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ORIGINAL RESEARCH ARTICLE

Changes in agroforestry practices in response to climate change and associated factors in Mangsebung Rural Municipality, Ilam district, Eastern Nepal

Vijay Kumar Yadav[1*], Tarjan Limbu[1], Salina Rai[1] and Punit Yadav[2]

[1]Institute of Forestry, Hetauda, Tribhuwan University, Nepal
[2]Faculty of Forestry, Hetauda, Agriculture and Forestry University, Nepal
[*]Corresponding author's E-mail: vijay.yadav@hc.tu.edu.np.com

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ABSTRACT

Agroforestry is a cornerstone of rural livelihoods in the mid-hills of Nepal, but its patterns are being reshaped by climate change and a set of associated socio-economic and technological factors. This study aimed to document the prevailing agroforestry practices, identify the drivers of change in those practices, and assess the contribution of evolving technologies in Mangsebung Rural Municipality of Ilam district in Nepal. A cross-sectional study was carried out using a structured household questionnaire, supplemented by key informant interviews, focus group discussions and direct field observations. Data was analyzed in Microsoft Excel using descriptive statistics. Results revealed that four major agroforestry practices were identified in the study area including home garden, horticulture-based agroforestry, agri-silviculture, and silvi-pasture. Climate change emerged as the most frequently cited driver of change, followed by market demand, community participation, government policies, and invasive species. Cardamom (under *Alnus nepalensis*), broom grass (*Thysanolaena maxima*), kiwi, and coffee have largely replaced traditional subsistence crops such as millet and barley, reflecting a marked transition from subsistence to commercial agroforestry. Major constraints include weather extremes, pest and disease pressure, irrigation scarcity, labor shortage, and weak institutional support. The study concludes that targeted policy support, climate-resilient species, and farmer training are required to sustain agroforestry-based livelihoods in the eastern mid-hills of Nepal.

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INTRODUCTION

Agroforestry is the deliberate integration of woody perennials with crops and/or livestock on the same land-management unit, either spatially or temporally, to generate ecological and socio-economic benefits (Sinclair, 1999; Jose, 2009). In Nepal, where more than 65% of the population depends on agriculture and where farm holdings are small and fragmented, agroforestry contributes to food security, household income, soil and water conservation, biodiversity conservation, and carbon sequestration (Aryal *et al*., 2019; Khadka *et al*., 2021; Dhakal *et al*., 2022). The mid-hill belt of Nepal, characterized by sloping terrain, terraced cultivation, and a mosaic of land uses, has historically supported a rich diversity of indigenous agroforestry systems, including home gardens, agri-silviculture, and silvi-pasture (Bhattarai *et al*., 2025). Climate change is now altering the conditions under which these systems operate. Long-term shifts in temperature and precipitation, the increasing frequency of droughts, floods, landslides, glacial retreat, and the spread of pests, diseases, and invasive species are reshaping the agro-ecological envelope of the Himalayan region (Rasul & Molden, 2019; Mishra *et al*., 2019; Quandt *et al*., 2023). At the same time, non-climatic drivers like market demand, government policies, labor migration, new technology, and community networks are interacting with climate signals to modify how farmers select species, allocate land, and manage trees (Gentle & Maraseni, 2012; Dhakal *et al.*, 2022; Verma *et al.*, 2024).

Ilam District of Eastern Nepal is widely recognized for its commercial agroforestry, particularly large cardamom (*Amomum subulatum*), tea, and broom grass (*Thysanolaena maxima*) grown under *Alnus nepalensis* (Aryal *et al.*, 2019; Dahal *et al.*, 2025). Although several studies have documented agroforestry systems in the central mid-hills of Nepal (Khadka *et al.*, 2021), there is limited recent empirical evidence on how farmers in the eastern mid-hills are altering their agroforestry choices in response to the combined pressures of climate change and other associated factors. Specifically, the linkage between technological innovation and shifting agroforestry patterns at the rural municipality scale remains under-documented.

This study was therefore designed to address this gap by examining changes in agroforestry practices. The specific objectives were: (i) to identify the prevailing agroforestry practices in the study area; (ii) to assess the drivers of change in agroforestry; and (iii) to evaluate the contribution of evolving technologies to changes in agroforestry. The findings are expected to inform local-level adaptation planning and to provide a basis for future research on climate-resilient agroforestry in the eastern mid-hills of Nepal.

MATERIALS AND METHODS

Study area

The study was conducted in Mangsebung Rural Municipality, Ilam District, Province No. 1, Eastern Nepal. The rural municipality lies in the mid-hill belt and is characterized by sub-tropical to temperate climate, sloping terrain and a mixed farming system dominated by cardamom, tea, broom grass and small-scale livestock. The location of the study area is shown in Figure 1.

Sampling design and data collection

A cross-sectional, mixed-methods design was adopted. The target population comprised 200 households (873 individuals; 445 males, 428 females) within the selected wards of the rural municipality. A sample of 100 households (60 male-headed and 40 female-headed respondents) was selected using simple random sampling, following the procedure described by Cochran (1977), to give a 50% sample intensity. Primary data were collected through:

- Household questionnaire survey using a semi-structured schedule covering household demographics, land holding, existing agroforestry practices, perceived climate impacts, drivers of change and constraints.
- Key informant interviews (n = 4) with the ward chairperson, an agricultural extension officer, a forest ranger and a local agroforestry farmer.
- Focus group discussions (n = 2) with mixed-gender groups of 8–10 farmers, following the procedure of Krueger & Casey (2014).
- Direct field observation of representative agroforestry plots, with documentation of species composition, spatial arrangement and management practices.
- Secondary data were obtained from published peer-reviewed literature and from records of the District Agriculture Development Office (DADO), Division Forest Office (DFO), Department of Forests (DoF), District Soil Conservation Office (DSCO), and relevant NGOs and INGOs working in the area.

Data analysis

All quantitative data were entered, cleaned and analyzed in Microsoft Excel 2019 using descriptive statistics (frequency, percentage and mean). Qualitative information from key informant interviews and focus group discussions was analyzed thematically following Braun & Clarke (2006) and triangulated with field observations.

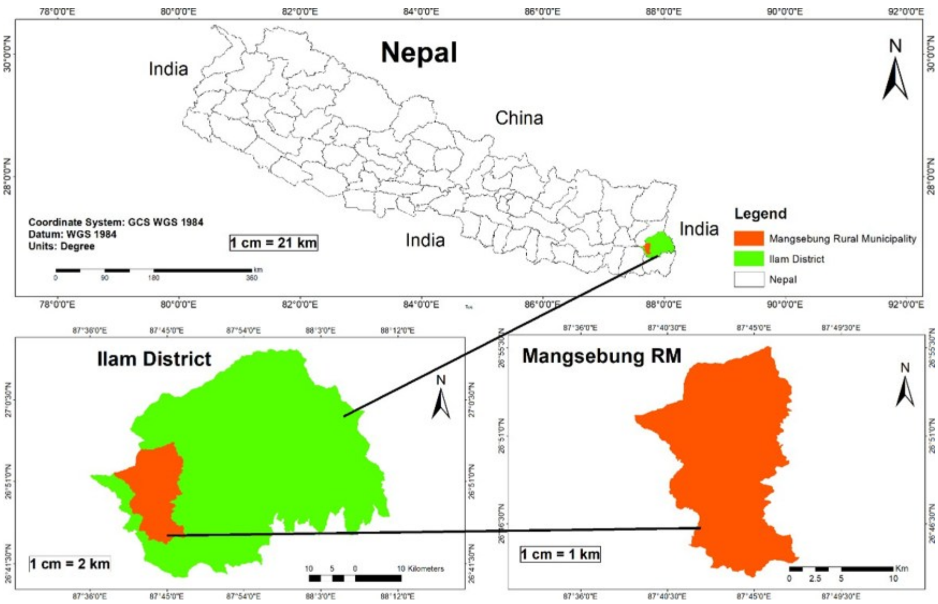

Figure 1. *Map showing study area in Ilam district, Nepal.*

RESULTS AND DISCUSSION

Demographic profile and exposure to climate change

The study area had a total population of 873 distributed across 200 households (mean household size 4.37). Of the 100 sampled respondents, 60 were male and 40 were female. Land-holding patterns showed that 10 households held less than 5 Ropani (≈ 0.25 ha), 15 held 5–10 Ropani, 35 held 10–20 Ropani and 50 held more than 20 Ropani. Reported climate-change impact was severe in 50 households, moderate in 30, slight in 15 and absent in 5. The high proportion of severely affected households is consistent with the regional vulnerability assessment of Mishra *et al.* (2019), who reported that mid-hill communities in the Hindu Kush Himalaya are among the most exposed populations to climate-induced shocks.

Existing agroforestry practices

Home garden

Home gardens were the most common agroforestry practice in the study area. They typically consisted of a mix of fruit trees, vegetables, medicinal plants and spices grown in or adjacent to the homestead. Households cultivated bananas, papayas, guavas, citrus fruits and coffee alongside vegetables such as tomatoes, beans and leafy greens. Fodder trees commonly included Koiralo (*Bauhinia variegata*), Bakaino (*Melia azedarach*), Kadam (*Anthocephalus chinensis*), Dudhilo (*Ficus neriifolia*) and Kabro (*Ficus lacor*). Home gardens not only provided food security and nutrition but also a source of supplementary income. Trees in these gardens provided shade, improved soil fertility and enhanced the microclimate around the homestead. Similar multifunctional roles of home gardens in have been reported by Bhattarai *et al.* (2025) and Dahal *et al.* (2025).

Horticulture-based agroforestry

Horticulture-based agroforestry involved the cultivation of high-value horticultural crops in combination with trees. In the study area, this commonly included orchards of mango (*Mangifera indica*), papaya (*Carica papaya*), pear (*Pyrus communis*), orange (*Citrus sinensis*), peach (*Prunus persica*) and plum (*Prunus domestica*) intercropped with shade-tolerant vegetables and legumes such as pumpkin (*Cucurbita maxima*), ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*), particularly on productive, flat land. Farmers managed tree canopies carefully to optimize light penetration for the understory crops. This system maximized land productivity, diversified income sources and supported biodiversity and soil health.

Agri-silviculture

In this system, trees were grown in and around agricultural fields, most commonly on *Bari* (rainfed upland) land where maize, millet and vegetables were cultivated together with fodder and fuelwood/timber species. Multipurpose trees were planted on terrace edges and sloping risers while crops were produced on the terrace. The most common sub-types observed were:

- Tea, cardamom or broom grass (Amriso) intercropped with seasonal crops on terraces and bunds, diversifying farmer income.
- Tea under *Alnus nepalensis* and *Albizia* species, in which the trees served primarily as shelter and were rarely harvested. This was the dominant tea-based commercial agroforestry system.
- Cardamom under *Alnus nepalensis*, planted either as a random mixture or with cardamom as an alley crop and *Alnus* on terrace risers.
- Cardamom and *Thysanolaena maxima* planted under *Elaeocarpus ganitrus*, *Alnus nepalensis*, *Schima wallichii* and other fodder species in mixed random patterns; the herbaceous species formed alley crops while the trees occupied risers.
- Cardamom and coffee under *Alnus nepalensis*, *Schima wallichii* and *Castanopsis* spp.
- Coffee, maize and seasonal vegetables under *Elaeocarpus ganitrus*, grown in a random mixed pattern; cereals and vegetables supported subsistence while coffee and *Elaeocarpus* generated cash income.
- *Thysanolaena maxima* with *Alnus nepalensis*, *Castanopsis* and other timber species, grown commercially and for fodder.
- Kiwi, cardamom and Chiraito with *Elaeocarpus ganitrus* and *Michelia champaca*; kiwi was planted at ~5 m spacing and the interspace was used for cardamom and timber species, all for commercial use.

The dominance of *Alnus nepalensis*-based cardamom systems is consistent with the findings of Aryal *et al.* (2019) and Dahal *et al.* (2025), who reported this species combination as the most economically important commercial agroforestry system of the eastern mid-hills.

Silvi-pasture system

Silvi-pasture involved the integration of trees with livestock grazing. Farmers managed pastures particularly in *Kharbari* land, collecting foliage from raised fodder trees and grazing understorey grasses and bushes. However, Kharbari was increasingly being converted to broom-grass (*Thysanolaena maxima*, locally Amriso) plantations because farmers obtained both fodder and substantial cash income from the sale of inflorescences used for broom-making. This conversion mirrors the commercialization trend reported by Dhakal *et al.* (2022) for the eastern mid-hills.

Drivers of changes in the agroforestry system

Six broad categories of drivers emerged from the household survey and key informant interviews (Table 1).

Climate change: Farmers reported shifts in the timing and intensity of monsoon rainfall, longer dry spells, higher summer temperatures and a perceived increase in extreme events, which together pushed them towards climate-resilient practices such as silvo-pastoral systems and soil-conservation agroforestry, in line with the global synthesis of Lobell & Field (2007) and the South Asia–focused work of Gentle & Maraseni (2012) and Quandt *et al.* (2023).

Table 1. Driver responsible for change in agroforestry.

Driver of change	Number of respondent	Specific impact	Example
Climate change	25	Altered rainfall pattern Temperature fluctuation Extreme weather events	Increased water scarcity Paddy field converted into *Thysanolaena maxima* with timber species
Market Demand	45	Fluctuation in crop prices Demand for specific products	Increased in demand and price of cardamom Amriso, coffee, kiwi and less production cost
Government Policies and support program	8	Supportive policies and subsidies	Policies of one village one product (kiwi)
Community participation and networking	12	Access to new knowledge and techniques	Adopting new systems which were practiced outside study area
Invasive species	5	Extinct of indigenous species	Adopting rotational farming (3-4 year agricultural land and cardamom / utis, amriso/utis
Other factor	5	Labor scarcity, technological advancement	Changes labor cost agricultural field into cash crops (Ginger, Coffee, Tea etc.)

Table 2. Change in pattern of agroforestry between 2010 and 2082 BS.

Time period	Land use pattern	Main crops and trees	Changes in land use pattern	Drivers/Factors
Before 2010 BS	Small-scale mixed farming, minimal agroforestry, mono cropping	Traditional crops (Millet, maize, barley), native species	-	-
2011 - 2050 BS	Shifting cultivation, intercropping, alley cropping	Introduction of cash crops (Tea, Amriso, Ginger, Cardamom) with native species	Conversion of subsistence agricultural fields to cash crops/agroforestry (e.g., planting cardamom with Alnus nepalensis)	Increasing market value, demand, lower production costs, climate change adaptation
2050 BS - Recent Time	Expansion of agroforestry with SALT technology, terracing, new technologies, shifting cultivation	More cultivation of cash crops (Cardamom, Amriso, Coffee, Tea) with fast- growing species (Utis, Chilaune, Siris)	Extinction of native species (Sal, Simal, Lampatee); conversion of irrigated paddy fields cardamom cultivation and unirrigated or dry fields are covered into amriso land due to irrigation issues. Conversion of silvi-pasture (kharbari) to amriso field with timber species	Climate change, market demand (national/ international), government policies, labor scarcity, and others

Market demand: Rising market prices for cardamom, broom grass, coffee and kiwi were the single most frequently cited driver (45% of respondents). Farmers reported substituting high-value tree–crop combinations for traditional cereals to diversify income, consistent with Dhakal *et al.* (2022). However, comparable studies of high-value forest commodity chains in Nepal show that producers typically capture only a small share of the final product value because chains are buyer-driven and information asymmetries favour traders and processors (Devkota *et al.*, 2025); this is a risk that warrants attention as agroforestry in Mangsebung shifts further towards commercial species.

Government policies and support: Targeted programs (e.g., the "one village, one product" initiative promoting kiwi) influenced species selection. However, only 8% of respondents reported being direct beneficiaries, suggesting limited coverage consistent with finding by Khadka *et al.* (2021) for central Nepal.

Community participation and social networks: Farmer cooperatives, user groups and informal peer networks facilitated knowledge exchange and accelerated the diffusion of innovations such as grafted fruit varieties and improved cardamom dryers, supporting the "in-development" paradigm advocated by Verma *et al.* (2024). The strength of such networks is, however, mediated by who participates as Bhattarai *et al.* (2025) show for community forestry in western Nepal, education, age and proximity to the user-group office strongly determine whether women and less-educated households take part in collective decision-making.

Invasive species. Invasive plants: Particularly *Lantana camara*, *Chromolaena odorata* (Siam weed) and *Ageratina adenophora* were colonizing farmlands, forest edges and pastures and outcompeting native vegetation, prompting farmers to adopt rotational agroforestry.

Other factors: Labor scarcity due to youth out-migration and new on-farm technologies were also cited as drivers of change.

Change in the pattern of the agroforestry system

Respondents and key informants identified three broad periods of change in agroforestry practices over the past ~70 years (Table 2). The earliest period (before 2010 BS) was dominated by small-scale mixed and mono-cropped farming with minimal tree integration. Between 2010 and 2050 BS, cash crops such as tea, ginger, broom grass and cardamom were progressively introduced alongside native species, often in alley-cropping or intercropping arrangements. From 2050 BS to the present, agroforestry has expanded markedly with the adoption of Sloping Agricultural Land Technology (SALT), terracing and fast-growing species such as *Alnus nepalensis* (Utis), *Schima wallichii* (Chilaune) and Albizia (Siris). Native species such as *Shorea robusta* (Sal), *Bombax ceiba* (Simal) and *Duabanga grandiflora* (Lampatee) have largely disappeared from cultivated land. Irrigated paddy fields have been converted to cardamom orchards, while rainfed plots have been replaced by broom-grass with timber overstoreys. This trajectory from subsistence indigenous agroforestry to commercial agroforestry is consistent with the regional findings of Dhakal *et al.* (2022) and Verma *et al.* (2024).

Contribution of technological innovations in agroforestry

Extension materials, training programs and the dissemination of climate-resilient tree varieties have enabled farmers in the study area to adopt more sustainable and productive agroforestry systems. The introduction of multipurpose farm machinery has reduced labor costs and increased efficiency, while propagation techniques such as grafting and tissue culture have improved planting-material quality and uniformity. These observations are in agreement with Sharma *et al.* (2024), who reported that access to improved technologies is a significant determinant of agroforestry adoption among mid-hill farmers.

Problems related to the agroforestry system

Despite the high potential of agroforestry in the study area, respondents identified the following constraints:

Weather extremes and crop resilience: Shifts in temperature and rainfall placed traditional species under stress, reducing productivity (consistent with Mishra *et al.*, 2019).

Pest and disease management: Climate change has expanded the range and intensity of pests and pathogens; farmers reported inadequate resources and knowledge to manage them.

Irrigation scarcity: Drying rivers and weak canal infrastructure limited irrigation during critical periods.

Economic viability: Lower yields, higher adaptation costs and volatile market prices reduced household profitability.

Labor scarcity: Out-migration of youth to towns and to foreign labor markets created a labor deficit, in line with Dhakal *et al.* (2022).

Knowledge and resource gaps: Many farmers lacked information on climate-smart agroforestry practices and access to credit or technical support.

Weak policy and institutional support: Training, financial aid and infrastructure for climate-resilient agroforestry from local government and non-governmental actors remained limited.

Taken together, these results suggest that agroforestry in Mangsebung is in transition from a primarily subsistence-oriented system to a commercially oriented one, driven by market signals and accelerated by climate change. The shift towards Alnus-based cardamom, broom-grass and kiwi systems is increasing household cash income but is also concentrating risk on a narrow set of high-value species, with implications for resilience that warrant further longitudinal study.

Conclusion and recommendation

This study assessed changes in agroforestry practices in Mangsebung Rural Municipality, Ilam District, Eastern Nepal. Four major agroforestry practices were identified: home garden, horticulture-based agroforestry, agri-silviculture and silvipasture. Market demand and climate change were the dominant drivers of change, with majority of households reporting moderate to severe climate-related impacts. The agroforestry landscape has shifted markedly over the last seven decades, with subsistence species being replaced by high-value commercial crops like cardamom, broom grass, kiwi and coffee grown predominantly under *Alnus nepalensis*. Major constraints to sustaining this transition include weather extremes, pest and disease pressure, irrigation scarcity, labor shortage, weak technical knowledge and limited institutional support. The findings underline the need for context-specific policy, locally adapted climate-resilient species and stronger extension support to maintain the ecological and livelihood benefits of agroforestry in the eastern mid-hills of Nepal. Develop and implement policies with financial incentives and subsidies that promote climate-resilient agroforestry. Improve access to irrigation, planting material and farm tools. Invest in research to identify and propagate climate-resilient, market-relevant tree and crop species suitable for the eastern mid-hills. Strengthen farmer training and extension services to disseminate new technologies and best practices.

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DECLARATION

Authors' contribution statement: Conceptualization: V.K.Y. and T.L.; Methodology: V.K.Y.; Software and validation: V.K.Y., T.L. and S.R.; Formal analysis: V.K.Y.; Investigation: V.K.Y., T.L. and S.R.; Resources: V.K.Y.; Data curation: V.K.Y.; Writing—original draft preparation: V.K.Y.; Writing—review and editing: V.K.Y., T.L., S.R. and P.Y.; Visualization: V.K.Y. and P.Y.; Supervision: P.Y.; Project administration: V.K.Y. All authors have read and agreed to the published version of the manuscript.

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