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ASSESSING THE SOCIO-ECONOMIC AND ENVIRONMENTAL PERFORMANCE OF AGROFORESTRY SYSTEMS IN KALINCHOWK RURAL MUNICIPALITY, NEPAL

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ABSTRACT

Agroforestry plays an important role in supporting rural livelihoods and enhancing environmental resilience in Nepalese hill farming systems. This study assessed the socio-economic and environmental performance of major agroforestry systems in Kalinchowk Rural Municipality, Dolakha District, Nepal, with particular emphasis on household livelihood status, food sufficiency, and climate adaptation. The study was based on a household survey of 136 households selected through simple random sampling, complemented by key informant interviews, field observations, and meteorological data obtained from the Department of Hydrology and Meteorology. Socio-economic indicators included landholding, livelihood strategies, livestock ownership, household assets, and food sufficiency, while environmental parameters focused on perceived climatic changes, local environmental conditions, and agroforestry-related ecosystem services. Data were analyzed using descriptive statistics and chi-square tests in SPSS and MS Excel. The results show that agriculture remains the primary occupation for 69.85% of households, yet food sufficiency is low, with only 27.9% of households meeting annual food requirements from own production and 25.7% producing food for less than six months. Based on a composite livelihood assessment, most households fell into low (50.0%) and medium (19.9%) livelihood categories. The dominant agroforestry systems dominated in the study area were agri-silviculture (66.18%), agri-horti-silviculture (18.38%), silvi-pastoral systems (10.29%), and home gardens. A statistically significant association was observed between agroforestry system type and household food sufficiency ($\chi^2 = 24.16$, $p < 0.05$), indicating better socio-economic performance and higher resilience among households practicing diversified systems, particularly agri-horti-silviculture and silvi-pastoral systems. Environmentally, 57.4% of households reported overall improvement in local environmental conditions, particularly in soil fertility and microclimate regulation. Despite these benefits, the performance of agroforestry systems is constrained by pest infestations, human–wildlife conflict, limited market access, and uneven institutional support, indicating the need for targeted technical extension, improved market linkages, inclusive support mechanisms, and the integration of agroforestry into local climate adaptation planning. Overall, the study indicates that agroforestry, especially agri-horti-silviculture offers balanced socio-economic and environmental benefits and represents a viable climate-smart land-use option for improving livelihood resilience and environmental sustainability in mid-hill and high-hill regions of Nepal.

Key words: *Agroforestry systems, livelihood, environmental performance, socio-economic performance*

INTRODUCTION

Integrated Agroforestry Farming System (IAFS) is a science that is responsible for the optimum utilization of land productivity, tackling the problem of economic farming sustainability, poverty, biodiversity, climate change, food and nutritional security and management (Atreya et al., 2021). These methods are essential for preventing deforestation, lowering poverty, and enhancing soil health in environmentally vulnerable areas on a global

scale (FAO, 2020). Agroforestry's strength is its capacity to provide several goods and ecosystem services at once, encouraging a variety of revenue sources and lowering reliance on monoculture of a single crop (Nair, 1993). In Nepal, agroforestry forms an essential component of the subsistence farming systems that dominate the country's mountainous landscapes. Given the limited and fragile nature of arable land, farmers have long practiced diversified production strategies that optimize the use of available resources (Ulak et al., 2021). Agriculture remains the backbone of the national economy, engaging over 65% of the population and contributing about 24% to the Gross Domestic Product (MoALD, 2022). Within this context, the integration of trees, crops, and livestock represents a defining feature of traditional hill farming systems. Diverse practices such as agri-silviculture (the combination of trees and crops), silvi-pastoral systems (trees and livestock), and the widely prevalent home gardens not only enhance food security but also supply vital resources such as fodder, fuelwood, and timber (Thapa & Paudel, 2000).

Socio-economic benefits of agroforestry

The socio-economic value of agroforestry lies in its ability to strengthen household income, food security, and community resilience. By diversifying production and providing a steady supply of fruits, vegetables, fodder, and non-timber forest products (NTFPs), agroforestry offers a critical safety net against crop failures and economic shocks (Tamale et al., 1995). Studies show that such diversified systems are more economically stable than mono-cropping, fostering small-scale enterprises from high-value products like fruits and medicinal plants and creating income opportunities, particularly for women and marginalized groups (Dhakal & Rai, 2023). These contributions directly support the Sustainable Development Goals on poverty reduction and food security, underscoring the importance of evaluating agroforestry's local economic performance in areas like Kalinchowk.

Environmental services and climate resilience of agroforestry

Beyond its economic value, agroforestry provides critical environmental services that support land restoration and climate resilience (IPCC, 2022). Trees integrated into farming systems improve soil structure and fertility through litter fall and nutrient cycling, reduce erosion on steep slopes, and regulate microclimates by offering shade and minimizing evapotranspiration (Kurtz et al., 1991). They also play a vital role in carbon sequestration, mitigating greenhouse gas emissions (IPCC, 2021).

The climatic anomalies due to aberrant weather created by global warming in the world has also negatively affected the agrarian farming system in hills and mountain of Nepal and it is suggested that the adaptation of scientific agro-forestry measures would be the economically feasible and environment friendly ecosystem-based climate resilient agriculture practices. In this regard, the adaptation of diversify agroforestry systems should be approachable targets (Pandit et al., 2021) to climate change adptation and mitigation. In Nepal's mountain regions, where erratic rainfall, droughts, and rising temperatures increasingly threaten agriculture (Meehl, 2023), the ecological diversity of agroforestry offers a practical, climate-smart solution that enhances both productivity and environmental stability.

While agroforestry's importance in Nepal is well recognized, detailed site-specific studies that quantify its socio-economic and environmental outcomes in high-hill regions remain limited. Given Dolakha's exposure to climatic and economic stresses, this study focused on Kalinchowk Rural Municipality to assess how different agroforestry systems

contribute to local livelihoods, food security, and environmental sustainability, while also identifying the key challenges and opportunities for their wider adoption. (Dhakal & Rai, 2023) reported that there are evidences of agroforestry improving farmers' livelihoods and food security and contributing to land restoration and biodiversity conservation and thereby positively contributing to many of the UN sustainable development goals (SDGs) such as eliminating poverty and climate action.

Despite considerable research conducted in agriculture sector, very little attention has been given to conduct study in agroforestry technology. Nepal Swiss Community Forestry Projects has implemented agroforestry programs in Dolakha district. But the socio-economic and environmental impacts and efficiency of such agroforestry practices with regards to farmers' profitability and long term environmental impacts on the region has not been conducted until now. Kalinchowk Rural Municipality of Dolakha district is a potential hub having an area of integrated farming system dominated by agroforestry farming and therefore, this study was conducted in this Rural Municipality of Nepal to assess the socio-economic and environmental performance of agro-forestry systems. This research would also contribute to the development of a more sustainable and equitable community in Kalinchowk, Dolakha, Nepal, by addressing the pressing need for effective and integrated agroforestry approaches to climate change adaptation for better livelihood.

MATERIALS AND METHODS

Site selection

The study was conducted in Kalinchowk Rural Municipality, located in the north-eastern part of Dolakha District, Bagmati Province, Nepal. Covering about 132.49 km², with a total population of 21,097, including 10,828 females and 10,269 males (CBS, 2021), the area lies within the mid- to high-hill ecological belt and is characterized by steep terrain, variable climate, and high vulnerability to landslides and droughts. Kalinchowk Rural Municipality was selected for its strong dependence on subsistence farming, diverse agroforestry practices, and ecological sensitivity.

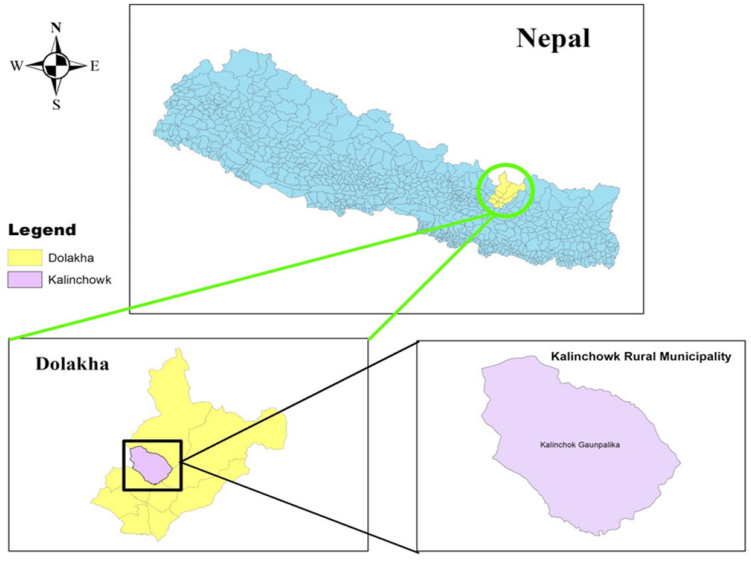


Figure 1: Kalinchowk Rural Municipality in Dolakha district of Nepal

Research design

The household survey was conducted with the help of a semi-structured interview schedule. A total of 136 households (using Cochran's formula) from selected wards (1-9) of Kalinchowk Rural Municipality were surveyed through the Simple Random Sampling technique.

Sampling and data collection

A descriptive research design was adopted, covering all nine wards of Kalinchowk Rural Municipality. According to the National Census Report 2021, Kalinchowk rural municipality comprises a total of 6,151 households. The required sample size of 136 households was determined using Cochran's formula. In the absence of a comprehensive database identifying agroforestry-practicing households, all households of the municipality were considered as the sampling frame. Households for the survey were selected from all wards using simple random sampling through the lottery (ball) method.

Primary data were gathered through semi-structured household surveys, key informant interviews (with officials, community leaders, and model farmers), and focus group discussions involving women, ethnic minorities, and general farmer groups. Field observations supported by informal SWOL analyses helped validate reported practices. Secondary data were obtained from local government offices, the Division Forest Office, and published literature, including agroforestry studies and time-series climate data from the Department of Hydrology and Meteorology.

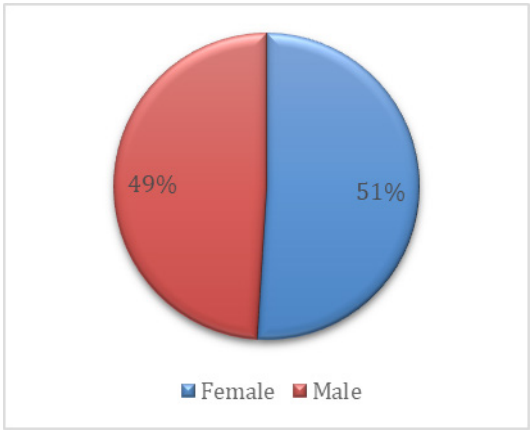
Data analysis

MS Excel 2013 was used for data entry. The stored data in the Excel file was run in IBM SPSS 25, and the descriptive analysis as well as statistical analysis (Chi-square test) of the study was done.

RESULTS AND DISCUSSION

Socio-demographic and livelihood characteristics

The socio-demographic and livelihood profile of respondents is summarized in Table 1 and Figures 2 to 5. The study revealed a typical socio-economic structure for the high-hill region. The majority of the sampled respondents belonged to the Brahmin and Chettri ethnic groups, followed by various Janajatis (Figure 2), with 51% female and 49% male population (Figure 3). Majority of the respondents were uneducated or attended upto SLC level (Figure 4). All respondents owned agricultural land, but the size of holdings varied considerably. While most households possessed more than 5 ropani (2500 sq. meter), only a small portion of their land was deployed for crop cultivation (Table 1). Most households relied primarily on agriculture as their main occupation (69.9%), followed by business (13.2%), remittance (12.5%), and services (3.7%) (Figure 5). A decade ago, almost all families were fully dependent on agriculture; however, recent climate-induced challenges, such as rising temperatures, erratic rainfall, and increased pest infestations have reduced crop yields, encouraging a gradual shift toward diversified livelihood strategies.



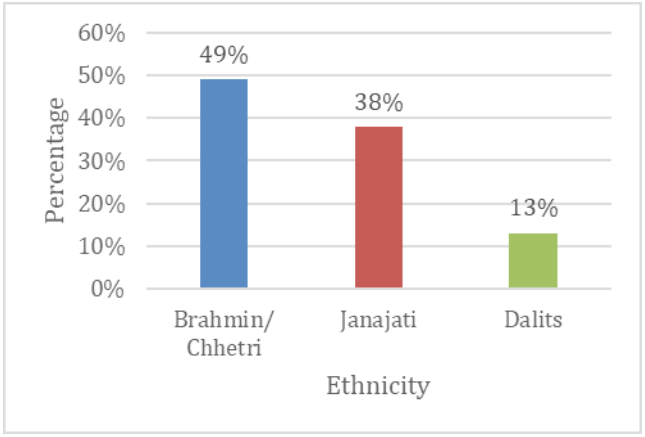


Figure 2: Ethnicity of the respondents **Figure 3: Gender of the respondents**

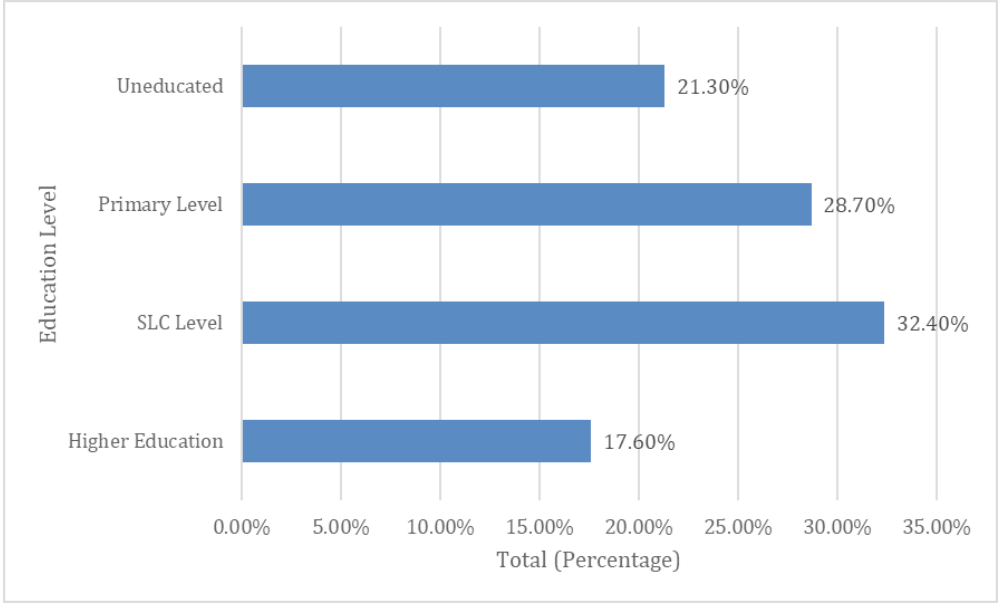


Figure 4: Education level of the respondents

Table 1. Land holding of the respondents

Land holding size (Ropani)	Percentage (%)
1-5	49
5-10	39
10-15	7
15-20	2
20-25	1
25-30	2
Total	100

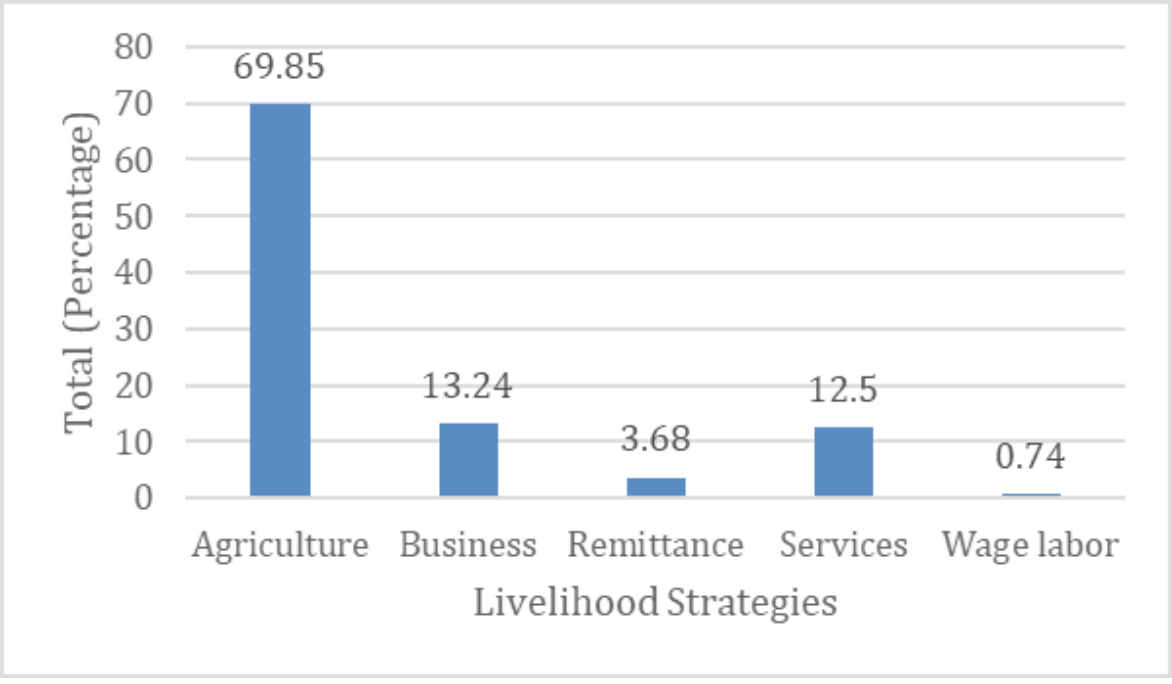


Figure 5: Occupation of the respondents

Food security status

A striking finding was the pervasive decline in food sufficiency, indicating a high level of vulnerability within the farming system. Information on household food sufficiency ten years prior to the survey was collected using a recall-based household interview method. Respondents were assisted by referring to major agricultural seasons and locally significant climatic events to improve recall accuracy. Food sufficiency was recorded as the number of months per year households were able to meet their food requirements from own production.

Table 2: Food sufficiency status during the interval of 10 years

Time interval	Food Sufficiency before 10 years (%)	Food Sufficiency now (%)
>12 months	59.6	27.9
9-12 months	39.7	22.1
6-9 months	0.7	24.3
3-6 months	-	22.8
< 3 months	-	2.9

As shown in table 2, only 27.9% of households produced enough food for the entire year. Alarmingly, 25.7% of households could not produce enough to last even six months, forcing them to purchase food for more than half the year. This situation is likely exacerbated by changing weather patterns, limited arable land, and the "brain drain" of productive labor. The reliance on market purchases for food security highlights the critical importance of cash income generated by diversified agroforestry products.

Livelihood status

Livelihood status was classified based on landholding, livestock ownership, and household assets, livelihood strategies and food sufficiency status. Household livelihood status was assessed using a composite livelihood scoring approach based on key socio-economic and farm-related indicators commonly applied in rural livelihood studies. The indicators included landholding size, main livelihood strategy, livestock holding, household livelihood assets, and food sufficiency status. Each indicator was categorized into three levels representing low, medium, and high conditions and assigned scores of 1, 2, and 3, respectively (Table 3).

Table 3: Composite livelihood scoring criteria used for household assessment

Indicator	Category	Score
Landholding size (ropani)	≤ 5	1
	5.1–10	2
	> 10	3
Main livelihood strategy	Wage labor / subsistence farming	1
	Mixed farming	2
	Agroforestry-based or diversified farming	3
Livestock holding	≤ 2 livestock units	1
	3–5 livestock units	2
	> 5 livestock units	3
Household livelihood assets	Low	1
	Medium	2
	High	3
Food sufficiency (months)	< 6	1
	6–9	2
	> 9	3

The individual indicator scores were summed to generate a composite livelihood score for each household. Based on the distribution of composite scores across the sampled households, livelihood status was classified into low, medium, and high categories using tercile division (Table 4). This approach allowed for a standardized comparison of livelihood conditions among households. Based on the composite livelihood score, 50.0% of households were classified under low livelihood status, followed by 30.1% under high and 19.9% under medium livelihood status (Table 4).

Table 4: Classification of households by livelihood status

Livelihood status	Frequency (n)	Percentage (%)
Low	68	50.0
Medium	27	19.9
High	41	30.1
Total	**136**	**100**

Note: Livelihood status categories were derived using tercile-based cut-off values of the composite livelihood score (Low: ≤7; Medium: 8; High: ≥9).

Perception of climatic changes

Respondents widely perceived noticeable shifts in local climatic conditions. As shown in Table 5, all households reported a rise in atmospheric temperature and irregular rainfall patterns over the past decades.

Table 5: People's perception on climatic environmental change

Parameters	Percentage (%)
Change in rainfall pattern	
Drought in winter and early summer	67.6
Pre-monsoon rain	9.6
Post-monsoon rain	22.8
Experienced weather pattern change	
Yes	99.3
No	0.7
Weather change patterns over the past 10-30 years	
Increase in temperature	13.24
Irregularity in rainfall (scatter rainfall and low and heavy rainfall)	33.82
Drought	23.53
All of the above	29.41

Most respondents (67.6%) mentioned increasing droughts during winter and early summer, while others observed unpredictable pre- and post-monsoon rainfall. Nearly all respondents (99.3%) agreed that the overall weather pattern had changed, highlighting increased temperature, irregular rainfall, and frequent droughts as the most evident indicators. The socio-demographic characteristics of households in Kalinchowk Rural Municipality reflect the broader structure of hill farming communities in Nepal. The near-equal gender representation among respondents (Figure 3) indicates that both men and women play active roles in agricultural and agroforestry activities. Agriculture remains the dominant livelihood source (Figure 5), which is consistent with national data showing a high dependence on farming-based livelihoods in rural municipalities (NSO, 2021).

Awareness and perceived impacts of climate change

Most respondents had limited understanding of the scientific concept of climate change, with about 62.5% unfamiliar with the term (Figure 6). However, many associated it with noticeable local effects such as irregular rainfall, prolonged droughts, extreme temperatures, and increased natural hazards like landslides. Residents of Ward No. 5, in particular, reported severe impacts including loss of farmland, damage to homes, and drying water sources. Overall, around one-third of respondents (32.4%) experienced multiple climate-related challenges, highlighting widespread vulnerability across Kalinchowk Rural Municipality (Table 6).

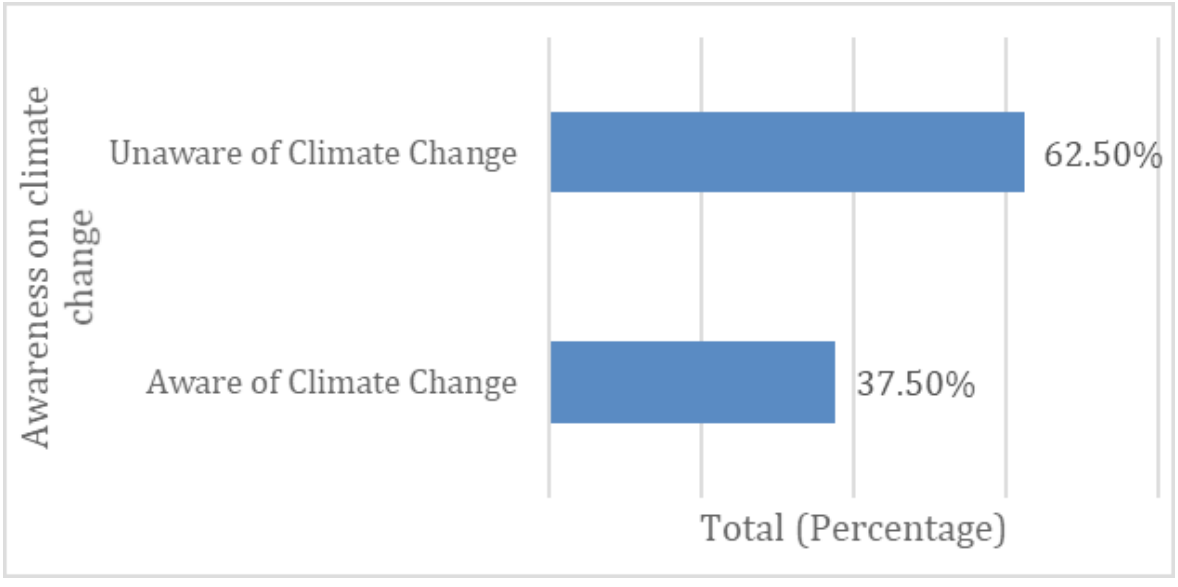


Figure 6: Awareness on climate change

Table 6: Perceptions of respondents over the climate change impacts

Climate Change Impacts	Percentage (%)
Don't Know	3.7
Change in rainfall pattern	27.2
Too hot summers and too cold winters	19.1
Increasing natural calamities such as landslides	17.6
All of the above	32.4
Total	100

Environmental benefits of agroforestry system

Environmental benefits associated with agroforestry adoption were widely perceived by respondents. More than half of the households reported overall improvements in the local environment, while others specifically noted better shade, air quality, and soil fertility (Table 12). These perceived changes are particularly important in steep and erosion-prone hill landscapes, where maintaining soil health and microclimatic stability is critical for sustainable production. The findings are consistent with earlier studies emphasizing agroforestry's role in enhancing ecosystem services and contributing to Sustainable Development Goals related to climate action, food security, and biodiversity conservation (Dhakal & Rai, 2023).

Despite these positive outcomes, the study also identified several constraints limiting the effectiveness and expansion of agroforestry systems. Climate-related stresses, including erratic rainfall patterns, increasing drought frequency, and temperature variability, were widely reported by farmers (Table 5 and Table 6). These perceptions are substantiated by meteorological analyses showing declining rainfall trends (Figure 7) and increasing temperature variability (Figures 8 and 9). In addition, severe human–wildlife conflict, particularly monkey damage affecting fruit-based systems in Ward No. 6, emerged as a critical challenge reducing productivity and discouraging investment in high-value agroforestry crops. Similar challenges have been observed elsewhere in Nepal, where insect infestations,

water scarcity, limited market access, and inadequate technical support remain major barriers to agroforestry adoption (Thapa, 2024).

Characterization and economics of agroforestry systems

Major agroforestry systems

The study area of Kalinchowk Rural Municipality, Dolakha district, features a diverse range of agroforestry systems that vary with altitude and land use. As shown in Table 7, the major systems include **agri-silviculture, agri-horti-silviculture, silvi-pastoral, horti-silviculture,** and **home gardens.** The **agri-silviculture system**, where trees are integrated into farmlands, was the most common practice, adopted by about **66% of respondents**, particularly in the mid-hill regions. In contrast, **silvi-pastoral systems** which combine trees with pasture and livestock, were mainly found in the high-hill areas such as Ward No. 1 and part of Ward No. 6. **Home gardens** were present in nearly all households, reflecting the importance of integrating trees, crops, and small livestock for household needs and income generation.

Table 7: Agroforestry system dominance in the study areas

Types of Agroforestry Systems	Percentage (%)
Agri-silviculture (Trees in and around farms)	66.18
Agri-horti-silviculture	18.38
Silvi-pastoral system	10.29
Horti-silviculture	5.15

Major tree species in agroforestry practices

Tree composition in the study area was dominated by fruit trees (55%), followed by fodder species (25%), fuelwood and timber trees (15%), and non-timber forest products (NTFPs) (5%).

Common fruit trees included kagati (*Citrus aurantifolia*), nibuwa (*Citrus limon*), orange (*Citrus sinensis*), avocado (*Persea americana*), Japanese persimmon (*Diospyros kaki*), guava (Psidium guajava), and kiwi.

Fodder trees were region-specific, Tanki (*Bauhinia purpurea*), Kavro (*Ficus lacor*), Ipil-ipil (*Leucaena leucocephala*), Debdabe (*Garuga pinnata*), and Kimbu (*Morus alba*) dominated the mid-hills, while Gogan (*Saurauia nepaulensis*), Dudhilo (*Ficus neriifolia*), and Khasru (*Quercus semecarpifolia*) were typical of high-hill zones.

For fuelwood and timber, the most common species were Uttis (*Alnus nepalensis*), Chilaune (*Schima wallichii*), and Pine (*Pinus wallichiana*). NTFPs included valuable species like Harro (*Terminalia chebula*), Okhar (*Juglans regia*), Lapsi (*Choerospondias axillaris*), Bamboo (*Bambusa vulgaris*), Laeocarpus ganitrus, and cardamom (*Elettaria cardamomum*).

Farmers also cultivated major crops and vegetables such as maize (*Zea mays*), paddy (Oryza sativa), barley (*Hordeum vulgare*), potato (*Solanum tuberosum*), cabbage (*Brassica oleracea var. capitata*), yam (*Dioscorea* spp.), tomato (*Solanum lycopersicum*), turmeric (*Curcuma longa*), and ginger (*Zingiber officinale*) within their agroforestry systems.

Agroforestry enterprises

Despite the prevalence of agroforestry practices, only 25% of respondents were aware of agroforestry as a potential enterprise, while the majority (75%) viewed it mainly as a

subsistence activity. Existing agroforestry-based enterprises in the area included nurseries, fruit orchards, honey production, kiwi and avocado farming, and vegetable farms. These ventures not only supplement household income but also demonstrate the potential of agroforestry to enhance rural livelihoods, food security, and climate resilience if promoted with better awareness, training, and market linkages.

Contribution and benefits of agroforestry systems

Agroforestry systems in Kalinchowk Rural Municipality have significantly supported local livelihoods, the environment, and community well-being. Half of the respondents (50%) reported improved financial conditions through income from fruits, vegetables, and NTFPs, which helped strengthen both human and physical capital. About 26% mentioned benefits to natural capital such as soil fertility and biodiversity conservation, while smaller portions highlighted gains in social (15%), physical (6%), and human (4%) capital through cooperation, infrastructure, and training.

Table 8: Contribution of AF system on the capital of the respondent farmers

Capital	Percentage (%)
Financial Capital (increasing income)	50.0
Natural Capital	25.7
Social Capital	14.7
Physical Capital	5.9
Human Capital	3.7

Agroforestry systems, beneficiaries, products, and constraints in the study area

The major agroforestry system adopted, benefitted households, main products, key benefits and their major constraints have been presented in Table 9. This clearly remarks that the adoption of agro-forestry system in the study area is basically governed by altitude, farmer's socio-economic status and various other external factors.

Table 9: Agroforestry systems, household characteristics, and key benefits in the study area

AF system type	Dominant components	Type of households benefited	Land type & location	Main products / NTFPs	Key benefits observed	Major constraints
Agri-silviculture	Annual crops + multipurpose trees	Low–medium livelihood status	Sloping bari land, rainfed	Fodder, fuelwood	Improved fodder security, soil protection	Small land size, long tree gestation
Agri-horticulture	Fruit trees + crops	Medium–high livelihood status	Larger plots, near roads	Fruits (cash income)	Higher income contribution	Market risk, delayed returns
Homegarden / silvo-pastoral	Trees + livestock + vegetables	All livelihood groups	Homestead areas	Fuelwood, vegetables, fodder	Income diversification	Limited scale, labor demand

Note: Classification is based on household survey responses and observed agroforestry practices.

Social and economic contribution of agroforestry to livelihood

Agroforestry contributed to household livelihoods through multiple social benefits in the study area (Table 10). A majority of respondents (57.4%) reported improvements in their

environment and overall livelihood conditions due to agroforestry practices, while others highlighted health benefits (24.3%) and improved food security and income contributing to enhanced social status (18.4%).

Table 10: Perceived social benefits of agroforestry system amongst the respondents

Social Benefits	Percentage (%)
Health Benefits	24.3
Better Environment and Livelihoods	57.4
Food security and income helping in improving social prestige	18.4

Agroforestry systems supported basic household needs by providing fodder, firewood, timber, non-timber forest products (NTFPs), and vegetables, thereby contributing to food security and income diversification. These benefits were particularly important in supplementing household resources to address seasonal food deficits.

Table 11: Association between agroforestry system and household food sufficiency

Observed frequencies (n = 136)

Agroforestry system	< 3 months	3–6 months	6–9 months	9–12 months	> 12 months	Total
Agri-silviculture	1	3	2	0	1	7
Agri-horti-silviculture	1	7	4	8	7	27
Home garden / mixed AF	2	21	27	21	23	94
Silvi-pastoral system	0	0	0	1	7	8
Total	4	31	33	30	38	136

Chi-square test results

Test	Value	df	p-value
Pearson Chi-square	24.16	12	0.019
Likelihood Ratio	25.87	12	0.011

Significant at $p < 0.05$

The contingency table (Table 11) shows that households practicing agri-horti-silviculture and silvi-pastoral systems had higher proportions of year-round food sufficiency (>12 months) compared to other systems. Pearson's chi-square test confirmed a statistically significant association between agroforestry system type and household food sufficiency ($\chi^2 = 24.16$, df = 12, p = 0.019)." Moreover, the perceived average annual income from agroforestry products stated that fruits, vegetables, livestock, and NTFPs contributed about NRs 39,000 as the average income per household. In the subsistence farming context of the study area, this income contributed to meeting essential household expenses, including food purchases, education, and healthcare. The presence of multiple agroforestry products such as fruits, vegetables, livestock, and NTFPs, indicates income diversification, which may help reduce household vulnerability to production or market fluctuations.

Environmental performance of agroforestry and climate change dynamics

Perceived environmental benefits

Farmers were asked to assess the changes in their local environment after adopting or intensifying agroforestry practices. The responses highlight the perceived positive impact. According to Table 12, a majority (57.4%) reported a general improvement in the local environment. Specifically, soil fertility improvement (22.1%) and the regulation of the microclimate through shade and fresh air (45.6%) were highly valued. These results strongly support the environmental claims made by agroforestry proponents (Nair, 1993; IPCC, 2021) and validate the system's role in local ecological stability

Table 12: Perceived environmental benefits of agroforestry system

Environmental Benefit Category	Frequency (n=136)	Percentage (%)
Overall local environment improvement	78	57.4%
Provision of shade and fresh air	62	45.6%
Soil fertility improvement	30	22.1%
Reduced soil erosion	15	11.0%
Increased biodiversity	8	5.9%

The observed distribution of agroforestry systems, agri-silviculture, agri-horti-silviculture, and home garden systems in the mid-hills, and silvi-pastoral systems at higher elevations highlights how agroforestry practices are closely shaped by local agro-ecological conditions, land use patterns, and livestock dependence. The study shows that households practicing agri-horti-silviculture and silvi-pastoral systems had higher proportions of year-round food sufficiency (>12 months) compared to other systems.

The study demonstrates that agroforestry contributes substantially to household resource security and livelihood diversification. A large proportion of households reported improved access to fodder, fuelwood, timber, and vegetables through integrated agroforestry practices, while enhancing on-farm productivity. Income-related benefits were also evident, with half of the respondents reporting improved financial conditions and food sufficiency status. The projected average annual agroforestry income of about NRs. 39,000 per household further supports these conclusions and emphasizes the economic significance of agroforestry in a farming system that is primarily focused on subsistence. Similar livelihood-enhancing effects of agroforestry have been documented in other hill regions of Nepal (Ghimire et al., 2024; Dhakal et al., 2022).

Climate change perception amongst the respondents and their validation

A significant finding was the disparity between formal awareness and experiential knowledge regarding climate change. While 62.5% of respondents admitted they were formally unaware of the term "climate change," almost 100% confirmed they had personally experienced changes in rainfall and weather patterns. The majority of the respondents reported the impacts of climate change on erratic and insufficient rainfall leading to droughts, increased incidence of pests/diseases, and temperature extremes. Therefore, to scientifically validate these perceptions, meteorological data were analyzed.

Rainfall trend

Analysis of the total annual rainfall over the past decade showed a distinct declining trend. Annual rainfall varied considerably over the decade, ranging from around 2000 mm in the early years to a peak of over 3000 mm in 2021, followed by a sharp decline to approximately 2289 mm in 2023 (Figure 7). This statistically validated the farmers' perception of insufficient rainfall and increasing drought conditions.

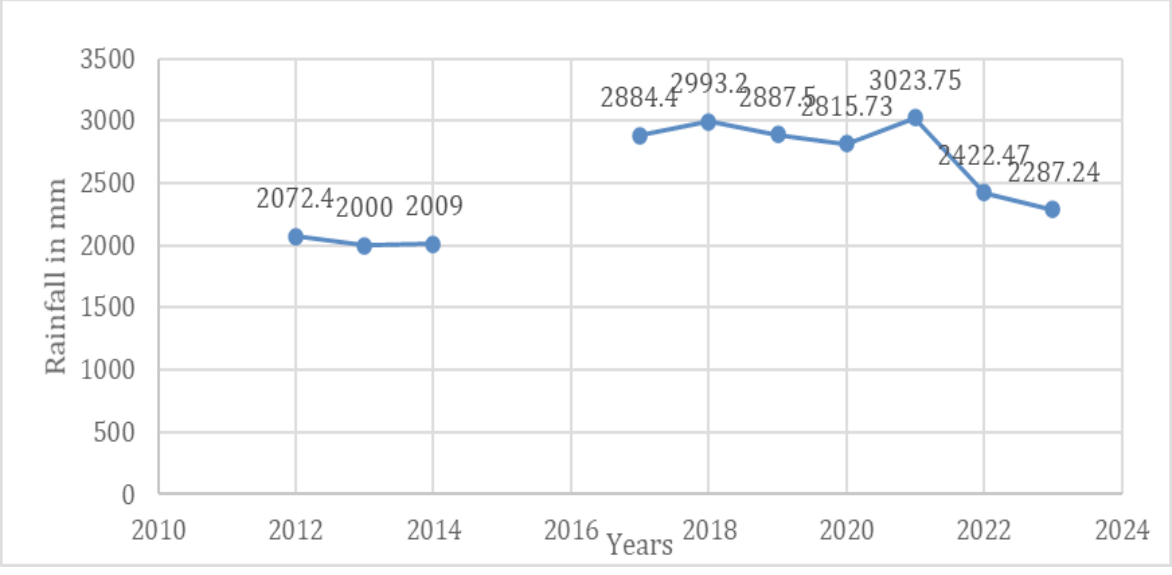


Figure 7: Total Annual Rainfall Pattern of Kalinchowk Rural Municipality (2013-2023 AD)

Temperature trend

Temperatures increased steadily from **23.0°C in 2013** to a peak of **27.9°C in 2019**, before slightly declining and stabilizing around **25.5°C** in 2023. Analysis of the average maximum air temperature in June showed a clear increasing trend, corresponding to farmers' reports of hotter summers (Figure 8). Conversely, the analysis of the yearly mean minimum air temperature showed a decreasing trend, confirming more extreme cold in winter (Figure 9).

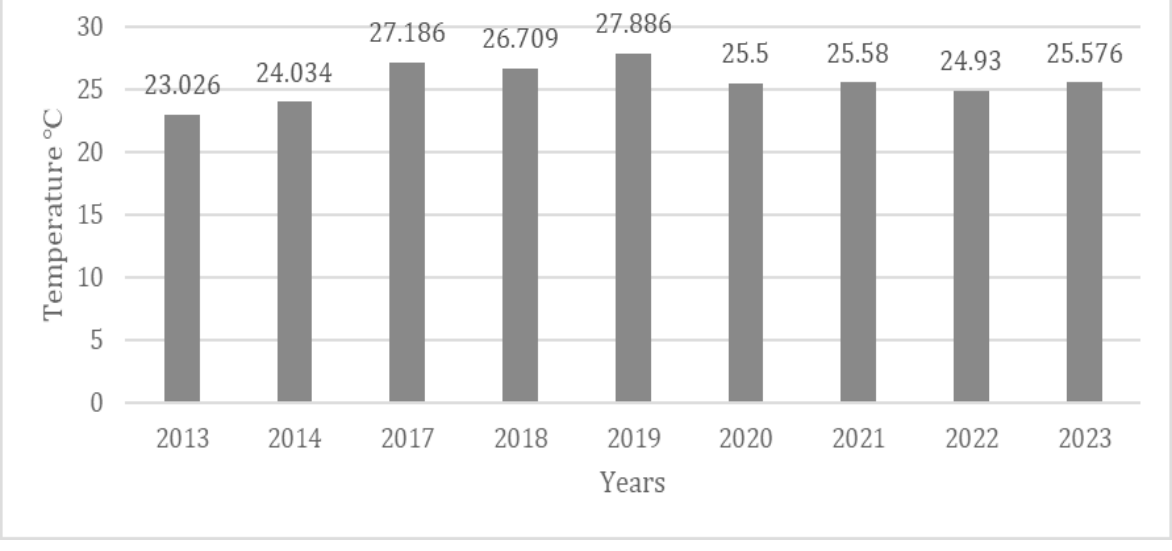


Figure 8: Average Maximum Temperature Pattern of June in Kalinchowk Rural Municipality (2013-2023 AD)

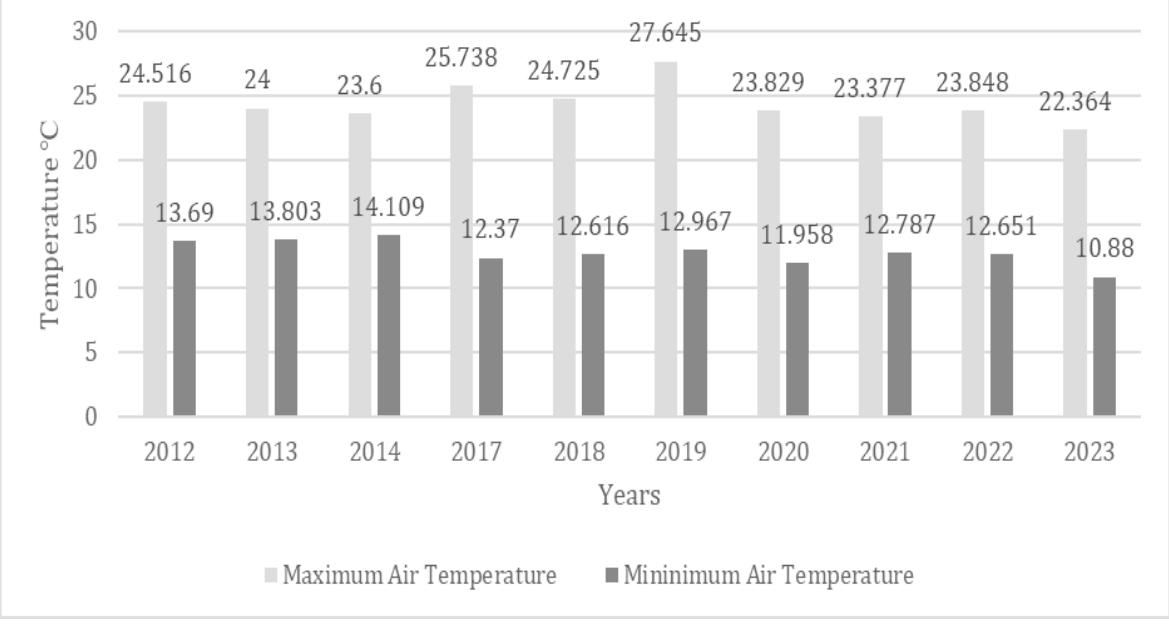


Figure 9: Average yearly mean temperature of Kalinchowk Rural Municipality (2013-2023 AD)

Overall, the data revealed that the study area has been experiencing declining rainfall and variable temperature trends, both of which are critical indicators of changing climatic conditions. Such instability has direct implications for agriculture, leading to disrupted monsoon timing, reduced crop productivity, and heightened vulnerability to droughts and extreme weather events. The data gap happened in 2015 and 2016 due to massive earthquake in 2015 that destroyed the weather station. The weather data supports what local people have been observing, showing a clear need for climate-smart solutions such as diversified agroforestry. The layered structure of agroforestry systems helps protect farms from extreme weather by keeping temperatures more stable and improving soil moisture retention (Tarasova et al., 2023).

Issues and constraints

Despite the documented benefits, the study identified several significant constraints hindering the full potential of agroforestry adoption and success in Kalinchowk,

Table 13: Major issues and constraints in agroforestry system in Kalinchowk rural municipality as reported by the respondents

Constraint/Issue	Contextual Detail
Climatic factors (Droughts/Erratic rainfall)	Most frequently reported challenge, impacting yield stability.
Pests and diseases (Insect infestations on fruit trees)	Requires technical intervention and appropriate pest management training.
Human-wildlife conflict (Monkeys destroying crops)	Reported to be severe, especially in the Thami community (Ward 6).
Economic factors (Limited market access)	Poor road conditions and lack of post-harvest facilities reduce profitability.
Knowledge and technical gaps	Lack of formal training in pest management and nursery techniques.
Social equity issues	Discrimination in incentive distribution based on gender and caste (women/disadvantaged groups).
Brain drain	Out-migration of youth leading to labor shortages.

The human-monkey conflict emerged as an acute issue, particularly for high-value fruit crops, leading to significant economic losses and potential disincentivizing of agroforestry expansion. Economically, while high-value products are grown, the lack of reliable local market access (8.8%) prevents farmers from realizing their full value, often leading to distress sales or post-harvest losses. Finally, the finding that women and disadvantaged groups face discrimination in accessing incentives is a crucial social constraint that requires immediate policy correction to ensure equitable benefits distribution (Pandit et al., 2021).

Agroforestry practices and support mechanisms in Kalinchowk Rural Municipality

Field observations in Kalinchowk Rural Municipality highlighted several successful agroforestry practices. Bhakta Bahadur Siwakoti (Ward 3) integrates avocado with seasonal crops over 30 ropani, earning about NPR 10 lakhs annually. Likewise, Sarki Thami (Ward 6) cultivates kiwi under an agri-silvi-horticultural system on 20 ropani, generating NPR 2–4 lakhs per year, while Hom Pathak (Ward 8) combines orange trees with seasonal crops and fodder species on 19 ropani, earning around NPR 2 lakhs annually. These examples suggest that agri-silvi-horticulture is the most productive and sustainable system in Kalinchowk, contributing both to livelihood improvement and environmental resilience. Despite this potential, awareness and institutional support remain limited. A majority (80.9%) of respondents were unaware of agroforestry-related government policies, and 77.9% reported no community initiatives, apart from a few Swiss-funded forestry projects. Government assistance was minimal, with only small proportions receiving water collection drums (26.5%), seeds (16.9%), or plastic sheets (13.2%), while 43.4% reported no support at all (Table 14) which was also verified by forest officer, Kamal Acharya. Reports of unequal distribution, particularly among women and marginalized groups, were also noted. Most respondents emphasized the urgent need for quality seeds, technical training, improved irrigation, and better market access to strengthen agroforestry-based integrated farming systems across the municipality.

Table 14: Summary of agroforestry practices, awareness, and government support in Kalinchowk

Category	Indicator	Findings
Best practices	Predominant systems	Agri-silvi-horticulture, agri-silviculture, homegardens (mid-hills), silvo-pastoral (high-hills)
	Successful examples	Siwakoti (Avocado, 30 ropani, NPR 10L/yr); Thami (Kiwi, 20 ropani, NPR 2–4L/yr); Pathak (Orange, 19 ropani, NPR 2L/yr)
Policy awareness	Aware of government agroforestry policies	19.1%
	Unaware of policies	80.9%
Community initiatives	Existing projects	Swiss-funded community forestry (22.1%)
	No local initiatives	77.9%
Government support (based on respondents' perception)	No support	43.4%
	Seeds distributed	16.9%
	Water collection drums	26.5%
	Plastic for farming	13.2%
Further needs	Major supports required	Quality seeds, technical training, irrigation, market access

Although some institutional support measures, such as the distribution of water collection drums, plastic sheets, and seeds, were reported by respondents (Table 15), their coverage remains limited and uneven. Low awareness of agroforestry-related government policies and reported disparities in access to support further indicate gaps in extension services and institutional outreach. Overall, the findings suggest that while agroforestry has demonstrated clear socio-economic and environmental benefits in Kalinchowk, its long-term sustainability and scalability depend on improved technical support, equitable institutional engagement, and stronger market linkages. Addressing these factors is essential for agroforestry to function effectively as a climate-resilient and inclusive livelihood strategy in high-hill environments.

CONCLUSION

This study demonstrates that agroforestry systems represent effective climate-smart land-use practices that enhance both the socio-economic and environmental performance of farming systems in Kalinchowk Rural Municipality, Dolakha. Socio-economically, agroforestry contributes to livelihood resilience by supporting household food security, diversifying farm production, and reducing vulnerability. The association between diversified agroforestry systems, particularly agri-horti-silviculture and higher levels of food sufficiency highlights their importance in strengthening household well-being under changing climatic conditions. Despite widespread knowledge of climate change impacts (erratic rainfall and extreme temperatures confirmed by DHM data), the full potential of agroforestry is

constrained by biological threats (pests/monkeys), technical gaps, and inadequate market infrastructure. Given the observed trends of declining rainfall and increasing temperature variability, agroforestry should also be formally integrated into local climate adaptation planning as a nature-based solution to enhance environmental resilience and livelihood sustainability. Overall, the findings indicate that agri-horti-silviculture offers the most balanced socio-economic and environmental outcomes and holds strong potential for wider adoption in Kalinchowk and similar high-hill regions of Nepal.

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