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Community empowerment as a pathway to sustainable agricultural productivity and biodiversity conservation in Nepal

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Abstract

The varied ecological zones of Nepal, which range from the Himalayan peaks in the north to the subtropical Terai in the south, have developed robust agricultural systems that support biodiversity. However, outmigration, the effects of climate change, and insufficient institutional support cause uneven productivity gains and biodiversity loss in this unique setting.This study demonstrated how empowered farming communities in Nepal contribute to enhanced agricultural productivity, while conserving biodiversity. The outcomes indicate that productivity increases are not uniform. The hills face diminishing yields and a loss of agrobiodiversity, while the Terai gains from infrastructure. However, productivity and ecology can be improved by integrated, community-based methods that make use of traditional ecological knowledge, participatory governance, climate-resilient practices, and sustainable market connections. Gender equity, market access, secure land rights for women, and participatory governance are important success elements. This research presents a scenario in which empowered farming communities act as both agents of biodiversity protection and production increase. The study comes to the conclusion that socially inclusive, locally relevant strategies that combine ecological integrity with rural development objectives are necessary for sustainable agriculture of Nepal.

Keywords: Agriculture, biodiversity, farming communities, empowerment, food security

Introduction

Nepal, a landlocked country in South Asia, has varied topography ranging from the Terai plains to mid-hills and high mountain regions, all of which contribute to its distinctive agricultural environment (Paudel *et al*. 2016). Significant elevation gradients in Nepal produce a number of agroecological zones that support a wide range of traditional farming practices. These ecological gradients extend from the low-lying Terai plains (< 500 m) to the mid-hill region (500-3000 m) and ascend to the high mountains, which surpass 3000 m (CBS 2019). This regional variety facilitates the cultivation of more than 500 species of edible plants, many of which are native and adapted to local temperatures and soil conditions (Joshi *et al*. 2022). Nepal is one of the notable biodiversity hotspots and a nation where nearly 65% of the population depends on agriculture for their livelihood (World Bank 2023).

Nepal's national GDP receives 27% from the agriculture sector (World Bank 2023). The sector faces confronting issues such as climate change consequences, fragmented land ownership, migration of working age people, and insufficient technology alongside weak agricultural infrastructure (Paudel *et al*. 2020, Shrestha *et al*. 2024). In Nepal, over 60% of farms are managed by small holders possessing less than 0.5 hectares of land (CBS 2022). Meanwhile labour migration is altering rural demographics and leaving behind ageing farming communities with fewer opportunities for innovation and labor-intensive approaches (Gartaula *et al*. 2012). Simultaneously, Nepal's biodiversity with over 118 ecosystems, 75 vegetation types, 35 forest types and 11.3% of the world bird's species in just 0.1% of global land area, faces threats from habitat loss, invasive species, overexploitation and climate change (MoFE, 2018). Basic methods build a conflict between environmental preservation and human needs. However, research shows that targeted farm designs enable simultaneous improvement of agriculture productivity alongside biodiversity conservation whenever local groups exercise stewardship over interventions (Sharma *et al*. 2016). Pretty *et al.* (2020) suggest that integrating agrobiodiversity, traditional ecological knowledge, and participatory governance safeguards the ecological

processes that sustain long-term agricultural resilience while also boosting productivity. International studies similarly emphasize that the power of local agencies, in conjunction with inclusive institutions, is among the reliable predictors of sustainable resources management (FAO 2019). Therefore, this study aims at recent trends in agricultural productivity across Nepal's ecological zones, highlights successful case studies integrating productivity with biodiversity conservation, identifies key factors supporting community-driven sustainability, and proposes a conceptual framework linking productivity, biodiversity, and community empowerment.

Land use patterns and agricultural systems in Nepal

Nepal's agricultural landscape is distinguished by a variety of farming systems and land use patterns that vary based on its geographical terrain and socioeconomic circumstances. Of the total area of Nepal, about 28.7% is agricultural land (4.2 million ha), and forests occupy 44.7 % (Department of Survey 2022). The Terai and lower valleys are governed by rice-based lowland systems, which include extensive monsoon-time rice farming followed by winter crops (vegetables, wheat, legumes, and oilseeds). In irrigated areas, double or triple cropping is standard practice and the cropping intensities in some of the Terai districts are 280 % (National Planning Commission 2019). Rainfed maize is the primary crop in medium hill systems, and it is frequently interplanted with vegetables, millets, or legumes in terraced regions. Such systems are generally characterized by integrated livestock and agroforestry systems (Subedi *et al*. 2021). High-value crops have specialization in production zones for commodities such as cardamom, tea, coffee, temperate fruits in the mid-hill region; vegetables-based systems close to urban markets; medicinal and aromatic plants in high mountains (National Cooperative Federation 2023). Through roughly 22266 community forest user groups, community forest-based systems employ integrated forms of land-use over 2.2 million hectares that combine conservation and sustainable exploitation of non-timber forest products, medicinal plants, and some forms of agroforestry (Federation of Community Forestry Users Nepal 2023).

Major agricultural production trends in Nepal

Over the past ten years, Nepalese agricultural productivity has shown inconsistent trends. Table 1 shows production data for major crops from 2014 to 2023, showing a modest overall growth in cereal production with significant year-to-year variance.

Production of major crops (rice, maize and wheat) consistently increases and maize occupied the highest position with 38.5% increase in a decade (MoALD 2023). Alternatively, production of millet decreased by 12.8% (NSSTRC 2023). Sharp increases in vegetables (34.9%) and fruits (36.8%) mirrors Nepal's emphasis on commercial and peri-urban agriculture, in line with changing dietary habits and market linkages (FAO 2022). While their nutrition role in diets can be vital, dry beans' minimal increase a marginal 7.1% in production, reveals a lack of investment and attention on pulse farming body (FAO 2019). Rice and wheat production variability above all is a manifestation of both climate variability and differential input and irrigation access (Shrestha *et al*. 2024).

Yield trends of different agricultural crops across the ecological zones in Nepal

The differences in production of rice between Nepal's ecological regions are shown in Table 2. As of 2023, the Terai area has the highest average yield at 3.9 MT/ha, compared to 3.6 MT/ha for the Mid-hills and 2.3 MT/ha for the Mountains (CBS 2023). Terai's comparative advantages in terms of irrigation, inputs, and market access are shown by this yield disparity. The difference has increased since 2014, with the Terai currently exceeding the mountain regions by over 80%, signifying a widening agroecological injustice (NPC 2019). Upland regions exhibit the most significant yield instability, signifying increased vulnerability to environmental stress and the need for location-specific adaptive strategies (Gauchan *et al*. 2020).

Crop diversity trends

Table 3 represents the decline in crop diversity between Nepal's ecological zones from 2014 to 2022, as measured by the Shannon Diversity Index (SDI) (MoALD 2020).

Table 1. Production of major crops in Nepal during the year 2014-2023

Crop	Production (Thousand Mt)					Change (%) during 2014-2023
	2014-15	2016-17	2018-19	2020-21	2022-23	
Rice	4788	5230	5610	5621	5430	+13.4%
Maize	2145	2300	2713	2833	2970	+38.5%
Wheat	1975	1879	2005	2184	2260	+14.5%
Millet	304	313	291	276	265	-12.8%
Vegetables	3422	3580	3958	4253	4615	+34.9%
Fruits	1105	1194	1254	1367	1512	+36.8%
Pulses	368	385	412	406	394	+7.1%

Table 2. Yield trends of different agricultural crops across three ecological zones in Nepal during the year 2014–2025.

Production duration	Yield (Thousand Mt)								
	Terai			Mid-hills			Mountains		
	Rice	Maize	Wheat	Rice	Maize	Wheat	Rice	Maize	Wheat
2014-2016	4.4	4.5	3.8	3.2	2.5	2.6	1.8	1.7	2.0
2017-2019	4.8	4.7	4.0	3.5	2.9	2.8	2.1	1.9	2.2
2020-2022	4.6	4.9	4.0	3.3	3.1	2.9	2.0	2.1	2.1
2023-2025	4.9	4.9	4.1	3.6	3.3	3.0	2.3	2.2	2.2

Table 3. Shannon diversity index for crop production across different ecological zones of Nepal during the year 2014 to 2022

Ecological zones	Shannon diversity index,					Change (%) in the year 2014 to 2022.
	2014	2016	2018	2020	2022	
Terai	2.43	2.39	2.31	2.25	2.18	(-10.29%)
Mid-hills	2.87	2.82	2.76	2.71	2.65	(-7.67%)
Mountains	3.12	3.08	3.01	2.92	2.84	(- 8.97%)
National	2.81	2.76	2.69	2.63	2.56	(- 8.90%)

The mountain (-8.97%) and mid-hill (-7.67%) regions were the next most severely impacted, after the Terai (-10.29%). Increased agricultural system uniformity is implied by this tendency, which could lessen ecological resilience to market and climate stresses. This decline highlights the need for policies that promote on-farm diversification and the conservation of traditional crops, particularly in fragile regions (Joshi *et al*. 2022).

Drivers related to agrobiodiveristy in Nepal

An apparent indication of a deterioration in agrobiodiversity in Nepal's farming systems is the steady decline in the Shannon diversity index observed in the Terai, mid-hills, and mountain ecological zones. This drop is caused by a number of interrelated variables, such as policy gaps, labor migration, market pressure, and climate variability (Figure 1).

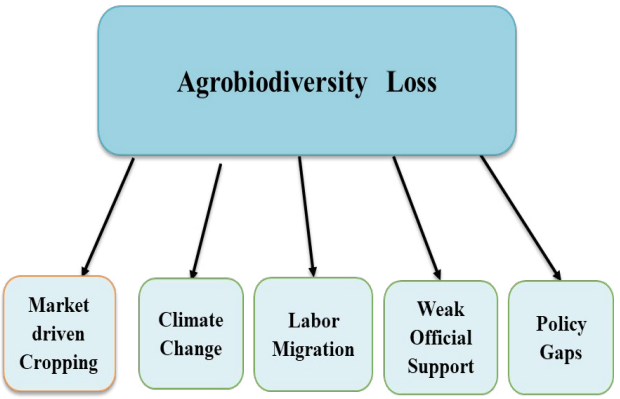

Figure 1. Major drivers of agrobiodiversity reduction in Nepal.

Climatic influence across ecological regions

The climate in each of Nepal's ecological areas varies considerably with environmental vulnerability. Climate-related indicators for Nepal's three ecological zones are shown in Table 4. The average temperature increases and rainfall variability is highest in mountain (1.7°C and +5%), reflecting the global pattern of high elevation areas warming faster than any changes elsewhere (Wester *et al*. 2019). This increases the likelihood of both climate sensitivity and drought. On the other hand, due to geographic exposure and decreased rainfall stability (−4%), the Terai region is also seeing the highest number of floods. The Mid-hills exhibit intermediate climate stress. These variances require climate-resilient agricultural plans in each zone (MoALD 2020).

Socioeconomic factors across ecological regions

Important socioeconomic factors that directly affect agricultural production and its sustainability in Nepal include regional disparities in landholding, migration, and services. According to table 5, the Terai region, which has relatively higher average landholdings (0.62 ha), plenty of access to irrigation facilities (71%), and relatively better agricultural extension services coverage (48%), provides a fair environment for the adoption of modern farm technology (CBS 2022). However, the mid-hills and mountains have lower irrigation and extension access (World Bank 2023), land fragmentation, high rates of young out-migration (42% and 51%, respectively), and structural limitations. With the lowest irrigation coverage (21%), the lowest average land size (0.38 ha), and the highest migratory intensity, the mountain region stands out as the most vulnerable, indicating a serious labor shortage in agricultural operations. Any strategy of empowerment of communities and biodiversity-based agriculture development should be locally tailored, according to the social-economic context and local agroecological conditions of each place, to ensure inclusiveness and sustainability of changes (Wester *et al*. 2019).

Gendered participation in different ecological zones

There is evident regional difference in women's involvement in agriculture, with stronger leadership and institutional access in upland areas (Table 6). Women hold about 47% of cooperative leadership roles in the mountains, compared to 39% in the mid-hills and only 20% in the Terai, reflecting greater involvement in community-based natural resource management (Tamang et al. 2014). Similarly, women's access to extension services and credit is higher in the mountains (53% and 28%, respectively) than in the Terai (32% and 14%), highlighting the impact of targeted NGO and government outreach in remote regions (FAO 2021).

Table 4. Indicators for climatic factors at different ecological zones in Nepal during the year 2014-2023

Ecological zone	Increasing (+) or decreasing (-)		Frequency of drought	Flood incident
	Temperature (°C)	Rainfall (%)		
Terai	+ 1.1	- 4	Low	High
Mid-hills	+ 1.4	+ 2	Moderate	Moderate
Mountains	+ 1.7	+ 5	High	Low

Table 5. Socioeconomic factors behind agricultural changes at different ecological zones in Nepal

Ecological zones	Land holding size (ha)	Youth migration (%)	Access to irrigation (%)	Access to extension (%)
Terai	0.62	27%	71%	48%
Mid-hills	0.46	42%	36%	34%
Mountains	0.38	51%	21%	29%

Table 6. Women involvement in agricultural cooperatives and services at different ecological zones in Nepal

Ecological zones	Access of women to different activities (%)		
	Cooperative leadership	Extension services	Credit
Terai	20	32	14
Mid-hills	39	46	23
Mountains	47	53	28

Integrated approaches to agricultural productivity and biodiversity conservation

Communities in the Begnas lake watershed of Kaski district implemented a biodiversity-based agricultural initiative (2016-2022) to enhance productivity while conserving agroecological diversity (Sthapit *et al*. 2014). The project revived traditional rice landraces, integrated fish culture into paddy systems, and established a community-managed seed bank, supported by farmer-to-farmer knowledge sharing and eco-tourism-linked markets (Rana *et al*. 2020). These approaches increased rice yields from 1.8 to 4.9 MT/ha, generated NPR 35000–45000 per ha annually from fish culture, restored 26 rice varieties, and raised bird species presence by 18%, alongside a rise in women's decision-making participation from 22% to 47% (Sthapit and Mijtović 2021).

Climate-resilient agriculture

The Chitwan–Annapurna Landscape (CHAL) implemented a resilience-based agricultural program (2017-2023) integrating conservation to enhance productivity across the Terai–Himalayan gradient (Chaudhary *et al*. 2024). Using watershed-based planning, the program promoted climate-resilient crops, efficient water use, payments for ecosystem services, and strengthened extension services through trained local resource persons (Chaudhary *et al*. 2024). As a result, cereal yields increased by 15–22% across 23 communities, water-use efficiency improved by 26%, soil erosion declined by 31%, forest cover expanded by 4.2%, and household income diversification rose from 0.32 to 0.51, with success driven by landscape-level connectivity, integrated knowledge systems, and strong institutional coordination (Chaudhary *et al*. 2024).

High-value medicinal and aromatic plants

Mountain communities in Karnali province implemented a program (2018–2023) to promote cultivation of high-value medicinal and aromatic plants (MAPs) as a strategy for sustainable agriculture and biodiversity conservation (Karki and Chowdhary 2019). The initiative focused on domestication of priority and threatened MAP species, sustainable harvesting, value-added processing, and market access through organic and fair-trade certification (Burnside 2023; Urfels *et al.* 2022). As a result, household incomes increased by an average of 65%, pressure on wild harvesting declined by 42%, four threatened species showed recovery, and processed MAP products generated 115% higher value, with success driven by community monitoring and a low-volume, high-value livelihood approach (Burnside, 2023; Karki and Chowdhary 2019; Urfels *et al.* 2022).

Table 7 summarizes the positive impacts of community-led agriculture across Nepal's ecological zones. The Begnas watershed shows increased rice yields, enhanced on-farm biodiversity, and strong women-led institutions. The CHAL landscape demonstrates higher cereal

productivity, improved forest cover and soil conservation, and active multi-stakeholder participation. In Karnali, MAPs initiatives reduced pressure on wild biodiversity while strengthening community institutions through cooperatives, certification, and return migration, despite not focusing on staple crop yields.

Factors empowering farming communities for sustainable agriculture

Several significant components that successfully enable farming communities to accomplish both the goals of agricultural productivity and biodiversity protection were identified using quantitative data.

Several case studies and field reports were reviewed in order to identify the determinants (table 8). Based on perceived impact and frequency of mention, each of these was rated from 1 to 5. The results of the research demonstrated that while infrastructure and technology are still important technical variables, the social, economic, and governance factors that have a greater impact are the most important for enabling communities. Gender equity, in particular, was the most highly ranked factor, and there was substantial evidence that interventions explicitly addressing gender inequities and performed better in terms of productivity and conservation (Sthapit *et al*. 2014, Chaudhary *et al*. 2024).

Policy and institutional context

Nepal's agricultural, biodiversity, and climate policies remain fragmented and sometimes contradictory, as seen in the promotion of traditional seeds alongside subsidies favoring commercial hybrids (MoALD 2023). Although decentralization policies provide a strong legal framework, local governments face capacity, data, and funding constraints that limit community-led implementation, while weak coordination has hindered effective execution

Table 7. Impact of community-led agriculture at different ecological zones in Nepal

Ecological zones	Positive (+) or negative (-) impact on		
	Crop yield	Biodiversity	Community involvement
Begnas Watershed	+ 28% in rice	+ Bird species	+ Women leaders, seed banks, cooperatives
CHAL Landscape	+ 15–22% in cereals	+ Forest cover (+4.2%), soil erosion (31%)	+ Multi-stakeholder initiatives, trained local agents
Karnali MAPs	N/A (non-staple food crop)	- Wild harvest (42%)	Return migration, cooperative running the community, certification

Table 8. Key empowerment factors and their relative importance in Nepal

Empowerment factors	Description	Importance
Secure land rights	Legal and tenure and guiding principles	4.6
Knowledge systems	Combining conventional and scientific understanding	4.5
Social capital	Strong community organizations trust and networks	4.4
Market access	Fair, stable and sustainable markets for all to access	4.2
Financial services	Access to appropriate credit, savings, and insurance	4.0
Technical support	Context-appropriate extension services and technical assistance	3.9
Policy environment	Legal policies that recognize farmer rights and roles	3.8
Infrastructure	Physical infrastructure adapted to local needs and conditions	3.7
Technology access	Affordable technologies that enhance productivity sustainably	3.6
Gender equity	Equal access, involvement, and benefit sharing for female farmers	4.7

*Note: Average importance: Average rank from a meta-analysis of multiple case studies-where 1 (least importance), 5 (Most importance).

of forest and climate strategies (Chaudhary *et al*. 2024). Strengthening co-created, pluralistic extension approaches is therefore essential for empowering communities and advancing sustainable agriculture across diverse contexts (Joshi *et al*. 2022).

In Table 9, seven national policies are ranked according to their ability to promote community empowerment and field-level realized implementation. The empowerment scores represent a composite of expert judgment, literature, case studies, and implementation reports (Chaudhary *et al*. 2024). The "implementation status" is a measure of the effectiveness of funding, inclusion, and delivery at the local level. Although its implementation varies, the Local Government Operation Act (2017) also has a good empowerment score (4.2). Both the Climate Change Policy (2019) and the Forest Sector Strategy (2016) have moderate potential and a wide range of applications. The Agrobiodiversity Policy (2007), a cornerstone policy about the on-farm diversity, has a low score for poor implementation as it has been less enforced (MoALD 2023). The present analysis points to the policy-implementation gap in the sustainability agenda in Nepal and the necessity of local institutional strengthening (Chaudhary *et al*. 2024)

Integrated analysis of agricultural productivity and biodiversity conservation

There is a detailed connection between agricultural productivity and the biodiversity conservation in Nepal. Although national productivity in major cops has increased, there is an alarming decline in agrobiodiversity and a growing disparity of prosperity between regions (FAO 2022; Joshi *et al*. 2022) as shown in Table 1. The evidence from community-based intervention- such as those in 3 case studies (Table 7) demonstrates that when specific permitting and governance conditions are met, integrated approaches can enhance both productivity and biodiversity (Burnside 2023).

National and global contextual broader implications

Ecological sustainability and agricultural productivity can be fostered simultaneously through inclusive, community-driven (Pretty *et al*. 2020). The success of decentralized initiatives in Nepal highlights the need to shift from top-down in agricultural sector toward community-based systems that priotize human rights, participatory approaches, gender equality, and indigenous knowledge (Dushkova and Ivlieva 2024). These results are aligned with SDG 2 (Zero hunger), as they involve sustainable food production, and SDG 13 (Climate Action) and also

Table 9. Assessment of key policies affecting agriculture and biodiversity in Nepal

Policy/strategy	Key Provisions	Empowerment Score	Implementation Status
Agrobiodiversity Policy (2007)	Conservation of genetic resources, traditional seeds	3.1	Limited
Agriculture Development Strategy (2015-2035)	Productivity; long term vision for inclusive, sustainable farming	3.8	Moderate
Forest Sector Strategy (2016)	Decentralizes forest governance;strengthens Community forestry.	3.6	Variable
Local Government Operation Act (2017)	Planning, budgeting and agricultural services	4.2	Variable
Climate Change Policy (2019)	Climate-smart practices; adaptation	3.6	Moderate
Land use policy (2015)	Categorizes land zones, sustainable land usage	3.3	Limited
Environment Protection Act (2019)	Maintain biodiversity, regulates environmental impact	3.0	Limited

contribute to SDG 15(Life on Land) due to biodiversity-related use (FAO 2022). Therefore, community empowerment is crucial to creating farm systems that are both ecologically sustainable and climate resilient, in addition to being context-appropriate.

Conclusion

Although performance is still uneven across ecological zones, this review shows that empowered farming communities can concurrently improve agricultural output and biodiversity protection in Nepal, with growth concentrated in the Terai and stagnation in hills and mountains due to infrastructure gaps, climate stress, and labor migration. Case studies from Begnas, CHAL and Karnali show that community-based, locally adapted interventions can improve productivity while conserving agrobiodiversity. Key supporting variables include secure land tenure, gender-equitable involvement, strong local institutions, participatory governance, and equitable market access. Overall, the proposed conceptual framework underscores the integration of indigenous and scientific knowledge within inclusive community-led systems as a viable pathway toward resilient and sustainable agriculture in Nepal.

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