender living in different geographic regions, such as Mountains, Mid Hills, and Tarai regions of six provinces[1] of Nepal (Fig. 1). It estimates food security conditions under three consumption scenarios. These

1 Madhesh Province is limited to the Tarai region. In this province food needs are assessed based on the subtropical climatic conditions where people involve in various activities partially using machineries because of its proximities to all weathered roads on mostly plain areas.

consumptive criteria include a) major crops such as maize, wheat, barley, pulses, rice, and milk; b) major and minor crops such as millet, buckwheat, pulses, potato, and milk; c) major, minor crops, milk, pulse, potato, and meat.

Land cover data for the year 2021 were extracted from global land cover Sentinel-2 surface reflectance at 10 m x 10 m resolution. These data were obtained from the Esri website (https://www.arcgis.com/) for UTM Zones 44 and 45 N. Satellite images were classified using a deep learning model that used over 5 billion hand-labelled Sentinel-2 pixels sampled from over 20,000 sites distributed across all major biomes of the world. Using a shapefile, only portions of Nepal's land use and cover datasets were extracted for the year 2021. Demographic information was obtained from the Central Bureau of Statistics (CBS) and the Election Commission, Nepal. The ward-level shapefile was obtained from the Ministry of land reform.

3.1 Methods

All demographic information was linked to the shapefile of Nepal with ward-level spatial information. Each ward was linked to available agricultural lands based on slope classes divided at 5 degrees intervals such as 0-4.99, 5-9.99, 10-14.99, 15-19.99, 20-24.99, 25-29.99, 30-34.99, 35-39.99, and 40 and above for the year 2021. Areas within 10 degrees slope and at the 5 km vicinities to the major rivers are considered as irrigated fields and others were considered semi-irrigated and rainfed agricultural land to grow different types of crops, but not irrigated paddy. Nutritional values for each crop were computed as in Table 1 to calculate the nutritional values available from different agricultural crops per unit of land.

Table 1: Crops grown in different regions, their calorific values and sources.

Crops	The geographic extent of production (Percent of agricultural land areas used to produce crops based on slope classes)	Nutritional values	Source
Maize	Tarai (65%) Mid Hills (100%) Mountains (50%)	1 ton = 3251595 calories Maize contains 10% husk.	Based on land use slope classes and CBS records. NIH: National Library of Medicine.
Wheat	Tarai (65%) Mid Hills (70%) Mountains (45%)	1 kg grain = 950 grams flour. 1 ton = 3083800 calories. Wheat contains 5% husk.	Based on land use slope classes and CBS records. WWF, QUORA. Traditional Oven (2023a)

Crops	The geographic extent of production (Percent of agricultural land areas used to produce crops based on slope classes)	Nutritional values	Source
Rice	Tarai (95%) Mid Hills (35%) Mountains (20%)	186 grams = 242 calories 1 gram = 1.31 calories 1 ton = 1180488 cal. Rice contains 72% rice and 28% husk.	Based on land use slope classes and CBS records. Rice Knowledge Bank. Verywellfit. IRRI Kit.
Millet	Tarai (15%) Mid Hills (60%) Mountains (70%)	1 ton = 1079017 calories Millet contains 10% husk	Based on land use slope classes and CBS records. Healthline, WebMed
Buckwheat including quinoa	Tarai (15%) Mid Hills (65%) Mountains (70%)	1 ton = 3111644 calories Buckwheat contains 15% husk.	Based on land use slope classes and CBS records. fatsecret. Good House Keeping. Fischer (2023).
Barley	Tarai (45%) Mid Hills (65%) Mountains (55%)	1 ton = 3208966 calories Barley contains 15% husk.	Based on land use slope classes and CBS records. Traditional Oven (2023b)
Potato	Tarai (45%) Mid Hills (65%) Mountains (70%)	1 ton = 680250 calories Potato contains 17.5% waste	Based on land use slope classes and CBS records. healthline
Pulses	Tarai (45%) Mid Hills (65%) Mountains (70%)	1 ton = 2670752 calories On average pulses contain 2% husk.	Based on land use slope classes and CBS records. Pulses and Nutrition
Milk	2.5 litres/household	1 liter = 628.98 calories Varies from sources such as cow, buffalo, goat, and yak. (Average is taken)	CBS records. INCHCALCULATOR, Nutritional Value of Milk, WebMD

Crops	The geographic extent of production (Percent of agricultural land areas used to produce crops based on slope classes)	Nutritional values	Source
Egg	0.25 eggs/household	1 egg =210 calories	CBS records, COVER CREEK FARM. Sparacie (2019). Onyenweaku et al. (2016)
Meat production	1.25 kg /household	1 kg meat = 2,500 to 3,500 calories	CBS records, COVER CREEK FARM, Our World in Data. Sparacie (2019).
Oil seed	Tarai (55%) Mid Hills (65%) Mountains (30%)	1 ton = 7709500 calories	The Features and Nutritive Values of Common Oil Crops Research Gate. De Lamo and Gomez (2018).
Sugarcane	Tarai (55%) Mid Hills (25%) Mountains (5%)	1 ton = 3401250 calories. Only 70 per cent of the product is usable	FITNigerian

Nutritional values are taken from the table above to calculate the average nutrition that can be obtained from different agricultural products. Nutritional values available from locally grown crops and food needs by everyone at the household level were determined to assess the food security situations under three models as discussed above. The average crop, milk, and meat production information was taken at the district level for a decade (2010 to 2020) from the Ministry of Agriculture & Livestock Development (MoALD, 2021). These values were averaged at the district levels and assigned to each individual polygon of each ward belonging to the municipalities of each district. Using the nutritional values from the above table, we calculated the calorific values for each agricultural product at each ward level. Energy needs for both males and females were computed as in Table 2 for each ecological region.

Table 2: Calorific values needed per person per day by region.

Ecological region	Calories need/day/person	
	Male	Female
Subtropical region (Tarai)	2,200	2,000
Temperate region (Mid Hills)	2,400	2,200
Alpine & artic (Mountain)	2,700	2,500
Average	2433	2233

3.2 3.2 Factors affecting food security situations in Nepal

The population distribution in three geographic regions belonging to six provinces and Madhesh Province belonging to the Tarai region is given in Fig. 1. People living in different geographic regions of seven provinces by gender require different calories. The population distribution in Nepal is not uniform across three geographic regions and across seven provinces as are the caloric needs of the people.

Many people live in the southern part—the Indo-Gangetic Plain. This is followed by the Mid Hills. The least number of people live in the Mountain region (Fig. 1). The agricultural land is more concentrated in the Tarai region followed by the Mid Hills. The Mountain region has the least areas of agricultural land (Fig. 2). Agricultural productivity also is higher in the Tarai region followed by the Mid Hills. Land productivity is very low in the Mountainous region. The elevation ranges increase from south to north (Fig. 3). As the elevation varies, different types of crops are grown at different elevational ranges and in different provinces. Since Nepal receives monsoon rainfall due to the orographic process from the storms originating from the Bay of Bengal, the amount of rainfall decreases from the east to the west and in different places (Fig. 4). Because of the variations in rainfall patterns (Fig. 4) and decreasing temperature from the south to the north (Fig. 5), different types of crops can be grown in Nepal.

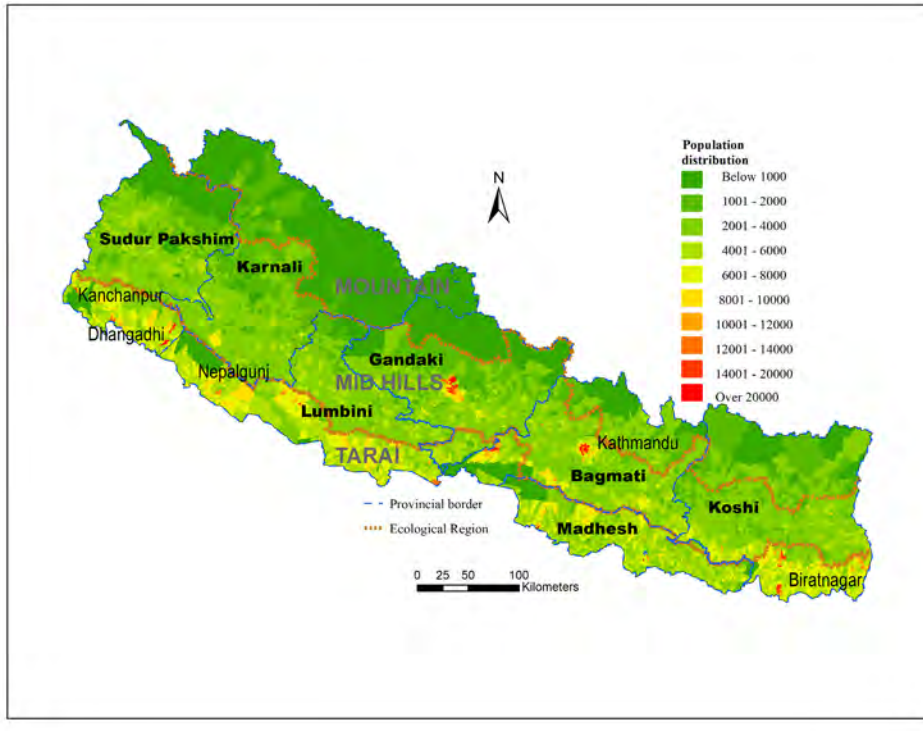

Fig. 1. Population distribution in Nepal based on Census 2021.

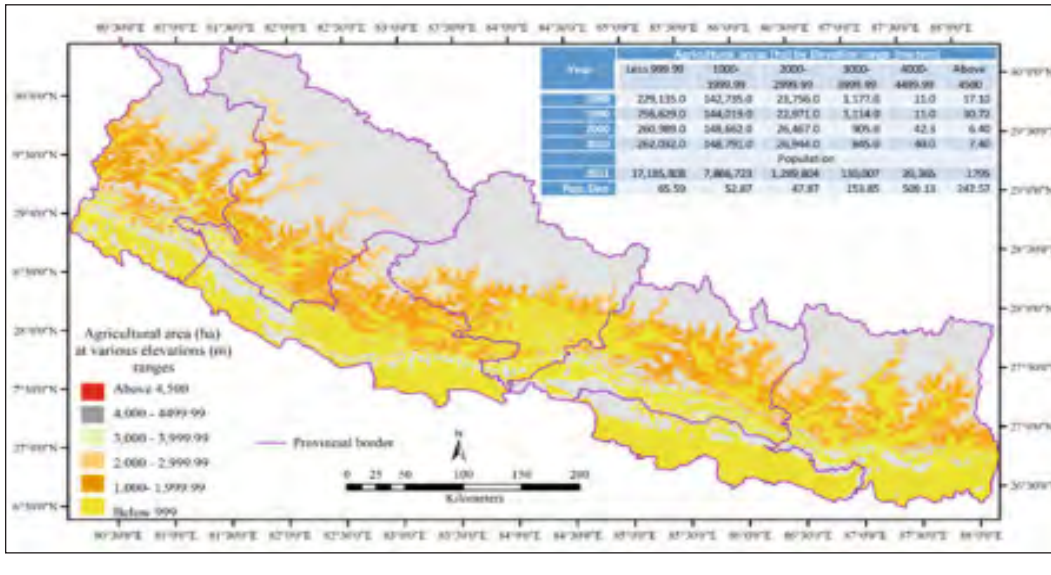

Fig.2. Agricultural land at different elevational ranges (Adapted from Bhattarai and Conway, 2021 with permission from the authors)

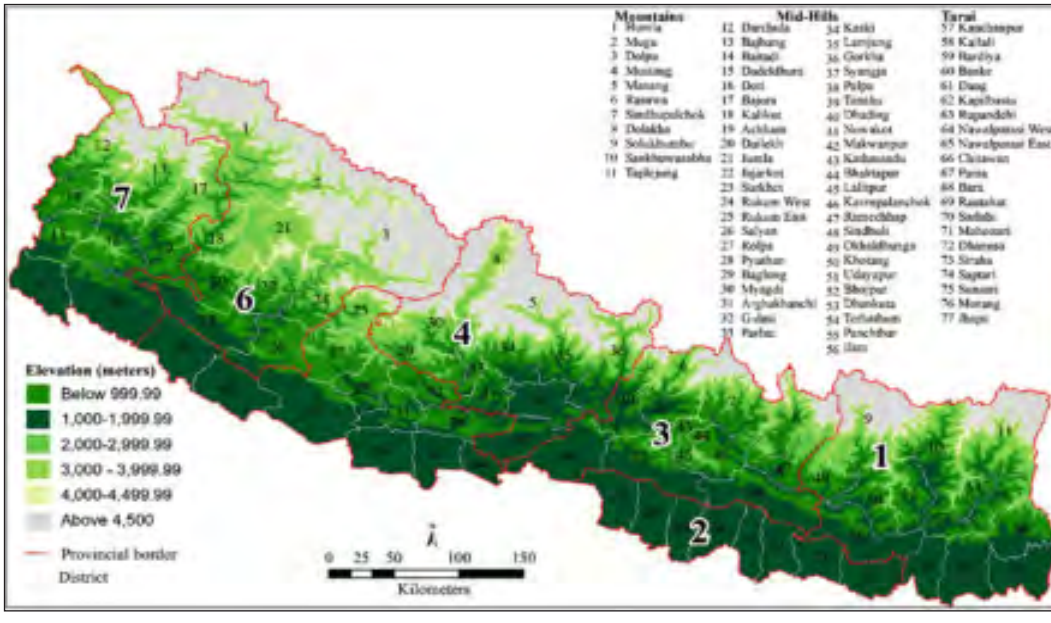

Fig. 3. Nepal- elevation range. [Map adapted from Bhattarai and Conway, 2021—with permission from the authors)

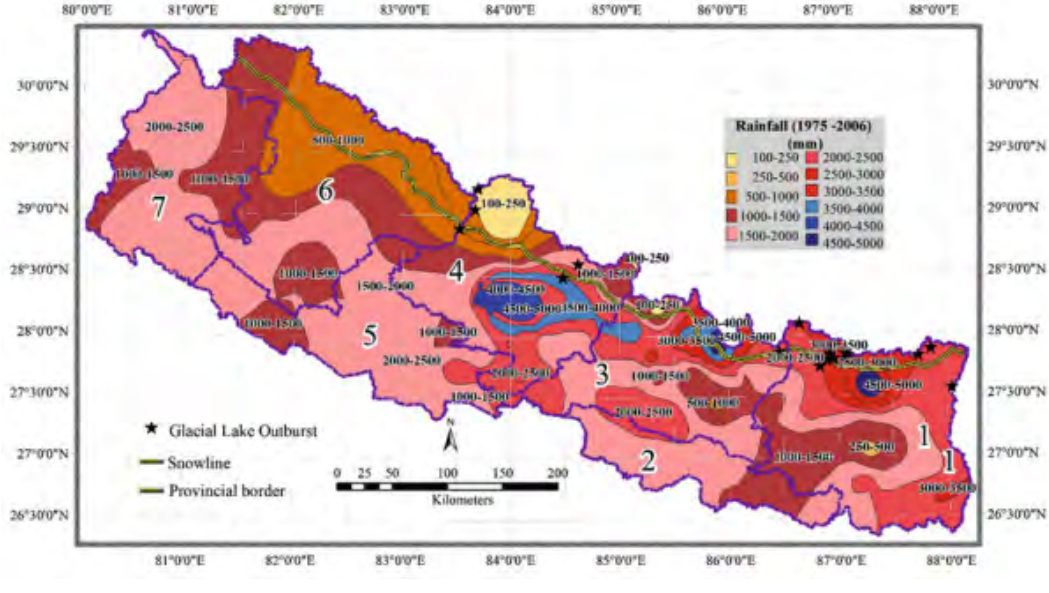

Fig. 4. Rainfall trends in Nepal (1975-2006). Adapted from Bhattarai and Conway with authors' permission.

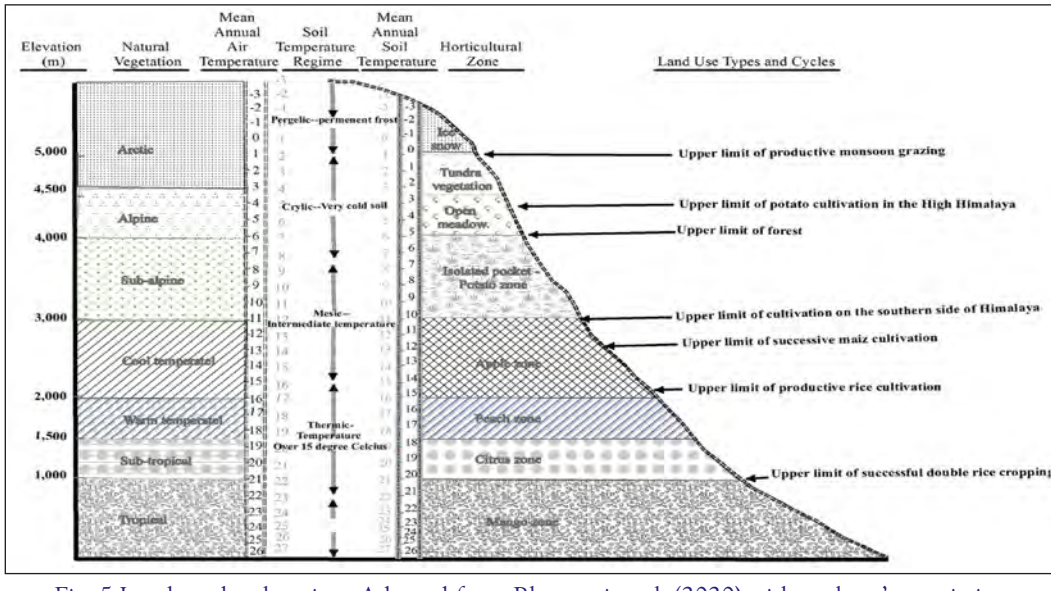

Fig. 5 Land use by elevation. Adapted from Bhattarai et al. (2020) with authors' permission.

The turnover rates of various crops are low in the mountainous region because of the alpine and arctic types of climates. Some areas with low slopes and elevation in the Mid Hills are as productive as in the Tarai region. These areas in the Mid Hills also have perennial irrigation facilities from local streams like in the Altiplanos of the Andean region of South America (Zubieta et al., 2021) despite their higher locations than the Tarai region. In the Tarai region, most of the agricultural areas are irrigated. Due to its subtropical nature, the turnover rate of various agricultural crops grown in this region is higher as compared to most of the Mid Hills region and can support more people per unit area of agricultural land than the Mid Hills and Mountainous region.

According to the Community Irrigation Project (RRP, NEP 38417-02) of the 2.60 million hectares (ha) arable land, 1.80 million ha is irrigated. Of the 1.8 million ha, 1.40 million ha is in the Tarai or plains. "The remaining 0.40 million ha is in river valleys, upland valleys, and terraces on hills and mountains." Almost 70 per cent of the command areas of surface water irrigation infrastructure is irrigated, with only 38 per cent of the agricultural land is irrigated perennially of which 75 per cent of the irrigation is managed by farmers and the government manages only 25 per cent. Shallow tube wells are used in irrigation in the Tarai region since the 1970s. Around 0.25 million ha is irrigated by groundwater in the Tarai region (ADB, 2009). Irrigation has helped to boost crop production and diversification.

We have taken these factors into consideration while evaluating the food security conditions in different geographic regions belonging to seven different provinces of Nepal.

4. Results

We have estimated the food security scenarios under three food consumption practices. Table 3, and presented the areas that face food scarcity in Figures 6, 7, and 8. It is assumed that maize is grown in 65 per cent of the agricultural land in the Mountainous region, 80 per cent in the Mid Hills and 55 per cent of agricultural land in the Tarai region.

Model A: Consumption of major crop such as maize, wheat, pulses, rice, potato, and milk.

a. **Model A**: Consumption of major crops produce such as maize, wheat, pulses, rice, and milk.
b. **Model B:** Consumption of major crop produce as in Model A (above) and minor crops such as millet, buckwheat, pulses, potato, and milk.
c. **Model C:** Consumption of major and minor crop produces (as in Models A and B above) and egg and meat products.

Table 3: Number of households and people by gender facing food deficits each day to meet their caloric needs per person and per household. The numerator number under the male and female columns are the numbers of males and females that face food shortages. The number in the denominators under the column males and females is the total number of males and females in Nepal. Also, on the household side, the denominators show the total number of households in each province. The numerator numbers represent the households that experience food shortages. Nutritious values are calculated based on Table 1. These nutritious values are taken to determine the calorific needs of both males and females.

Model	Number of people facing food deficit		Number of households facing food deficit each day to meet their required food calorie/day in each province under three models						
	Male	Female	Koshi	Mad-hesh	Bagmati	Ganda-ki	Lumbi-ni	Karnali	Sudur Pashim
Model A (Fig. 6, Table 4, Column 2)	3049257/ 12658606	3181622/ 13619480	38481/ 115069	22236/ 932087	596377/ 1269144	121454/ 584896	132594/ 881706	124715/ 300564	147522/ 469703
Model B (Fig. 7, Table 4, Column 3)	2954039	3083216	34241	22236	595454	115561	131522	112203	138139
Model C (Fig. 8, Table 4, Column 4)	2933920	3061473	34179	22236	588295	115086	130552	111054	138139

Figures 6 to 8 shows the geographical areas that face food shortages under different models.

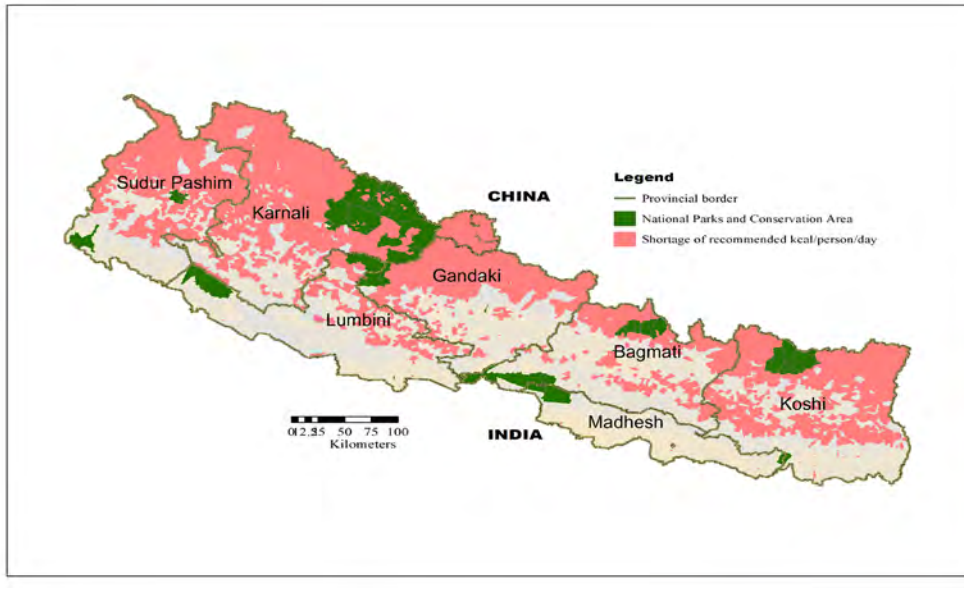

Fig. 6. Areas under scarcity as per Model A consumption of major crop produces. (Names of areas under food scarcity are given in Table 4).

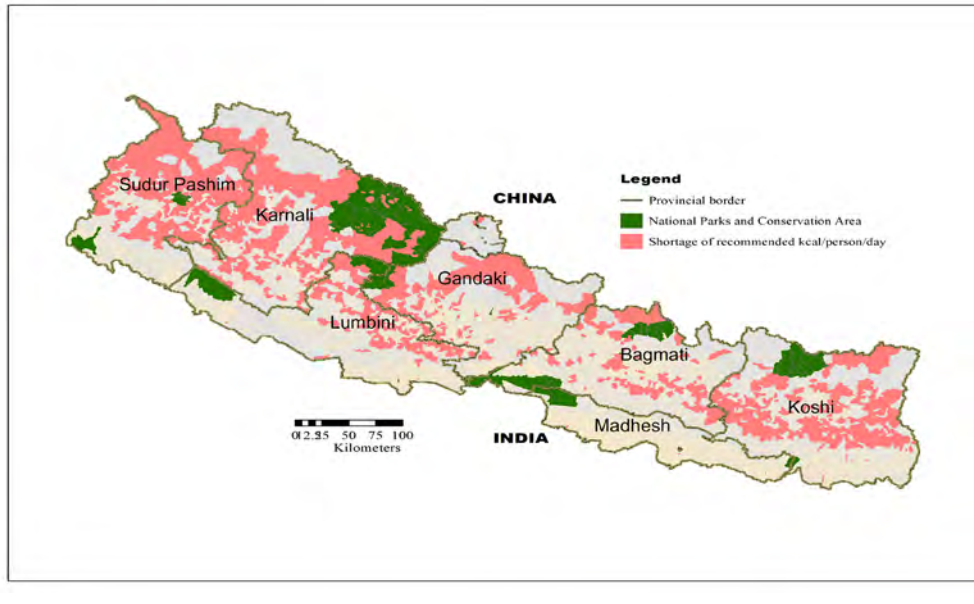

Fig. 7. Areas under scarcity as per Model B consumption of major and minor crop produces. (Names of areas under food scarcity are given in Table 4).

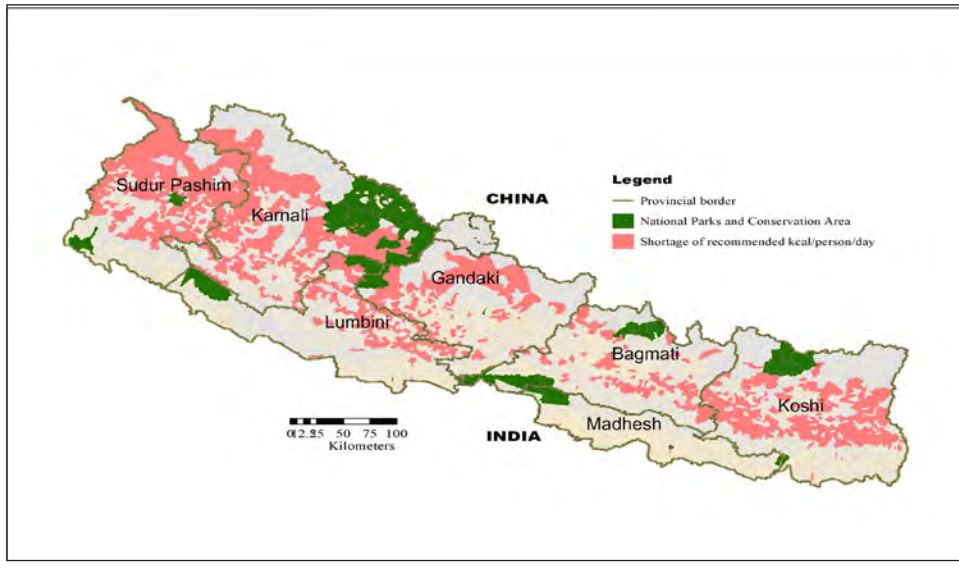

Fig. 8. Areas under scarcity as per Model C consumption of major and minor crop produces and egg and meat. (Names of areas under food scarcity are given in Table 4).

Table 4: Food shortage by provinces, districts and number of wards within the districts belonging to various rural and urban municipalities. The numerator numbers are food deficit wards in the district and the denominator numbers are the total number of wards in that district.

Province	Model A	Model B	Model C
Koshi	Taplejung (41/61), Terhathum (19/43), Udayapur (27/76)	Taplejung (39), Terhathum (10), Udayapur (22)	Taplejung (37), Terhathum (10), Udayapur (21)
Madhesh	Dhanusha (7/169), Parsa (10/114), Saptari (3/165), Sarlahi (2/200), Siraha (1/164)	Dhanusha (7), Parsa (10), Saptari (4), Sarlahi (2), Siraha (1)	Dhanusha (7), Parsa (10), Saptari (3), Sarlahi (2), Siraha (1)
Bagmati	Bhaktapur (18/34), Chitwan (4/99), Dhading (10/104), Dolkha (9/74), Kabhrepalanchok (31/135),	Bhaktapur (18), Chitwan (4), Dhading (9), Dolkha (7), Kabhrepalanchok (31),	Bhaktapur (18), Chitwan (4), Dhading (9), Dolkha (6), Kabhrepalanchok (30),

Province	Model A	Model B	Model C
	Kathmandu (101/138), Lalitpur (39/71), Makwanpur (7/104), Nuwakot (6/90), Ramechhap (29/64), Rasuwa (16/27), Sindhuli (15/79), Sindhupalchok (15/109).	Kathmandu (99), Lalitpur (39), Makwanpur (5), Nuwakot (6), Ramechhap (26), Rasuwa (12), Sindhuli (15), Sindhupalchok (7).	Kathmandu (100), Lalitpur (37), Makwanpur (5), Nuwakot (6), Ramechhap (25), Rasuwa (12), Sindhuli (14), Sindhupalchok (6).
Gandaki	Baglung (35/86), Gorkha (11/94), Kaski (23/83), Lamjung (16/75), Manang (25/28), Mustang (18/25), Myagdi (20/46), Nawalparasi East (6/93), Parbat (13/61), Syangja (19/97), Tanahu (6/85).	Baglung (35), Gorkha (10), Kaski (14), Lamjung (16), Manang (24), Mustang (16), Myagdi (20), Nawalparasi East (6), Parbat (12), Syangja (19), Tanahu (6).	Baglung (35), Gorkha (9), Kaski (14), Lamjung (16), Manang (23), Mustang (11), Myagdi (20), Nawalparasi East (6), Parbat (13), Syangja (18), Tanahu (6).
Lumbini	Arghakhanchi (25/61), Banke (6/81), Dang (2/100), Gulmi (44/93), Palpa (35/81), Nawalparasi West (1/74), Pyuthan (20/64), Rukum E (15/47), Rolpa (20/72), Rupandehi (15/156).	Arghakhanchi (25), Banke (6), Dang (2), Gulmi (34), Nawalparasi West (1), Palpa (35), Pyuthan (21), Rolpa (21), Rukum E (12), Rupandehi (15).	Arghakhanchi (25), Banke (5), Dang (2), Gulmi (34), Nawalparasi West (1), Palpa (35), Pyuthan (20), Rolpa (20), Rukum E (12), Rupandehi (15).
Karnali	Dailekh (36/90), Dolpa (55/76), Humla (39/44), Jajarkot (32/77),	Dailekh (36), Dolpa (55), Humla (37), Jajarkot (32),	Dailekh (36), Dolpa (55), Humla (36), Jajarkot (32),

Province	Model A	Model B	Model C
	Jumla (20/60), Kalikot (54/82), Mugu (33/45), Rukum West (29/62), Salyan (18/83), Surkhet (25/99).	Jumla (19), Kalikot (54), Mugu (33), Rukum West (29), Salyan (18), Surkhet (24).	Jumla (18), Kalikot (54), Mugu (33), Rukum West (25), Salyan (17), Surkhet (24).
Sudur Paschhim	Achham (47/92), Baitadi (54/84), Bajhang (73/95), Bajura (48/70), Dadeldhura (13/52), (Darchula (48/61), Doti (28/66), Kailali (4/82).	Achham (47), Baitadi (54), Bajhang (73), Bajura (48), Dadeldhura (13), (Darchula (47), Doti (28), Kailali (4).	Achham (46), Baitadi (54), Bajhang (73), Bajura (48), Dadeldhura (13), Darchula (47), Doti (28), Kailali (4).

5. Discussion and Policy Implications

Many districts in different provinces face food shortages. Within the district, some wards belonging to villages or municipalities are food sufficient while some wards face a food deficit. Table 4 shows the districts and the total number of wards (denominator) and the number of wards (numerator) facing food shortages. Districts with many urban areas face food shortages because urban areas do not produce the required amount of food. These areas need to import food from outside to meet their caloric needs.

Diversifying food consumption may help to improve the situation from food deficient to food sufficient ward. However, at the current rate of growth, there is no significant difference in various districts of the seven provinces that will improve food security situations even with crop diversification. Only a few wards and corresponding households in each district have been able to improve their food security situation with crop diversification that is growing both major and minor crops. Only a few wards are promoted to food sufficiency with crop diversification and consumption of both major and minor crops and meat and other food items such as eggs. Promoting large-scale production of minor and cash crops such as potato and quinoa will help improve the food security situation in Nepal.

The workforce always remains an invaluable asset for a country's economic growth, but food insecurity may obstruct the attainment of socioeconomic well-being of Nepali

people. Despite the fact that the Nepali constitution assures food security to every individual as per Part 3 Article 36 and Part 4 Article 51 of the Nepali Constitution, Nepal has not been able to achieve its food security. Policy instrumentation to pursue people to change eating habits based on the production possibilities of diverse food products that are healthy and nutritious to meet daily calorific needs may help make Nepal become food sufficient. Such adaption of dietary habits would help feed many people while growing food locally without importing much food from outside from long distances. The solution to sustainability and food security should integrate food safety considerations from the start considering what crops are supported by the physiographic conditions in different geographic regions of Nepal. Current agriculture production in Nepal is caught in a low equilibrium trap with low productivity of staples and supply shortfalls, low returns to farmers, and abandonment of farmlands due to various reasons including wild animal raids on crops and increasing exodus. It is high time for Nepal to unlock rural agriculture and learn from successful examples of agricultural revitalization efforts by capitalizing on the skills and resources that may be available from returnee migrants. Joining hands with various innovative organizations, such as "Nepal Innovation Center" and "Nepal Agriculture Research Council" implementing matching fund programs, may help engage the working age exuding human power to boost agricultural productivity. Delaying such efforts will be a lost opportunity for Nepal which will further suffer from severe food crises.

Planners and policymakers may utilize this information to craft policies to ameliorate food security. These include but are not limited to:

a. Promoting households to diversify their agricultural produces.
b. Providing incentives to start new crops that are suitable to location-specific agroecological conditions.
c. Encouraging remitters to start up new agricultural businesses by providing matching funds and guarantees of safe markets and preventing them from "falling prey to predatory lenders" (Bohara, 2023).
d. Encourage the diaspora to invest in agriculture with some matching funds as done in Mexico.
e. Collaborating with various innovation centres to practice new agricultural techniques.

6. Conclusion

In this paper, we utilized both spatial and aspatial data to analyze the food scenario in Nepal taking the decadal (2010-2020) average crop production information to

estimate the production of various crops at the ward levels of different municipalities of three geographic regions of seven provinces. We assessed farmlands at the ward levels and estimated the possible production scenarios for various agricultural crops and evaluated the nutritional values of each crop. We gathered calorific information for different crops and estimated the total amount of calorific nutrients that are available from each crop at the ward level. We computed the food energy needs by gender at each ward level and compared those needs with the available crop yields. We projected three scenarios: a) consuming only the major crops; b) consuming major and minor crops, and c) consuming major, and minor crops, fruit, and meat products. We also estimated the food calorific values that will be available under every three scenarios then we calculated the number of people facing food crises. We then decomposed the number of people at the national levels to provincial levels to municipal and to ward levels to assess how many households may face food deficits under three scenarios (Figs. 6-8, and Table 4). Finally, we concluded that food security follows three principles accessibility, availability, and affordability. Looking at the food deficit scenarios at each province, district, municipality, and ward, planners and policymakers need to develop policies that will intervene in the slow process of governance and start providing incentives or matching funds to engage exuding working-age people to vitalize the agricultural production of Nepal in order to improve food supply chain at the ward, village and municipalities, districts, provincial and national levels.

Authors Contribution

Keshav Bhattarai: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/ evidence collection; Report initial draft/review/ final draft polishing.

Shiva P Gautam: Review of final draft and polishing.

Buddhi R. Gyawali: Review of final draft and polishing.

Conflict of Interest

The authors declared no conflict of interest.

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Cooperatives as Pillar of Economy to Improve Agriculture Production and Marketing

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Abstract

This paper focuses on the important role played by cooperatives in agriculture production and marketing in Nepal. The paper evaluates the role of cooperatives, their contribution to agriculture, current policies that have paved the way for development within the agriculture and cooperative sectors and recommendations for improving agriculture production and marketing. The methodology employed includes a review of existing literature on agriculture and cooperative policies, as well as discussions with key informants in the cooperative movement. The study highlights the need for support from government and non-government agencies to improve the service of agricultural cooperatives in various ways, particularly through policy intervention. The paper provides policy recommendations for the future, including the need for improved coordination between government agencies and cooperatives, capacity-building programs, commercialization of agro-products, ways of increasing agro-productivity and capacity-building for cooperative leaders, and better access to credit and markets. Overall, the study underscores the importance of cooperatives in the sustainable development of the agriculture sector in Nepal.

Keywords: Cooperatives, agriculture production, marketing, cooperative movement, government support, policy intervention, capacity-building, commercialization, agro-products, agro-productivity, credit, sustainable development

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1. Role of Agriculture in Nepal

The agriculture sector in Nepal contributes significantly to the country's economy, accounting for approximately 23.9% of the GDP and engaging around 60.4% of the labor force. This sector generates a diverse range of employment opportunities, from farming to small-scale enterprises (World Bank, 2022). However, the growth rate of the agriculture sector over the past two decades has been volatile, with a negative growth indicator in 2019/20 (MOALD, 2021). Despite receiving top priority in each of the periodic plans and fiscal years, the sector has been subject to low budgetary disbursement. In fact, the state has allocated less than 5% of its total annual budget to the agriculture sector, despite its significant contribution to the national economy (Deshar, 2013).

This underinvestment has resulted in the predominance of small-scale subsistence and integrated farming systems in Nepal, which lack economies of scale in production and marketing, and consequently, suffer from low productivity and production of agricultural commodities (Basnet & Pandey, 2018). The average agriculture land holding per individual in Nepal is only 0.2 ha, which limits farmers' ability to increase production and earn a higher income from the given area of land (Basnet & Pandey, 2018). Nepal's agriculture sector is facing challenges related to low productivity, limited land availability, and inadequate investment. The production capacity of agriculture in Nepal is not growing at a rate that can meet the demand of the growing population. The production of major cereals, such as rice, maize, wheat, and millet, has been stagnant or declining over the past five years (MOALD, 2021). In contrast, the population has been growing at a rate of 1.3% annually (World Bank, 2022), putting pressure on the country's food security. Moreover, Nepal is also vulnerable to food insecurity and recurring natural disasters such as floods, droughts, landslides, earthquakes, diseases, and pest outbreaks (FAO, 2019).

Nepal has the potential to increase its agricultural production and become self-sufficient in food production. The country has a diverse agro-climatic condition, allowing the cultivation of a wide range of crops throughout the year. Nepal exports certain agricultural commodities, such as tea, cardamom, and ginger. In 2020, Nepal exported 5,063 metric tons of tea worth USD 7.1 million, and 2,181 metric tons of cardamom worth USD 34.4 million, while ginger export was 36,131 metric tons worth USD 25.2 million (Trade Map, 2021).

Nepal's agriculture sector needs more investment and support to increase its productivity and competitiveness in the global market. The government needs to allocate more resources to the sector and develop policies that can address the challenges related to small-scale farming and natural disasters. The private sector can

also play a crucial role in investing in technology and providing access to finance for small-scale farmers. With the right policies and investment, Nepal's agriculture sector can play a significant role in reducing poverty, promoting rural development, and achieving food security for its population.

2. Agricultura-Related Policies of Nepal

Nepal Government's policies for the development of the agriculture sector are based on the Constitution of Nepal (Article 51-e) that emphasizes agriculture development: protecting and promoting rights and interests by utilizing the land use policy for increasing production and productivity of agriculture for commercialization, industrialization, diversification and modernization of agriculture. There are several policies for the agriculture sector that have played a major role in shaping the agriculture ecosystem today.

The Nepal Agricultural Policy emphasizes the development of high-value crops, livestock, and fisheries to promote sustainable agricultural growth. The policy also aims to improve irrigation infrastructure, enhance access to credit and technology, and promote agribusiness development. Overall, Nepal's agricultural policy aims to address the challenges facing the agricultural sector and promote sustainable agricultural growth. The policy emphasizes the development of high-value crops, livestock, and fisheries, investment in irrigation infrastructure, access to credit and technology, and promotion of agribusiness development.

3. Research Methodology

The study is based on an extensive qualitative literature review and consultation with the leaders of the cooperative movement. The paper has explored policies, periodic reports and findings published by the government sector like the Ministry of Agriculture and Livestock Development, Department of Cooperatives, Ministry of Finance and Nepal Rastra Bank. Likewise, the research articles and publications were also reviewed for secondary information.

4. Background of Agriculture Cooperative in Nepal

Nepal's cooperative sector has been growing rapidly and has become a crucial part of the country's economy. There are different types of agricultural cooperatives in Nepal based on their functioning, which include marketing, farm supply, service provider, production, and processing cooperatives. The cooperative sector encompasses various industries, including agricultural production, dairy and livestock, manufacturing, financial services, energy, healthcare, and consumer services (Kathiwada, 2014). As of

2077, there were 29,886 registered cooperatives in Nepal, with around 70% focused on agriculture, livestock, and forestry. These cooperatives served 7,307,463 members, with 56% of women participation (MoALD, 2021). The cooperative sector has now established its presence in all local bodies in Nepal except for four, including Dolpa District: 3 rural municipalities: Dolpobuddha, Shephokshundo & Chharka Tangsong and one in Narpa bhumi of Manang District.

The National Agriculture Policy 2004 guides agricultural development in Nepal and recognizes the important role of agricultural cooperatives and emphasizes the need to strengthen and promote the cooperative movement in Nepal to fulfill its objectives. The Agriculture Policy 2004 emphasizes capacity building for cooperatives, promotion of cooperatives-based agricultural industries and enterprise, incentives to attract cooperatives for investment in commercial production, processing, and marketing of agro products, development and extension of market information systems, wholesale and seasonal markets, and institutional development of cooperatives through mobilizing and promoting local small capital and resources and cooperative societies in rural areas to be developed as local delivery points (NAP, 2004). The government of Nepal has prioritized the agriculture sector in its budget for the coming fiscal year 2021-22. The policies and programs are primarily focused on enhancing livelihoods and creating jobs through the commercialization and mechanization of agriculture. Digitalization of agriculture, including online farmer registration, digital soil mapping, and the Mero Kitta app for land management, has also been highlighted in the government's yearly budget plan. Additionally, the construction of a factory for chemical fertilizers in Nepal is in progress to provide a consistent and ongoing supply of plant nutrients (MoF, 2021).

5. Cooperatives as the Pillar of Economy

The cooperative sector has been expanding rapidly and has helped improve the agricultural landscape in Nepal by providing farmers with access to credit, technology, and inputs, as well as by facilitating market linkages. Cooperatives have also played a crucial role in building the capacity of farmers, enhancing their bargaining power, and increasing their incomes. The cooperative sector has not only helped improve the livelihoods of farmers but has also contributed significantly to the overall economic growth of Nepal. Some key ways cooperatives are helping the agriculture sector are listed below:

5.1 The crop yields and income of cooperative farmers

According to a study carried out by NACCFL in 2017 that employed a survey questionnaire to collect quantitative data from a sample of 600 cooperative farmers

and 600 non-cooperative farmers from 12 districts in Nepal, cooperative farmers in Nepal were generally found to achieve higher crop yields and income compared to their non-cooperative counterparts. The study found that cooperative farmers had a higher yield of maize, paddy, and wheat than non-cooperative farmers. One of the main reasons for this difference is the access to training and technical support on modern agricultural practices that cooperative members receive. Agriculture cooperatives in Nepal like NACCFL provide their members with training and guidance on the use of modern farming techniques, such as improved seed varieties, fertilizers, and irrigation systems.

Through these initiatives, cooperatives help their members to adopt better agricultural practices that can significantly increase crop yields. Moreover, these modern farming inputs can help farmers to produce crops that are of better quality, more disease-resistant, and can withstand weather changes, leading to a higher value of produce. Cooperative farmers benefit significantly from these interventions, and the resulting increase in crop yields and quality ultimately leads to higher incomes for them.

5.2 Cooperative to Cooperative Marketing

The cooperative-to-cooperative marketing model refers to a collaborative marketing approach employed by agricultural cooperatives to enhance their marketing capabilities. Through this model, individual cooperatives pool their resources and combine their products to create a larger entity, which allows them to leverage economies of scale to negotiate better prices for their members' products. This strategy permits each cooperative to maintain autonomy while enjoying the benefits of collective marketing, including increased bargaining power, access to larger markets, and stable income for farmers. Cooperatives utilize this model by consolidating their products and selling them to larger buyers such as processors, wholesalers, and retailers, thereby offering larger volumes, consistent quality, and better packaging, which appeals to buyers.

Cooperative-to-cooperative marketing practice is becoming increasingly popular in Nepal as it enables small farmers and producers to access larger markets and increase their bargaining power. NACCFL has been promoting and facilitating cooperative-to-cooperative marketing through its network. There is a system of regional and district-level cooperative federations that work closely with primary cooperatives to organize collective marketing activities. For example, there are marketing alliances between vegetable cooperatives to collect and sell their different kind of products to larger markets. The cooperative-to-cooperative marketing by NACCFL also enable cooperatives from different districts to collaborate and sell their products efficiently

in different regions as per the market demand. Overall, the cooperative-to-cooperative marketing model provides numerous benefits that individual cooperatives would not have access to on their own (Kathiwada, 2014; MOALD, 2021).

5.3 The prices received by cooperative farmers

According to a study conducted by the International Labour Organization (ILO) and the National Cooperatives Federation of Nepal (NCF), cooperative farmers in Nepal receive higher prices for their products compared to non-cooperative farmers. The study found that cooperatives were able to offer better prices for crops such as rice, maize, and vegetables, with cooperative farmers receiving prices that were on average 10-20% higher than those received by non-cooperative farmers. One reason for this is the collective marketing approach of cooperatives, which enables them to negotiate better prices with buyers due to the larger volumes and more consistent quality of their products. Additionally, cooperatives can invest in better packaging and branding, which makes their products more attractive to buyers. For example, the study found that the price of maize sold through cooperatives was 15% higher than the price received by non-cooperative farmers. Similarly, the price of vegetables sold through cooperatives was found to be 20% higher than the price received by non-cooperative farmers.

5.4 Access to credit

Access to credit is crucial for farmers in Nepal. It enables them to invest in their crops and equipment, and ultimately increase production and productivity to improve their livelihoods. Agriculture cooperatives play an important role in providing credit to farmers, particularly small-scale and marginalized farmers who may not have sufficient collateral to secure loans from formal financial institutions. According to a study by the International Labour Organization (ILO) and the National Cooperatives Federation of Nepal (NCF), cooperatives have helped farmers in Nepal to overcome financial barriers that might limit their access to such resources. Likewise, the study conducted by Shrestha and Adhikari (2019) shows farmers who had access to credit were more likely to adopt modern farm technologies such as irrigation systems, improved seeds, and fertilizers. Agricultural cooperatives in Nepal provide about 30% of the total credit in the agricultural sector (CBS, 2019). This access to credit has allowed farmers to invest in modern inputs, such as improved seeds and fertilizers, and irrigation systems, which has led to an increase in crop yield.

5.5 Post-harvesting support

Cooperatives in Nepal have made significant investments in post-harvest infrastructure to help farmers reduce post-harvest losses and improve the quality of their products.

For example, the National Cooperative Federation of Nepal (NCF) has facilitated the establishment of several modern processing plants and storage facilities across the country, benefiting thousands of farmers. These facilities have helped farmers to reduce post-harvest losses by up to 50%, which has resulted in improved quality of products and better prices for farmers (NCF, 2021). Furthermore, cooperatives have also established transportation networks to facilitate the movement of products from farms to markets.

The National Cooperatives Development Board (NCDB) has established several collection centers and transportation hubs in different parts of the country to make it easier for farmers to transport their products to markets (NCDB, 2021). The investments in post-harvest infrastructure by cooperatives have contributed significantly to the improvement of the value chain of agricultural commodities in Nepal. According to a study by the International Labour Organization (ILO), the investments made by cooperatives in storage facilities have helped to reduce post-harvest losses and improve the quality of products, resulting in better prices for farmers (ILO, 2018).

Cooperatives like NACCFL have also facilitated the reduction of post-harvest loss by providing various capacity development training related to value chain strengthening. Co-operatives in Nepal are helping farmers market their products better by providing access to markets and services, increasing negotiating power, reducing post-harvest losses, and enabling farmers to achieve higher yields and better access to markets. However, it is important to note that the impact of agricultural co-operatives can vary depending on the specific context and conditions of the farmers involved (NACCFL, 2018).

6. Policy Recommendations

6.1 Supporting Cooperatives

Cooperatives are the main or only financial service providers in the remote rural area especially for the smallholders as banking and financial institutions are mainly concentrated in urban areas making their role in agriculture production and marketing invaluable. Because of the important space they occupy in society, cooperatives should be involved in national dialogues and opportunities should be provided for them to share their experiences with policymakers. In addition, the government should support cooperative societies at an early stage in terms of technical, financial, and institutional capacity development; formulate clear exit strategies; and let cooperatives function without a lot of government intervention.

The government should ensure production sustainability and food security through proper policy incentives and support for farmers' cooperatives. These include cooperative cultivation, mechanization, commercialization, marketing, processing and credit help at the grassroots level of the village. In addition, capacity building of FGs/Coops also needs to be continued until they become sustainable and capable of operating the business by themselves. Governmental support systems should be established in accordance with the needs of the cooperatives. The support system and facilities should be based on the value of their contribution to agriculture production.

a. Develop policies that encourage financial institutions to expand their services in rural areas where cooperatives are currently the only financial service provider.
b. Develop policies that encourage the involvement of cooperatives in national dialogues on agriculture and rural development, and provide opportunities for them to share their experiences with policymakers.
c. Develop policies that support cooperative societies at an early stage in terms of technical, financial, and institutional capacity development. This includes providing financial assistance for cooperative development, training programs for members and staff, and technical assistance for business development and marketing.
d. Formulate clear exit strategies for government intervention in cooperatives. The government should provide support and guidance to cooperatives until they become self-sustaining, but should eventually exit from direct involvement in cooperative operations.
e. Provide policy incentives and support for farmers' cooperatives to ensure production sustainability and food security. This includes supporting cooperative cultivation, mechanization, commercialization, marketing, processing and credit help at the grassroots level of the village.
f. Continue capacity building of FGs/Coops until they become sustainable and capable of operating the business by themselves.
g. Establish governmental support systems that meet the specific needs of cooperatives. The support system and facilities should be based on the value of their contribution to agricultural production
h. Government should facilitate the establishment of agriculture service centers, with demonstrations to create awareness and impart knowledge to other cooperative or cooperative members.

6.2 Cost of Production

At present, the greatest impediments to enhancing production are mainly the high cost of production, improved quality standards and an efficient marketing system. Because farmers are individually too small and possess a small land area, achieving economies of scale in terms of production and marketing becomes difficult. They face problems with timely information on inputs (fertilizers, improved seeds, markets, price of the products in the alternative markets, etc.), transport bottlenecks, weak bargaining power and a lot of uncertainty all of which discourage production beyond subsistence levels. Agricultural cooperatives in this sense can play a huge role to improve food security and assist in poverty alleviation.

Another hurdle to production is the unavailability of quality seeds in the market. Seed security plays a very important role to strengthen the food security of small farmers. In the case of Nepal, the timely and sufficient supply of quality seeds of high-yielding varieties has the potential to increase crop yields by about 15-25% (Gauchan et al., 2014)

a. The government should establish and support agricultural cooperatives to help farmers gain access to information, inputs, credit, and markets. The cooperatives can also help in achieving economies of scale by pooling resources and knowledge of smallholders.
b. The government should also promote mechanization to improve efficiency and reduce the high cost of production. This can be achieved through providing subsidies and other incentives for small farmers to acquire farm machinery and tools.
c. The government should work to strengthen market linkages by providing information and training to farmers on marketing and pricing strategies. This can help farmers obtain better prices for their products and increase their bargaining power.
d. The government should also encourage private sector investment in agriculture by providing tax incentives and other benefits to companies that invest in agricultural production, processing, and marketing. This can help improve the efficiency and competitiveness of the agricultural sector.
e. Policies have to focus on a well-performing seed system that ensures access to new and quality seeds to farmers without making them dependent on limited suppliers and rigidly certified quality. In addition, policies should also ensure that crop diversity is circulated among actors in the seed value chain and that genetic diversity isn't put at risk.

f. Government should also strongly encourage cooperative farming. By pooling their resources in certain areas of activity, farmers are allowed to do what big farms do like buying inputs at a bulk rate, increasing the volume of sales and opening new markets and lowering the per-use cost of equipment.

6.3 Commercialization of Agriculture Product

The 2021/22 budget included provisions for commercializing apple production in Manang, Jumla, and Mustang as well as commercial animal farming in the Himalayan region. It also granted tax deductions of up to 50% on profits from commercial agriculture and provisioned the commercialisation of apple farming in Manang, Jumla, and Mustang and commercial livestock farming in the Himalayan region. There are currently no grants or subsidies available for commercialization, with the exception of crop insurance and land leasing (Basnyat, 2022).

For proper marketing and commercialization, policies should address a proper marketing mechanism that allows the collection of farmers' production through local-level warehousing. The government should see to it that feasibility studies are conducted before local collection points and sales outlets are established. To increase market acceptance, the product should then be properly graded, packaged, and branded. Additionally, cooperatives can greatly aid in the marketing of farmers' produce by fostering cross-disciplinary linkages for a larger audience and market. Institutions (such as the educational sector) must be encouraged by policy to purchase locally produced goods in order to meet their needs. The need for support and links with government and non-government agencies is critical if agricultural cooperatives are to be strengthened and modern farming technology replicated.

a. Develop a proper marketing mechanism for the collection of farmers' production through local-level warehousing. The government should conduct feasibility studies before establishing local collection points and sales outlets. This can improve market acceptance and ensure the product is properly graded, packaged, and branded, which will attract higher prices for the farmers.
b. Foster cross-disciplinary linkages between cooperatives and other institutions, such as the educational sector, to expand their audience and market. Encourage these institutions to purchase locally produced goods to meet their needs, which will create a reliable market for farmers.
c. Strengthen and modernize agricultural cooperatives by providing support and links with government and non-government agencies. This will help replicate modern farming technology and improve production efficiency, which will in turn reduce the high cost of production.

d. Provide training and technical assistance to farmers to improve the quality standards of their products, which will help them meet market requirements and increase their competitiveness. This can be done through partnerships with agricultural universities and research institutions, which can provide technical assistance and training to farmers.

6.4 Agribusiness Practices

Because of its naturally diverse environment, Nepal has an advantage in developing specialized agricultural products to meet the demands of the open national and international markets. The country's sustainable agricultural development can be achieved through competitive agribusinesses, the adoption of environmental protection measures, and the promotion of exports while pursuing an import substitution and import replacement plan (Ghimire, 2009). The major challenge to our domestic production and marketing is the availability of comparatively cheaper import products from the neighbouring countries.

The government can introduce The Minimum Support Price (MSP) to prevent the farmers from getting a lower price for the local vegetable than the cost of the production. In addition, policies should be introduced that support farmers in the event of price fluctuation and price gaps through various linkage programs.

6.5 Agriculture Insurance

The enrollment of farmers in agricultural insurance in Nepal remains low, with only 3% of the total agricultural households enrolled as of the fiscal year 2020/2021 (MoALD, 2021). Among the insured farmers, crop and fishery insurance have a significantly lower share. A study by Mishra et al. (2017) found that agricultural insurance significantly improves the productivity and profitability of farmers in India. The study reveals that insured farmers invest more in agro-production activities, such as purchasing better quality inputs, utilizing advanced technologies, and following recommended agricultural practices, leading to enhanced agricultural productivity and profitability. It is likely that the findings of the Indian study could also be relevant to the Nepalese context.

Therefore, increasing agricultural insurance with the support of the government is crucial. To ensure that the subsidized loans have been used in the agriculture production system, it is essential to establish a monitoring mechanism.

a. The government should work to introduce more insurance schemes for crops, livestock, and fisheries. These schemes should be designed to be affordable and accessible to smallholder farmers.

b. Agricultural cooperatives can play a significant role in increasing the uptake of agricultural insurance. The government should provide technical assistance and training to cooperatives to help them better understand insurance products and promote them to their members.
c. The government should establish a robust monitoring and evaluation system to track the implementation and impact of agricultural insurance schemes. This will help to identify any gaps or issues and allow for adjustments to be made accordingly.

6.6 Promotion of Agro-entrepreneurship

With the large number of youths moving abroad, there needs to be stronger incentives for the younger generation to move into agriculture. In 2022 alone, nearly 3000 youth went abroad each day in search of employment opportunities (DOFE, 2022). The absence of irrigation, unpredictable weather, poor seed quality, pest infestation, and ongoing fertilizer shortage make farming in Nepal riskier (Basnyat, 2022). The government needs to find measures to reduce risks in order to encourage interested entities and individuals (particularly youths) to pursue agriculture. In addition, governing bodies also have to digitize agricultural services and encourage seed capital to agro-entrepreneurs specializing in finding solutions within the agricultural value chain through technological intervention.

a. The government can introduce various schemes and incentives to encourage youth to take up agriculture, such as providing loans at subsidized rates, offering free training and mentoring programs, and offering tax breaks and other financial incentives.
b. The government should invest in building and maintaining irrigation systems, improving seed quality, and developing pest control mechanisms. This will reduce the risks associated with farming and make it more attractive to potential farmers, particularly the youth.
c. The government should digitize agricultural services such as weather forecasting, crop monitoring, and pest management. This will help farmers make informed decisions and reduce risks associated with agriculture.
d. The government can offer seed capital to agro-entrepreneurs who specialize in finding technological solutions within the agricultural value chain. This will help bridge the gap between technology and agriculture, making it more attractive to the youth.
e. The government can strengthen partnerships between universities, research institutes, and private companies to develop innovative solutions to improve the

agriculture sector. This will create more opportunities for the youth to get involved in agriculture and attract more investments in the sector.

Way Forward

The rapid growth of cooperatives in Nepal has had a significant impact on the development of the country's agricultural sector. With approximately 30,000 registered cooperatives serving 7.3 million members, their micro-financing, capacity building, technology transfer, and lobbying have proven to be of great significance. The cooperatives have played a crucial role in steering the agricultural potential of Nepal and contributing to its economic growth.

Although various policies and strategies have recognized the importance of cooperatives in the past, there is still a considerable amount of work that needs to be done. The agricultural sector accounts for about 30% of Nepal's GDP, yet the budget allocated for its growth in the fiscal year 2022-23 is only 3% of the total budget. This budget allocation is insufficient and places both food security and the future of the farming community at risk. To improve the operations and outcomes of agricultural cooperatives and develop a robust, sustainable, and productive agriculture sector, government bodies must prioritize them on a policy level.

By prioritizing agricultural cooperatives, farmers can increase productivity and incomes, ultimately reducing poverty and hunger while steering the country towards agricultural sufficiency. Cooperatives can assist farmers in joint purchases of inputs and increase investment in productive areas such as capacity building, production, storage, processing, and marketing facilities for prioritized commodities. Therefore, it is critical to recognize the importance of cooperatives in Nepal and prioritize their development for a brighter and more prosperous future.

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Authors Contribution

Rudra Bhattarai - Conceiving ideas; formulation of overarching research goals and aims, Provision of study materials, reagents, materials, instrumentation,

computing resources,

Manashi Pandit - Conducting a research and investigation process, Application of statistical, mathematical, computational, or other formal, specifically performing the experiments, or data/evidence collection, Provision of study materials, reagents, materials, instrumentation, computing resources, Report initial draft/review/ final draft polishing

Conflict of Interest

The authors declared no conflict of interest.

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Authors Bio

Rudra Bhattarai

Mr. Rudra Bhattarai is an agriculture cooperative expert with a wide experience of more than 40 years in the development of the cooperatives sector of Nepal as a whole. Currently working as the General Manager of Nepal Agriculture Cooperative Central Federation Limited (NACCFL). Mr Bhattarai has a Masters in Sociology and possesses an effective and profound capacity for the institutional development of the cooperatives.

Manashi Pandit

Ms. Manashi Pandit is currently working as a Business Development Head at Alliance Sports Services Pvt. Ltd. an emerging Nepali startup providing software solutions to sports and recreational centre in and around Katmandu Valley. Ms Pandit has worked in an agriculture cooperative, an INGO and a media house. She has invloved in the development of 'Kisan Ko Poko' (Farmer's market), for Nepal Agricultural Cooperative Central Federation Limited (NACCFL). As a research officer/ associate, she has been involved in research work focused on agriculture value chain, micro-finance, agriculture enterprise, gender equality and more. Ms. Pandit holds a Bachelor degree in Business Administration with major in Finance from The British College Kathmandu.

Annex

Table A1 List of policies in Agriculture sector

i.	Nepal Agriculture Perspective Plan, APP (1995-2015)	ii.	National Fertilizer Policy 2058 (2001),
iii.	The National Agriculture Policy, 2004	iv.	Irrigation Policy 2060 (2003),
v.	Agricultural Development Strategy (ADS) 2014	vi.	Poultry Policy 2068 (2011),
vii.	Nepal Trade Integration Strategy 2016. (NTIS 2016)	viii.	Pasture Policy 2068 (2011),
ix.	National Science and technology act 1989	x.	Floral Promotion Policy 2069 (2012),
xi.	Three-year interim plan (2007 – 2010)	xii.	National Land Use Policy 2069 (2012),
xiii.	First to fifteenth Five-year plan.	xiv.	National Cooperatives Policy 2069 (2012),

xv. National Agriculture Policy 2061 (2004),	xvi. Commerce Policy 2065 (2008),
xvii. Agri-Business Promotion Policy 2063 (2006),	xviii. Climate Change Policy 2067 (2010),
xix. Agriculture Biodiversity Policy 2063 (2006),	xx. Industrial Policy 2067 (2010),
xxi. National Tea Policy 2057 (2000),	xxii. Supply Policy 2069 (2012),
xxiii. National Coffee Policy 2060 (2003),	xxiv. Science and Technology Policy 2069 (2012),
xxv. Dairy Development Policy 2064 (2007),	xxvi. Biotechnology Policy 2063 (2006)
xxvii. National Seeds Policy 2056 (1999),	

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Plant Breeding and Intellectual Property Rights in Nepal

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Abstract

This article examines the adoption of plant breeders' rights (PBR), also known as intellectual property rights (IPR), pertaining to plant breeding and genetics in various nations. Its main goal is to offer direction for the growth of an organized and competitive plant breeding industry in Nepal. The paper seeks to analyze the mechanisms that ensure adequate protection of intellectual property and returns on investment in plant breeding, drawing on international practices and treaties like the Convention on Biodiversity, Trade Related Aspect of Intellectual Property (TRIPS), and the International Union for the Protection of New Varieties of Plants (UPOV). The paper presents case studies to demonstrate how these issues are addressed by looking at the current IPR landscape in Asia, Europe, and North America. These results are the basis of policy recommendations to aid Nepal in developing a strong plant breeding industry.

Keywords: Biodiversity, Geographical Indication, Intellectual Property, Plant breeders' rights, Plant breeding, UPOV

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1. Introduction

Plant breeding has a significant role in increasing crop yield. It is estimated that about 60% of yield gain is due to plant breeding and genetic improvement over the years in agriculture (Ci et al., 2011; Hallauer, 2007; Rozman et al., 1996; Schulthess et al., 2022). Plant breeding and related research started in Nepal in Khumaltar in 1951. More systematic research was initiated with the establishment of commodity programs in 1971 (Joshi, 2017). While plant breeding is an important business in Europe and America, it has yet to develop well in Nepal. Various components of plant breeding, including germplasm management, its maintenance and utilization, and the use of modern tools of plant breeding, are yet to be utilized. As a result, plant breeding has not progressed as much as it could develop in Nepal.

The current situation of plant breeding in the private sector is almost non-existent. Plant Breeding leads to the formation of plant variety or varieties which is referred to a specific group of plants within a particular botanical category, distinguished by the expression of certain characteristics resulting from a specific genotype or combination of genotypes. The protection of these plant varieties has been an important obligation aftermath the introductions of Trade Related Aspect of Intellectual Property framework within the regime of World Trade Organization, which recognized production of Plant Variety as an intellectual activity subject to protection under the rights of Intellectual Property. The intellectual property, which is the creation of intellectual activities that may give a noble product accepts plant building as one of its facetes. In plant breeding, there are a lot of intellectual activities because it has science and art involved, including the innovation, efforts of the breeders within it leading to increased interest and debate within the Plant Variety Protection (PVP) right within the Intellectual Property Rights. Thus, the paper seeks to analyze the mechanisms that ensure adequate protection of intellectual property and returns on investment in plant breeding, drawing on international practices and treaties like the Convention on Biodiversity, TRIPS, and the International Union for the Protection of New Varieties of Plants (UPOV). The paper presents case studies to demonstrate how these issues are addressed by looking at the current IPR landscape in Asia, Europe, and North America.

2. Conventions Associated with IPR

The IPR has received international attention, even in the United Nations forum. To safeguard traditional knowledge and prevent biopiracy, two global agreements were established: the Convention on Biological Diversity (CBD) in 1992 and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA)

in 2001. These agreements urge participating nations to enable resource access in a way that promotes the preservation and sustainable utilization of biological resources. Additionally, they aim to safeguard the rights of local communities, indigenous groups, and farmers.

The Convention on Biological Diversity was opened for signature in 1992 at the United Nations Conference and entered into force in 1993. The Convention's had three objectives: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits from utilizing genetic resources (Secretariat of the Convention on Biological Diversity, 2011). Although the idea was conceptualized in the 1990s, it took more than a decade to develop the detailed procedure and adopt the articles only after the Nagoya convention. The convention advanced the third objective by providing a legal basis for sharing genetic resources. The protocol also has the provision to foster and protect traditional knowledge. These provisions will benefit the indigenous and local communities by utilizing genetic resources. Overall, the protocol aims to enhance the contribution of biological diversity for sustainable development and human well-being. There are 36 articles in this protocol (Secretariat of the Convention on Biological Diversity, 2011). The primary emphasis is to access and utilize genetic resources and share ownership. The Nagoya convention has provided the basis for the rights in the available genetic resources in the country. It provides the framework to initiate the discussion and drafting of laws related to plant breeding rights. This law should provide protection, development, and the utilization of available genetic resources. Some of the countries have already benefited from the provisions of the protocol of this convention. Nepal should move ahead quickly, drafting and implementing the laws as soon as possible.

After more than 15 sessions of the FAO Committee on Genetic Resources and its subsidiary bodies, ITPGRFA was approved during the FAO conference in 2001. The Treaty was introduced to harmonise the International Undertaking on Plant Genetic Resources signed in 1983 with CBD. The Treaty came into force on 29 June 2004 and, until now, 116 countries have ratified it. Nepal ratified ITPGRFA on 2 January 2007. The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) holds great significance for breeders, as it recognizes their pivotal role in developing new plant varieties for food and agriculture. The treaty grants breeders access to a diverse range of plant genetic resources, housed in gene banks worldwide, enabling them to enhance crop productivity and create improved varieties with desirable traits. The ITPGRFA specifically focuses on plant

genetic resources for food and agriculture, encompassing 64 resources that are vital for food security. The treaty acknowledges the contributions of farmers in preserving, enhancing, and providing these resources, while recognizing their rights to benefit from such contributions through a multilateral system. Farmers are acknowledged as custodians of plant genetic resources, and Article 9 explicitly recognizes their rights to use, exchange, and sell farm-saved seeds and other propagating materials.

Furthermore, the treaty places a strong emphasis on farmers' rights to traditional knowledge, participation in benefit sharing, and involvement in national decision-making processes. It mandates contracting parties to safeguard and promote farmers' rights in accordance with their specific needs and priorities, while considering their national legal frameworks. Farmers are also considered in the treaty's provisions related to general obligations and financial resources. Breeders derive significant benefits from the ITPGRFA as it grants them access to a wide array of plant genetic resources for the development of improved crop varieties. Simultaneously, it acknowledges and protects the rights of farmers, as well as their participation in resource conservation and utilization.

The International Union for the Protection of New Varieties of Plants (UPOV) was established in 1961 and has provided broad guidelines for adopting PVP (https://www.upov.int/members/en/). This was founded in Europe, considering the plant breeding activities on the continent. It prepared the outline to protect intellectual property and provided the necessary guidelines. After the subsequent conventions, they modified their provisions, particularly in 1978 and 1991. The PVP via UPOV is a harmonized system that awards IPR to organizations in its 78 member countries. Distinctness (D), uniformity (U), and stability (S) are the basis for a new variety, which can be tested by measuring phenotypic traits in multi-location trials, molecular marker-based testing systems, or sequence-based testing systems. They can verify the traits by one or more than one testing systems collected from multiple locations. It should be noted that PVP is more common in Europe, whereas the plant patenting system is standard practice in the United States of America (USA). Plant patenting was started in the 1930s in asexually propagated crops. The provision of the same system was extended by the court ruling in the rest of the crops in 1984, which covers the plant patent system. Both systems are equally valid and can be recognized anywhere in the world. Some of the components of the system are compared below in Table 1.

Table 1: Criteria for recognizing a novel crop variety to issue a license under UPOV and plant pattern system (Tripp et al., 2007).

Criteria	UPOV 1978	UPOV 1991	Utility Patents (USA)
Requirements	Novelty (in trade) Distinctness Uniformity Stability	Novelty (in trade) Distinctness Uniformity Stability	Novelty (in the invention) Utility Non-obviousness Industrial application
Seed saving	Allowed for private and non-commercial use	For use on own holding only	Not allowed without the consent of the patent holder
Seed exchange	Allowed for non-commercial use	Not allowed without the consent of the right holder	Not allowed without the consent of the patent holder
Breeder's exemption	Use in breeding allowed	Use in breeding allowed (but sharing rights in case of essentially derived varieties-EDVs)	Not allowed without the consent of the patent holder

The PBR or PVP has led to good harmonization within the European Union (EU) (Dons, 2013). About 80 countries have signed UPOV 1978 or 1991 or adopted UPOV guidelines (https://www.upov.int/members/en/).

The Agreement on Trade-Related Aspects of Intellectual Property Rights by the World Trade Organization states that countries shall provide for the protection of plant varieties either by patents or an effective system of the country's choice (sui generis system), or a combination of the two approaches. Such an effective sui generis system was established in 1961 and revised in 1978 and 1991. The rationale premised behind plant variety protection in TRIPS is the requirement to support innovation, economic growth, fair competition, biodiversity preservation, and food security.

3. Biodiversity and Geographical Indication (GI)

Nepal is very rich in Plant biodiversity. This is an enormous resource for agriculture improvement. It is estimated that about 2000 plant species need to be utilized for the

benefit of Nepali farmers (Baul & McDonald, 2014; Paudel et al., 2011). These species are rich in medicinal value, nutritional importance, disease resistance, and other traits of agricultural importance. Some species are yet to be characterized well. The Nagoya Convention has addressed the issue of biodiversity and its utilization, as mentioned above. Based on that, Nepal can benefit from its rich biodiversity.

A geographical indication (GI) is a sign (or name) used on products with a specific geographical origin and possessing unique qualities or a reputation associated with the outcome of the origin (Baul & McDonald, 2014; Paudel et al., 2011). Its significance is for business purposes. Examples are Basmati rice, Citrus, Coffee, Jumli beans, Jumli rice, Junar, and many more. Nepal has not realized the benefits of these unique local germplasms. Several countries have filed and obtained the license of GI recognition for agriculture and related products. Nepal needs to progress a lot in this process. This is the area to work on by capturing the legal framework.

4. Legal Framework of IPR

4.1 International Legal Framework for Plant Breeding and Plant Variety Protection

The ratification of the Biodiversity Convention by Nepal establishes a fundamental framework for the conservation and utilization of biological resources. It confirms Nepal's sovereignty over its biological resources but also recognizes the concept of "common concern," indicating that the protection of biodiversity in Nepal is important for the country and the international community as a whole. In the context of plant variety protection, the Convention's provisions on access to biological resources and the sharing of benefits become relevant. It establishes that countries providing micro-organisms, plants, or animals for commercial use have the right to receive a fair share of the benefits derived from their utilization. This aspect emphasizes the importance of recognizing and protecting the rights of those who contribute to developing and conserving plant varieties. Furthermore, the Biodiversity Convention addresses the relationship between the management of biological resources and intellectual property rights. Article 16 of the Convention specifically states that intellectual property rights should not undermine the functioning of the Convention. This recognition ensures that the protection of intellectual property rights, including plant breeders' rights, should be in harmony with the goals and principles of biodiversity conservation and the fair and equitable sharing of benefits.

Therefore, Nepal's ratification of the Biodiversity Convention provides a broader context for considering plant variety protection. It underscores the importance of ensuring that intellectual property rights, including rights related to plant varieties,

align with the objectives of conserving biodiversity and promoting equitable sharing of benefits derived from the use of biological resources. Similarly, Nepal has also ratified the Plant Genetic Resources for Food and Agriculture (PGRFA) Treaty. This treaty aligns closely with the principles of the Biodiversity Convention and emphasizes the interconnected goals of conservation, sustainable use, and benefit sharing. The overarching objective of the PGRFA Treaty is to promote sustainable agriculture and ensure food security. The significance of the PGRFA Treaty lies in its transformative impact on the legal status of plant genetic resources in international law. Unlike its predecessor, the 1983 International Undertaking, which primarily focused on resource sharing, the PGRFA Treaty affirms the sovereign rights of states over their Plant-Originating Farming Systems (PORFA). Moreover, the treaty acknowledges the introduction of intellectual property rights in relation to these resources.

From a plant breeder's standpoint, one of the key contributions of the PGRFA Treaty is its emphasis on the role of farmers and their significant contribution to the conservation of agro-biodiversity. The treaty recognizes the rights of farmers over their tangible assets, such as seeds, as well as their rights to a lesser extent concerning traditional knowledge. Overall, the ratification of the PGRFA Treaty by Nepal provides a favorable legal framework that acknowledges the importance of sustainable agriculture, food security, and the rights of farmers in relation to plant genetic resources. This treaty complements the objectives of the Biodiversity Convention and reinforces the recognition of intellectual property rights within the context of plant breeding and genetic resource utilization. Nepal is not Party to UPOV.

According to the TRIPS Art. 27.3(b), new plant varieties should be protected by patents, by an effective sui-generis system, or a combination of both. The Options for the protection of plant varieties in TRIPS are enlisted as:

a. WTO Members can choose to protect plant varieties through patents
b. WTO Members can develop an effective sui generis system to protect plant varieties. This means they should bring an effective national law that grants IPR over new plant varieties through breeders' rights certificates.
c. WTO Members can develop a system that gives patents and plant breeders' rights certificates to protect plant varieties.

During Nepal's accession process to the World Trade Organization (WTO), it made a conscious decision to establish a distinctive framework for safeguarding plant varieties known as a sui generis system. Under this system, the creators of new plant varietes are granted certificates of plant breeders' rights instead of patents. The *Sui*

Generis system, chosen by Nepal offers a range of possibilities, allowing Nepal a significant flexibility in designing its own mechanisms for protecting plant varieties taking into account of various factors, including the level of economic development, available resources, agricultural and industrial policies, the state of its public and private research capabilities, as well as the unique needs and circumstances of small-scale farmers and indigenous communities in Nepal.

4.2 *Lex Generalis* of IPR in Nepal

Nepal is a signatory to the 1886 Berne Convention, 1883 Paris Convention, and World Intellectual Property Organization (WIPO). On April 23, 2004, Nepal became WTO's 147th member as first least developed country (LDC) member of the organization, becoming party to TRIPS. Wherein, Nepal was allowed a 10-year transitional period to improve its system and legal arrangement to make itself able to implement the basic requirements outlined in the TRIPS Agreement during the accession discussions. Nepal, now enjoys the benefits and extended transitional period for LDCs until 1 January 2033. Prior to joining the WTO, Nepal had two legislations viz. the Copyright Act of 2002 and the Patent, Design, and Trademark Act of 1965, which have continued to be the major IP laws in Nepal up until this point showcasing the present structure of present IPR not adhering to global norms and procedures.

The concept of Plant Variety Protection, Breeder's right are not recognized within these legislative framework. Provided that, the Constitution of Nepal has included Intellectual Property Right as Fundamental Right under Article 25, Right to Property. Moreover, the promulgation of Intellectual Property Policy, 2017 can be show casted as the initiation of Policy and Legislative Reform in the Intellectual Property Regime in Nepal. The objective of the Intellectual Property (IP) Policy is to encourage the protection, promotion, and development of IP while ensuring a balanced IP system, creating awareness about the social, economic, and cultural aspects of IP, promoting the commercialization of IP, and strengthening the legal, administrative, and human resources for effective IP protection and enforcement. With the preview of these objectives, the Policy recognizes unconventional signs for trademark registration, emphasizing the protection of well-known trademarks, and advocates for legal frameworks to safeguard various IP rights including the newer dimension of IP such as PVP. The policy also acknowledges the contributions of indigenous people, seeks to protect traditional knowledge, and supports innovation through utility models emphasizing the importance of compulsory licensing, IP audit, and valuation methods. However, the policy falls short in seeing Nepal's status as an LDC and its flexibilities under the TRIPS.

4.3 *Lex Specialis* Framework of Plant Variety Protection in Nepal

The Intellectual Property Policy of Nepal, 2017, recognizes the significance of providing legal protection for various aspects such as geographical indications, plant variety protection, trade secrets, biodiversity, integrated circuits, traditional knowledge, and traditional cultural expressions. It emphasizes the need for safeguarding these intellectual property (IP) rights through sui generis models, which are uniquely tailored mechanisms acknowledging the invaluable contributions of indigenous people towards preserving and sustainably utilizing biodiversity. It calls for justly rewarding indigenous communities for their efforts in this regard through fair benefit sharing. The policy seeks to address the issues highlighted therein by enacting laws within a two-year timeframe, which has been the case of a major failure in implementation and execution.

Unlike other jurisdictions, there no specific policy or lex specialis for plant breeding and genetics in Nepal. However, The Seed Act, 2045 has defined the breeder as "*a person, organization or body which brings into use any variety of the crops by breeding or selecting it for the first time*." The act, in Section 3, has envisioned the National Seeds Board in to carry following major functions relating to plant variety protection, including the approval, release and registration of the Seeds of new variety as prescribed along with testing of the specialty, uniformity, and permanency of the Seeds of new Variety and grant the right of ownership to the Breeder as prescribed. Moreover, the provision of "restriction for imports of seed variety which cause damage to the agricultural activities in Nepal" is progressive in terms of farmers right, protecting the famers discards the treaty obligation of "National Treatment" within TRIPS. However, certain lacunas in the act require readdressed, including the provisions on granting ownership rights to breeders needing improvement in clarity and structure. The scope and procedures for claiming ownership rights are undefined, causing confusion to the breeders to acquire their rights. Registration of new plant varieties is required, and there are restrictions on marketing unregistered and unmodified seeds, which necessitate a letter of permission creating extra procedural hurdles for breeders leading to demotivation on innovation and improvisation.

Although punishments are established for violating legal provisions in the act, they do not address infringements of ownership rights explicitly. Furthermore, there is a provision for granting ownership rights to traditional local varieties, but the specific details are unspecified. Similarly, Nepal Government, aiming to provide compensation in case of faulty and misrepresented seeds provided by breeders, has introduced Seed Compensation Directive, 2073. The compensation shall be provided as determined by Evaluation Committee envisioned within the directive. Furthermore, National

Seed Vision (2013- 2025) has also recognized a sui-generis method to strike a balance with breeders right. Nepal had drafted the two-draft bill: Access to Genetic Resources and Benefit Sharing, 2002 and Plant Variety Protection and Farmers Rights bill, 2008, which could not be passed by the Parliament and are now repealed.

4.4 Practices of IPR in Various Countries

Plant breeders change the genetic makeup of crops so that new cultivars have a higher yield and quality and are better adapted to the needs of farmers, food processors, and consumers. The plant breeding industry is one of the most innovative sectors in the world. It is estimated that 15 to 25% of turnover is used for research and development, a figure far higher than most other industrial sectors where R&D plays an important role. This explains why IPR is such a crucial issue in plant breeding. New inventions and creations of cultivars must be effectively protected so that the plant breeder can realize a fair return on investment and therefore has an incentive for additional investments in the future (Dons, 2013). This is all about supporting future investment and fostering the breeding industry. A comparative cost analysis is presented in Table 2 to give some idea about how much effort it involves before getting the certificate of a variety by fulfilling the DUS (distinctness, uniformity, and stability) requirements.

Table 2: Relative cost associated with the application fee, a plant variety protection license, and a patenting system in China, Europe, and the United States (Tripp et al., 2007).

Item	China	EU	US
Application	$217	$1,115	$432
Testing	$556	$1,490	$3,220
Granting of rights	-	-	$682
Cost of PVP and ten years of protection	$3,340	$7,780	$4,344
Cost of PVP and 15 years of protection	$5,687	$10,480	$4,344

We describe the examples of intellectual property rights in various countries below. Although UPOV provides the main framework, countries have used intellectual property rights based on the needs of their own country. Regardless of the practice, they follow the main core value of distinctness, uniformity, and stability (DUS) for a new variety. Regarding the use of the IPR, they have modified it based on the involvement of plant breeder and their need. That's where they are specific to the national need, availability of the germplasm in the country, plant breeding

requirement, plant breeders' participation, and national agriculture situation. Obtaining the UPOV certificate, getting membership, and preparing IPR-related legislations are centered on these issues. Utility patents generally provide 20 years of IP protection, while the length of protection under PVP is limited to the time it takes to create a distinct new variety from the germplasm introduced by the original research. Dawson et al. (2018) suggest that PVP rules are weaker than utility patents due to the breeders' and farmers' exemptions. However, they also mention that stricter PVP rules may restrain access to germplasm, slow innovation, and decrease research and development (R&D) (Dawson et al., 2018).

4.4.1 Scenarios of UPOV in Asia, Africa, and South America

There are very few UPOV member countries from the developing world. As of April 2006, UPOV membership for industrialized countries included eight countries under the 1978 convention and 18 under the 1991 convention. The membership for countries classified as developing, newly industrialized, or economies in transition was 17 (1978) and 15 (1991) (Tripp et al., 2007). Several other countries are at various stages of the application process (Dawson et al., 2018). No countries in sub-Saharan Africa, South or Southeast Asia (except Singapore), or Latin America joined UPOV in 1991. The African Intellectual Property Organization (OAPI) system represents a harmonized regional approach to PVP in which one application covers all member countries. This is similar to the service of the European Community Plant Variety Office (CPVO), although separate national PVP systems also exist in member countries. Several developing countries that belong to UPOV 1978 (e.g., Colombia and Kenya) are considering changes in their legislation to make it more consistent with UPOV 1991(Tripp et al., 2007). Other scenarios and systems developed in other developing countries are presented in Table 3.

Table 3: Some of the legal provisions and their scope of coverage in various developing countries for protecting plant breeders' rights UPOV systems (Tripp et al., 2007).

Country	Legislation	Scope of Coverage	Plant variety patents
China	Regulation of the PRC on the Protection of New Varieties of Plants (1999). Member of UPOV (1978) since 2000.	Forty-one crops are currently eligible. Certificates have been issued for 15 species through 2004.	Hybrids may fall under the scope of patents for a breeding or selection methodology.

Country	Legislation	Scope of Coverage	Plant variety patents
Columbia	Member of UPOV (1978) since 1996. Law 243 (1995) establishes PVP. Resolution 2046 (2003) defines limitations on seed saving.	All crops were eligible for practice certificates issued for seven cereals and 15 horticultural crops.	Plant varieties cannot be patented, but transgenic varieties may be patented because they are not found in nature.
India	The protection of Plant Varieties and Farmers' Right Act (2001) establishes PVP. Application to join UPOV (1978) pending. Implementation began in 2005.	No crops were excluded, but the exemption for varieties whose commercial exploitation would be a danger to public order, public and health.	No patents of plant varieties are allowed.
Kenya	Seed and Plant Varieties Act (Cap 326) was amended in 1991 and 1994 to establish PVP. Kenya joined UPOV (1978) in	No crops excluded; applications have been accepted for 31 field crops and 23 horticultural crops.	No patents of plant varieties allowed
Uganda	Draft Plant Variety Protection Act is still before Parliament. It defines PVP as well as farmer and community rights.	No crops are excluded in the draft bill	No patents of plant varieties allowed

4.4.2 Scenarios of UPOV in Europe

European Patent Convention (EPC) takes account of UPOV. The EC regulations and rules that make up the Community Plant Variety Rights (CPVR) have protected the innovative breeding companies in all EU Member States for about 15 years, although there are some differences between crops. Transgenic plants have yet to become a commercial success in the EU, and governments have typically funded much of the basic work of introducing exotic germplasm, which has primarily been directed towards specific quality or disease and insect resistance genes (Lence et al.,

2016). Therefore, the traditional breeding programs conducted by the private sector in the EU are typically favored under a PVP system. The situation makes patenting in Europe complicated. If the process of sexual crossing and selection includes an additional step of a technical nature, including genome modification affecting a trait, this can be patentable. Many seed companies, policymakers, and scientists in the EU favor PVP, while those in the US favor patent laws (Lence et al., 2016). There may be circumstances under which both perspectives are correct. Patents can incentivize firms to conduct expensive and long-lasting research programs leading to the development of transgenic plants or novel varieties and introducing exotic germplasm into commercial products by the private sector.

4.4.3 North America

Canada enacted the plant breeders rights (PBR) Act in 1990 based on the 1978 revision of the UPOV convention (Carew et al., 2017). The Act was amended and updated in 2015. Under the revised PBR, it was extended from 18 to 25 years for fruit trees and vine varieties and 20 years for other crops. The PBR system allows farm-saved seed use, while plant breeders can use germplasm in new breeding activities in Canada (Carew et al., 2017). Plant varieties can be protected in the USA under a system of plant patents, utility patents, or the PVPA. The Plant Patent Act (1930) gives patent protection to new varieties of non-tuberous asexually propagated plants in the USA (Pardey et al., 2013). The US Supreme Court ruling of 1984 covered seeds under the same Act. The PVP in the USA provides IP protection for breeders of new varieties.

4.4.4 Experience of Nepal

Developing countries like Nepal needs to establish an appropriate PVP system as a part of a broader, improved national seed systems, issues such as the 'patenting of food crops' may put of technology ownership and restrictions on farmer seed systems, there are issues such as the 'patenting of food crops' that may put small farmers off being denied access to their seed. To address all these issues, Nepal should be able to integrate the PVP system into the national seed system and address the issues raised by the national agriculture and seed system plan. This will avoid any possible questions related to the PVP.

While the Nepalese Seed Act permits anyone to apply for variety registration and release, the National Seed Board imposes stringent requirements on applicants, including the possession of at least an MSc degree and the availability of breeding infrastructure that meets specific criteria. The registration of the improved '*Pokhareli Jethobudho*' was made possible through the establishment of the community project

known as the "Fewa Seed Producers Group system," which supplied farming communities throughout the Pokhara valley. The registration mechanism for such agricultural biodiversity by farmers should be accumulating to their rights.

Moreover, there is a risk that such varieties may later be claimed as the intellectual property of breeding companies, thereby leading to the practice of "bioprospecting." In this process, farmers' prior informed consent is not considered. Consequently, farmers bear the consequences of this situation, as the existing seed legislation fails to support local farmers in registering their seeds, primarily due to the rules that oblige them to fulfill specific technical and infrastructural requirements.

5. Conclusions and Policy Recommendations

We should have a strong PVP-related law in place to encourage public and private sectors investment in Plant breeding and genetics programs in Nepal. However, it should also make balance farmer's rights also make the balance with farmer's right and traditional knowledge of the communities of Nepal. Nepal government and policymakers should view PVP as a tool for achieving national agricultural development goals. However, the country should cross-check the bio piracy. Nepal shall duly adopt the international mechanism wherein the IPR applicants are obligated to reveal the origin of biological resources and the related traditional knowledge (TK), while also presenting evidence of Access and Benefit Sharing (ABS) and Prior Informed Consent (PIC) agreements empower the country to regulate unauthorized entry into agricultural biodiversity and associated knowledge effectively. As a result, it acts as a safeguard against the risks of bio-piracy and the inappropriate exploitation of local or traditional knowledge.

The PVP should be part of a broader strategy for developing a commercial seed system in Nepal. While adopting the PVP policy and approach, we should watch the strategy of India and China closely, which can influence the national IPR policy significantly.

We strongly suggest that stakeholders of Nepal's agriculture research and development, including the Ministry of Agriculture, Nepal Agriculture Research Council, universities (Agriculture and Forestry University and Tribhuvan University), private seed industries, and growers' associations, should be involved in developing the PVP act, including farmers' rights and IPR. Such a legal framework should be broad enough to accommodate the potential novel traits developed or introduced in the country from abroad by biotechnological tools, including genetic transformation, genome editing, or any other advanced tools for the genetic improvement of crop plants. Adopting IPR laws by the government will be critical to encouraging private

sector investment in plant breeding and biotechnology. It will play a very important role in protecting our natural germplasm in agriculture, medicinal, and forest-related natural resources. Amendment of the Seed Act, To enhance understanding and effectiveness, is necessary and it must have clearly defined scope and procedures for claiming ownership rights, specific details about granting ownership rights to traditional local varieties and additionally, incorporate punishments specifically related to the infringement of ownership rights would strengthen the legal framework and discourage violations.

The carefully outlined legal provisions can also encourage private and public sectors to work together for national development by fostering the plant breeding industry in the long run. A sovereign and agriculture-based country like Nepal should have our strong IPR law for a healthy and productive agricultural system. The carefully outlined legal provisions can also encourage private and public sectors to work together for national development by fostering the plant breeding industry in the long run. Briefly, we need:

a. Strategy and action plan for effective implementation of IPR in relation to plant breeding, genetics, and agrobiodiversity.
b. To discuss drafting the PVP, breeder's rights, and farmer's rights and its approval and make specific legislation for the protection and promotion of breeder's rights paralleling balancing the farmer's right and traditional knowledge.
c. Immediate legal action is to protect against the loss of native genetic resources because many imported exotic technologies are replacing native genetic resources and traditional technologies, and there is a trend of losing IPR along with these losses.
d. Law, regulation, and guidelines because IPR policy exists, but due to a lack of related legal systems, none of the breeding-related IPRs, including geographical indication, are licensed and protected.
e. To initiate incentive mechanisms for breeders, geneticists, and conservationists.
f. To develop simple and practical working guidelines suitable to all relevant stakeholders, including farmers.

Authors Contribution

Dilip R. Panthee: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Conducting a research and investigation process, specifically data/evidence collection; Report initial draft/review/ final draft polishing.

Khusi R. Tiwari: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Conducting a research and investigation process, specifically data/evidence collection; Report initial draft/review/ final draft polishing.

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Kalidas Subedi: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Conducting a research and investigation process, specifically data/evidence collection; Report initial draft/review/ final draft polishing.

Pooja Panthee: Review of final draft and polishing.

Conflict of Interest

The authors declared no conflict of interest.

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Going for Hybrid Crops Breeding in Nepal: Strategies and Policy Dimensions

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Abstract

Crop Breeding programs were initiated in Nepal in 1951 with a focus on the varietal improvement of cereal crops. These varieties, however, have limited impact in the farmers' field due to their low adaptation and low yield potential. Nepal annually imports hybrid seeds of cereals, vegetables, and flowers from India, China, and elsewhere costing billions of Rupees. It is estimated that approximately 73% of the vegetable seeds and over 60% of the hybrid seeds of maize and rice are imported annually. Hybrid seeds generally produce 20-25% more yield than conventional varieties. Despite this fact, only about 15% of maize and <10% of rice acreage in Nepal has hybrid seeds compared to over 50-60% in China. Nepal is behind in developing policies for genetic innovations, including genetics and breeding, utilizing genetic diversity, and using new biotechnological traits such as golden rice and drought-tolerant wheat, which could be important for Nepal in the future. Nepal has the technical knowledge, skilled human resources, and appropriate environment to produce hybrid and improved seeds for most of the crops in Nepal, but there is a lack of proper policies in place. Nepal can learn lessons from our neighboring countries, including India, China, Philippines, and Bangladesh, which are highly engaged in a new technology of crop genetics, hybrid breeding, proper Plant Variety Protection (PVP) laws, and private-sector entrepreneurship. In addition, Nepal should aim to be self-sufficient and export quality hybrid seeds of cereals and vegetables that can be produced in its diverse geographies and production niches.

Keywords: Hybrid crop breeding, Agriculture policy, Crop breeding strategy

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1. Introduction

Nepal is an agricultural country, and it is of utmost importance to be self-sufficient in seed production and supply systems for increased food production. Cereal crops are the most critical components of food systems, followed by legumes, vegetables, and fruit crops. With the rapidly growing population and shrinking agricultural lands, we have obligation to meet the increased demand for food by improving the yield potential.

Rice (*Oryza sativa* L.), maize (*Zea mays* L.), and wheat (*Triticum aestivum* L.) are the three most important cereal crops, followed by finger millet (*Eleusine coracana*), barley (*Hordeum vulgare*)), oat (*Avena sativa*) and buckwheat (*Fagopyrum esculentum*) accounting for over 95 percent of all cereal production in Nepal (Tiwari et al., 2020). Nepal has a diverse agroecosystem with three major agroecological zones, *Terai* (plains), hills, and mountains. The *Terai* region is often called the bread basket of Nepal due to its capability of producing most of the food for its population. The *Terai* region comprises only 23 % of the total land area and over 56% of national cereal production.

Plant breeding and crop improvement programs are essential to increase yield potential and feed the growing population. In Nepal, systematic breeding work was initiated in 1967 after the Agriculture Botany Division (ABD) was established under the Department of Agriculture although the initial rice research program was started in 1951 (Bhattarai, 1969; Joshi, 2017). Currently, the National Rice Research Program (NRRP) is headquartered in Hardinath, Dhanusha, National Maize Research Program (NMRP) is in Rampur, Chitwan, and National Wheat Research Program (NWRP) in Bhairahawa, Rupandehi. These programs have the national mandate to develop superior cultivars suitable for different cropping systems (Joshi, 2017). However, their primary focus has been developing open-pollinated (OP) cultivars despite hybrids being superior to open-pollinated ones.

Heterosis or hybrid vigor, the phenomenon where hybrids perform superior to their parents, has been exploited to improve the economic yields of major crops. This is more common with cross-pollinated species such as maize, sorghum (Troyer & Wellin, 2009) and canola (Rahman, Bennett, & Yang, 2016). With maize, hybrid cultivars have been shown to produce at least twice as much compared to inbred lines (Troyer & Wellin, 2009). In general, self-pollinated crops are not expected to produce the same level of heterosis as the cross-pollinated species. Nonetheless, hybrid cultivars of rice have been shown to substantially increase grain yield (Yuan & Virmani, 1998). In China, over 50 percent of the rice area is planted with hybrid cultivars, showing 20 percent higher yields than the inbred varieties (Yuan & Virmani, 1998). In recent

years, Nepal's demand for hybrids and hybrid technology has increased tremendously. Hybrids are preferred over open-pollinated varieties because of their higher yields, greater uniformity in plant height, maturity, and other vital traits.

2. Research Methodology

This review paper was prepared using secondary data supported by Key Informant Interviews (KIIs) with major stakeholders in Nepal. We collected information from scientific literature available online, based on the experience of Nepalese researchers, and the Government of Nepal (goN) data sources. We collected national and international literature and analyzed the relevant information for the manuscript. Emphasis has been placed on generating new ideas and methodology utilizing global literature available. Authors have also expressed their own views, experiences, and knowledge to some extent where applicable.

3. Results and Discussions

Nepal has developed and adopted a ten-year agriculture development plan called Agriculture Development Strategy (ADS) of Nepal, and National Seed Vision (NSV) 2025. Both documents have emphasized various aspects of research and seed production to make it self-sufficient and explore market opportunities in Nepal and improve the economy of the country. The ADS describes farmers-oriented research by reforming the NARC and designing the breeding programs and variety evaluation process (Government of Nepal, 2014a). The ADS also plans to have real-time information on seed supply and seed demand so that farmers can get the input on timely basis to use quality seeds of improved varieties. It also emphasizes the capacity building for research, extension, and education, which includes seed production facilities in the country. It emphasizes the public-private venture to reduce the poverty by enhancing agriculture productivity (Government of Nepal, 2014a). The ultimate goal is to initiate commercial agriculture and create jobs in the country hence improving the economic conditions. For that, hybrid production will be invaluable.

Consistent with the ADS policies, the NSV envisions promoting domestic production of cereals and vegetable seeds by exploiting the local climatic conditions and available human resources in the country. It aims to increase crop productivity, raise income and generate employment opportunities through self-sufficiency, import substitution, and export promotion of quality seeds (Government of Nepal, 2014b). The document reports that the use of maize, rice, and vegetable hybrid seeds is on the rise, Seed replacement rate is also as high as 66%. Therefore, the NSV emphasizes the options to provide more varieties including open-pollinated as well as hybrids, which we

discussed in the current manuscript. Rapid breeding cycle by using the modern breeding tools could be used to develop varieties in as short period of time (Government of Nepal, 2014b). Joint venture with a multi-national seed companies is emphasized to fulfill the national demand and to increase the export promotion by exploiting the unique available climatic conditions. Public-private working relationship is emphasized to address the national demand and to create job opportunities in agriculture.

Current breeding policy as such is not discouraging, particularly in cereal crops. They have developed a large number of new varieties in rice, maize and wheat in Nepal. However, there is a question in their adaptability and farmers preference. The variety selection approach can be changed to participatory so that farmers and the private sector seed traders can provide their input and select the variety of their choice. Slow variety replacement due to availability of farmers preferred variety is one of the issue in the current breeding system (Government of Nepal, 2014b). Low investment in demand-driven breeding is another issue leading to lack of unavailability of farmers preferred varieties on timely basis. Lack of competitiveness in seed production is another issue leading to the availability of quality seeds of improved varieties for growers. Poor performance of the varieties, which is not addressing the farmers expectations is a big gap, that needs to be addressed by implementing noble breeding as envisioned in Seed vision 2025 (Government of Nepal, 2014b). For that, we should encourage the active participation of the private sector actors including farmers in the varietal development and seed production. Plant breeders are not motivated to do a better job and develop better varieties, we should strengthen the human resources situation and motivate them by introducing incentive mechanism such as PVP act. Poor international collaboration is another factor causing poor performing varieties, linkages should be strengthened as outlined in this report.

3.1 Hybrid Rice

In Nepal, by 2020 National Seed Board (NSB) has released and recommended 87 varieties of rice. More than two-thirds of the genetic improvements in rice in Nepal came from the International Rice Research Institute (IRRI) followed by Nepal and India (KC et al., 2021). The establishment of a Hybrid Research Unit (HRU) under the National Commodity Programs and Divisions was recently proposed. It is envisaged that 40 hybrids, including eight rice hybrids, will be developed, and promoted by 2025. In addition, the private sectors expect to develop and promote 20 hybrids, including five rice hybrids (KC et al., 2021).

Although, some hybrid varieties are planted in some parts of *Terai* with seeds introduced mainly from India, the official registration of hybrid cultivars began in 2010 (Gauchan, Thapa Magar, & Gautam, 2010). These hybrids have shown up to 45 percent higher grain yields compared to main season inbred varieties released for the Terai and Inner Terai regions. In 2016, only 7.4 percent of the country's rice area was under hybrid cultivars. This shows that there is a huge potential for expanding hybrid cultivars to increase total rice production. Most hybrid cultivars currently available in Nepal are introduced from India and China. The procedure for hybrid seed production in rice has been established. Vernet et al. (2022) reported that synthetic apomixis can be achieved in an F1 hybrid rice by inducing inactivation of conversion of meiosis into mitosis (MiMe) mutations and egg cell expression of BABYBOOM1 (BBM1) in a single step. They generated hybrid plants that produce more than 95% clonal seeds across multiple generations. Clonal apomictic plants maintain the phenotype of the F1 hybrid along successive generations which allows farmers to use their seed for the following growing season. This is a significant milestone for hybrid crops where seed production can be expensive.

In addition to hybrid rice, Nepal should also be evaluating new technologies, including golden rice to enhance vitamin A content in our diet. The IRRI is developing new strains with significantly high levels of vitamin A content as compared to regular white rice. Results from confined tests in the Philippines and Bangladesh have shown that GR2E introgression lines matched the performance of the recurrent parents for agronomic and yield performance, and the key components of grain quality. Moreover, no differences were observed in terms of pest and disease reactions (Swamy et al., 2021). The Philippines has officially approved for cultivation and utilization of golden rice, and Bangladesh is expected for commercial release in the near future.

3.2 Perennial and Direct Seeded Rice

Nepal could benefit from using perennial rice, saving significant labor and time. Crop perennialization, the conversion of annual grains to perennial forms, has shown such a possibility (Figure1). Recently, a domesticated annual Asian rice (*Oryza sativa*) was hybridized with its perennial African relative (*Oryza longistaminata*) and PR23 was developed and is being cultivated on several thousand hectares in China (Zhang et al., 2022). From a single planting, irrigated perennial rice produced grain for eight consecutive harvests over four years, averaging 6.8 ton/ha/harvest versus the 6.7 tons/ha/harvest of replanted annual rice, which required additional labor and seed. Direct-seeded rice (DSR) is also making a comeback under a changing climate and labor shortages. The DSR saves water, reduces the duration to maturity as well as the

labor required, and reduces negative environmental footprints, including Methane emissions (Shekhawat, Rathore, & Chauhan, 2020).

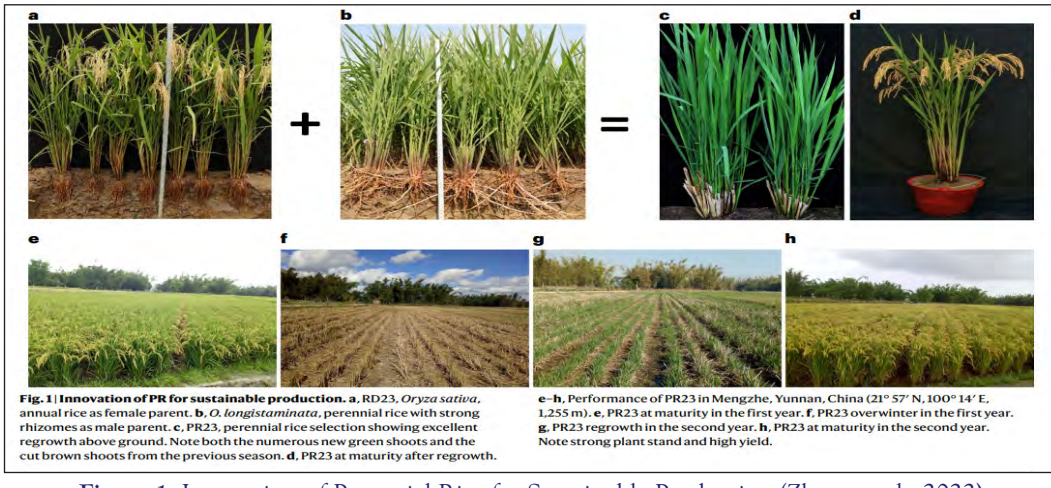

Fig. 1 | Innovation of PR for sustainable production. a, RD23, *Oryza sativa*, annual rice as female parent. **b**, *O. longistaminata*, perennial rice with strong rhizomes as male parent. **c**, PR23, perennial rice selection showing excellent regrowth above ground. Note both the numerous new green shoots and the cut brown shoots from the previous season. **d**, PR23 at maturity after regrowth. **e–h**, Performance of PR23 in Mengzhe, Yunnan, China (21° 57′ N, 100° 14′ E, 1,255 m). **e**, PR23 at maturity in the first year. **f**, PR23 overwinter in the first year. **g**, PR23 regrowth in the second year. **h**, PR23 at maturity in the second year. Note strong plant stand and high yield.

Figure 1. Innovation of Perennial Rice for Sustainable Production (Zhang et al., 2022).

3.3 Hybrid Maize

The NMRP initiated hybrid maize research in 1987 by testing nine maize hybrids developed by multinational seed companies based in India. The systematic inbred lines development was initiated in 1998 following continuous selfing from Arun-2 and Rampur Composite. The ABD also developed the 100 S4 (selfing generation-four) lines from Manakamana-2 and Arun-4 and their crosses are being evaluated in the mid-hill environments. A single cross hybrid named "Gaurav" was released in 2003 for commercial cultivation in *Terai*. The NMRP is evaluating multinational hybrids to identify high yielding hybrids (Tripathi, Shrestha, & Gurung, 2016). Several new hybrids have been recently released by NMRP - Rampur Hybrid-10, Rampur Hybrid-12, Rampur Hybrid-14, and Rampur hybrid 16. Yield potential, agronomics, and adoption need to be evaluated in the next few years.

Adopting hybrid technology is the best way to increase maize production to meet Nepal's ever-increasing demand for maize grains. There is a lack of reliable maize hybrids seeds production and distribution systems in Nepal. For this, the NMRP needs to emphasize hybrid breeding programs so that the programs could develop and release competitive inbreeds and hybrids. The other option would be to work together with the private sector, where the NARC may focus on inbred development and let the private industry focus more on seed production and marketing. It may be necessary to set up a royalty system for NARC or Universities to fund and encourage inbred development efforts. A smaller portion of breeding efforts may be continued

for open-pollinated varieties. However, emphasis should be given to developing inbreeds and hybrids.

In Nepal, it is high time to go for hybrid maize technology to increase maize production. Hybrids are preferred over OPVs due to high yields, greater uniformity in maturity and plant height, ear height, and tolerance to abiotic stresses compared to OPVs. The current maize production can be doubled by utilizing hybrid seeds and appropriate inputs. To achieve this goal, a hybrid breeding program of the NMRP/NARC should be strengthened, well-funded, and energized. To meet seed production demands, private companies should be encouraged so hybrids can be developed and released regularly. In the US, hybrids have been extensively used since the 1930s, and currently, OPVs cover less than two percent of the land under maize production (Troyer & Wellin, 2009). Similarly, hybrids are extensively used in many Asian countries, including India, China, Pakistan, Thailand, the Philippines, and Vietnam. As evident from Figure 2, the US Corn yield increased significantly after adopting hybrid technology.

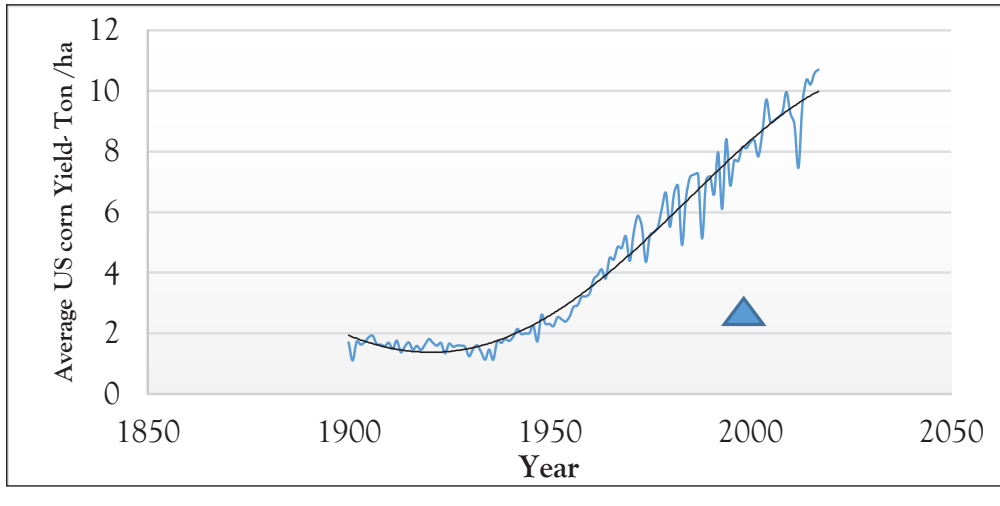

Figure 2. Average U.S. corn yields from 1900 to 2021. Source- United States Department of Agriculture, National Agricultural Statistical Services (NASS, 2021). ▲ Average corn yield in Nepal (~ 3 T/ha).

3.4 Wheat Improvement

Wheat crossing in Nepal started in the early 1970s at the ABD Khumaltar (Joshi, 2017). Later, the NWRP at Bhairahawa was charged with coordinating the country's overall wheat research. The NWRP focuses its breeding activities targeting four production environments: the irrigated ecosystem of Terai, Tars, and valleys under timely planting conditions, late-sown irrigated conditions, rainfed environment, and

irrigated hill environment, while the ABD focuses on cultivar development for the irrigated and rainfed conditions of the mid and high hills and durum wheat for the far-western plains. The Lumle Agriculture Research Station is also involved in cultivar research for high-hill environments. Nepalese breed lines along with the advanced lines received from the CIMMYT, are evaluated at the NWRP, Bhairahawa, and the ABD, Khumaltar, and various NARC research centers, and the superior lines are proposed for release. CIMMYT has been an important part of wheat breeding in Nepal (Joshi, 2017). Several wheat varieties have been developed and released for different agro-climatic regions (Tiwari et al., 2020).

Recently, Molero et al. (2023) reported that wheat containing exotic DNA from wild relatives (*Aegilops tauschii)* benefits from up to 50 percent higher yields in hot weather compared with elite lines lacking these genes. They identified an *Aegilops tauschii* introgressed regions on these lines underlying the most significant of these associations with drought tolerance. Incorporating these exotic alleles into breeding programmes could serve as a pre-emptive strategy to produce high yielding wheat cultivars that are resilient to the effects of future climatic uncertainty (Molero et al., 2023). This is very important as there is growing uncertainty around the ability of major food crops to continue to meet global demand as temperatures rise and weather events become more extreme. Importantly, the exotic lines didn't perform any worse than the elite lines under normal conditions.

Despite the earlier failures, renewed efforts in recent years have been made for hybrid wheat, and hybrid varieties with desirable attributes have been produced and marketed (Matuchke, Mishra, & Qain, 2007). In Europe and USA, hybrid wheat production started in the 1990s, and over 60 hybrid wheat varieties have been marketed, with the majority of varieties released in Europe (Gupta et al., 2019). According to some reports, the area under hybrid wheat in Europe increased from ~ 100,000 ha in 2002 to 560,000 ha in 2017–2018 (Figure 3). In the public sector, wheat breeders from Texas A&M AgriLife Research and the University of Nebraska-Lincoln in the USA are jointly developing hybrid wheat varieties. Recently, Tucker et al. (2017) reported *Ms1*, a gene proposed for use in large-scale, low-cost production of male-sterile (*ms*) female lines necessary for hybrid wheat seed production. Lately, the CIMMYT is also initiating research work on hybrid wheat and making good progress. Nepal needs to plan and start organizing heterotic pools and developing CMS lines. In addition, transgenic wheat varieties are being developed in Argentina by introgressing a gene *(HaHB4)* from sunflower *(Helianthus annus),* which provides significantly better drought tolerance (Gonzalez et al., 2019; Sheridan, 2021).

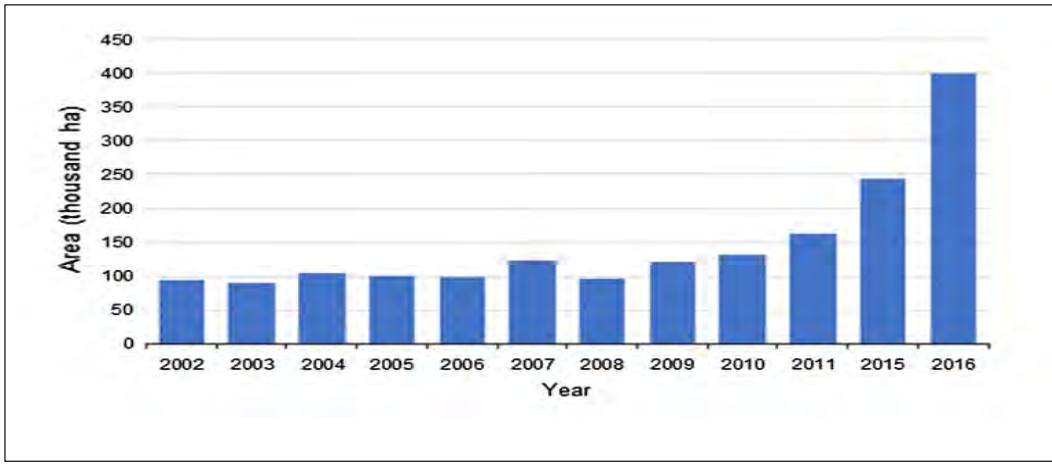

Figure 3. The area occupied by hybrid wheat in France during 2002–2016

3.5 Hybrid Vegetables

The use of hybrid varieties of major vegetable crops like cabbage, tomato, cauliflower, cucurbits, onion, carrot, is increasing every year in Nepal. About 73% of the vegetable production area is estimated to be covered by hybrid varieties in Nepal. A huge volume of hybrid seeds of vegetable crops is imported from India, China, Thailand, Japan, Korea, and the Netherlands (Gotame, Gautam, Shreshtha, & Pradhan, 2021). Hybrids have preferable characteristics, including high yield, better disease, and stress tolerance, therefore, higher demand by farmers. Demand for hybrids is increasing not only among commercial farmers but also small farmers.

Considering the urgent need to increase productivity and the high demand of Nepalese farmers, the National Horticulture Research Centre (NHRC), Khumaltar has started hybrid breeding in tomatoes since 2002/03 and hybrid tomato SRIJANA was released in 2010 (Gotame et al., 2021). In 2021, two tomato hybrids 'Khumal Hybrid Tomato-2' and 'Khumal Hybrid Tomato3' were released by the National Seed Board (NSB). Hybrid breeding of cucumber was also initiated in 2007/08 along with hybrid breeding in brinjal, hot pepper, and bitter gourd.

The seed sector in Nepal has a high comparative advantage, and the Government of Nepal has also emphasized developing and strengthening the seed supply system in Nepal (Regmi & Gauchan, 2012). Vegetable seeds are recognized as a lucrative enterprise for improving the livelihood of farmers and addressing the issues of self-sufficiency, food security, and economic development in remote areas (Timsina & Shivakoti, 2018). Vegetable seeds give 3–5 times higher income than alternative cereal crops, enabling farmers to buy at least three times more food than growing traditional

food crops. Most of the socio-economic research studies reported that vegetable seed production is more profitable than food grain crops. Emphasis should be given to exploiting the micro-climate available throughout the country for vegetable seed production. This production should aim to fulfil the national demand and replace the foreign import. If seed production is launched in more systematic way, seed export is not difficult in Nepal.

4. Conclusions and Policy Recommendations

Hybrid cultivars have shown tremendous potential to increase food production in cereals. Many improved varieties of major cereal crops have been released in Nepal during the past six decades, however, most of these varieties have not been adopted by growers for various reasons. Maize, rice, wheat, and vegetable crops have enormous potential to benefit from hybrid technology; thus, the immediate focus should be directed to utilizing hybrid technology for cereal and vegetable crops. The development of hybrid breeding technology will also enhance opportunities for small-scale seed entrepreneurship.

The government should prioritize potential areas for agriculture and agro-based industries and follow policy to support their growth and development. Nepal should learn from neighboring countries including India and China, which are highly engaged with new technology, hybrid breeding, proper Plant Variety Protection (PVP) laws, and private-sector entrepreneurship. It is high time to make and use PVP laws to encourage private sector investment. NARC, Agriculture and Forestry University (AFU), Tribhuvan University (TU), and other agricultural institutions should also need to be heavily involved in agriculture research and plant breeding activities as part of graduate students' training. During the initial phase of private sector strengthening, NARC, TU, and AFU can focus their research efforts on inbred line development and maintenance. Private companies should be charged a royalty for using public inbreeds and these funds can be used to fund cultivar breeding research. Hybrid seed production, marketing, and distribution should be left and encouraged for private companies.

The application of modern biotechnological tools in crop improvement is very important; however, low investment in agricultural research, particularly crop breeding, is detrimental. National programs should be equipped with well-funded labs and qualified scientists. Advancement in genetics and data sciences is developing very rapidly and we should be able to take advantage of the new technology including gene editing (Feng et al., 2013; Shalem, Sanjana, & Zhang, 2015) transgenic approaches (Sheridan, 2021; Swamy et al., 2021) and molecular markers to improve

efficiency in breeding and agricultural production. NARC and the Ministry of Agriculture should seriously consider developing new laws to test and evaluate biotechnological products such as golden rice and drought-tolerant wheat as soon as possible. Investment in new technology is the key to long-term sustainability and food sufficiency.

The Consultative Group on International Agricultural Research (CGIAR) have played a definitive role in boosting the national crop production and productivity in Nepal. Elite lines/varieties generated by the IRRI, CIMMYT, and ICRISAT have been extensively tested under different agroecological zones. In addition, our national programs have used these lines to make crosses with our local germplasm in rice, maize, wheat and legumes. The CGIAR centers have been generously supporting our national programs for the last five decades. Such collaborations should be strengthened to ensure a continuous exchange of germplasms, visits, and exchange of scientists and on-the-job training of research workers.

Increasing crop productivity should remain a top priority of Nepal's agricultural research and extension services. To be self-sufficient in food production, the growth rate in crop yield must be ahead of the population growth rate. A focused breeding program should be initiated with crops of neglected and underutilized species (NUS). A strong government commitment to adequate infrastructure development, funding for high-quality agricultural research, training, and skills development and attractive employee compensation are important areas for improvement.

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Authors Contribution

Khusi R. Tiwari: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/ evidence collection; Report initial draft/review/ final draft polishing;

Dilip R. Panthee: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/

evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/ final draft polishing;

Bal K. Joshi: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Provision of study materials, reagents, meterials, instrumentation, computing resources; Report initial draft/review/ final draft polishing;

Kalidas. Subedi: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Conducting a research and investigation process, specifically performing the experiments, or data/ evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/ final draft polishing;

Conflict of Interest

The authors declared no conflict of interest.

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