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Agrobiodiversity integration in farming systems for income generation and livelihood options of smallholder farmers in Nepal: A case study of Bhimphedi Municipality

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NTFPs

FGD

Traditional practices

Nepal

ABSTRACT

Food and nutrition security are critical global concerns, particularly for smallholder farmers in Nepal who face challenges with resources and inputs. This study explores how the Chabeli Farmers Group in Bhimphedi Municipality can utilize agrobiodiversity to enhance their farming systems and income. To achieve this, a survey was conducted involving 20 farmers (10 male and 10 female), supplemented by focus group discussions and field observations. The study identified 60 species across cereals, vegetables, fruits, forage, and fodder crops, representing 99 genotypes and 10 types of livestock. Farmers preserve and manage these species through traditional practices, such as storing seeds in Bhakari containers made of bamboo and mud. The findings of this study highlight the importance of passing knowledge from one generation to the next and the role of traditional methods in protecting biodiversity. Additionally, a Participatory Guarantee System (PGS) facilitates the sale of organic cash crops. The study demonstrates that effective biodiversity management enhances resilience, diversifies income, and improves market access. In conclusion, integrating agrobiodiversity with community-driven systems improves food security, protects biocultural heritage, and offers scalable solutions for long-term sustainable farming.

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1 Introduction

Agrobiodiversity is a complex and multidimensional concept used to assess biodiversity in agricultural lands. It encompasses the biological diversity within land use and food systems, as well as social-ecological activities. including sociocultural skills, economic influences, and political interactions. Agrobiodiversity includes genetic, species, and ecosystem levels essential for sustaining key functions (Parris 2001; Zimmerer and Vaca 2016; Matthies et al. 2023). There are several ways to develop indicators for agrobiodiversity. The Convention on Biological Diversity defines three indicators, each focusing on one of the levels: genetic diversity, species diversity, and ecosystem diversity (Gugerli et al. 2008). Furthermore, agrobiodiversity is considered a crucial adaptation strategy for mitigating risks associated with climate change. It enhances food security, promotes sustainable land management, supports biodiversity, improves soil quality, and fosters ecosystem services (Chaudhary et al. 2020; Cordoba Vargas et al. 2020; Rist et al. 2020; Agnoletti and Santoro 2022; Liu et al. 2022).

Agrobiodiversity is seen as particularly significant for farmers who cultivate relatively small areas due to its relevance for environmental sustainability, food security, and climate adaptation (Altieri et al. 2012; Williams 2017; Zimmerer et al. 2018; Bukchin-Peles and Fishman 2021). The terms "family farmers" and "smallholders" are often used interchangeably (Garner and de la O Campos 2014), with small farms or smallholders typically classified as family farms with less than two hectares of land (Lowder et al. 2021). In addition to contributing to 70-80% of food production, smallholder farming methods provide around 60% of household income and are essential for boosting food security. These farming practices also serve as vital pathways for preserving agrobiodiversity (Forsythe 2017; Fan and Rue 2020; Gautam et al. 2020; Guarin et al. 2020; Lowder et al. 2021; Dagunga et al. 2023).

Macqueen (2024) highlights the various benefits of agrobiodiversity, which include food security, livelihood resilience (Zimmerer and de Haan 2020; Kerr et al. 2021), nutritional and health benefits (Fanzo et al. 2013; Remans et al. 2014; Harris et al. 2022; Zaccari et al. 2023), provision of biomass energy and household materials (Immerzeel et al. 2013; Subedi et al. 2020), preservation of biocultural heritage (Agnoletti and Santoro 2022; Swiderska et al. 2022), and ecosystem services, including climate change mitigation (Altieri 1999; Gerits et al. 2021; Drucker et al. 2022).

Eighty percent of the world's population lives in impoverished rural areas (FAO 2019), where agriculture, often practiced in smallholdings, is the dominant activity. Significant changes are needed in the global agriculture system to meet the future food demands of a growing, increasingly wealthy, and urbanized population. In this context, smallholder farmers in developing countries are crucial in ensuring food security. Over 80% of the world's farms operate on less than 2 hectares of land. Though these smallholder farms account for only 12% of the world's farmland, they produce 80% of the food in Asia and sub-Saharan Africa (Lowder et al. 2014).

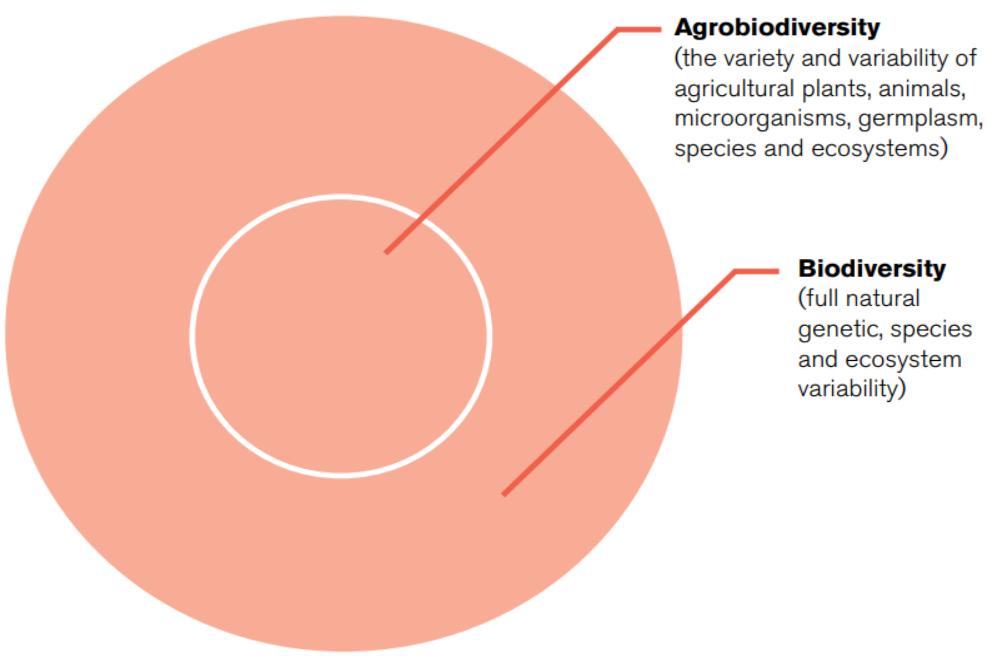

Figure 1 Agrobiodiversity as a subset of biodiversity (adopted from Macqueen 2024)

Smallholder farms face both naturally occurring challenges and man-made obstacles that impact their ability to increase production and transition to more commercial and profit-driven farming systems. In many developing countries, women play a vital role in agriculture, making up 43% of the workforce on small farms. However, they face numerous barriers, including limited access to essential resources such as land, livestock, agricultural inputs, technology, markets, and financial or extension services. These challenges hinder their ability to improve their livelihoods and contribute fully to the agricultural economy (FAO 2011). Smallholder farmers must either intensify their farming practices or shift from agriculture to overcome these constraints. Promoting land rights and efficient land markets, enhancing risk management and adaptation strategies, supporting inclusive food value chains, closing gender gaps, fostering young farmers, and scaling up productive cross-sector social safety nets are essential steps in this process. The potential for positive change is within reach, offering hope and driving necessary actions (Fan and Rue 2020).

The concept of smallholders' livelihoods is closely tied to sustainability. According to the UNDP (2010), sustainable livelihoods enable smallholder farmers to cope with and recover from shocks and stressors, paving the way for a brighter future for them and their future generations. This sustainable approach, which does not exploit natural resources, offers long-term benefits. Livelihoods encompass the activities, assets, and access that collectively determine the living conditions of individuals or households (Ellis 1998). According to Nzima et al. (2024), household food security and income are vital for sustainable global, national, and local development. Additionally, the factors influencing farmers' adoption of income-generating activities and adaptive strategies in vulnerable contexts have been widely discussed worldwide (Wang et al. 2023). Bravo-Pena and Yoder (2024) assert that agrobiodiversity is often regarded as a crucial adaptation strategy for mitigating the risks associated with climate change, enhancing the system's resilience and responsiveness to external shocks.

In Nepal, agrobiodiversity is a critical component of biodiversity, encompassing six significant elements: crops, forages, livestock, aquatic species, insects, and microorganisms. It also includes four sub-components: domesticated species, semi-domesticated varieties, wild relatives, and wild edibles (Joshi et al. 2020). Many farming areas in Nepal are environmentally marginal and increasingly at risk of land degradation and biodiversity loss due to climate change. Agrobiodiversity's ongoing availability and use, especially among smallholder farmers, are vital for adapting to these climate challenges (Regmi and Paudyal 2009). Agriculture remains a cornerstone of Nepal's economy, contributing 27.6% to the GDP and involving 66% of smallholder farmers engaged in agricultural activities to ensure national food security (Karki et al. 2020). Smallholders farming less than 0.5 hectares per household account for over 50% of Nepalese farmers (Central Bureau of Statistics 2011). Research has shown that agricultural diversification positively impacts dietary diversity and enhances the livelihoods of smallholder farmers. A varied farming system increases the availability of healthy foods and promotes environmental stability and resilience (Wilson 2010). A recent study by Nepali et al. (2024) demonstrated a positive relationship between agricultural diversification and dietary diversity. This study focuses on the Chabeli Farmer Group and provides valuable insights into how incorporating agrobiodiversity into farming practices can strengthen livelihoods and enhance stability through innovative farming methods. It highlights the significant contributions of smallholder and marginalized farmer groups in managing agrobiodiversity. Their efforts in integrating diverse crop varieties, livestock species, and wild varieties support agrobiodiversity and honor traditional and Indigenous knowledge systems. The study aims to explore how integrating agrobiodiversity into smallholder farming systems in Bhimphedi Municipality, Nepal, can enhance income generation, improve livelihoods, and strengthen community resilience. It seeks to document traditional knowledge, biodiversity management practices, and the role of community-driven initiatives like the Chabeli Farmers Group in fostering sustainable agriculture through diverse crop and livestock systems. Additionally, the study aims to assess the impact of these practices on food security, market access, and climate adaptation strategies.

2 Methodology

2.1 Description of the case study area and Chabeli Farmer Group

This case study was conducted in the Makwanpur District of Bagmati Province, Nepal. It is located 23 km from Hetauda Bazar, the headquarters of Bagmati Province, and 53 km from Kathmandu, the capital city of Nepal. The district has an altitude ranging from 300 to 1800 meters and features subtropical to temperate climatic conditions. Geographically, it lies at approximately 27.4217°N latitude and 85.0301°E longitude. The annual rainfall in the study area is 1700 mm, primarily occurring during the monsoon season from June to September. The soil in the area predominantly consists of loamy types.

The region is home to subtropical broadleaf forests at lower altitudes, characterized by a diverse range of tree species, including Sal (*Shorea robusta*), Indian rosewood (*Dalbergia sissoo*), khayar (*Acacia catechu*), and chir pine (*Pinus roxburghii*). Subtropical pine forests, which are represented by chir pine, can be found in drier regions. In contrast, oak forests dominate at higher altitudes and are characterized by temperate broadleaf and mixed forests (Nepal and Koirala 2023).

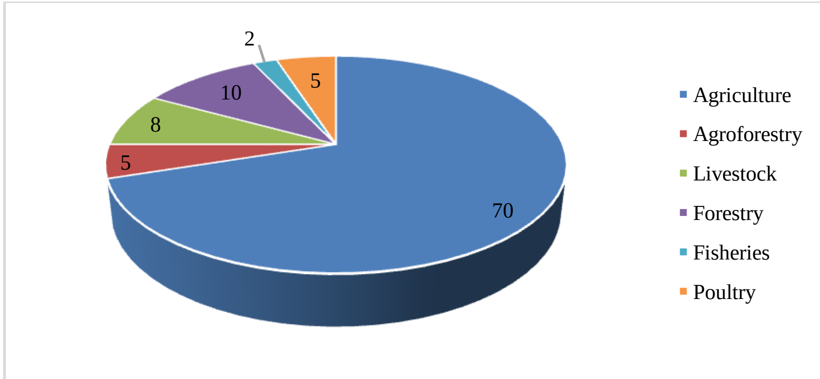

Figure 2 Use of formal agricultural land by land-use categories share (in % age)

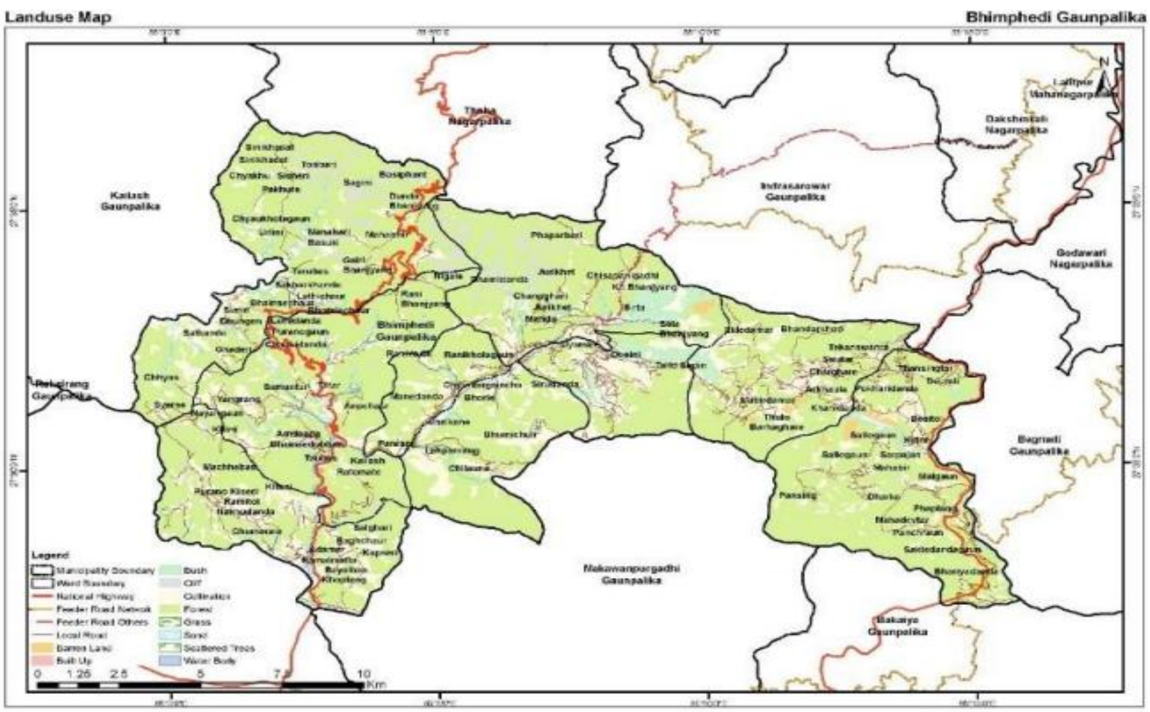

Figure 3 Land-use map of Bhimphedi Municipality (Source: Department of Forest Research and Survey 2017)

The Chabeli Farmers Group was established in 2012 AD (2069 BS) and comprises 40 smallholder farmers from various ethnic and caste groups: 8 members from the Brahman and Chhetri communities, 22 members from Indigenous communities, 7 members from Dalit communities, and 3 members from other castes and ethnicities. The members of the Chabeli Farmers Group are categorized into two groups: marginal farmers, who have landholdings of 0.01 to 0.5 hectares, and smallholder farmers, who have landholdings ranging from 0.5 to 8.0 hectares. The income sources of the group members are diverse, with 11% generated from agroforestry activities, 78% from agriculture (both subsistence and commercial), and 11% from livestock production and poultry management (Nepal and Koirala 2023; Macqueen 2024).

Bhimphedi Municipality consists of rural and hilly areas, with 95% of the land comprising hilly terraces and 5% flat slopes. Of the municipality's total land area, 48% is covered by forest. Agriculture occupies 70% of the land used, while the remaining 30% includes other income-generating activities such as agroforestry, livestock, forestry, fisheries, and poultry (Figures 2 and 3).

2.2 Arrangement of the field study: Questionnaire development and arrangement of the field study

To gather primary data and gain a better understanding of the agrobiodiversity practices of the Chabeli Farmer Group, a questionnaire was developed to collect information on the following areas: (i) Geographical Structure: Climate conditions and weather patterns, (ii) Demographic Information: Age, gender, household composition, and landholding sizes, (iii) Composition of the Farmer Group: Male, female, and youth representation, (iv) Land Use Patterns: Agroforestry, types of agriculture, types of forests present, and forest-based resources, (v) Agricultural Practices: Gender-specific practices regarding crop production and sales, wild harvesting, livestock preferences, neighborhood transfer, in-house transfer, and the types of commercial and subsistence crops grown, along with the crop varieties used, (vi) Bio-Cultural Heritage: Selection of seeds for crops grown for nutritional security and the influence of cultural and traditional practices based on market goals and farm functions, (vii) Knowledge Sources and Transfer: Identification of traditional knowledge, training received at home, sources of agricultural information, neighborhood knowledge sources, knowledge transfer within households, and community knowledge networks, and (viii) Market and Enterprises: Strategies for enterprises and challenges faced in accessing markets for their products. Based on the prepared questionnaire, the field study was conducted with assistance from lead farmers and volunteers, supported by local leaders and the farmer group to ensure community participation.

2.3 Field study and data (primary) collection and analysis of the study

A series of orientations were conducted with volunteer farmers to assess the feasibility of data collection. The primary data gathered included information on crop diversity, gender roles in managing agrobiodiversity, the use of cultural and medicinal plants, challenges encountered in farming, and sources of knowledge. This data was collected through surveys, interviews, and focus group discussions. In addition, a Focused Group Discussion (FGD) was held to identify the necessary information and sources. Interviews were conducted with 10 male and 10 female group members, concentrating on the commercial and subsistence crops grown and identifying the agrobiodiversity managed by different genders, including youth members. The volunteer farmers were categorized into three distinct respondent groups based on age and gender: women aged 30–65, men aged 30–70, and youth aged 16–35.

The survey revealed that the Chabeli Farmers Group utilizes a variety of crops and plants for multiple purposes, such as food and livestock production, as well as medicinal, cultural, and religious uses. Members of the farmer group manage 56 different plant species, including a range of varieties. Data collection involved both quantitative and qualitative methods. The quantitative approach was used to analyze numerical data gathered from questionnaires. In contrast, the qualitative approach included FGDs and open-ended responses to identify challenges, knowledge sources, and agrobiodiversity management. The findings assessed the effectiveness of Farmer-Focused Producer Organizations (FFPOs) and apex organizations like the Chabeli Farmers Group in promoting and preserving agrobiodiversity. The results also emphasized how integrating traditional knowledge with modern practices, including climate-smart techniques, has enhanced resilience against climate change impacts and improved the socioeconomic patterns of local development through diversified farming systems. This methodology provided a comprehensive understanding of the Chabeli Farmers Group's operations. It is a model for other farmer groups seeking to enhance their agricultural practices through community collaboration and knowledge sharing.

2.4 Secondary data collection

The secondary data was extracted and reviewed from a previous report, case studies, and a midterm evaluation of the Forest and Farm Facility (FFF) project conducted by FAO in 2021. This project aims to support forest and farm producers in showcasing climate-resilient landscapes and improving livelihoods. The evaluation highlighted the purpose and priorities of Forest and Farm Producer Organizations (FFPOs) concerning national and sub-national policies that address governance, advocacy, issue-based discussions, entrepreneurship, and sustainable forest management. The project's progress has demonstrated improvements in service delivery, responsible governance, green skill development, and the protection and promotion of indigenous knowledge. The report indicates that sustaining the project requires responsible governance and entrepreneurship while recognizing that external factors such as market dynamics and land tenure present additional challenges. Similarly, a case study reviewed a document published by IIED titled "*Selling Stories that Conserve Bio-Cultural Diversity and Promote Resilience*". This document describes how FFPOs operate Nepal's Participatory Guarantee System (PGS). The source focuses on agroecological practices and a certification system that targets smallholder and marginalized farmers, aligning with community-driven approaches. The study reveals that the National Farmer's Group Federation (NFGF) and its apex organizations, such as the Chabeli Farmer Group, promote organic farming and participatory grant systems, enabling smallholder farmers to connect with better markets and improve product quality. However, challenges remain in accessing finance, local government support, policy endorsement, and skills training. Additional publications, such as "*Food Security in Nepal*" and "*Agriculture Model Learning Facilitation Resource Book*," highlight various case studies and frameworks about agricultural development and learning models adopted in the country. Another article discussing policies and perspectives on food health and safety in Nepal provides an academic viewpoint on food safety challenges and readiness (Koirala 2023). A report overviewing agricultural biodiversity contributes to a global perspective on sustaining agricultural functions (FAO 1999). These sources were selected based on their relevance, research focus, credibility, and level of detail. The data was chosen to cover topics like PGSs, agricultural governance, apex organizations, and community-driven agricultural practices. This ensured a comprehensive understanding of the implications for Nepalese smallholder farmers and food sovereignty. The selected topics also consider the socioeconomic status of smallholder farmers and the influence of top organizations, farmer groups, and local chains in strengthening the community. The sources, articles, and publications from National Farmers Group Federation Nepal (NFGF) aided in contextualizing the overall process and findings.

3 Results

3.1 Status of agrobiodiversity utilization

3.1.1 Gender-wise cultivation of commercial crops

The study examined gender participation in the commercial cultivation of various agricultural products, including cereal crops, grain legumes (pulses), horticultural fruits and vegetables, oilseed crops, livestock, poultry, wild harvests, and medicinal herbs (Table 1). The assessment revealed that men and women play significant agricultural roles and actively contribute to agrobiodiversity management. However, men are more involved in commercial cultivation, with 80% of men reported to be engaged in the commercial production of these crops (Lima and Cunha 2024). Additionally, the findings indicated that women primarily focus on family care and prioritize maintaining household nutritional values. They tend to sell larger quantities of products specifically grown for market purposes. For instance, 70% of women reported growing vegetable crops for commercial sale. In livestock production, women typically concentrate on small animals, such as goats and chickens, which they raise for subsistence and market needs. Women generally sell these animals within their communities and prefer to sell dairy products, as they can generate quick cash income.

Table 1 Gender participation in crop production and estimates of Sales (in % age)

Gender Participation in Commercial and Subsistence Crop Production								
S.N	Crops	Participation in Commercial crop Production		Involvement of Males and Females in Sales of commercial crops (%)		Participation in Subsistence crop production		Crops classification
		Male	Female	Male	Female	Male	Female	
1	Maize	Yes	Yes	90.0	90.0	Yes	Yes	Cereals
2	Wheat	Yes	Yes	90.0	90.0	Yes	Yes	Cereals
3	Buckwheat	Yes	Yes	80.0	80.0	Yes	Yes	Cereals
4	Paddy	Yes	Yes	80.0	80.0	Yes	Yes	Cereals
5	Finger Millet	Yes	Yes	90.0	90.0	Yes	Yes	Cereals
6	Barley	Yes	Yes	90.0	80.0	Yes	Yes	Cereals
7	Pigeon Pea	Yes	Yes	90.0	80.0	Yes	Yes	Legumes /Pulses
8	Chick Pea	Yes	Yes	90.0	90.0	Yes	Yes	Legumes /Pulses
9	Green Pea	Yes	Yes	95.0	90.0	Yes	Yes	Legumes /Pulses
10	Yellow Pea	Yes	Yes	95.0	90.0	Yes	Yes	Legumes /Pulses
11	Kidney Beans	Yes	Yes	95.0	80.0	Yes	Yes	Legumes /Pulses
12	Butter Beans	Yes	Yes	95.0	80.0	Yes	Yes	Legumes /Pulses
13	Fawa Beans	Yes	Yes	95.0	80.0	Yes	Yes	Legumes /Pulses
14	Soybeans	Yes	Yes	95.0	90.0	Yes	Yes	Legumes /Pulses
15	Black Grams	Yes	Yes	95.0	80.0	Yes	Yes	Legumes /Pulses
16	Green Gram	Yes	Yes	95.0	90.0	Yes	Yes	Legumes /Pulses
17	Red Lentil	Yes	Yes	90.0	80.0	Yes	Yes	Legumes /Pulses
18	Banana	Yes	Yes	90.0	75.0	Yes	Yes	Fruits
19	Jackfruit	Yes	Yes	90.0	75.0	Yes	Yes	Fruits
20	Peach	Yes	Yes	90.0	80.0	Yes	Yes	Fruits

S.N	Crops	Gender Participation in Commercial and Subsistence Crop Production						Crops classification
		Participation in Commercial crop Production		Involvement of Males and Females in Sales of commercial crops (%)		Participation in Subsistence crop production		
		Male	Female	Male	Female	Male	Female	
21	Persimmons	Yes	Yes	90.0	80.0	Yes	Yes	Fruits
22	Raspberries	Yes	Yes	95.0	80.0	Yes	Yes	Fruits
23	Strawberries	Yes	Yes	95.0	80.0	Yes	Yes	Fruits
24	Pears	Yes	Yes	90.0	90.0	Yes	Yes	Fruits
25	Plums	Yes	Yes	90.0	90.0	Yes	Yes	Fruits
26	Kiwi	Yes	Yes	95.0	95.0	Yes	Yes	Fruits
27	Avocado	Yes	Yes	95.0	95.0	Yes	Yes	Fruits
28	Potato	Yes	Yes	85.0	80.0	Yes	Yes	Vegetables
29	Cabbage	Yes	Yes	85.0	80.0	Yes	Yes	Vegetables
30	Raddish	Yes	Yes	85.0	80.0	Yes	Yes	Vegetables
31	Carrot	Yes	Yes	85.0	80.0	Yes	Yes	Vegetables
32	Turnip	Yes	Yes	85.0	85.0	Yes	Yes	Vegetables
33	Tomatoes	Yes	Yes	90.0	80.0	Yes	Yes	Vegetables
34	Chilly	Yes	Yes	90.0	75.0	Yes	Yes	Vegetables
35	Cucumber	Yes	Yes	90.0	90.0	Yes	Yes	Vegetables
36	Pumpkin	Yes	Yes	90.0	90.0	Yes	Yes	Vegetables
37	Bottle gourd	Yes	Yes	90.0	90.0	Yes	Yes	Vegetables
38	Okra	Yes	Yes	90.0	90.0	Yes	Yes	Vegetables
39	Chayote	Yes	Yes	100.0	80.0	Yes	Yes	Vegetables
40	Cauliflower	Yes	Yes	90.0	80.0	Yes	Yes	Vegetables
41	Bamboo Shoots	Yes	Yes	95.0	85.0	Yes	Yes	Vegetables
42	Mushroom	Yes	Yes	95.0	90.0	Yes	Yes	Vegetables
43	Black Mustard	Yes	Yes	95.0	80.0	Yes	Yes	Oilseeds
44	Sesame	Yes	Yes	95.0	80.0	Yes	Yes	Oilseeds
45	Linseed/Flaxseed	Yes	Yes	95.0	80.0	Yes	Yes	Oilseeds
46	Soybean	Yes	Yes	95.0	80.0	Yes	Yes	Oilseeds
47	Cows	Yes	Yes	40.0	30.0	Yes	Yes	Livestock
48	Buffaloes	Yes	Yes	30.0	25.0	Yes	Yes	Livestock
49	Goats	Yes	Yes	70.0	85.0	Yes	Yes	Livestock
50	Pigs	Yes	Yes	60.0	55.0	Yes	Yes	Livestock
51	Ducks, Geese, Quail, Pigeons	No	No	-	-	Yes	Yes	Poultry Birds
52	Indian gooseberry	Yes	Yes	95.0	90.0	Yes	Yes	Wild Harvests
53	Malabar nut	Yes	Yes	90.0	95.0	Yes	Yes	Wild Harvests

S.N	Crops	Gender Participation in Commercial and Subsistence Crop Production						Crops classification
		Participation in Commercial crop Production		Involvement of Males and Females in Sales of commercial crops (%)		Participation in Subsistence crop production		
		Male	Female	Male	Female	Male	Female	
54	Red Silk Cotton	Yes	Yes	100.0	100.0	No	No	Wild Harvests
55	Stinging Nettle Leaf	No	Yes	0	95.0	Yes	Yes	Wild Harvests
56	Fiddle Head Wild Fern	No	Yes	0	90.0	Yes	Yes	Wild Harvests
57	Ginger	Yes	Yes	95.0	80.0	Yes	Yes	Medicinal herbs
58	Garlic	Yes	Yes	95.0	80.0	Yes	Yes	Medicinal herbs
59	Holy Basils	Yes	Yes	95.0	95.0	Yes	Yes	Medicinal herbs
60	Chirata	Yes	Yes	95.0	95.0	Yes	Yes	Medicinal herbs

3.1.2 Gender-wise raising of subsistence crops and Livestock

The study revealed that male farmers are involved periodically and seasonally in growing crops for household purposes, especially when cultivating labor-intensive cereal crops like maize and wheat. To maximize land use, these crops are often intercropped (Rusinamhodzi et al., 2012). Men tend to be less involved in kitchen and home garden management, which includes producing various vegetables, spices, and fruits, as their primary responsibilities focus on land preparation and fertilizer management (Abebe and Mulu 2017). Male respondents noted that when production is geared toward subsistence farming, they share the workload of livestock management since it is very time-consuming to rear animals. Interviews with farmers indicated that women are responsible for intercultural operations and other tasks related to the cultivation of subsistence crops. Similarly, women raise livestock, such as cows and buffaloes, for dairy products, goats, and chickens for sale in the neighborhood. They are also responsible for related tasks, including preparing biogas and managing livestock manure to enhance soil fertility (Binge et al. 2023). Additionally, women handle crop harvesting and post-harvest management, selecting and storing seeds for the next season.

3.1.3 Gender-wise harvesting of wild crops "Non-timber forest crops" (NTFPs)

Various wild plants, mentioned below, have been gathered and utilized to prepare organic manure. Men are primarily involved in the collection of these wild plants, which include several commonly collected resources (i) Malabar nut and mulberry are valued for their medicinal properties and serve as fodder and forage (Gupta et al. 2021), (ii) Stinging nettle leaves are used for both food and medicine (Ghasemi et al. 2024), and (iii) Chinaberry is collected explicitly for manure preparation (Ahmed et al. 2023).

On the other hand, women harvest various wild berries, including raspberries, blueberries, and blackberries, which are particularly beneficial as a fruit source for children. Wild ferns are gathered for household consumption and sold in local markets. These nutrient-rich ferns are often found in forests near canal sources (Rahmawati et al. 2017).

Other commonly collected resources include: (i) Stinging nettle leaves (used as food and medicine) (Ghasemi et al. 2024), (ii) Mushrooms, which serve as a dietary staple, (iii) Bamboo shoots (locally known as *Tama*), consumed as a food source, and (iv) Wild ferns, which are used as leafy greens and a source of nutrition (Rahmawati et al. 2017).

3.1.4 Existing agrobiodiversity of the area

The main crop varieties cultivated by the members of the Chabeli Farmers Group include additional valuable species, such as crops, oilseed crops, fodder and forage crops, species used for plant protection, and medicinal herbs, totaling 99 plant varieties (Table 2).

3.2 Knowledge transfer system for crops cultivation and animal management

Centuries-old traditional practices play a significant role in maintaining and protecting agro-biodiversity, as highlighted by Leoni (2024). Farmers in the local community engage in various methods of food cultivation, production, and value addition. These practices are influenced by cultural traditions associated with caste and religion. Their ancestors' Critical knowledge, incorporating local cultural and religious practices, has been passed down. For instance, the Janjati communities possess extensive knowledge of wild edibles and depend on forests for these forest foods, which are integral to their traditional culture. They rely on various resources, including wild mushrooms, bamboo shoots, wild ferns, berries, and medicinal herbs. These plants serve multiple purposes: food, medicine, fodder,

Table 2 Existing agrobiodiversity amongst the Chabeli groups

English/Local Name	Scientific Name	Characteristics of genotype	Genotype
A. Cereal Crops			
Maize (Makai)	*Zea mays*	Hybrids	Arun-2
			Manakamana-4
			Rampur Composite
			Sikhar-1
Wheat (Gahu)	*Triticum aestivum*	Improved/Semi-dwarf Varieties/High Yield	Gautam(improved)
			NL-971(semi-dwarf)
			WK 1204(semi-dwarft)
			NL 1110(high-yield)
Buckwheat (Fapar)	*Fagopyrum esculentum*	Early grown/Cold resistance	Jyoti
			Manang Local
			Rangli
			Madhupati
Paddy (Dhan)	*Oryza sativa*	Resistance varieties of Paddy	Dhan
			Khumal-4
			Radha-4
			Mansuli
Finger Millet(Kodo)	*Setaria Millet*	Foxtail Millet	Kaguno
	Pennisetum glaucum	Pearl Millet	MotiKodo
	Panicum miliaceum	Proso Millet	Chino
Barley (jau)	*Hordeum vulgare*	Improved /Local	Himalayan-4(improved)
			Goutum(local)
			Harsha(local)
Sorghum	*Sorghum bicolor*	Improved varieties	Lalit
B. Grain Legumes and Pulses			
Pigeon pea (Rahar Dal)	*Cajanus arietinum*	Local Varieties	Dhan Maya
			Madhukanya
Chickpea (Chana)	*Cicer arietinum*	High Yield	ICCV-10
			V-4
Yellow Pea (Pahelo Matar)	*Pisum sativum*	High yield/Disease resistance	Green Arrow
			Lincoln
Cow Pea (Bodhi)	*Vigna unguiculata*	High Yield	Arkel
Kidney Bean (Rajma)	*Phaseolus vulgaris*	High Yield	Red Kidney
			White Kidney
Butter Beans (Ghiu Simi)	*Phaseolus lunatus*	High Yield	Fordhook 242
Fawa Beans (Bacula)	*Vicia faba*	High Yield	Windsor

English/Local Name	Scientific Name	Characteristics of genotype	Genotype
Soyabeans (Bhatmas)	*Glycine max*		
Black Gram (Kalo Mas)	*Vigna mungo*	High Yield	T9
Green Gram (Hariyo Mas)	*Vigna radiata*	Early Maturity	NM-92
Red Lentil (Masoor)	*Lens culinaris*	High Yield Potential	Dhaulagiri
C. Horticulture (Fruit crops)			
Banana (Kera)	*Musa sapientum*	Large (size)	Rajapuri
		Medium(size)	Basrai
		Small(size)	Rasthali
Jackfruit (Katahar)	*Artocarpus heterophyllus*	Large (size)	Katahar
Peach (Aru)	*Prunus persica*	Prunuspersica	Elberta
Apricot (Khubani)	*Prunus armeniaca*	Taste(Sweet)	Goldcot
Persimmons (Lapsi)	*Diospyros kaki*	Astringent	Hachiya
Berries	*Rubus idaeus*	Taste	Raspberries(Aiselu)
	Rubus fruitcosus		Blackberries(KaloAiselu)
	Fragaria ananassa		Strawberries(Chino)
Pears (Naspati)	*Pyrus communis*	Popular Variety	Barlett
Plums (Aloo Bukhara)	*Prunus domestica*	Popular Variety	Methley
D. Horticulture (Vegetable crops)			
Potato (Aalu)	*Solanum tuberosum*	Popular Variety	KhumalRato
Cabbage (Banda)	*Brassica oleracea*	Popular Variety	Green Cabbage
Raddish (Mula)	*Raphanus sativus*	Popular Variety	Red Radish
		Popular Variety	White Radish
Carrot (Gajar)	*Daucus carota*	Hybrid	Nepa-Dhim
Turnip (Salgum)	*Brassica rapasubsp*	Size /Popular Variety	Purple Top Turnip
			White Globe Turnip
			Golden Ball Turnip
Tomato (Tamatar)	*Solanum lycopersicum*	Popular Variety	Cherry Tomato
			Surakhsya
Chilli (Khursani)	*Capsicum annuum*	Popular Variety	Chilli Pepper
	Capsicum chinense Habanero	Popular Variety	Habanero Chilli
Cucumber (Kakro)	*Cucumissativus*	Popular Variety	Dynasty
Pumpkin (Farsi)	*Cucurbita moschata*	Popular Variety	Chhanga
Bottle gourd (Lauka)	*Lagenaria siceraria*	Popular Variety	Pandhera
Okra (Bhindi)	*Abelmoschus esculentus*	Popular Variety	DharaneBhindi
Chayote (Iskush)	*Sechium edule*	Popular Variety	Iskus
Cauliflower (Kauli)	*Brassica oleracea var. botrytis*	Popular Variety	Phoolkobi

English/Local Name	Scientific Name	Characteristics of genotype	Genotype
Bamboo Shoot (Tama)	*Bambusa vulagaris*(sp.)	Popular Variety	Bans
Mushroom (Chiyau)	*Pleurotus ostreatus*	Popular Variety	Oyster Mushroom
Stinging Nettle Leaf (Sisno)	*Urticodiocia*	Wild Variety	
Fiddle Head Wild Fern (Ningro)	*Matteuccia struthiopteris*	Wild Variety	
E. Oil Seeds			
Black Mustard (KaloToori)	*Brassica nigra*	Popular Variety	Varuna
Sesame (Teel)	*Sesamum indicum*	Hybrid	-
Linseed/Flaxseed	*Linum usitatissimum*	Popular Variety	-
Soybean	*Glycine max*	Popular Variety	-
F. Fodder and Forage			
Berseem	*Trifolium alexandrinum*	Popular Variety	-
Malabar nut	*Justicia adhatoda*	Wild Variety	-
Mulberry	*Morus nigra*	Wild Variety	-
Stinging nettle leaf	*Urtica dioica*	Wild Variety	-
G. Materials used for Plant Protection			
Red Silk Cotton	*Bombax ceiba*	Popular Variety	-
Rhododendron	*Rhododendron arboretum*	Wild	-
Malabur nut	*Justicia adhatoda*	Wild	-
Neem	*Azadirachta indica*	Popular Variety	-
China Berry	*Melia azedarach*	Wild	-
Indian gooseberry	*Phyllanthus embica*	Wild	-
Holy Basil	*Ocimum tenuiflorum*	Wild	-
Gokshura	*Tribulus terrestris*	Wild	-
Sarpagandha	*Rauvolfia serpentina*	Wild	-
Livestock Dung	-	-	-
Livestock urine	-	-	-
H. Medicinals Herbs			
Ginger	*Zingiber officinale*	Popular Variety	-
Garlic	*Allium sativum*	Popular Variety	-
Satavari	*Asparagus racemosus*	Wild	-
Spikenard	*Nardostachys jatamansi*	Wild	-
Holy Basils	*Ocimum tenuiflorum*	Wild	-
Chirata	*Swertia chirayita*	Wild	-
I. I.ivestock and Poutry			
Cow (jersey)	*Bos taurus*	Popular	-
Buffalo	*Bubalus bubalis*	Popular	-

English/Local Name	Scientific Name	Characteristics of genotype	Genotype
Goat	*Capra aegagrushircus*	Popular	-
Pig	*Sus scrofa domesticus*	Popular	-
Ox	*Bos taurus*	Popular	-
Chicken	*Gallus domesticus*	Popular	-
Duck	*Anas platyrhynchos domesticus*	Popular	-
Pigeon	*Columba livia*	Popular	-
Geese	*Anser anser domesticus*	Popular	-
Quails	*Coturnix japonica*	Popular	-

and insect and pest repellents. Similarly, Newari communities have unique cultural and religious practices tied to the cropping cycle and food that correspond with the changing seasons. They celebrate various rituals and festivals aligned with agricultural production practices. Notably, they are famous for producing a popular local wine called Chyang, which is made from cereals such as rice, millet, and sorghum.

3.2.1 Medicine and Pesticide Preparation Using Plants

There are longstanding practices for preparing medicine and pesticides from wild plants, including: (a) The creation of liquid manure using Asuro and livestock excreta and urine to control pests and manage diseases (Tiwari et al. 2023), (b) The use of cow urine and Mugwort (*Artemisia vulgaris*) for pest management (Baruah et al. 2024), (c) The application of medicinal herbs such as Bozo (*Acorus calamus*) for sore throats, Holy Basil for coughs and fevers, and ginger for inflammation (Nair and Groot 2021), (d) Various wild (such as Tanki "*Bauhinia purpurea"*) and cultivated legumes are utilized to maintain soil fertility and provide fodder, and (e) The incorporation of wild edible herbs and fruits, including cardamom, chiraito, bamboo shoots, berries, chili, and turmeric, which are commonly used spices that enhance flavor in cooking and meet dietary needs (Thapa et al. 2018).

3.2.2 Bio-cultural heritage

Farmers primarily grow staple crops to ensure food security and nutrition for their families, making staple crop production a key priority for farming households (Andriessen et al. 2025). They actively preserve agrobiodiversity by cultivating traditional crop varieties with cultural and nutritional significance. These farmer-selected varieties, including rice, maize, millet, beans, vegetables, fruits, and livestock breeds, have evolved through local farmers' selection, adaptation, and improvement processes over generations. Approximately 80% of staple crops such as rice, maize, millet, and barley are sold in the market, while the remaining 20% is stored for household consumption or livestock feed. However, the growing emphasis on commercial farming and adopting high-yielding crop varieties has led farmers to explore alternative production systems, such as vegetable farming (Nguyen and Singh 2024). Most vegetables cultivated are modern varieties designed to meet market demand and secure higher prices. For instance, farmers in the Chabeli group incorporate various fodder and forage species to enhance dairy production.

Additionally, farmers grow neglected and underutilized crops, such as *Amaranthus spp*., naked barley, and sesame, to provide essential micronutrients (Akram et al. 2023). Staple crops like wheat, rice, maize, and millet are primarily grown as daily sources of carbohydrates, with only surplus production being sold. Vegetables and fruits, including root crops like potatoes and yams, and others like tomatoes, onions, chilies, cauliflower, and cabbages are cultivated for their vitamins, minerals, and dietary fiber (Górska-Warsewicz et al. 2021). Certain crops are cultivated due to their cultural and religious significance:

1. Rice (*Oryza sativa*): Rice is considered sacred and is used in various ceremonies, such as weddings, death rituals, and the traditional rice-feeding ceremony for infants (Malla 2018).

2. Wheat (*Triticum aestivum*): Wheat symbolizes the sun's power and is integral to rituals associated with the sun.

3. Holy Basil (*Ocimum sanctum*): A sacred plant in Hinduism, holy basil is used in religious ceremonies and is known for its medicinal properties, including reducing inflammation and aiding digestion.

4. Asparagus (*Asparagus racemosus*): This plant is used in Ayurvedic medicine to address digestion, respiration, and reproductive health issues.

5. Amla (*Emblica officinalis*): Amla is known for boosting immunity and improving digestion. It has both medicinal and religious significance.

6. Ginger (*Zingiber officinale*): Valued for its medicinal properties, ginger also carries spiritual significance in traditional Hindu practices.

Farmers are increasingly attracted to cultivating high-value horticultural crops such as kiwi, avocado, and strawberry as cash crops (Rai and Rai 2024a; Rai and Rai 2024b). These fruits are gaining popularity in Bhimphedi Municipality, where agricultural officers and local governments provide training and support in organic farming, organic manure preparation, and mushroom cultivation to enhance commercial viability. Such initiatives also aim to engage youth and reduce migration rates. Additionally, common spices like ginger, garlic, turmeric, and chilies are widely grown and processed by microenterprises for sale.

Farmers raise chickens, goats, and pigs for meat and eggs, while cows and buffaloes are raised for dairy products like milk, butter, and ghee. Although livestock production traditionally focuses on meeting household nutritional needs, it is becoming increasingly market-oriented (Yitayih et al. 2024). Farmers also use local plants for various farming functions, such as planting fodder along traditional canals to reduce seepage. Fodder and forage species are grown on terrace risers to stabilize the terraces and prevent soil erosion, reducing dependence on forest resources.

3.2.3 Crop Management Practices

Farmers in this region integrate traditional cultural practices into their planting, harvesting, and seed-sowing activities. These practices continually evolve as they incorporate scientific techniques to adapt to changing environmental and agricultural conditions (Ismail et al. 2025). Smallholder farmers play an active role in conserving agro-biodiversity through these varied approaches. Many farmers practice crop rotation to improve soil fertility, control pests and diseases, and prevent soil erosion (Akbar et al. 2024). The commonly used crop rotation patterns identified in the study include: (i) Maize-Paddy-Wheat-Finger Millet: This traditional rotation involves growing maize in the summer, paddy during the rainy season, and wheat and finger millet in the winter, (ii) Maize-Beans/Vegetables: Maize is grown in the summer, while beans are cultivated in the winter. This combination helps maintain soil fertility and reduces labor costs, (iii) Paddy-Wheat: This rotation is favored due to the high demand for rice and wheat. Paddy is grown during the rainy season, followed by wheat in the winter. In spring, cold-resistant paddy varieties such as Sukha-4, Chandanath-1, and Khumal-4 are planted, which require less water, and (iv) Root Crops Followed by Fruits: Farmers grow root crops like ginger and carrots alongside fruit crops. They believe this mixture enhances productivity, as root crops deplete nitrogen from the soil, while fruit and legume crops replenish it.

3.2.3.1 Integrated Systems: Mixed Cropping/Intercropping

This practice involves planting multiple crops to enhance biodiversity, reduce soil erosion, and improve soil fertility (Li et al. 2024). Examples include: (i) Maize and beans: These complementary crops grow well together, (ii) Cucumbers and pumpkins intercropped with maize or millet: Vegetables are grown alongside cereal crops to optimize space and time, benefiting household and commercial production.

3.2.3.2 Cover Cropping

Cover crops are cultivated not for harvest but to enhance soil health and decrease reliance on synthetic fertilizers (Priya and Ramesh Kumar 2025). Some effective combinations of cover crops include: (i) Alfalfa with Maize or Potatoes: This combination helps reduce weed growth, prevents soil erosion, and increases the organic matter in the soil, (ii) Legumes (Peas, Beans, Lentils): These crops improve soil fertility and provide a food source for farmers and livestock.

3.2.3.3 Traditional Seed Storage and Mulching

Farmers utilize techniques like Mór storage, which is particularly effective for storing potatoes. Additionally, leaves from local trees, such as maple and banana, are commonly used for mulching to conserve soil moisture and suppress weeds.

3.2.3.4 Biocontrol Agents and Biopesticides

Farmers protect their crops using traditional biocontrol methods and plant-based biopesticides made from local materials. These practices promote sustainable pest and disease management while minimizing the use of chemical inputs. By integrating traditional knowledge with modern techniques, farmers create sustainable ecosystems, maintain soil health, and protect biodiversity while adapting to contemporary agriculture's challenges.

3.2.3.5 Traditional method of nursery preparation

Farmers have reported that the traditional method of nursery preparation involves planting seedlings using wild tree leaves. This approach helps keep the nursery bed free of weeds. Additionally, these practices are cost-effective as they use locally available materials to create a healthy nursery environment. This method is particularly effective for preparing nurseries for climbing and creeping plants.

3.3 Knowledge transfer system

3.3.1 Generation to generational knowledge transfer (within the household)

Farmers play a crucial role in preserving various plant species on their land and nearby forests to meet the needs of their households and farming communities (Czembor et al. 2024). These needs include food, fodder, medicinal plants, and spices. Knowledge and practices related to plant conservation have been passed down through generations and are deeply rooted in local and traditional wisdom. This intergenerational knowledge transfer occurs during daily farm work and interactions, ensuring that sociocultural beliefs and traditional practices are maintained while managing the farms.

3.3.2 Knowledge transfer (Neighbor)

Farmers can share knowledge with their neighbors through informal interactions (Wei et al. 2025). More structured opportunities arise during local events, fairs, and festivals. Additionally, the establishment of farmer groups, such as the Chabeli Farmers Group and the Mai Farmers Group, has further improved the exchange of information. These groups allow lead farmers to demonstrate best practices, fostering learning among their fellow farmers. Such gatherings also provide valuable platforms for sharing experiences related to modern farming techniques and introducing new crop varieties and livestock breeds. Events like seed fairs, farmer field schools, and integrated pest management (IPM) initiatives, organized by various supporting institutions collaborating with farmers' groups, offer opportunities to exchange seeds, plant cuttings, and other planting materials.

3.3.3 Group (Chabeli) Knowledge Network

The Chabeli Farmers Group actively promotes knowledge sharing among its members. For instance, the group demonstrates biofertilizer production techniques at designated demonstration sites supported by the NFGF. Farmers quickly recognized that biofertilizer production builds on their traditional knowledge while adapting it to modern practices, and they soon began replicating these techniques on their farms. With guidance, the group also adopted advanced composting methods, such as mixing *Trichoderma* with animal dung to produce vermicompost. This method has gained significant popularity among farmers in Bhimphedi Municipality for organic vegetable cultivation. Furthermore, the group has encouraged adopting climate-resilient practices, including rehabilitating traditional reservoir ponds, harvesting rainwater, and collecting wastewater. Wastewater from households and farms is stored in ponds to cultivate algae, an effective biofertilizer. Additionally, tree species are integrated into degraded or abandoned agricultural land, transforming into productive agroforestry systems. Farmers have highlighted the benefits of domesticating and sustainably managing wild tree species, which enhance dietary diversity and provide wood for various farm needs. Some tree species are also valued for improving livestock feed, medicinal uses, and plant protection measures, reflecting a holistic approach to sustainable farming. The Chabeli Farmers Group has established a demonstration garden to showcase agro-biodiversity organic farming practices. The garden features a mix of local and improved crop and vegetable varieties. Group members are encouraged to learn from this site and implement the practices on their farms.

3.3.4 Forest and Farm Producer Organizations (FFPOs) Knowledge Network

As part of the NFGF, the group benefits from a knowledge-sharing network that provides advanced insights into farm management and production, including (i) Technical expertise in organic farming, updated soil fertility management practices, establishing and managing a participatory guarantee system (PGS), and strategies for building resilient production systems, and (ii) Market-oriented farming knowledge is disseminated through farmer field schools, exchange visits, and targeted coaching sessions on specific agricultural topics.

Additionally, the group engages with specialized knowledge and technologies through various initiatives, such as (a) Participatory action planning to promote the adoption of resilient and proven techniques that combine traditional and modern practices, (b) Onsite pest and disease management training to enhance farmers' skills and capacities, (c) Access to diverse information sources, including publications, agri-bulletins, radio programs from the National Agricultural Research Council (NARC), and materials shared by local governments and civil society organizations, (d) Market access facilitation supported by programs like the Forest and Farm Facility (FFF), (e) Agroforestry improvements that upgrade traditional practices for sustainable land use, (f) Capacity development for PGS implementation to enhance production standards and certification, and (g) Adopt climate-smart water management practices emphasizing efficient water use and conservation techniques.

Table 3 Lists of Traditional Biopesticides used by Chabeli

S. N.	Name of Bio pesticides (Traditionally Used)	Common name of Bio pesticides	Applications
1	Neem Oil,Titepati Extract	Neem Oil	Neem is a natural pesticide extracted from the seeds of the neem tree. It is effective against many pests and is commonly used in Nepal to control aphids, thrips, whiteflies, and caterpillars.
2	Garlic-based Biopesticides	Lasunkojhol	Garlic is known for its antifungal and antibacterial properties, which make it an effective natural pesticide. Garlic extract is used in Nepal to control fungal diseases in crops such as potatoes and tomatoes.
3	Liquid Manure	Jholmal	Biological control liquid manure against insect pests such as aphids, whiteflies, and mealybugs. It effectively controls pests in various crops, including vegetables, fruits, and ornamental plants.

These initiatives strengthen the group's ability to integrate sustainable, innovative, and market-responsive farming methods while preserving and enhancing traditional agricultural practices.

3.4 Resource management system (Crop seeds for cultivation and Livestock raising)

3.4.1 Self-provisioning and multiplication

Farmers rely on traditional methods for managing seeds for personal use and selling at local markets. These practices include: (i) Seed collection and storage: Farmers gather seeds from locally adapted plants, including traditional and heirloom varieties. They carefully dry and store these seeds in optimal, dry conditions to ensure seed viability (Davidson et al. 2024), (ii) Labeling and organization: Each seed packet includes the plant name, variety, and relevant details about its characteristics or growing requirements. Farmers organize their seed collections systematically to allow for easy access and retrieval, (iii) Record keeping: Detailed logs are maintained, noting the collection date, location, and other plant observations. These records help track seed performance and identify potential issues, (iv) Marketing: Farmers sell their collected seeds at local markets while sourcing seeds from other producers, fostering a dynamic exchange of planting materials.

These practices help ensure seed quality, promote agrobiodiversity, and support local agricultural economies.

Grains are stored in a Bhakari, a traditional container made from bamboo and mud. Typically, Bhakaris have a single chamber, although some variants have two chambers. The double-chambered Bhakari is especially useful in regions prone to flooding, as it allows farmers to use the grains from the lower chamber first, reserving the contents of the upper chamber for the monsoon season. These containers can hold up to two tons of grains.

Another storage method involves using Ghaita, clay pots for holding beans and mustard seeds. These pots are filled with seeds and sealed with clay lids. To help retain moisture, a layer of straw may be placed inside the Ghaita. Additionally, the Chaaita technique uses bamboo to store smaller quantities of seed grain. This method involves covering the Chaaita with mud to protect it from pests and moths. Such practices are commonly observed among Janajati or Indigenous communities.

3.4.2 Neighbor barter or purchase

As the leading federation of Forest and farm producer organizations (FFPO), the NFGF organizes regular fairs and exchanges to facilitate seed sharing among farming communities. Its goal is to promote agrobiodiversity and enhance local seed stocks. Community members actively participate in seed fairs hosted by producers in the Bhimphedi municipality. These fairs showcase unique local seed varieties well-adapted to the region's soil, climate, and environmental conditions, making them invaluable for farmers and breeders. Such events also strengthen connections between farmers and market actors, supporting seed swaps and encouraging collaboration.

The Chabeli Farmers Group contributes by hosting a demonstration stand at nutrition fairs organized by schools and local governments. These fairs highlight the group's diverse produce and aim to inspire young people to engage in agriculture while emphasizing the importance of nutritional values.

The NFGF has also introduced mobile applications, including the Krishipath and Krishi Guru apps. These platforms provide farmers with a wealth of resources, such as information on crops and varieties, seed availability, market prices, production guidelines, crop insurance, and government schemes. The Chabeli Farmers Group utilizes these apps to connect with fellow farmers and agricultural experts, facilitating experience sharing and mutual support. These tools empower farmers with the knowledge and resources to identify high-quality seeds and improve their agricultural practices.

3.4.3 Formal system of a community seed bank

Smallholder farmers actively participate in on-farm conservation practices, focusing on preserving crop landrace seeds for both household use and market sales. These farmers rely heavily on traditional and local knowledge to carefully select and store viable seeds for the next planting cycle. This approach ensures farmers have easy and reliable access to seeds and planting materials for various crops. The apex producer organization supports and advocates for these practices, emphasizing the importance of farmers' rights and food sovereignty. Local seed preservation efforts typically concentrate on maintaining native varieties of key crops, including maize, millet, spices, and horticultural products, thus safeguarding their agricultural heritage and enhancing resilience.

3.5 Enterprise strategies and agrobiodiversity

The Chabeli Farmers Group, in partnership with the local government, operates an integrated pest management (IPM) learning center. This initiative has allowed the group to adopt more environmentally friendly agricultural practices, enhancing market opportunities. The center has also trained five additional farmer groups from neighboring communities and four community-led farmers from each group. The IPM center promotes organic and climate-resilient farming through improved soil and pest management techniques.

The Chabeli Farmers Group is dedicated to producing various products using organic methods, mainly focusing on local varieties of legumes and vegetables. They prioritize the conservation of these traditional varieties and cultivate them using organic practices. Their strategy includes selling vegetables in commercial markets and targeting niche markets with diverse local products.

NFGF is implementing a Participatory Guarantee System (PGS) to improve its services and add value. This system enables farmer groups within the same area to agree on organic standards and ensure compliance through peer audits. These groups receive support from NFGF, the local government, and the FFF program to develop enterprise plans that establish a clear vision and actionable steps for their agribusiness ventures.

3.5.1 Cash crops

The primary commodity the farmer group sells is organically produced vegetables, although they also cultivate local varieties of cereals and legumes. The commercially grown crops include leafy greens, tomatoes, cereal grains, and legumes. However, the shift toward commercial organic vegetable production in Bhimphedi may lead to a reduction in on-farm agro-biodiversity as new and improved vegetable varieties such as black tomatoes and fruit species like strawberries, kiwis, and avocados replace areas previously dedicated to local crops. Despite this shift, farmers continue to rely on traditional knowledge and agro-biodiversity to maintain organic production, utilizing wild plant materials for pest management and soil fertility.

Farmers are encouraged to incorporate sustainable traditional practices, such as crop rotation, minimum tillage, using natural mulching sources, and integrating beneficial fodder, forage, and horticultural species. They are also urged to protect and manage beneficial plants from forests, maintaining integrated forest-farm systems. The rise in commercial production has raised environmental concerns, such as the increased use of polybags, plastics, and machinery, which contribute to climate pollution and a decline in traditional practices like intercropping, crop rotations, and zero tillage. The impact of these changes on soil health and microbial organisms remains unclear. Furthermore, introducing improved varieties may lead to replacing traditional local crops, and some improved varieties may be more susceptible to pests and diseases, potentially reducing the resilience of the agricultural system to climate change.

Despite these challenges, farmers, the local government, and the National Farmers' Group Federation (NFGF) are collaborating to align commercial production more closely with traditional methods. They also advocate for environmentally friendly practices that are resilient to climate change and focus on protecting natural plants, animals, and crop varieties. Additionally, adopting value-added agroforestry is encouraged, allowing marginalized farmers to grow marketable fodder plants, like Malabar nuts, alongside horticultural crops such as fruits and vegetables.

3.5.2 Changing pattern of cash crops cultivation

Farmers initially produced local varieties of cereals and legumes, taking advantage of their unique characteristics and flavors. These commodities were sold in local markets and nearby cities. There was also a focus on seasonal vegetable production in Bhimphedi municipality, including the Chabeli farmer groups. However, due to the growing demand for their vegetables, these farmers are now transitioning to commercial production, including seasonal and off-season crops.

3.5.3 The role of the Chabeli Farmers Group in Shaping sale and income generation

The Chabeli Farmers Group is increasingly becoming a recognized brand for safe and organic vegetable production while strengthening its relationships with various market stakeholders. To maintain consistent quality and scalability, the group has developed a crop calendar that guides the cultivation of their crops. While commercial production has expanded the variety of crops and animal species being raised, there are concerns that this dominance might threaten agro-biodiversity.

Additionally, the group has received training in mushroom production from local municipality officials and has adopted new methods for growing mushrooms, including systematically preparing dark houses. These mushrooms are now packaged and sold at local markets in Bhimphedi. Furthermore, the group is promoting the development of value-added enterprises, such as crop processing and packaging, which are expected to enhance the value of their products and provide additional sources of income.

3.5.4 Future Enterprise Plan

The Chabeli farmer group aims to transform their area into an organic production hub and enhance their capacity to produce local products, thereby preserving local agro-biodiversity. They have begun promoting their organic products in local and provincial markets and have developed a marketing strategy that emphasizes the benefits of organic farming, particularly its positive effects on biodiversity and climate change. The group encourages farmers to participate in local farmers' markets and connect with online platforms, establishing a direct link to consumers.

This approach has been identified as a crucial strategy for building resilience against the impacts of climate change. By implementing these plans, they can contribute to biodiversity conservation, mitigate the effects of climate change, and promote healthy, sustainable food production. Smallholder farmers are prepared to engage with microfinancing options to scale up the production and distribution of commercial products. Additionally, they have partnered with the local government to initiate a Participatory Guarantee System (PGS) to recognize and brand their local and organic products.

A case study by Karki et al. (2020) on climate change adaptation among subsistence and smallholder farmers revealed both climatic and non-climatic factors that influence adaptation practices. Moreover, diversifying income sources is one of the primary adaptation strategies. Climatic factors beyond human control pose significant threats to the livelihoods of rural smallholders, whose income relies heavily on natural resources.

The food system will substantially change to address nutrition, food security, and sustainability challenges. These changes will enhance resilience, democracy, and sustainability to support the ever-growing population while mitigating the adverse environmental impacts on agriculture (Chaudhary et al. 2023). Furthermore, in the context of Nepal, research on farming systems plays a vital role in improving agricultural productivity, sustainability, and the livelihoods of smallholder farmers (Shrestha et al. 2024). In contrast to conventional agricultural practices, which contribute to resource degradation and biodiversity loss, sustainable agricultural methods, mainly organic bio-intensive farming and agroecological practices, have proven effective in conserving natural resources, improving rural livelihoods, diversifying farm income, and stabilizing the agricultural sector (Rai et al. 2024).

Conclusion

In summary, smallholder farmers are crucial in preserving and enhancing agrobiodiversity through their traditional, regionally adapted agricultural methods. Despite the challenges posed by modern technologies and hybrid varieties, these farmers maintain a rich knowledge repository that has been developed over generations. Their reliance on local practices promotes sustainable and environmentally friendly farming while revitalizing Nepal's unique agricultural and culinary heritage. The business-oriented actions of agricultural producer groups have facilitated the rise of organic farming and the establishment of local certification systems, making it easier for farmers to access profitable markets.

Furthermore, the shift towards ecological production has empowered farmers to transform traditional farming systems into resilient and sustainable practices that benefit plant and animal health. This approach reduces dependency on external inputs and better equips farmers to manage challenges posed by climate change and other external pressures. Farmers enhance their self-sufficiency by adopting agroecology-based value chains and actively contributing to local biodiversity conservation. Combining advanced technologies with indigenous knowledge continues to reshape local agricultural practices, ensuring long-term sustainability and prosperity of smallholder farming communities.

Recommendations

The Chabeli farmer group is actively engaged in their community and deserves recognition for their efforts. Documenting their traditional knowledge and practices is essential. Mechanisms like seed banks should be promoted to manage farmer landraces sustainably while safeguarding their rights to natural resources. Seed banks can help smallholder farmer groups, such as Chabeli, conserve and sustainably utilize seed resources, thereby supporting the maintenance of agrobiodiversity.

Additionally, the group should analyze market trends and develop a specific strategy for local niche products to ensure sustainable production and distribution of their goods. Gaining product recognition is vital, so they need to enhance their branding efforts and systematically label their products.

In partnership with farmers, the local government should prioritize the documentation and registration of agrobiodiversity and traditional knowledge, as local cultivars and native plants are gradually disappearing. The local government must identify and protect the agrobiodiversity that local communities have conserved and utilized. This collaboration is vital to ensure a resilient supply of seeds and promote agrobiodiversity conservation. Additionally, it is essential to recognize the value of agrobiodiversity. There is a need to develop mechanisms that compensate farmers for their efforts in using and conserving biodiversity, and these mechanisms should be established and formalized.

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Conflict of Interest

The authors declare that they have no prevailing conflict of interest in terms of financial, academic, commercial, political, or personal regarding the conduct of case studies and the content and authors' position in the manuscript.

Ethical Clearance

Not Applicable.

References

Abebe, T., & Mulu, D. (2017). The role of women in the management and utilization of home garden: The case of Dale

District in Southern Ethiopia. *Asian Journal of Plant Science and Research, 7*(4), 41-54.

Agnoletti, M., & Santoro, A. (2022). Agricultural heritage systems and agrobiodiversity. *Biodiversity and Conservation, 31*(10), 2231–2241. https://doi.org/10.1007/s10531-022-02460-3

Ahmed, M. S., Yasin, M., Zia, M. U., & Nadeem, M. A. (2023). Composted *Melia azedarach* L. (Chinaberry tree) sawdust mixtures regulate the sprouting and growth of single bud node seedlings of sugarcane. *Journal of Soil Science and Plant Nutrition, 23,* 2465-2475.

Akbar, A., Arshad, K., Shehnaz, S., Ahmad, W., Ullah, A., Sattar, A., & Ali, A. (2024). The role of sustainable farming practices in enhancing soil fertility and crop yield. *Dialogue Social Science Review (DSSR), 2*(5), 137–147.

Akram, I., Layla, A., & Ismail, T. (2023). Exploring neglected and underutilized plant foods to fight malnutrition and hunger in South Asia. In T. Ismail, S. Akhtar, C.E. Lazarte, (Eds), *Neglected plant foods of South Asia: Exploring and valorizing nature to feed hunger* (pp. 51–71). Springer, Cham. https://doi.org/10.1007/978-3-031-37077-9_3.

Altieri, M. A. (1999). Applying agroecology to enhance the productivity of peasant farming systems in Latin America. *Environment, Development and Sustainability, 1*, 197–217.

Altieri, M. A., Funes-Monzote, F. R., & Petersen, P. (2012). Agroecological efficient agricultural systems for smallholder farmers: Contributions to food sovereignty. *Agronomy for Sustainable Development, 32*(1), 1–13. https://doi.org/10.1007/s13593-011-0065-6

Andriessen, T., van der Horst, H., & Morrow, O. (2025). Forms of autonomy and dependence in food aid: Unravelling how they are related and perceived by recipients. *Agriculture and Human Values*, 1–15. https://doi.org/10.1007/s10460-025-10715-2

Baruah, K., Rana, M., & Sharma, L. (2024). Ethnobotanical insights into the medicinal, agricultural, and veterinary applications of *Artemisia vulgaris* in the Sikkim region. *Ecology Environment and Conservation, 30*(4), 1780-1784. DOI:10.53550/EEC.2024.v30i04.052.

Binge, B., Jalango, D., & Tesfaye, L. (2023). Post-harvest losses management through climate-smart innovations: A collaborative approach among value chain actors. Retrieved from https://www.cgiar.org/research/publication/post-harvest-losses-management-through-climate-smart-innovations-collaborative-approach-among-value-chain-actors/ accessed on 15th January 2025.

Bravo-Peña, F., & Yoder, L. (2024). Agrobiodiversity and smallholder resilience: A scoping review. *Journal of Environmental Management, 351*, 119882.

Bukchin-Peles, S., & Fishman, R. (2021). Should long-term climate change adaptation be focused on smallholders? *Environmental Research Letters, 16*(11), 114011.

Central Bureau of Statistics. (2011). *National living standard survey, 2010/2011*. (Commission, N. P. ed.). Kathmandu, Nepal: Government of Nepal.

Chaudhary, P., Upadhya, D., Dhakal, B., Dhakal, R., & Gauchan, D. (2020). Generation, gender, and knowledge gap in agrobiodiversity among smallholders in Nepal. *Journal of Agricultural Science, 12*(9), 62-73.

Chaudhary, S., Shrestha, A. K., Rai, S., Acharya, D. K., Subedi, S., & Rai, R. (2023). Agroecology integrates science, practice, movement, and future food systems. *Journal of Multidisciplinary Sciences, 5*(2), 39–60.

Córdoba Vargas, C. A., Hortúa Romero, S., & León-Sicard, T. (2020). Resilience to climate variability: The role of perceptions and traditional knowledge in the Colombian Andes. *Agroecology and Sustainable Food Systems, 44*(4), 419–445. https://doi.org/10.1080/21683565.2019.1649782

Czembor, E., Tratwal, A., Pukacki, J., Krystek, M., &Czembor, J. H. (2024). Managing fungal pathogens of field crops in sustainable agriculture and AgroVariety internet application as a case study. *Journal of Plant Protection Research.* Retrieved from https://www.plantprotection.pl/Managing-fungal-pathogens-of-field-crops-in-sustainable-agriculture-and-AgroVariety,192507,0,2.html.

Dagunga, G., Ayamga, M., Laube, W., Ansah, I. G. K., Kornher, L., & Kotu, B. H. (2023). Agroecology and resilience of smallholder food security: A systematic review. *Frontiers in Sustainable Food Systems, 7*, 1267630.

Davidson, T., DeSa, M., & Pérez, H. (2024). A beginner’s guide to producing and saving open-pollinated seeds for North Florida farmers and gardeners: ENH1383/EP647, 12/2024. *EDIS, 2024*(6). DOI:10.32473/edis-ep647-2024.

Department of Forest Research and Survey (2017) CFUG database record available in MIS. Community Forestry Division, Department of Forest and Survey, Kathmandu.

Drucker, A. G., Pradel, W., Scott, C., Elmes, S., Arpazi Valero, K. G., & Zander, K. K. (2022). Are public good ecosystem services generated by on-farm conservation of crop diversity valued by the general public? Preprint available at *Research Square.* https://bit.ly/3N5tqeu

Ellis, F. (1998). Household strategies and rural livelihood diversification. *The Journal of Development Studies*, *35*(1), 1–38. https://doi.org/10.1080/00220389808422553.

Fan, S., & Rue, C. (2020). The role of smallholder farms in a changing world. In *S. Fan & C. Rue (Eds.), The role of smallholder farms in food and nutrition security* (pp. 13–28). Springer. https://doi.org/10.1007/978-3-030-42148-9_2

Fanzo, J., Hunter, D., Borelli, T., & Mattei, M. (2013). *Diversifying food and diets: Using agricultural biodiversity to improve nutrition and health.* Routledge Taylor & Francis.

FAO. (2019). *FAO framework on rural extreme poverty: Towards reaching target 1.1 of the sustainable development goals.* Retrieved from http://www.fao.org/3/ca4811en/ca4811en.pdf

Food and Agriculture Organization of the United Nations (FAO). (1999). *Agricultural biodiversity, multifunctional character of agriculture and land conference.* Background Paper 1. Maastricht, Netherlands.

Food and Agriculture Organization of the United Nations (FAO). (2011). *Save and grow A—Policymaker's guide to the sustainable intensification of smallholder crop production.* Rome.

Forsythe, L. (2017). *The impact of staple crop value chain participation on the livelihoods of smallholder farmers in Nigeria and Malawi: Changes in poverty, gender relations, and food security*. Doctoral dissertation submitted to the University of Greenwich, London.

Garner, E., & de la O Campos, A. (2014). Identifying the "family farm": An informal discussion of the concepts and definitions. *ESA Working Paper 14-10.* Food and Agriculture Organization of the United Nations (FAO).

Gautam, A., Bishwakarma, P., &Paudel, I. P. (2020). *Scaling up climate-resilient agriculture for sustainable livelihood of smallholder farmers in Nepal.* Local Initiatives for Biodiversity, Research and Development (LI-BIRD), Nepal. Retrieved from https://libird.org/wp-content/uploads/2022/04/CRA_Baseline_Report_Final.pdf.

Gerits, F., Messely, L., Reubens, B., &Verheyen, K. (2021). A social–ecological framework and toolbox to help strengthen functional agrobiodiversity-supported ecosystem services at the landscape scale. *Ambio, 50*(2), 360–374. https://bit.ly/47Y0JYQ

Ghasemi, P., Behbahani, B. A., & Noshad, M. (2024). Assessment of the Antioxidant Effects of *Urtica dioica* Aqueous Extract on Free Radical Scavenging, Determination of Total Phenol and Flavonoid Content, and the Bioactive Compound Groups. *Journal of Food Science & Technology, 21* (154), 163-173. DOI: 10.22034/FSCT.21.154.163.

Górska-Warsewicz, H., Rejman, K., Kaczorowska, J., & Laskowski, W. (2021). Vegetables, potatoes, and their products as sources of energy and nutrients to the average diet in Poland. *International Journal of Environmental Research and Public Health, 18*(6), 3217.

Guarín, A., Rivera, M., Pinto-Correia, T., Guiomar, N., Šūmane, S., & Moreno-Pérez, O. M. (2020). A new typology of small farms in Europe. *Global Food Security, 26*, 100389. https://doi.org/10.1016/j.gfs.2020.100389

Gugerli, F., Englisch, T., Niklfeld, H., Tribsch, A., Mirek, Z., et al. (2008). Relationships among levels of biodiversity and the relevance of intraspecific diversity in conservation – A project synopsis. *Perspectives in Plant Ecology, Evolution and Systematics, 10*(4), 259–281. https://doi.org/10.1016/j.ppees.2008.07.001

Gupta, S., Verma, D., Tufchi, N., Kamboj, A., Bachheti, A., Bachheti, R.K., & Husen, A. (2021). Food, fodder, and fuelwoods from forests. In A. Husen, R.K. Bachheti, & A. Bachheti (Eds) *Non-Timber Forest Products* (pp.383-425). Springer, Cham. https://doi.org/10.1007/978-3-030-73077-2_17.

Harris, J., van Zonneveld, M., Achigan-Dako, E. G., Bajwa, B., Brouwer, I. D., et al. (2022). Fruit and vegetable biodiversity for nutritionally diverse diets: Challenges, opportunities, and knowledge gaps. *Global Food Security, 33*, 100618. https://bit.ly/3uBVH6b

Immerzeel, D. J., Verweij, P. A., van der Hilst, F., & Faaij, A. P. C. (2013). Biodiversity impacts of bioenergy crop production: A state-of-the-art review. *Bioenergy*, *6*(3), 183–209. https://bit.ly/3N6287I

Ismail, K. A., Lino, F. A., Teggar, M., Laouer, A., Henriquez, J. R., & Rocha, T. T. (2025). Potential applications of phase change materials in the food industry: A review. *Journal of Energy Storage, 115*, 115946.

Joshi, B. K., Gorkhali, N. A., Pradhan, N., Ghimire, K. H., Gotame, T. P., et al. (2020). Agrobiodiversity and its conservation in Nepal. *Journal of Nepal Agricultural Research Council, 6*, 14–33. https://doi.org/10.3126/jnarc.v6i0.28111

Karki, S., Burton, P., & Mackey, B. (2020). Climate change adaptation by subsistence and smallholder farmers: Insights from three agroecological regions of Nepal. *Cogent Social Sciences*, *6*(1), 1720555.

Kerr, R. B., Madsen, S., Stüber, M., Liebert, J., Enloe, S., et al. (2021). Can agroecology improve food security and nutrition? A review. *Global Food Security, 29*, 100540. https://bit.ly/46G7Sfr

Koirala, N. (2023). Policies and perspectives of food health and safety in Nepal: Is Nepal ready? *EFood, 4*(1), e56. https://doi.org/10.1002/efd2.56.

Leoni, V. (2024). Characterization of agro-biodiversity products for the enhancement of marginal and mountain environments.

Li, Z., Li, Y., Yao, B., & Carmona, C. (2024). Optimising management practices to secure grassland agroecosystems' sustainability. *Frontiers in Sustainable Food Systems, 8*, 1507692.

Lima, H. S. M., & Cunha, H. F. A. (2024). The role of women and the obstacles to biodiversity conservation in developed and developing countries. *Environment, Development and Sustainability.* https://doi.org/10.1007/s10668-024-05407-6

Liu, Q., Sun, X., Wu, W., Liu, Z., Fang, G., & Yang, P. (2022). Agroecosystem services: A review of concepts, indicators, assessment methods, and future research perspectives. *Ecological Indicators, 142*, 109218.

Lowder, S. K., Sanchez, M. V., &Bertini, R. (2021). Which farms feed the world and has farmland become more concentrated? *World Development, 142*, 105455. https://doi.org/10.1016/j.worlddev.2021.105455

Lowder, S., Skoet, J., & Singh, S. (2014). What do we really know about the number and distribution of farms and family farms in the world? *ESA Working Paper 14–02*. Food and Agriculture Organization of the United Nations (FAO), Agricultural Development Economics Division.

Macqueen, D. (2024). *Advancing agrobiodiversity: Why organizations of smallholders and Indigenous Peoples are vital.* IIED London. Available at https://www.iied.org/22251iied.

Malla, M. (2018). Newajewellery–New insights on the jewellery of Nepal. *SAARC Culture, 122.*

Matthies, A. E., Fayet, C. M., O'Connor, L. M., &Verburg, P. H. (2023). Mapping agrobiodiversity in Europe: Different indicators, different priority areas. *Ecological Indicators, 154*, 110744. https://doi.org/10.1016/j.ecolind.2023.110744

Nair, M. B., & Groot, M. J. (2021). *Medicinal plants for home herbal gardens, institutional gardens, and animal health.* Natural Livestock Farming India.

Nepal, A., & Koirala, K. (2023). *Integrating agrobiodiversity for livelihood options in Bhimphedi municipality, Nepal.* National Farmers Group Federation (NFGF) and IIED. Available at https://www.iied.org/21496g

Nepali, B., Jackson, T., & Johns, C. (2024). Exploring the potential of agriculture diversification as a pathway to an improved smallholder livelihood dietary system in Nepal. *Sustainability, 16*, 9384. https://doi.org/10.3390/su16219384

Nguyen, G., Singh, Z., eds. (2024). Recent advances in research and development for vegetable crops under protected cultivation. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-5261-2

Nzima, W. M., Ip, R. H., Bhatti, M. A., Godfrey, S. S., Eik, L. O., Gondwe, S. R., & Divon, S. A. (2024). Diversity and heterogeneity of smallholder vegetable farming systems and their impact on food security and income in Malawi. *Frontiers in Sustainable Food Systems, 8*, 1387912.

Parris, K. (2001). *OECD agri-biodiversity indicators: Background paper*. Paper presented at the OECD Expert Meeting on Agri-biodiversity Indicators, 5–8 November 2001, Zurich. Available at https://bit.ly/3N60lzJ

Priya, K., & Ramesh Kumar, S. (2025). Cultivating under-utilized vegetables using organic resources: Unlocking nutritional security and sustainable agriculture. *International Journal of Vegetable Science, 1-23.* https://doi.org/10.1080/19315260.2025.2466493

Rahmawati, D., Hashidoko, Y., & Djajakirana, G. (2017). Concentration of some trace elements in two wild edible ferns, *Diplazium esculentum* and *Stenochlaena palustris*, inhabiting tropical peatlands under different environmental conditions. *Eurasian Journal of Forest Research, 20*(2), 43–56.

Rai S. & Rai R. (2024b). Advancements and practices in budding techniques for kiwifruit propagation. *Journal of Multidisciplinary Sciences*, 6(2), 11- 16.DOI:https://doi.org/10.33888/jms.2024.622

Rai, R., Shrestha, A., Rai, S., Chaudhary, S., Acharya, D. K., & Subedi, S. (2024). Conversion of farming systems into organic bio intensive farming systems and the transition to sustainability in agro-ecology: Pathways towards sustainable agriculture and food systems. *Journal of Multidisciplinary Sciences, 6*(2), 25–34.

Rai, S., & Rai, R. (2024a). Advancement of kiwifruit cultivation in Nepal: Top working techniques. *Journal of Multidisciplinary Sciences, 6*(1), 11–16.

Regmi, B., Paudyal, A., & Bordoni, P. (2009). *Climate change and agrobiodiversity in Nepal: Opportunities to include agrobiodiversity maintenance to support Nepal's National Adaptation Programme of Action (NAPA).* Retrieved from https://openknowledge.fao.org/items/cedc110f-1e6d-4538-a14c-f84c310e6873.

Remans, R., Wood, S. A., Saha, N., Anderman, T. L., & DeFries, R. S. (2014). Measuring nutritional diversity of national food supplies. *Global Food Security, 3*(3–4), 174–182.

Rist, S., Bonanomi, E. B., Giger, M., Hett, C., Scharrer, B., Jacobi, J., & Lannen, A. (2020). Variety is the source of life: Agrobiodiversity benefits, challenges, and needs. *Zenodo*. https://doi.org/10.5281/ZENODO.3568133

Rusinamhodzi, L., Corbeels, M., & Nyamangara, J. (2012). Maize–grain legume intercropping as an option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field Crops Research, 136*, 12–22.

Shrestha, A. K., Chaudhary, S., Subedi, S., Rai, S., Acharya, D. K., & Rai, R. (2024). Farming systems research in Nepal: Concepts, design, and methodology for enhancing agricultural productivity and sustainability. *Journal of Multidisciplinary Sciences, 6*(1), 17–25.

Subedi, R., Karki, M., & Panday, D. (2020). Food system and water–energy–biodiversity nexus in Nepal: A review. *Agronomy*, *10*(8), 1129. Available at https://doi.org/10.3390/agronomy10081129.

Swiderska, K., Argumedo, A., Wekesa, C., Ndalilo, L., Song, Y., Rastogi, A., & Ryan, P. (2022). Indigenous Peoples' food systems and biocultural heritage: Addressing Indigenous priorities using decolonial and interdisciplinary research approaches. *Sustainability, 14*(18), 11311. https://doi.org/10.3390/su141811311

Thapa, S., Poudel, S., Aryal, K., Kandel, P., Uddin, K., & Karki, S. (2018). A multidimensional assessment of ecosystems and ecosystem services in Taplejung, Nepal. *ICIMOD Working Paper 2018/6. DOI:10.53055/ICIMOD.705*

Tiwari, S., Rai, S., Adhikari, J., & Bista, S. (2023). Organic farming: A reliable strategy for sustainable agriculture in Nepal. *Science Heritage Journal, 7*(2), 91–103.

United Nations Development Program (UNDP). (2010). *Guidance note on recovery: Livelihood.* https://doi.org/10.1017/CBO9781107415324.004

Wang, J., Jiang, H., & He, Y. (2023). Determinants of smallholder farmers' income-generating activities in rubber monoculture dominated region based on sustainable livelihood framework. *Land, 12*, 281. https://doi.org/10.3390/land12020281

Wei, B., Chen, H., Shao, L., Huo, X., & Xia, X. (2025). Roles of strong and weak social ties in collaborative network formation for building livelihood resilience of herders: A case study on the Qinghai-Tibetan Plateau. *Rangeland Ecology & Management, 100*, 14–26.

Williams, D.E. (2017) Agricultural biodiversity and the Columbian Exchange. In: D. Hunter, L. Guarino, C. Spillane, & P.C. McKeown (Eds). *Routledge handbook of agricultural biodiversity* (pp. 192-212). Routledge, London.

Wilson, G. (2010). Multifunctional 'quality' and rural community resilience. *Transactions of the Institute of British Geographers, 35*(3), 364–381.

Yitayih, M., Goromela, E. H., Gemiyo, D., Ouko, O., Phem, M., Tum, S., & Dessie, T. (2024). An inclusive scaling business model for transforming traditional small-scale poultry production to market-oriented production. *TPGS Experience*. Available at https://hdl.handle.net/10568/169006.

Zaccari, C., De Vivo, R., Pawera, L., Termote, C., Hunter, D., Borelli, T., & Gee, E. (2023). Lessons learned from the Second International Agrobiodiversity Congress: Adopting agricultural biodiversity as a catalyst for transformative global food systems. *Current Opinion in Environmental Science & Health, 31*, 100411.

Zimmerer, K. S., & de Haan, S. (2020). Informal food chains and agrobiodiversity need strengthening—not weakening—to address food security amidst the COVID-19 crisis in South America. *Food Security*, *12*, 891–894.

Zimmerer, K. S., & Vaca, H. L. R. (2016). Fine-grain spatial patterning and dynamics of land use and agrobiodiversity amid global changes in the Bolivian Andes. *Regional Environmental Change, 16*, 2199–2214. https://doi.org/10.1007/s10113-015-0897-8.

Zimmerer, K. S., Lambin, E. F., &Vanek, S. J. (2018). Smallholder telecoupling and potential sustainability. *Ecology and Society, 23*(1), 30. . https://doi.org/10.5751/ES-09935-230130.