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Exploring status of tree species in farmland and challenges of farm based agroforestry in Makwanpur district, Central Nepal

Samik Bista[1], Gyan Bandhu Sharma[1], Bishnu Thapa[2] and Asmi BK[1]

[1]Faculty of Forestry, Agriculture and Forestry University, Hetauda, Bagmati Province, Nepal
[2]Humanitarian and Biodiversity Conservation Society (HBCS), Chitwan, Bagmati Province, Nepal

ABSTRACT

This study examines tree species diversity and the challenges associated with adopting farm-based agroforestry in Makwanpur Gadhi Rural Municipality, Central Nepal. Data were gathered through 372 household surveys, Five Focus Group Discussions (FGDs), and 27 Key Informant Interviews (KIIs). The data were analyzed using MS-Excel, with thematic analysis, and results were presented in tables, bar graphs, and pie charts. Challenges were ranked using the relative threats and challenge ranking method. A total of 73 tree species were identified, categorized into fruit-bearing species (25) were the most prevalent, followed by those used for Timber (8), Fuelwood (5), Fodder (20), Medicinal purposes (10) and Religious and Ornamental use (5). Preferred species included *Shorea robusta* (Sal) for timber, *Ficus semicordata* (Dhungre) for fodder, and *Mangifera indica* (Mango) for fruit. The Shannon-Wiener Index yielded a diversity score of 1.905, with an evenness index of 0.215, indicating a relatively high species diversity but uneven distribution dominated by a few species. Farm-based agroforestry practices were found to positively influence biodiversity, enhance soil quality, and diversify farmers' incomes, reducing dependence on forest resources and supporting sustainable land use. However, several challenges, such as crop raiding by wildlife, irrigation issues, and limited access to quality seedlings, hinder widespread adoption. To address these barriers, the study recommends implementing community-based initiatives, government subsidies, and capacity-building programs for farmers. These measures are expected to enhance farm-based agroforestry adoption, improving forest health, ecosystem stability, and rural livelihoods. This study highlights the potential of farm-based agroforestry to promote both environmental conservation and socio-economic resilience in the region.

KEYWORDS

Farm-based agroforestry; Tree species; Species diversity; Farmland; Sustainability.

ARTICLE HISTORY

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Introduction

Agroforestry is the purposeful integration of agricultural and forestry practices to develop land-use systems that are diverse, productive, economically sound, and environmentally sustainable [1]. These systems are often complex, with impacts that extend from individual plots to broader landscapes [2]. Agroforestry encompasses a wide range of systems including silvo-pastoral models for livestock, home gardens, on-farm timber production, tree-crop combinations, and biomass plantations, all adapted to varying biophysical and socio-ecological contexts [3]. It is a broad term that refers to systems combining trees with crops and/or livestock within the same land management unit. In contrast, farm forestry refers specifically to tree cultivation and management on private land. However, researchers frequently use the terms interchangeably [4]. In Nepal, tree planting on farmland is commonly referred to as private forestry. Agriculture is the main source of livelihood for the majority of Nepal's population. Trees on farmland are integral to the farming system, providing timber, fuel wood, fodder, grass, and nutrients. With rising human and livestock populations, there is increasing pressure on both forested and arable lands [5,6]. As a result, forest resources are steadily declining in quantity, quality, and biodiversity. Forest cover, which exceeded 45% in 1964, dropped to 29% by 1998 [7,8]. Trees in farming systems help meet farmers' livelihood needs, and farm forestry plays a crucial role in sustaining rural communities by providing diverse tree-based resources [9,10].

Limited research exists on tree species diversity, use value, preferred species, and challenges of agroforestry adoption in farmland. This study aims to bridge knowledge gaps by establishing baseline information on tree diversity, uses, preferences, and challenges, and providing recommendations for farm-based agroforestry in this understudied region. The findings will support future implementation and promotion of sustainable agroforestry practices in the region.

Materials and Methods

Study area

The study area was selected based on three criteria: the presence of agroforestry systems integrating a variety of tree species on farmland, active involvement of local communities in agriculture, and accessibility to ensure efficient data collection

*Correspondence: Samik Bista, Faculty of Forestry, Agriculture and Forestry University, Hetauda, Bagmati Province, Nepal, India. e-mail: samikbista293@gmail.com

through field surveys, interviews, and site visits. The research was conducted in Makawanpur Gadhi Rural Municipality of Makawanpur District, Nepal (Figure 1). This municipality comprises 8 wards and has a total of 5,285 households. It is situated at an elevation of approximately 1,308 meters above mean sea level and is bordered by Bakaiya Rural Municipality to the east, Bhimphedi Rural Municipality to the west and north, and Hetauda Sub-metropolitan City to the south. The district lies between 27°10' to 27°40' N latitude and 84°41' to 85°31' E longitude, with Makawanpur Gadhi located about 34 km south of Kathmandu and 17 km north of Hetauda. The area experiences a tropical to subtropical climate, with an average annual temperature of 28°C and annual rainfall around 240 mm. Geologically, it encompasses alternating strata of the upper Chure and lower Mahabharat ranges, composed of shale, schist, quartzite, phyllite, limestone, granite, and gneiss [11,12]. Agriculture and livestock farming are the primary sources of livelihood in the region.

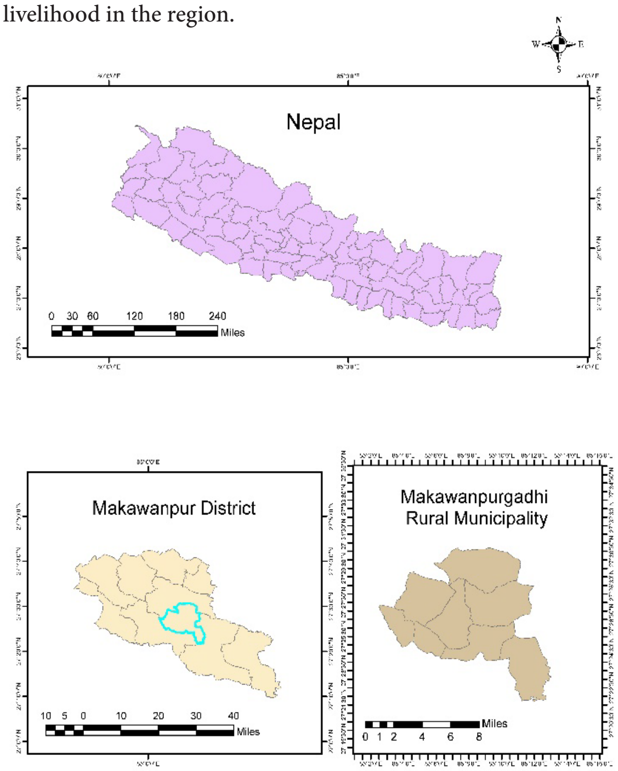

Figure 1. Map showing Study Area

Data collection

Sampling design

To ensure robust data collection and minimize sampling error, the sample size was determined using Yamane's formula. According to Yamane, the sample size for a finite population is calculated using the formula [13]:

$$n = N / (1 + N * e^2)$$

Where:

n = sample size
N = population size
e = margin of error (in decimal form)

Given:

N = 5,285 households
e = 0.05 (5% margin of error)
Now, applying the formula step by step:
$n = 5285 / (1 + 5285 \times 0.05^2)$
$n = 5285 / (1 + 5285 \times 0.0025)$
$n = 5285 / (1 + 13.2125)$
$n = 5285 / 14.2125$
$n \approx 372$

Therefore, the required sample size is approximately 372 households.

Focus Group Discussions (FGD)

Focus group discussions (FGDs) proved valuable in understanding tree species diversity, challenges in farm based agroforestry adoption, and potential solutions for promoting agroforestry practices. A total of five FGDs were conducted, one each with a local teacher and a ward member, and three with farmers residing near study area. These discussions provided critical qualitative data aligned with the study's objectives.

Field observation and household questionnaire survey

A total of 372 households were surveyed using structured questionnaires to gather data on tree species diversity, preferred species, and agroforestry practices in farmlands. Random walk sampling was adopted to reduce response bias and ensure representation of diverse farming households. Simultaneously, field observations were conducted to assess the distribution of tree species within the sampled farmlands. All individual trees above 1.3 meters in height were recorded, irrespective of their age, as per the method outlined by Kharal and Oli [14].

Species diversity index and evenness

Shannon-Weiner Diversity Index

The Shannon-Weiner Index considers both species abundance and evenness in a community [15]. It is a commonly used metric for quantifying biodiversity.

The index is represented by H, and calculated as:

$$H = -\sum (P_i \times \ln P_i)$$

Where:

H = Shannon-Weiner Diversity Index
P_i = Proportion of individuals belonging to the i-th species (i.e., $P_i = n_i/N$, where n_i is the number of individuals of species i and N is the total number of individuals)

Evenness (E)

Evenness reflects how evenly individuals are distributed across the different species and is calculated using the formula:

$$E = H / \ln(S)$$

Where:

E = Evenness
H = Shannon-Weiner Index
S = Total number of species in the community

Challenge assessment for farm-based agroforestry

Initially, 27 key informant interviews with (each Ward

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Chairperson, each Ward Secretary, Chairperson of the Manakamana Community Forest, Chairperson of the Manakamana Dairy Cooperative, and the Principals of schools) were conducted to identify the major challenges associated with the adoption of farm-based agroforestry practices. These challenges were then prioritized using the Relative Ranking Method, as applied in similar studies by Kafle et al. and Neupane et al. [17-19]. Three criteria scope, severity, and urgency were used to evaluate each challenge. The average of each criterion was calculated first, followed by the computation of the overall average weightage RII to systematically rank the challenges hindering the adoption and sustainability of agroforestry practices in farmland.

Data Analysis

The collected data were analyzed using MS Excel and SPSS, and the results were presented using tables, graphs, figures, and charts to enable clear and logical interpretation.

Results

Tree species, use value and mode of regeneration

We recorded a total of 73 tree species from farm-based agroforestry systems in Makwanpur Gadhi Rural Municipality. Among these, fruit-bearing species (25) were the most prevalent, followed by those used for Timber (8), Fuelwood (5), Fodder (20), Medicinal purposes (10) and Religious and Ornamental use (5).

Table 1. Showing Challenges ranking criteria.

Criteria	Scale	Classification	Description
Scope	4	Very High	Likely to affect 71–100% of farm-based agroforestry productivity
	3	High	Likely to affect 31–70% of farm-based agroforestry productivity
	2	Medium	Likely to affect 11–30% of farm-based agroforestry productivity
	1	Low	Likely to affect 1–10% of farm-based agroforestry productivity
Severity	4	Very High	Expected to reduce farm-based agroforestry productivity by 71–100% within 10 years
	3	High	Expected to reduce farm-based agroforestry productivity by 31–70% within 10 years
	2	Medium	Expected to reduce farm-based agroforestry productivity by 11–30% within 10 years
	1	Low	Expected to reduce farm-based agroforestry productivity by 1–10% within 10 years
Urgency	4	Very High	Impacts are irreversible or restoration takes over 100 years
	3	High	Reversible with restoration taking 21–100 years
	2	Medium	Reversible with restoration taking 6–20 years
	1	Low	Easily reversible within 0–5 years

Table 2. Showing Trees species recorded in Farmland with Local name, scientific name, Family Name and major use.

SN	Nepali (Local) Name	Scientific Name	Family Name	Major Use
1	Dhungre	*Ficus semichordata*	Moraceae	Fodder
2	Nimaro	*Ficus rosenbergii*	Moraceae	Fodder
3	Dumri	*Ficus racemosa*	Moraceae	Fodder
4	Kavro	*Ficus lacor*	Moraceae	Fodder
5	Thotne	*Ficus hispida*	Moraceae	Fodder
6	Kutmero	*Litsea monopetala*	Lauraceae	Fodder
7	Royani	*Mallotus philippensis*	Euphorbiaceae	Fodder
8	Bakaino	*Melia azedarach*	Meliaceae	Fodder
9	Ipilipil	*Leucaena leucocephala*	Fabaceae	Fodder
10	Gaaye	*Bridelia retusa*	Phyllanthaceae	Fodder
11	Dar	*Pouzolzia rugulosa*	Urticaceae	Fodder
12	Dabdabbe	*Garuga pinnata*	Burseraceae	Fodder
13	Koiralo	*Bauhinia variegata*	Fabaceae	Fodder
14	Tanki	*Bauhinia purpurea*	Fabaceae	Fodder
15	Tatelo	*Oroxylum indicum*	Bignoniaceae	Fodder

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16	Chuletro	*Brassiopsis hainla*	Araliaceae	Fodder
17	Pakhari	*Ficus glaberrima*	Moraceae	Fodder
18	Sandhan	*Ficus roxburghii*	Moraceae	Fodder
19	Tatelo	*Oroxylum indicum*	Bignoniaceae	Fodder
20	Faledo	*Erythrina stricta*	Fabaceae	Fodder
21	Sittalchini	*Moringa oleifera*	Moringaceae	Fruit
22	Litchi	*Litchi chinensis*	Sapindaceae	Fruit
23	Bel	*Aegle marmelos*	Rutaceae	Fruit
24	Chuiri	*Aesandra butyracea*	Sapotaceae	Fruit
25	Emilie	*Tamarindus indica*	Fabaceae	Fruit
26	Katahar	*Artocarpus heterophyllus*	Moraceae	Fruit
27	Badahar	*Artocarpus lakoocha*	Moraceae	Fruit
28	Mango	*Mangifera indica*	Anacardiaceae	Fruit
29	Bhogate	*Maesa macrophylla*	Primulaceae	Fruit
30	Jamuna	*Syzygium cumini*	Myrtaceae	Fruit
31	Kimbu (Kafal)	*Morus alba*	Moraceae	Fruit
32	Kyamuno	*Syzygium nervosum*	Myrtaceae	Fruit
33	Suntala	*Citrus aurantium*	Rutaceae	Fruit
34	Nibuwa	*Citrus limon*	Rutaceae	Fruit
35	Bimiro	*Citrus medica*	Rutaceae	Fruit
36	Kagati	*Citrus aurantifolia*	Rutaceae	Fruit
37	Aru	*Prunus armeniaca*	Rosaceae	Fruit
38	Belauti	*Psidium guajava*	Myrtaceae	Fruit
39	Mewa	*Carica papaya*	Caricaceae	Fruit
40	Naspati	*Pyrus communis*	Rosaceae	Fruit
41	Painyu	*Betula alnoides*	Betulaceae	Fruit
42	Amala	*Phyllanthus emblica*	Phyllanthaceae	Fruit
43	Avacado	*Persea americana*	Lauraceae	Fruits
44	Haluwabed	*Diospyros kaki*	Ebenaceae	Fruits
45	Aalu Bhokhada/ Plum	*Prunus domestica*	Rosaceae	Fruits
46	Amaro	*Spondias bipinnata*	Anacardiaceae	Medicinal
47	Tejpat	*Cinnamomum tamala*	Lauraceae	Medicinal
48	Neem	*Azadirachta indica*	Meliaceae	Medicinal
49	Khirro	*Falconeria insignis*	Euphorbiaceae	Medicinal
50	Barro	*Terminalia bellirica*	Combretaceae	Medicinal
51	Rajbriksh	*Cassia fistula*	Fabaceae	Medicinal
52	Khayar	*Acacia catechu*	Fabaceae	Medicinal
53	Vellor	*Mallotus nudiflorus*	Euphorbiaceae	Medicinal

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54	Harro	*Terminalia chebula*	Combretaceae	Medicinal
55	Vakeamilo	*Brucea javanica*	Simaroubaceae	Medicinal
56	Bar	*Ficus benghalensis*	Moraceae	Religious and Ornamental
57	Parijat	*Nyctanthes arbor-tristis*	Oleaceae	Religious and Ornamental
58	Pipal	*Ficus religiosa*	Moraceae	Religious and Ornamental
59	Swami	*Ficus benjamina*	Moraceae	Religious and Ornamental
60	Karam	*Adina cordifolia*	Rubiaceae	Religious and Ornamental
61	Sal	*Shorea robusta*	Dipterocarpaceae	Timber
62	Teak	*Tectona grandis*	Lamiaceae	Timber
63	Saaj	*Terminalia alata*	Combretaceae	Timber
64	Chatiwan	*Alstonia scholaris*	Apocynaceae	Timber
65	Tooni	*Toona ciliata*	Meliaceae	Timber
66	Khamari	*Gmelina arborea*	Lamiaceae	Timber
67	Champ	*Magnolia champaca*	Magnoliaceae	Timber
68	Masala	*Eucalyptus camaldulensis*	Myrtaceae	Timber
69	Gidhari	*Premna integrifolia*	Lamiaceae	Fuelwood
70	Sisoo	*Dalbergia sissoo*	Fabaceae	Fuelwood
71	Bot dhayero	*Lagerstroemia parviflora*	Lythraceae	Fuelwood
72	Chilaune	*Schima wallichii*	Theaceae	Fuelwood
73	Padke	*Carpesium nepalense*	Asteraceae	Fuelwood

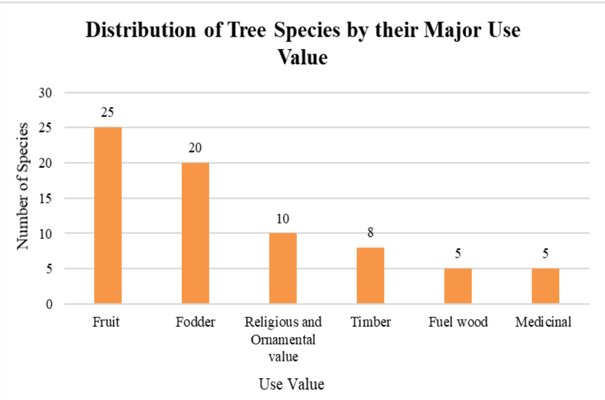

Figure 2. Bar graph showing number of species with their use value.

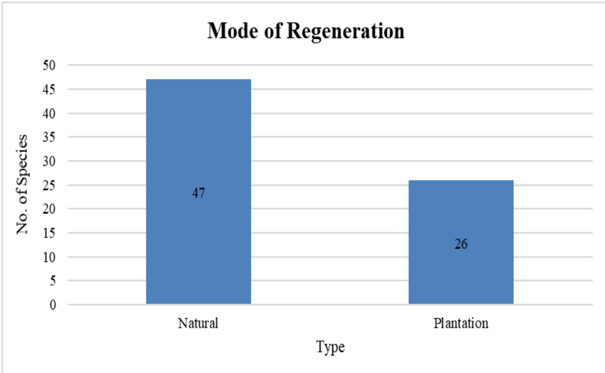

Figure 3. Bar Graph Showing number of species and mode of regenerations

In terms of regeneration origin, 47 species (64.38%) were naturally regenerated, which are retained by farmers, whereas 26 species (35.62%) were established through plantation efforts. Notably, fruit-bearing, religious, ornamental, and exotic species were predominantly introduced through plantations. The floristic composition was largely indigenous, with 71 species (95.89%) native to the region. Only two species, *Tectona grandis* and *Eucalyptus camaldulensis*, were recorded as exotic, representing 4.11% of the total.

Preferred species

The study documented household preferences for tree species based on their primary uses, including timber, fuelwood, fodder, and fruit production. *Shorea robusta* emerged as the most preferred species for both timber and Premna integrifolia for fuelwood purposes, selected by 226 households, accounting for 68.48% of the total respondents. This was followed by *Schima wallichii*, favored by 185 households (56.06%), and *Terminalia alata*, used by 163 households (49.39%). These

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species were widely recognized for their durable wood and high fuel value, making them integral to rural subsistence and construction practices. In terms of fodder provision, *Ficus semicordata* and *Litsea monopetala* were the most frequently used species, reported by 226 households (68.48%) and 200 households (60.61%), respectively. These species are highly valued for their year-round availability of palatable foliage and their adaptability to agroforestry systems.

Regarding fruit trees, *Mangifera indica* was the most cultivated and preferred species, grown by 256 households (77.58%), reflecting its high market and nutritional value. This was followed by *Litchi chinensis*, reported by 180 households (54.55%), and *Citrus maxima*, recorded in 160 households (48.48%). The preference for these fruit species underscores their significance in enhancing household food security and income generation.

These findings highlight the multifunctional role of tree species in supporting rural livelihoods, with species selection strongly influenced by both ecological suitability and socio-economic benefits in farm-based agroforestry.

Species diversity index

The species diversity within the agroforestry system was evaluated using the Shannon-Wiener Diversity Index and Evenness value. The calculated Shannon-Wiener Index (H') of 1.908 reflects a moderate level of species diversity, indicating a relatively rich assemblage of tree species in the study area. This suggests that the agroforestry system supports a reasonably diverse composition, which may contribute to ecological stability and resilience.

However, the calculated Evenness value of 0.215 indicates a notable imbalance in species distribution. This low Evenness value suggests that a few dominant species, particularly *Shorea robusta* and *Schima wallichii*, account for a disproportionate share of the total abundance. Thus, while overall species diversity is moderate, the dominance of certain species results in limited ecological uniformity across the system.

Challenges of farm based agroforestry

Key challenges affecting the adoption and sustainability of farm-based agroforestry practices in the study area were identified through a participatory assessment involving Key Informant Interviews (KIIs). Each challenge was ranked based on a Relative Ranking Method reflecting its perceived importance among local stakeholders, with higher scores of the Relative Ranking Index indicating greater priority.

Farm-based agroforestry in the study area faces multiple challenges that hinder its successful adoption. Crop raiding by wild animals such as spotted deer (*Axis axis*), barking deer (*Muntiacus muntjak*), langurs (*Semnopithecus*), and monkeys (*Macaca* spp.) significantly reduces agricultural productivity by up to 50% undermining food security and economic sustainability. Inadequate irrigation facilities pose another major constraint, especially during dry seasons when trees require consistent watering. The region's reliance on rain-fed agriculture makes integrating tree crop systems difficult. A lack of knowledge and technical skills among farmers further limits adoption, as many are unaware of suitable species, management practices, and long-term benefits. Additionally, unclear policies on land use, tree ownership, and harvesting regulations create uncertainty and discourage farmers from planting trees. Poor access to quality, disease-resistant seedlings and the prevalence of pests and diseases in both crops and trees result in low survival rates and high management costs. Land tenure issues, particularly near community forest areas, also hinder agroforestry implementation, with unauthorized forest clearing impacting conservation goals. Finally, limited access to markets prevents farmers from profiting from agroforestry products like fruits and timber, reducing the incentive to adopt such systems. Together, these challenges identified through KIIs, FGDs, and household surveys contribute to low uptake of agroforestry practices, despite their potential to enhance sustainability and biodiversity. Addressing these barriers through integrated policy support, training, infrastructure development, and market linkage is essential to promote wider adoption of agroforestry in the region. The ranking of these challenges are shown in the table below:

Table 3. Presents the ranking of challenges with respective to average weighted RRI.

Challenges of Farm based Agroforestry	Average Weightage RRI	Rank
Crop raiding by wild animals	0.9954	1
Inadequate irrigation facilities	0.9225	2
Limited knowledge and technical skills	0.8995	3
Ambiguity in farm-based agroforestry-related policies	0.85555	4
Limited access to quality seedlings	0.7985	5
Pest and disease prevalence	0.75555	6
Land tenure insecurity	0.666667	7

Discussion

In Nepal, 110 tree species are utilized in farm-based agroforestry practices [20]. The present study documented 73 tree species, representing about 66.36% of the total agroforestry tree species reported nationally. Comparable findings were observed in Chitwan, where Regmi and Garforth (n.d.) recorded 66 plant species cultivated in agricultural lands [21].

The diversity indices also align with earlier research. Kharal and Oli reported a Shannon-Wiener Index of 1.80 and a species richness index of 5.01 in rural Chitwan, which closely

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parallels the current study's Shannon-Wiener Index of 1.908 [14]. Both studies reveal low to moderate species diversity and the dominance of a limited number of tree species in farm-based agroforestry systems. While Kharal and Oli documented 60 species in their study area, this study reported 73 species. However, the variation in elevation, 500 m to 700 m in the present study versus lower elevations in Chitwan, may account for differences in species composition. Tree species diversity in the current study is comparatively lower than that observed in similar agroforestry systems across South Asia. For instance, Bashar reported a Shannon-Wiener Index of 3.24 for fruit trees in Bangladeshi homegardens, while Sellathurai documented a higher index of 3.93 in Sri Lanka [20,22]. This lower biodiversity can be attributed to the overwhelming dominance of a few tree species within the study area. Nonetheless, some households displayed higher biodiversity, indicating the potential for enhancing species richness through improved household-level management.

Other studies from Nepal further emphasize this contrast. Das noted over 60 tree species in the farmlands of eastern Nepal [8]. Carter identified 101 tree species in Nepal's middle hills, and Rusten recorded 127 species at similar elevations [23,24]. These studies suggest that hill regions generally support greater tree species diversity than the Terai plains, likely due to the multifunctional role of trees in hill farming systems. In these areas, farmers depend more heavily on diverse species for essential resources like fodder, firewood, and soil conservation due to limited access to external inputs.

Table 4. Presents a literature review that supports the results and compares tree species diversity across various studies conducted in Nepal.

SN.	Study Location	Main Author	Number of tree species recorded	Shannon-Wiener Index	Findings
1	Chitwan Inner valley of Nepal	[14]	60	1.80	Similar diversity pattern, lower elevation, limited species distribution
2	Chitwan Inner valley of Nepal	[21]	66	--	Farmland diversity in Terai region
3	Middle Hills of Nepal	[23]	101	--	Higher diversity; hill regions favor multifunctional tree use
4	Middle Hills of Nepal	[24]	127	--	High diversity; reflects intensive household-level species management
5	Our Study	Samik Bista	73	1.908	Moderate diversity; dominance of few species; variation due to elevation
6	Farmland of Bangladesh	[19]	--	3.24 for fruit trees in Bangladeshi home gardens	Higher Diversity Than Our Study Area
7	Farmland of Srilanka	[20]	--	3.93	Higher Diversity Than Our Study Area

Conclusions

This study underscores the significant potential of farm-based agroforestry in the study area, as reflected by the presence of 73 tree species and a moderately high level of biodiversity. Despite this promise, the widespread adoption of agroforestry is hindered by several key challenges, including crop raiding by wild animals, inadequate irrigation infrastructure, limited access to quality planting material, pest and disease pressures, lack of technical knowledge, and ambiguous policy frameworks. Addressing these challenges requires integrated and context-specific interventions. These include establishing compensation schemes for wildlife-induced crop damage, improving irrigation facilities, ensuring timely availability of high-quality seedlings, and clarifying agroforestry-related policies.

Furthermore, capacity-building programs and community -based initiatives are critical to equipping farmers with the necessary knowledge and skills to sustainably manage agroforestry systems. Ultimately, the successful integration of farm-based agroforestry into agricultural landscapes is vital for enhancing rural livelihoods, conserving biodiversity, and ensuring the long-term sustainability of forest ecosystems. The future of forest conservation in the region is closely tied to our ability to promote and implement agroforestry practices effectively at the farm level.

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Competing Interests

The authors declare no competing interests.

Author Contributions

SB and GBS developed the project concept. SB and AB

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conducted the fieldwork, while SB and BT performed data analysis and drafted the manuscript. GBS provided overall supervision of the research and supported manuscript refinement.

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