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What Determines the Adoption of Agroforestry Practices in Farmlands and Public Lands? A Case Study from the Terai Region in Nepal

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ABSTRACT

While agroforestry has been well acknowledged for its influential role and benefits in integrated resource management in the global south, its adoption in forest-rich countries with existing community conflict situations is under-explored. Through structured questionnaire surveys and focus group discussions, this study explored the context and factors influencing the adoption of agroforestry practices on farmlands and public lands in the Terai region of southern Nepal. Results from logistic regression models revealed that adoption of agroforestry practices on both farmland and public land could contribute to mitigating conflicts between northern and southern communities. In addition, the adoption of agroforestry practices can be explained by socio-demographic and economic factors such as education, ethnicity, well-being, and gender. Strong cooperation between agroforestry initiatives and local institutions such as forest user groups and local governments in educating and empowering local people from lower socio-economic backgrounds is critical for widespread adoption of agroforestry practices in similar resource-use conflict regions.

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Introduction

While Agroforestry has a history spanning centuries (Nair, Kumar, and Nair 2021), the study and adoption of modern agroforestry practices have advanced mainly in the last 40 years (Mercer 2004; Dagar and Tewari 2018). Agroforestry is a land use management strategy that creates livelihood and biodiversity benefits, which not only include increased primary production of cereals, income and food security and forest resources (Dhakal 2013; Sollen-Norrlin, Ghaley, and Rintoul 2020) but also improve sustainability of land management, biodiversity, and soil quality (Harvey, Gonzalez, and Somarriba 2006; Neupane and Thapa 2001; Raj et al. 2019). Agroforestry is also considered a critical conflict management strategy in the use and management of natural resources (Sanginga, Kamugisha, and Martin 2007).

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Despite the widespread realization of the multiple benefits of agroforestry in the global south (Awazi and Avana-Tientcheu 2020; Dhakal and Kumar Rai 2020), the adoption of agroforestry differs in both spatial and temporal scales and is driven by various socio-economic, ecological, and institutional factors (Dhakal and Kumar Rai 2020; Ojha et al. 2019; Bhattarai et al. 2021). Improved economic status, land size, agriculture as primary income sources, effective techniques and knowledge sharing, and higher potential benefits can motivate people toward agroforestry development (Khadka et al. 2021; Dhakal and Kumar Rai 2020).

In the southern plains of the Terai in Nepal, conflict between southern users – indigenous Madhesi and Dalit communities – and northern users – migrants from hill regions – for forest resources is widely prevalent (Gartaula and Niehof 2013; Satyal Pravat and Humphreys 2013) for the use, control and management of existing natural forests near the east-west national highway. The increased resource control and authority of northern people over forest management and utilization with community forestry rights has worsened the situation (Ojha et al. 2019). Although actions related to forest use and access have been implemented to reduce tension between these northern and southern communities (Paudel et al. 2018), they are not effective yet at the community level. Agroforestry can be a tool to mitigate conflict between these two communities. Most households in the southern communities rely on conventional agriculture as their primary source of income and production where women play a crucial key role in crop production and harvesting. Looking at the potential to manage these lands effectively can be an essential asset for southern communities to fulfill their timber and fuelwood demand (Bhattarai et al. 2021).

Several studies examined the contribution of agroforestry to biodiversity conservation and socio-economic upliftment in the mid-hills of Nepal (Cedamon et al. 2018; Pandit et al. 2019), mostly focused on exploring adoption factors in private farmlands (Dhakal and Kumar Rai 2020). Nevertheless, 423,725 ha. (about 17%) of total public land is spread across Terai districts in Nepal (Sapkota 2016). Public lands refer to pasture lands, ponds, paths, wells and their banks, grazing areas, sports ground, marketplace used by the general public or community (GoN 1964). Employing agroforestry practices in unused public lands can generate additional forest goods and services, for more livelihood opportunities, and ultimately reduce conflict (Bhattarai et al. 2021).

Several factors are found to influence agroforestry development, adoption and implementation, which act at various levels, singly or combined, varied by places and policies (Dhyani et al. 2021; Jha, Kaechele, and Sieber 2021; Dhakal and Kumar Rai 2020). Direct output in terms of cash profit (Duguma 2013), perceived knowledge of agroforestry (Paudel and Thapa 2004), and negative perception of people toward trees on farmlands (Cedamon, Nuberg, and Shrestha 2017) are reported to be the impediments to the agroforestry adoption. In recent literature, other socio-economic challenges such as unclear tree and land tenure (Dhyani et al. 2021), caste and gender-based activities (Dhakal and Kumar Rai 2020; Jha, Kaechele, and Sieber 2021), and community conflict (Awazi and Avana-Tientcheu 2020) have emerged as newer issues in agroforestry adoption.

Exploring options to utilize the public lands for the overall benefit to the local Terai people is a crucial research question. Large chunks of underutilized or denuded public lands, if restored, with particular provision for poor and marginalized communities, can provide benefits and improve livelihood through more extensive access to common resources (NPC 2019; Bhattarai et al. 2021). Therefore, this study explores agroforestry adoption, current practices, and the factors influencing its implementation and expansion in public lands and private farmlands in the southern plains of the Terai in Nepal. Specifically, our research questions include: (1) what agroforestry practices have been adopted along with their issues and challenges? and (2) what factors influence agroforestry adoption in the private farmland and public land in the region? The findings of this study offer broader implications related to the adoption and promotion of agroforestry practices in Nepal’s Terai region.

Methods and Materials

Study Area

The study site, Nawalparasi district in Gandaki province, was chosen due to the availability of ample public lands (Sapkota 2016) and the growing conflict for forest resources between the northern and southern communities (Ojha et al. 2019; Bhattarai et al. 2021). The study area is in the flat lowland Terai region of southwestern Nepal, which covers wards 12 & 13 of Bardaghat Municipality, wards 5 & 6 of Sarawal Rural Municipality, and ward 1 of Palhi-Nandan Rural Municipality in Nawalparasi district (Figure 1). The municipalities adjoin the border of India to their south and the Chure

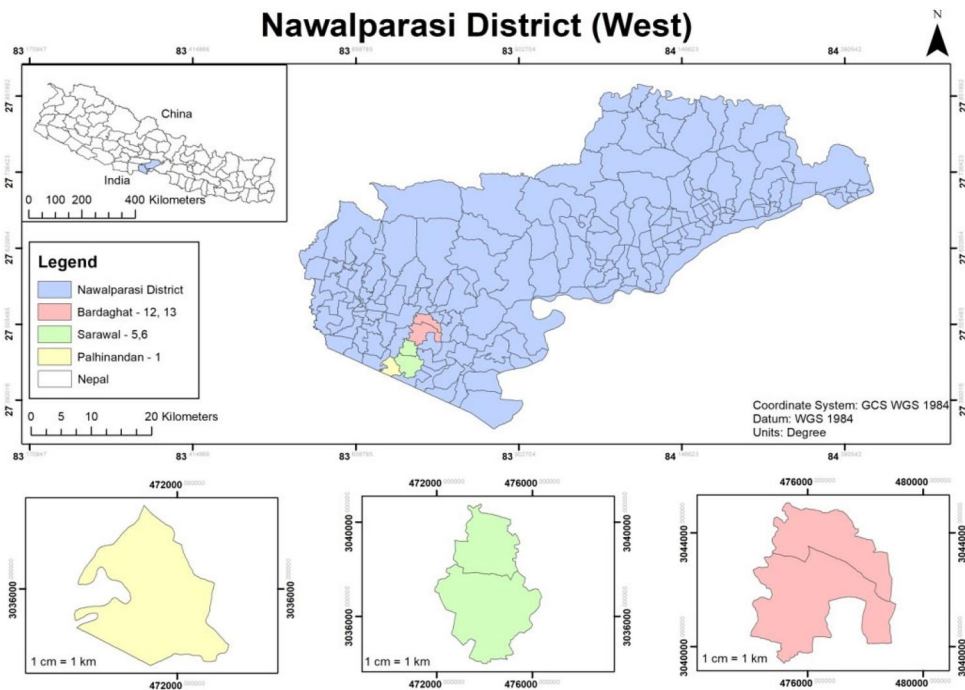


Figure 1. The Map of the study area (numbers in the legend denote wards).

hills to the north. Nearly 3,350 households in these municipalities utilize the forest products of Chisapani Community Forest User Group (CFUG) of Nawalparasi District. The Chisapani CFUG (registered in 2009) covers 495 hectares of forestland. The distant users comprise 60% of total user households living approximately 18 kilometers (KM) from the forest area. We define the distant users as the Madhesi community, who have been historically living in this region and are culturally distinct from migrants, or Pahade residing south of the forested belt. The dense settlements of Madhesi and Dalit communities dominate the southern belt of our study area up to the Indian border. The migrants, dominated by Brahmin and Chhetri from the mid-hills, occupy the northern belt of the region.

The region is primarily covered by natural forests of Nepal, where Sal (*Shorea robusta*) represents roughly 70% of the forestland. The total area of unmanaged public land is about 34,000 hectares, which is fertile for agricultural production (Deuja 2007). Local people in the southern belt whose main occupation is agriculture, adopt traditional agroforestry practices by intermixing regular agricultural crops with boundary plantations, home gardens, and scattered trees and fruit woodlots. However, agroforestry in the public land area appears to be negligible. Fuelwood is the primary cooking source of local people and they collected around 300 cubic meters per household each year from Chisapani CFUG (Bhusal et al. 2015).

Data Collection and Analysis

We employed structured questionnaire surveys and semi-structured stakeholder interviews along with focus group discussions to collect the primary data on various aspects of agroforestry practices, socio-demographic information of residents, and forest and agricultural land use practices. Before administering surveys and discussions, we conducted a series of interactions with officials and local people using participatory research and adaptive learning strategy, like Ojha et al. (2019). Several stakeholder groups, including the CFUG executive committee, southern communities, forest officials, and local governments were consulted to assess the socio-political context, existing agricultural practices, and forest and farm use dynamics.

Six focus groups, up to two and half hours long, were conducted with local people from each ward of the study municipality and CFUG executive committee. Each focus group included about 15 southern residents, including local farmers and leaders that represented various socio-demographic (Dalit and poor) and gender (female) status. Those focus groups were guided by semi-structured questions which emphasized the current state of agroforestry in private and public lands, challenges and issues in agroforestry adoption and implementation, and the role of public agencies and local institutions such as CFUGs. We identified key informants (KI) from each focus group to conduct in-depth interviews to investigate non-disclosed issues during the group discussion. In total, 10 KI interviews with leaders of Chisapani CFUG and FECOFUN district chapter were conducted. The main discussion during KI interviews was on the challenges and potential of agroforestry adoption and development in the southern Terai. The reflections from FGDs and KI interviews were useful in developing the household survey instrument.

For the household survey, 200 random households were selected in wards 12 and 13 of Bardaghat municipality, wards 5 and 6 of Sarawal Rural Municipality, and ward 1 of Palhi Nandan Rural Municipality within Chisapani CFUG (Figure 1). Various social, economic, and demographic criteria such as gender, caste, and economic well-being of heads of households were considered while selecting those households. The questionnaire comprised three sections: (i) general information about the socio-demographic and forest dependency of respondents, (ii) respondent's knowledge on agroforestry practices, and (iii) issues and challenges for agroforestry adoption and implementation in the study region. Pre-testing of the survey instrument was conducted with a few southern households and the feedback was incorporated into the final version of the household survey.

Furthermore, we collected various information from secondary sources such as the CFUG annual records of forest resource collection and distribution, as well as published literature on agroforestry and its adoption and implementation, including project reports of Livelihood Forestry Program (LFP) and Multi-stakeholders Forestry Programme (MSFP), Which have been involved in public land management and agroforestry promotion in the Terai region of Nepal.

In terms of data analysis, we began with descriptive statistics of the present context of agroforestry in the study region, including the agroforestry practices followed by the issues and challenges faced by the local users. As a statistical modeling approach, we developed and estimated logistic regression models to explore the factors influencing the adoption of agroforestry on private farmland and public land. We used the binomial responses of agroforestry adoption (yes or no) as the dependent variables for both farmland and public land separately.

Our empirical model is grounded on the adoption theory (Anderson 1997) and aided by various past literature on agroforestry adoption across the globe. The explanatory variable selections were informed and supported by a synthesis of recognized theoretical viewpoints prior to running the model. The goal of such support was to capture the numerous causes of practice adoption and community engagement in natural resource management thoroughly. Using Rogers (2003) as a guide, we chose explanatory variables based on ideas about the adoption of new practices and change. These ideas are further enriched by Anderson (1997), which explains the theories on concern-based adoption models rooted in innovation and the adoption of new changes. Furthermore, studies on the determinants of local community participation in natural resource management from Nepal and South Asia (Chhetri et al. 2013; Lestari, Kotani, and Kakinaka 2015) supported our framework which captures region-specific insights into the determinants of local community engagement in resource management. While demographic variables such as gender, ethnicity, and wellbeing have been important in determining people's choice of new practices (Cedamon et al. 2018; Chhetri et al. 2013; Dhakal 2013), social beliefs and practices have strong relationships to any community-based practices (Bhattarai et al. 2020), and it is clear that people's choices of any practice are primarily guided by the perceived benefits and issues that may arise after practicing the particular system (Dhakal and kumar Rai 2020). Based on these theories and the findings of previous studies, we postulated the empirical model as:

Table 1. Names of explanatory variables used in logistic models.

Dependent Variables	Levels	Variable Name	Description
Farmland agroforestry	Binary (Yes or No)	af.farmland	Practice agroforestry in your private farmland
Public land agroforestry	Binary (Yes or No)	af.publicland	Practice agroforestry in public land
Continuous Variables	Units	Variable Name	Description
Age	Years	Age	Age of the respondent
Formal Education	Years	edu.yr	School attended by the respondent
Categorical Variables	Levels	Name	Description
Household Head	Female	hh.hdFemale	Gender of Household head of the family
Caste/ethnic group	Madhesi	eth.grpMadhesi	Madhesi: Terai specific ethnic group
Source of income	Agriculture	Agriculture	Agriculture as a main source of income of the family
Well-being Ranking	Rich Medium Poor Very poor	wbrRich wbrMedium wbrPoor wbrVerypoor	Well-being ranking of the family in the community forest user group
Source of fuelwood	Binary (Yes or No)	private.source	Source of fuelwood used by the respondents: own private land. Other sources include markets and community forests
Benefit of AF	Binary (Yes or No)	con.mit	AF benefit on northern-southern community conflict mitigation
Issue of AF	1-5 likert scale	Knowledge	Lack of knowledge of agroforestry practices (severity of the issue: 1-very low, 5-very high)
Issue of AF	1-5 likert scale	Beliefs	Social beliefs and practices (severity of the issue: 1- very low, 5-very high)

$$Y = f(\text{age}, \text{edu.yr}, \text{hh.hdFemale}, \text{eth.grpMadhesi}, \text{agriculture}, \text{wbrRich}, \text{wbrMedium}, \text{wbrPoor}, \text{wbrVerypoor}, \text{private.source}, \text{conflict.mitigate}, \text{knowledge}, \text{beliefs})$$

Where, Y represents the dependent variables (af.farmland and af.publicland) which represent whether the respondents practiced (adopted) any agroforestry practices (Yes) or not (No) in private farmland and public land. All the explanatory variables are presented in detail with their levels, variable names, and description in [Table 1](#).

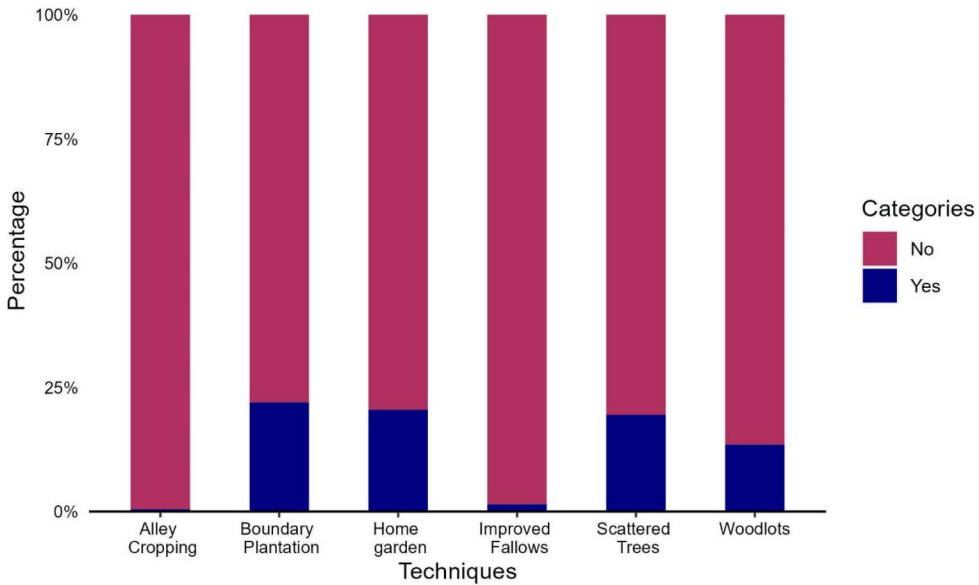
Results

Demographic Characteristics of the Respondents

Out of 200 respondents interviewed in a household survey, 82% were men and 18% were women ([Table 2](#)). In terms of ethnicity of the respondents, 36.5% were Madhesi, followed by Janajati (36%) and Dalits (13%). Brahmins and other ethnic groups were the minority group among the respondents ([Table 2](#)). The average age of the respondents was about 43 years old which is well above the national mean age of Nepalese people across the country (CBS 2012). Furthermore, agriculture was found to be the primary source of income for 77% of the respondents, as 90% of the respondents possessed the land. In terms of well-being, about one-third of respondents represented the poor or very-poor category. The average size of landholding, on average, was less than one hectare per household, and they own just about 1.2 units of livestock per respondent.

Table 2. Descriptive statistics of the variables (N = 200).

Dependent Variables	Level	Frequency (%)
af.farmland	Yes	138 (69)
af.publicland	Yes	62 (31)
Continuous Variables	Mean \pm SD	Median [Min, Max]
Age (Years)	42.6 \pm 13.9	41.0 [18.0, 81.0]
Formal Education (in years)	5.04 \pm 4.12	5.0[0, 14.0]
Categorical Variables	Level	Frequency (%)
Household Head	Female	14 (7)
Caste/ ethnic groups	Madhesi	73 (37)
Source of income	Agriculture	154 (77)
Well-being Ranking	Rich	93 (46.5)
	Medium	41 (20.5)
	Poor	41 (20.5)
	Very poor	25 (12.5)
Source of fuelwood: private land	Yes	53 (27)
Benefit of AF: conflict mitigation	Yes	171 (86)
Issue of AF: Knowledge	Mean (1–5 scale)	4.1
Issue of AF: Beliefs	Mean (1–5 scale)	2.9


Figure 2. Agroforestry practices adopted in private farmlands (N = 200).

Current Agroforestry Practices in the Study Region

Adoption of agroforestry systems: We compiled the list of the prevailing agroforestry practices in the central Terai region (Amatya, Cedamon, and Nuberg 2018), and asked the respondents whether they adopted those practices. Most of the respondents (n = 138) were not involved in any agroforestry systems on the public land, and about one-third of the respondents adopted no agroforestry practices on their private farmland. Among the practices adopted in the private farmlands, boundary plantation was found to be the most adopted system (22%), followed by home garden (21%), and scattered tree systems (20%) (Figure 2). Agroforestry practices such as alley cropping had a very low adoption rate, as it is relatedly complex and requires extensive technical know-how.

Table 3. Frequency of top 5 species planted in various agroforestry systems (BP: boundary plantation; HG: home garden; WL: woodlots; ST: scattered trees).

SN	Species (local name)	Scientific Name	Type	BP	HG	WL	ST
1.	Bakaino	<i>Melia azedarach</i>	Tree/fodder	7	9	2	4
2.	Kadam	<i>Neolamarckia cadamba</i>	Tree/fodder	13	27	6	17
3.	Sagawan/teak	<i>Tectona grandis</i>	Tree/fodder	8	2	5	3
4.	Sissoo	<i>Dalbergia sissoo</i>	Tree/fodder	27	11	20	19
5.	Aanp	<i>Mangifera indica</i>	Fruit	16	24	8	20

Crops and Trees within the Agroforestry System

Timber and fruit trees (hortosilviculture) and trees and crops (agrisilvicultural) combinations were found to be the more dominant crops within the agroforestry systems. In total, 32 tree species primarily *Dalbergia sissoo*, *Mangifera indica*, *Neolamarckia cadamba*, *Melia azedarach*, and *Tectona grandis* in various combinations were planted in agroforestry practices (Table 3). As alley cropping and improved fallows had a lower adoption rate, not many tree species other than *Leucaena latisiliqua* were present in those systems. We found *Camellia sinensis* planted extensively in combination with some fruit and tree species such as *Mangifera indica*, *Melia azedarach*, and *Artocarpus lakoocha*. While there was a higher demand for timber, fewer high-value timber trees (e.g., *Shorea robusta*) were planted than several low-value trees (for example e.g., *Neolamarckia cadamba*). This pattern was quite prevalent because non-*Shorea* tree species, relatively fast-growing trees, also have excellent multipurpose functions such as fuelwood, fodder, and dry leaves. Similarly, the strict harvesting rules and legal complexities on selling *Shorea robusta* timber could be the lower interest among local people in planting and managing *Shorea* trees.

Issues and Challenges Affecting the Adoption of Agroforestry

Figure 3 presents the respondent's ranking of nine identified issues impacting the agroforestry adoption in the study region. The ranking was recorded on a five-point ordinal likert scale ranging from 1 (very low) to 5 (very high). Land tenure, lack of knowledge of agroforestry practices, and lack of appropriate technology and personnel were ranked the top three issues impacting the adoption as well as implementation of agroforestry practices in the study sites. Anecdotally and based on the key informants' discussion, limited extension and outreach efforts in the region could also be a factor because most of local people were found unsatisfied with the existing programs in outreach and knowledge dissemination. Nevertheless, farmers' age and gender, and social beliefs and practices were regarded less of an issue in terms of agroforestry adoption.

In terms of challenges, respondents believed that four out of five factors were primarily responsible for limiting the adoption and development of agroforestry in the region (Figure 4). Limited technical skills and inadequate capital to implement the appropriate agroforestry practices were found to be the major challenges for farmers. Similarly, respondents rated the lack of manpower and limited qualified seeds as crucial challenges in agroforestry development in the study region. The income from traditional agriculture practices was lower compared to the modern agricultural practices with newer

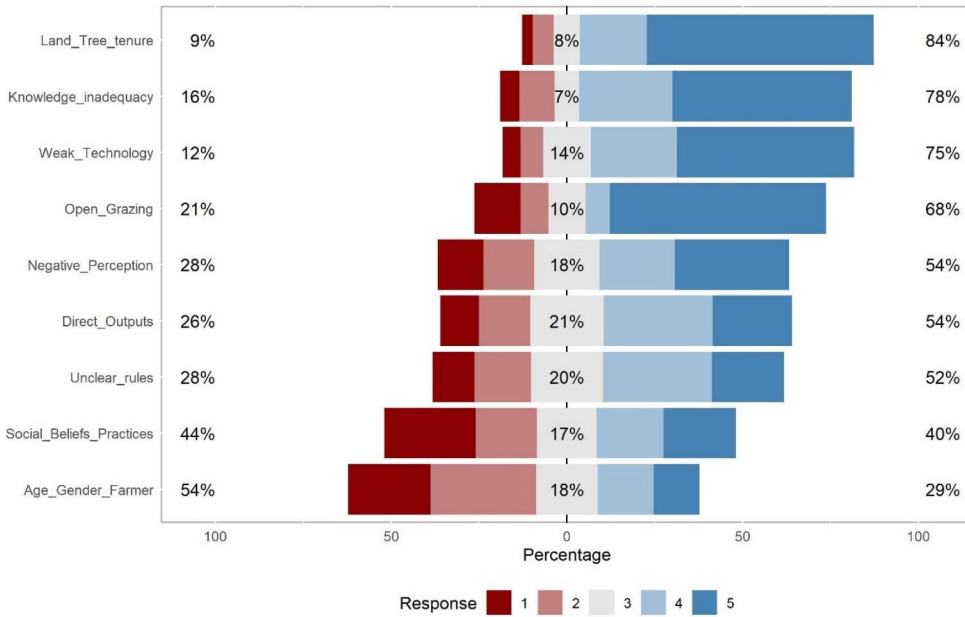


Figure 3. Issues persisted in the agroforestry systems in the Terai region, 1= very low to 5= very high (percentages expressed as the nearest whole number, N = 200).

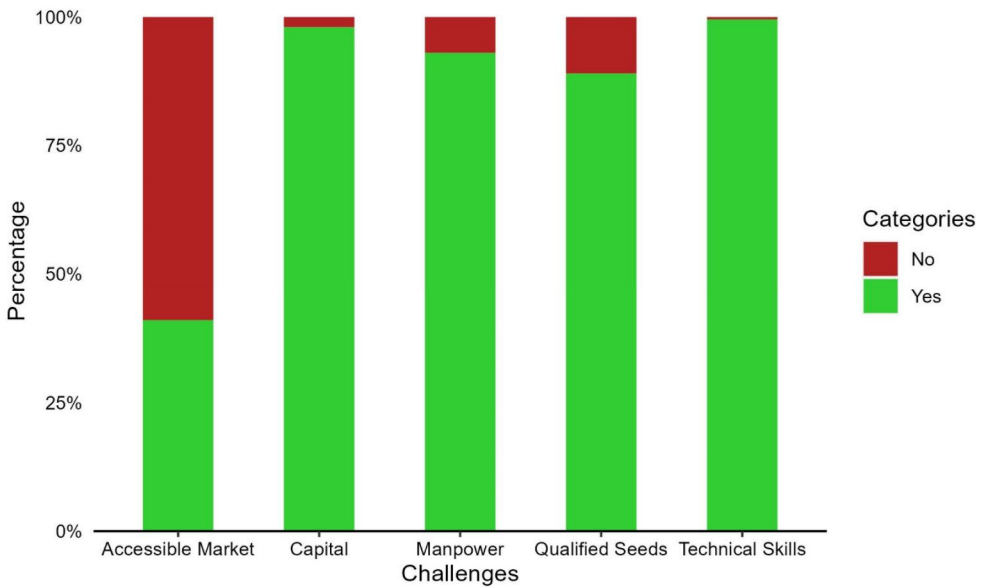


Figure 4. Persisted challenges for agroforestry development in the region (N = 200).

technologies. On the other hand, access to market was reported to be a less of a challenge, as by and large, subsistence farming and forestry practices were prevalent among the respondents and they worried less about marketing agriculture and forest products at a commercial scale.

Table 4. Logistic regression results exploring the determinants of adoption of agroforestry practices in farmland and public land in the Terai region of Nepal (N = 200).

Variable	Farmland		Public Land	
	Estimate (robust std. error)	Odds Ratio	Estimate (robust std. error)	Odds Ratio
Intercept	-0.23 (1.43)	0.79	-5.43 *** (1.67)	0.01
age	0.02 (0.01)	1.02	0.04 *** (0.02)	1.04
edu.yr	0.10 ** (0.05)	1.10	0.17 *** (0.05)	1.18
hh.hdFemale ^a	-1.16 * (0.69)	0.31	-0.37 (0.77)	0.69
eth.grpMadhesi	-1.09 *** (0.38)	0.34	-0.42 (0.35)	0.65
agriculture	0.50 (0.45)	1.65	0.32 (0.45)	1.38
wbrMedium ^b	0.02 (0.53)	1.02	0.52 (0.50)	1.68
wbrPoor ^b	-0.90 * (0.54)	0.41	0.34 (0.58)	1.40
wbrVerypoor ^b	-1.44 ** (0.66)	0.24	1.70 *** (0.65)	5.45
private.source	0.83 (0.51)	2.29	-0.40 (0.43)	0.67
con.mit	0.99 ** (0.49)	2.69	1.68 ** (0.84)	5.35
knowledge	-0.24 (0.20)	0.79	-0.25 * (0.15)	0.77
beliefs	0.08 (0.13)	1.09	0.35 *** (0.13)	1.41

For a: male, and b: Rich are the reference categories. * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Factors Describing the Adoption of Agroforestry Practices

Agroforestry practices in the private farmland: Table 4 presents the logistic regression results describing the determinants of agroforestry practices adoption and implementation in both private farmland and public land in the study region. In the farmland model, several socio-demographic and economic factors: education level of the respondents, female-led households, being Madhesi in terms of ethnicity, and poor and very poor in terms of well-being ranking were found to be statistically significant at 10% or less level of significance. The coefficient estimate associated with education is 0.10 with an odds ratio of 1.02, which indicates that one additional year of education could increase the odds of practicing agroforestry in the private farmland by 1.02, holding all other variables constant. Moreover, another statistically significant and positive determinant is the perceived benefit of agroforestry as a conflict mitigation strategy between northern and southern communities.

On the other hand, results suggest that agroforestry practices are relatively less implemented by households with a female head, Madhesi ethnic background, or poor or very poor in terms of well-being ranking. Although Madhesi households are the region's largest population group, their average landholding per household is relatively smaller than other ethnic groups such as Janajati and Brahmin/Chhetri. For instance, based on our survey, the mean total landholding of Madhesi households was found to be about 0.70 hectares whereas Janajati households' average landholding was approximately 1.3 hectares in the study region. Similarly, poor and very poor households own less private land as well as fewer livestock units, compared to rich and medium-ranked households, implying that poor households have less resources to practice agroforestry. The diversified ethnic groups with varied occupation and well-being ranking indicates that a blanket education strategy about agroforestry is unlikely to work across all groups in the Terai region of Nepal.

Agroforestry practices in the public land: In the public land model, logistic regression results suggest that agroforestry practices adopted in public lands could be explained by various socio-demographic, economic factors, as well as respondents' perceived benefits

and issues of agroforestry (Table 4). Both age and education level of the respondents are found to be statistically significant and positive determinants of adopting agroforestry practices in the public land. Similarly, as expected, very poor households, compared to rich respondents were found more likely to practice agroforestry in public lands, since they, on average, own less private land which explains their more dependency on the available public fallow lands. Moreover, respondents, who rated the benefits of agroforestry for conflict mitigation between southern and northern communities highly, were more likely to practice agroforestry in public lands in the study region. In terms of issues of agroforestry, the respondents who rated the social beliefs and practices highly as a major issue for agroforestry development and implementation were more likely to practice agroforestry. However, those who valued the lack of knowledge of agroforestry practices highly as a perceived issue of agroforestry in the study region were less likely to practice agroforestry. These results on two issues also reinforce the understanding that inadequate knowledge on technical details of agroforestry prevailed in the region, and the social beliefs of residents on farming practices matter in adopting and implementing various agroforestry practices.

Discussion

Agroforestry Context and Practices

A limited number of households utilize public land agroforestry, whereas the vast majority practice conventional farmland agroforestry, such as boundary plantation, home gardens, scattered tree systems, and small woodlots. The Terai region in Nepal noted for its high fertility and agricultural dominance has vast untapped and underutilized public lands that might be utilized for agroforestry practices. Deuja (2007) estimated that 20–23% of public land in Terai areas is unused and unmanaged. Only the three Terai districts, Nawalparasi, Rupandehi, and Kapilbastu have more than 56,000 hectares of public land (Sapkota 2016). As a result, managing these areas efficiently provides a significant opportunity for southern communities in the Terai region to meet the demand for forest products, and, most importantly, could offer livelihood possibilities.

Adopting agroforestry practices in public lands by the southern Terai community is very low and needs multiple strategic interventions. As reported by Dhakal and Kumar Rai (2020) in Dhanusha district of Nepal, the mounting challenges around public land agroforestry management including unclear land tenure and harvesting rights, play a vital role in adopting agroforestry practices (Bhattarai et al. 2020; Bhusal et al. 2015). Equally, the differences in the recognition of land rights based on the economic and ethnic composition of the community were also visible in the study region. Interventions for securing land rights and access are truly critical for agroforestry adoption in public areas.

In private farmland agroforestry, the southern community adopted many agroforestry practices, including boundary plantation, home gardens, scattered tree systems, and woodlots. This can be attributed to the clear land tenure and tree harvesting rights. At the same time, government rules and processes for harvesting and trading durable timber are complex (Kiyani et al. 2017; Dhakal, Cockfield, and Maraseni 2015). On the

other hand, there was a lower adoption rate of alley cropping and improved fallows in the farmland. These systems need a high knowledge base for optimum benefits and frequent management activities (Amatya, Cedamon, and Nuberg 2018). Most households were unaware of agroforestry techniques involving crop combinations and different practices. Instead, horto-silviculture and agri-silvicultural practices were dominant in the larger parts of the southern Terai region of Nawalparasi District. Most tree species like *Dalbergia sissoo*, *Mangifera indica*, *Neolamarckia cadamba*, *Melia azedarach*, and *Tectona grandis* were combined with crops. These are economically low-valued species but are multi-used for fodder, fuelwood, and timber. The lower adoption of high-value trees in farmland agroforestry likely relates to stricter rules on harvesting *Shorea robusta* and other slow-growing species.

The main perceived benefit of agroforestry as a mitigation strategy of northern and southern communities' conflict over forest resources could be instrumental in managing longstanding resource conflict in Nepal's Terai. In both farmland and public land models, this factor is found to be positive and statistically significant. By reducing resource pressure on available natural forests, agroforestry in the public land and farms creates a newer resource base and enhances forest conditions (Pandit, Shrestha, and Bhattarai 2014). Poor people in the southern Terai of Nepal have weak access to and control of community forest resources (Ojha et al. 2019). Public land agroforestry could be a vital instrument to support the increasing forest needs of the southern Terai, where the southern communities are far from the natural forest that lies in the northern Churia region (Ojha et al. 2019; Bhattarai et al. 2020). The study findings by Sanginga, Kamugisha, and Martin (2007) and Awazi and Avana-Tientcheu (2020) in Uganda and Cameroon resonate with similar arguments. Similarly, conflicts could positively enhance the adoption of agroforestry by generating incentives (Sanginga, Kamugisha, and Martin 2007), and in the case of Nepal's southern Terai, the pond, fisheries, fodder, and fuelwood around the agroforestry systems have supported the livelihood needs of the households (Dhakal, Cockfield, and Maraseni 2012). Thus, public land agroforestry could be one of the best strategies to minimize the northern and southern communities' forest resource conflict in Nepal's Terai.

Socio-Demographic and Economic Factors Affect the Adoption of Agroforestry Practices

Agroforestry adoption in private farmland was positively associated with the respondent's years of education. It is obvious that higher-educated households are more likely to have better access to information and make relatively more rational land use decisions (Cedamon et al. 2018; Dhakal and Kumar Rai 2020). On the other hand, households with a female head, Madhesi ethnic background, or poor or very poor ranking in terms of well-being were found to be less likely to practice agroforestry practices. The community composition plays a significant role in agroforestry adoption (Nguyen et al. 2021), and as reported by Khatri et al. (2023), male usually influence the agroforestry adoption decision. The Madhesi ethnic group, the largest population group in the region, is less likely to own land, mainly where agroforestry can be implemented. Our results also show that Madhesi households had almost half the average landholding of

other groups in the study region. Further, their livelihood sources in recent years have shifted to commercial farming and remittances. The rising emigration has increased remittance flow while decreasing the agriculture dependency of local rural communities (K.C., Wang, and Gentle 2017; Khatri 2018).

The socio-economic and contextual factors must be considered before implementing an agroforestry promotion and adoption program (Nguyen et al. 2021). As agroforestry benefits the small landholders (Bhattarai et al. 2020), awareness strategies targeting the poor and Dalit households within the Madhesi and other traditional ethnic groups would work effectively for farm-level agroforestry adoption. While raising awareness should be the first step toward scaling agroforestry, further efforts should include the rigorous involvement of the communities and the institutionalization of the process. The institutionalization process could lead the local forest user groups to address the inconsistency that while agroforestry should benefit low-income people, the same group cannot fully engage in it. One problem, however, is that the increasing youth emigration for jobs increases labor shortages for agroforestry. Engaging in farming activities requires intense labor in the case of Nepal, where technological advancement is very limited, and the manual labor is critically needed.

Adoption of Agroforestry Practices in Public Land is Limited

Agroforestry adoption in public lands was related to many factors, both positively and negatively. Agroforestry adoption on public lands was positively associated with household head age, education, very poor, benefit as a conflict mitigation strategy between northern and southern communities, and social beliefs. Likewise, the negative associations of agroforestry adoption were related to knowledge, implying that households with less knowledge have relatively less probability of adopting agroforestry practices. The Ghana study by Oduro et al. (2018) also illustrated that a lack of knowledge about agroforestry techniques could constrain agroforestry practices.

Logistic regression results also suggest that social beliefs and norms are considered a crucial issue for agroforestry development in the region. For instance, in the forest-fishpond-livestock system of agroforestry, several components are incorporated such as fishes, trees (ornamental and timber) surrounding the pond, and livestock that drink water from the pond. Such a system is considered a traditional way of managing public lands that has been generating incentives for households for decades. Such social beliefs and subjective norms including forest protection, conservation, and traditional ceremonies influence agroforestry adoption (Nguyen et al. 2021), which could have encouraged households to invest their labor and time in agroforestry on public lands.

Terai region is highly stratified with a complex social system (Ojha et al. 2019), where Brahmin/Chhetri and Madhesi elites still handle resource access and control decision-making. Confined control and access to shared resources like community forestry by elites result in the distance of users from resources (Bhusal et al. 2015; Satyal Pravat and Humphreys 2013). Public land management can be the best option to uplift the livelihood of poor households, including women, Dalits, and marginalized groups. Moreover, this also serves as a solution to decrease the rising pressure on national

(natural) forest resources resulting from complex resource distribution complied with increasing population pressure in the Terai region of Nepal.

Conclusion

Our study explored the potential of agroforestry adoption in private farmlands and public lands along with their determinants in the Terai region of Nepal. Within farmland agroforestry, traditional agroforestry practices like boundary plantation, home gardens, scattered tree systems, and woodlots were more common than advanced agroforestry practices like alley cropping. Increasing livelihood diversification from agriculture toward remittances has added further challenges to agroforestry adoption. Developing agroforestry practices on the public lands in the southern Terai region of Nepal may add benefits to the farm and forest dependent poor households. Similarly, adoption of agroforestry practices on both farmland and public land would produce positive impact in mitigating conflicts between northern and southern communities.

In the case of agroforestry adoption in farmlands, cautious intervention in both socio-economic conditions and processes is crucial to enhance the relationship between local people and agroforestry systems. Various socio-economic factors such as education, ethnicity, economic wellbeing as poor and very poor, and the gender of the household head play a significant role in agroforestry adoption in farmland. The wellbeing ranking interacts with the primary income source of the household, as people with more land are more likely to be rich. Similarly, our results show the minimal use of farmland by the Dalits, Madhesi, and minor ethnicities, suggesting that the Brahmin/Chhetri group is primarily driving agroforestry adoption in private lands.

It is worth noting that the positive relationship between very poor households and agroforestry adoption in public lands suggests that it is currently the poorer demographic which believes in the benefits of improving the resources available on public lands. Thus, agroforestry education and training should be targeted toward the very poor people where its uptake and implementation will be the most effective and provide the most significant benefits. On the other hand, it is crucial to encourage and uplift poor and marginalized households into decision-making positions which are currently largely dominated by Brahmin and Chhetri groups. We suggest institutionalization of agroforestry initiatives with local institutions like community forest user groups and local governments could enhance agroforestry adoption and harness its benefits and long-term outcomes. The institutionalization process focusing on inclusive participation, education and field demonstrations could help address the issues and challenges in agroforestry adoption in the region.

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