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# Who Adopts Agroforestry in a Subsistence Economy?—Lessons from the Terai of Nepal

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**Abstract:** Agroforestry is recognized as a sustainable land use practice. However, the uptake of such a promising land use practice is slow. Through this research, carried out in a Terai district of Nepal, we thoroughly examine what influences farmers' choice of agroforestry adoption and what discourages the adoption. For this, a total of 288 households were surveyed using a structured questionnaire. Two agroforestry practices were compared with conventional agriculture with the help of the Multinomial Logistic Regression (MNL) model. The likelihood of adoption was found to be influenced by gender: the male-headed households were more likely to adopt the tree-based farming practice. Having a source of off-farm income was positively associated with the adoption decision of farmers. Area of farmland was found as the major constraint to agroforestry adoption for smallholder farmers. Some other variables that affected positively included livestock herd size, provision of extension service, home-to- forest distance, farmers' group membership and awareness of farmers about environmental benefits of agroforestry. Irrigation was another adoption constraint that the study area farmers were faced with. The households with a means of transport and with a larger family (household) size were found to be reluctant regarding agroforestry adoption. A collective farming practice could be a strategy to engage the smallholder farmers in agroforestry.

**Keywords:** agroforestry practices; adoption determinants; smallholder farmers; Nepal

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## 1. Introduction

Land degradation, a persistent decline in soil quality and its productivity caused by natural or anthropogenic factors, has adversely affected food production, the supply of ecosystem services and livelihoods globally [1]. Even though it occurs throughout the world, the extent and degree of degradation vary with region. For instance, dryland areas of African countries and Australia, mountain ranges of the Himalayas, and densely populated areas of South Asia are more vulnerable [2,3]. The consequences of land degradation are severe as they impact adversely on farm-productivity, and hence on food security [4]. By 2030, the demand for food is expected to increase by at least 50%, which requires conservation and restoration of the productivity of agricultural land. It is estimated that a 60% increase in agricultural productivity, will be necessary by 2050 in order to overcome hunger and food insecurity [5].

Many factors are responsible for the global spread of agricultural land degradation. The spread and growth of populations, inappropriate land-use practices, excessive use of chemicals, mechanized agriculture and natural phenomena such as erosion, floods and drought are the proximate causes of degradation [4]. In countries like Nepal, where the demographic pattern is changing substantially due to the outmigration of the economically active population, agriculture land degradation is becoming a serious issue [6]. In a subsistence economy, farmers are forced to cultivate marginal lands, use agrochemicals, and follow intensive farming and mechanized agriculture to sustain their livelihoods. All these activities have supported a gradual decline in soil fertility [7,8].

Since the underlying causes of land degradation are multifaceted, it requires an integrated approach of land management [4]. A single strategy may be counterproductive, for instance, a reduction in chemical fertilizer application may result in decreased crop yield and, hence, food insecurity. In this context, agroforestry, which is an integrated tree-based farming system, has come into the forefront given its potential to address land degradation with additional environmental and social benefits [9,10]. Agroforestry supports biodiversity conservation [11–14]. Similarly, it has higher financial returns compared to that of conventional agriculture [15]. It also provides biosafety, as the crop failure is less likely compared to the treeless system [16]. This may be because the agroforestry system restores soil fertility [15,17] and rehabilitates degraded agricultural land [18]. The scientific evidence clearly indicates that agroforestry can be a viable land-use option with its potential to address various issues ranging from household-level issues such as food insecurity to global issues including climate change and biodiversity. It is of the utmost urgency to make such a promising land-use reach a wider geographic coverage and motivate farmers to adopt it.

Having so many economic and environmental benefits, agroforestry should be a widely adopted practice. However, the status of agroforestry adoption is not encouraging and not widespread as expected, even though several national and international organizations are involved in its promotion and extension. There might be disincentives to establishing trees including lack of knowledge, upfront costs, length of time until there is a return and a short-to-medium-term reduction in cash flow and/or household food production [19]. Nonetheless, there has been a wealth of research works on agroforestry adoption and the factors associated with it [20]. The existing agroforestry literature documents four broad categories of factors/determinants influencing farmers' adoption decisions: farmers' preferences, resource endowments, institutional impediments and risk/uncertainty [21]. However, the influence of these determinants/factors on the adoption decision of farmers differs from one place to another. For example, in some African countries (Sudan and Uganda), factors such as gender of household head, household family size, level of education, farmer's experience, membership within farmers' associations, contact with extension workers, land tenure security, agroecological zone, distance of the village from the nearest town, village accessibility and income were the major factors that determined the adoption of agroforestry systems by the smallholder farmers [22,23]. On the contrary, a study by Beyene et al. [24] in Ethiopia reveals that gender has no role in the agroforestry adoption decision of farmers. A similar result was documented by Oli et al. [25] from a mid-hills district of Nepal, that agroforestry practice is a gender-neutral activity. In another study carried out in Vietnam by Catacutan and Naz [26], female-headed households were found to be less likely to adopt agroforestry practices. Likewise, the issue of land tenure security is the prominent one influencing the adoption decision of African farmers, while this has no impact in the Nepalese context [22–24,27]. Therefore, understanding the region-specific determinants of agroforestry adoption is crucial for the successful uptake and diffusion of agroforestry practices in that region.

Against the above backdrop, this study attempts to assesses the determining factors of adoption of two agroforestry practices, agroforest/woodlot system (AFS) and alley cropping system (ACS), in Nepal. The findings of the study are useful for policymakers, development agencies and academicians.

## 2. Materials and Methods

### *2.1. Study Area and Descriptions*

Dhanusha district, which is in the southern part of Nepal and shares a border with India, was selected for this study. About 60% of the land comes under agriculture out of the total area of the district, 119,000 ha. Data were collected from May through August 2014. Like other parts of Nepal, agriculture is the major economy of the district, where about 90% of people are actively engaged in the cultivation of rice, maize, wheat and sugarcane [28]. After the state federalization, the district now falls in province no. 2. Located approximately 95 m above the sea level, the district is one of the hottest districts of Nepal with the average annual rainfall being 2199 mm. The meteorological data show that April is the warmest month, with the average temperature being 39.6 °C, while January is the coldest, with the average temperature of 21.4 °C [29].

Administratively, the district consists of one sub-metropolitan city, eleven urban municipalities and six rural municipalities. The Terai Private Forest Development Association (TPFDA), a local NGO, has worked to promote a tree-based farming practice in then nine Village Development Committees (VDCs), covering 10,500 hectares (Figure 1). Therefore, these nine VDCs were selected as the study site. After the state is restructured, some parts of the study site fall in the urban municipality while most parts are still VDCs, now known as rural municipalities.

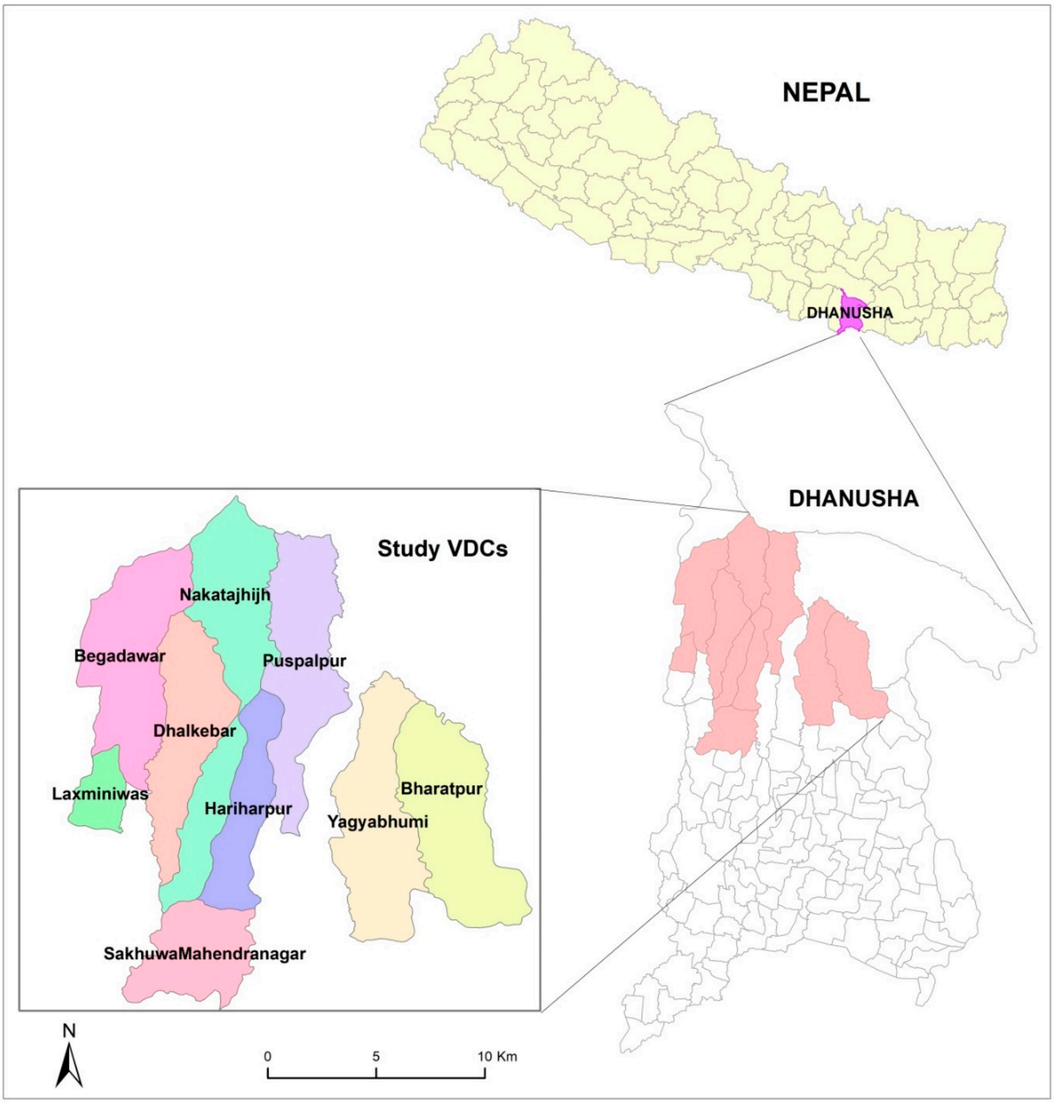


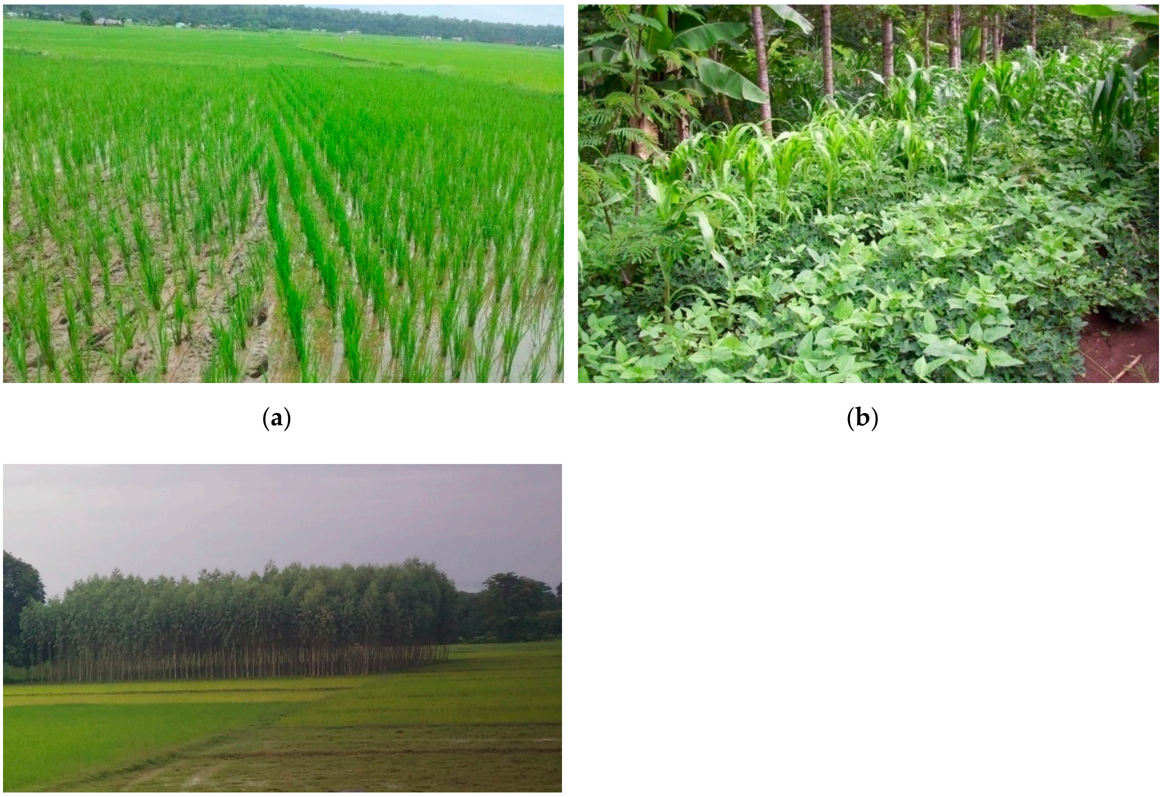

**Figure 1.** Study area.

## 2.2. *Overview of Farming Systems in the Study Area*

Dhakal et al. [11] documented two forms of farming systems in the study area: conventional agriculture and agroforestry. Under agroforestry, they identified three variants depending on the arrangement of trees on the farmland: alley cropping, agroforest/woodlot and a combination of the two variants. Dhakal [16] added one more variant to the list, boundary plantation, however, this practice is very scanty. Since the trees grown along the farm boundary have an adverse impact on the field crops of adjoining farmland of fellow farmers due to shading, boundary plantation is not an acceptable practice in the study area.

Conventional agriculture is a cereal-based farming system in the study area that has evolved over the years from a simple mono-cropping to a complex and intensive multi-cropping system [11] (Figure 2a). This practice includes rice, wheat/mustard and maize as major crops, and lentil, beans, groundnuts, pea and millet as inter-crops. The mono-cropping of sugarcane is also a part of conventional agriculture in the area [28].

Alley cropping is an agroforestry system in which trees are grown on the farm bunds as an alley. *Eucalyptus camaldulensis*, *Bauhinia variegata*, *Leucaena leucocephala* and *Melia azedarach* are most preferred by farmers for alley cropping [16] (Figure 2b). Agroforest/woodlot is a kind of agroforestry, which is grown as a plantation for a commercial purpose, requiring a separate patch of farmland. Farmers prefer multipurpose tree species such as *Eucalyptus camaldulensis*, *Gmelia arborea*, *Tectona grandis*, *Melia azedarach* and *Anthocephalus chinensis* as agroforest species [30] (Figure 2c). Both agroforestry systems are spread in the study district as spillover effects of the Sagarnath Forestry Project, which promoted production forestry and Taungya cultivation of *Eucalyptus camaldulensis* and *Dalbergia sissoo* [16]. The further spread of these systems was supported by Nepal Agroforestry Foundation (NAF) by introducing a private forestry project in the district. However, most farmers ceased continuing to grow trees on their farmlands upon completion of the project [31].



(**a**) (**b**) (**c**)

**Figure 2.** (**a**). Conventional agriculture (Paddy), (**b**) Alley cropping, (**c**) Agroforest/woodlot.

### 2.3. Selection of Farmers for Questionnaire Survey

A two-stage sampling approach was chosen for this study. This approach is widely used in agroforestry adoption studies [32–34]. At the first stage, one representative ward (Ward is the lowest administrative unit) from each VDC was selected, thus making altogether nine wards [33]. These nine wards were selected for two reasons: 1) the community in these wards is composed of both the native

(Madhesi ethnic group) and the migrants, coming from hilly regions of Nepal and northern India and; 2) agroforestry and conventional agriculture, a cereal-based farming practice, are the two most dominant forms of agriculture in the wards [11]. In the second stage, we considered the total number of households in the wards while determining the sample size for this study. The VDC records showed the total households in each ward falling in the range from 309 to 338 while the average number of households was 320. Since there is no vast difference in household numbers across the sample wards, we took the average as a reference and assumed a 10% sample size would serve our purpose. Hence, there were thirty-two households from each ward, and they were selected randomly. This means 288 sample households were selected. In-person interviews were conducted with the head of the sample households using a structured questionnaire. A total of 18 households were dropped out of the analysis since these households were practicing a combination of two or more agroforestry practices, agroforest/woodlot, boundary plantation and alley cropping.

### *2.4. Analytical Model*

Multinomial probit and logit models are the two commonly used regression models when there are more than two dependent variables and the dependent variables are unordered and categorical [35,36]. We chose the Multinomial Logit (MNL) model over the probit model for this study because: (1) It gives more precise parameter estimation [37]; (2) It estimates the likelihood of adoption of non-reference categories against a reference (base) category in terms of relative risk ratio (RRR) [36]; (3) The model has been more commonly used in recent studies [36,38–40]; (4) The Probit model is not usually used, largely because of the practical difficulty involved in its estimation process [35]; and (5) The model is the best choice when the data are not normally distributed [35].

With three farming practices in place, farmers can choose the one they prefer the most from the three alternatives. That means their choice is mutually exclusive. We assumed farmers follow the random utility theory, while making the choice out of the three farming practices available. Therefore, we used a random utility model while determining the farmers' choice of farming practices, as given by Greene [41]

$$U_{ij} = \beta_j X_{ij} + \varepsilon_{ij} \tag{1}$$

where $U_{ij}$ denotes the utility of farmer i obtained from farming choice j, $X_{ij}$ denotes all the factors affecting farmers' decision to adopt a farming practice j and $\beta_j$ is the parameter that reflects changes in $U_{ij}$ due to changes in $X_{ij}$. We assumed the error terms to have an independent and identical distribution (iid) [42]. According to profit maximization, farmer i will, thus, only choose a specific alternative j if $U_{ij}$ > Uik for all k ≠ j., which means when each farming practice is considered as a possible adoption decision, it is expected that farmers will choose the alternative that maximizes utility given the three farming practices available. This choice of j depends on a number of independent variables, as denoted by $X_{ij}$ in the above equation. If $Y_i$ is a random choice that a farmer can make, the MNL model can be expressed as

$$\text{Prob}\ (Yi = j) = \frac{e^{\beta_j x_i}}{\sum_{j=1}^{j} e^{\beta_j x_i}} \tag{2}$$

the above equation estimates probabilities for j+1 farming choices, i.e., three practices for farmers with a number of independent variables, $X_{ij}$. Here, we estimate the probabilities of two non-reference farming practices, agroforest system and Alley cropping system against the reference category, i.e., conventional agriculture. Therefore, the probabilities can be estimated by the following equation.

$$\text{Prob}\ (Yi = j) = \frac{e^{\beta_j x_i}}{1 + \sum_{j=1}^{j} e^{\beta_j x_i}} \tag{3}$$

## 2.5. Variables Defined

We extensively reviewed the contemporary literature on adoption to identify and determine independent variables. The independent variables included socio-economic, biophysical and institutional characteristics. We hypothesized these variables as adoption determinants and constraints (Table 1). However, some variables were excluded in the model. The variable 'farmers' perception on agroforestry' was dropped off the model because studies suggest it had no relationship with adoption [43–46] and the methodological challenge we faced to precisely measure the perception made us drop this variable off the model [47]. The 'slope gradient' is another variable we ignored because of little altitudinal variation across the sampled households. The third variable 'access to credit facility' was also excluded because of no financial guarantee from the financial institutions for agroforestry promotion in the study area.

**Table 1.** Description of the independent variables specified in the multinomial logistic model.

| Variables | Description | Type of Measure | Expected Sign |
|---|---|---|---|
| Education | Years of formal education of household head | Years | + |
| Age | Age of the household head | Years | − |
| Sex | Sex of the household head | 1 if male, 0 otherwise | + |
| Household size | Number of family members between 15 to 60 years | Years | − |
| Off-farm income | Farmer has any off-farm source of income | 1 if yes, 0 otherwise | + |
| Landholding size | Total cultivated area | Katha [1] | + |
| Livestock herd size | Total livestock standard units (LSU) [2] kept by a surveyed household | Numbers | + |
| Extension service | Total number of training received and visits by extension workers in the last five years | Numbers | + |
| Home to forest distance | Distance from home to nearest government forest | Kilometers | + |
| Transport | Means of transport possessed by the surveyed household | 1 if a farmer has own means of transport, 0 otherwise | +, - |
| Irrigation facility | Farm has any source of irrigation | 1 if yes, 0 otherwise | + |
| Membership | Member of farmers' group and organization | 1 if yes, 0 otherwise | + |
| Origin | Farmer is native | 1 if yes, 0 otherwise | + |
| Risk taking attitude | Farmer is risk-averse, risk-neutral and risk loving | 1 if risk loving, 2 if risk-neutral and 3 if risk-averse | + |
| Awareness | Farmer is aware of environmental benefits of an agroforestry practice | 1 if yes, 0 otherwise | + |

[1] Katha is a unit of area. 30 Katha= 1 hector. [2] adult buffalo = 1 LSU, 2 young buffalos (1.5 to 3 years) = 1 LSU, 2 cattle = 1 LSU and 3 young cattle = 1 LSU.

The dependent variable is the choice of farming practices by farmers as denoted by Yi. For MNL model, the dependent variable was denoted as:

Yi = 0 if a household adopts conventional agriculture system (CAS) -reference category- (j = 0);
Yi = 1 if a household adopts agroforest system (AFS)- non-reference category- (j = 1);
Yi = 2 if a household adopts alley cropping system (ACS)- non-reference category- ((j = 2).

Before the model is run, all the hypothesized independent variables were tested for multicollinearity using the variance inflation factor (VIF). We found the VIFs of the independent variables were below 10 (1.09–2.03), indicating that there is no issue of multicollinearity [35].

The estimation of the MNL model for this study was undertaken by selecting CAS as the base category. The odds of two other farming systems, namely AFS and ACS, against the CAS were estimated in this study. Since the CAS was the base category, it was hypothesized that most predictor variables will positively impact the adoption of the tree-based farming practices, i.e., a one-unit increase in an independent variable will increase the likelihood of AFS and ACS adoption.

## 2.6. Method of Data Analysis

The household survey data were analyzed by descriptive statistics and multinomial logit model using STATA (version 14).

## 3. Results

### 3.1. Socio-Economic, Biophysical and Institutional Characteristics of Sample Households

Out of 270 sample households surveyed, 60% were involved in conventional agriculture. The average age of the sampled household heads was 44 years with a minimum of 26 years and a maximum of 75 years. AFS farmers were younger than the other two (Table 2). The survey results showed that 57% were males, while the remainder (43%) were females. The family size of the sample household ranged from two to 14, with a mean family size of seven, which is nearly 1.5 times larger than the national average national, i.e., 4.9 people per family [29]. If only the economically active family members (year 15 to year 60) are considered, the average household size was 4.5 with the lowest household size in the AFS group (Table 2). The survey results indicated that out of the total sample households, the majority (57%) had no source of off-farm income, while 75% of AFS households had off-farm income sources, which is the highest among the three farming groups (Table 2). In terms of access to irrigation, the survey reveals that 56% of the sample farm households had no access to any kind of irrigation facility. However, if we see specifically, the majority of the AFS households had access to irrigation. About 15% of sample household heads had no formal education, of which 94% were females. On average, the household head had 6 years of schooling. Among the three farming groups, the AFS household head had the highest education.

**Table 2.** Characteristics of sample households in the study area.

| Variables. | Mean Values of the Variables | | |
|---|---|---|---|
| | CAS ($n$ = 162) | ACS ($n$ = 60) | AFS ($n$ = 48) |
| Education (Years of schooling) | 5.0 (3.6) [a] | 6.3 (3.7) [b] | 9.6 (4.0) [c] |
| Age of household head | 46.6 (13.2) [a] | 43.6 (9.9) | 39.4 (10.0) [b] |
| Sex of household head | 0.55 (0.50) | 0.56 (0.50) | 0.64 (0.48) |
| Household size | 4.7 (2.1) [a] | 4.4 (1.9) | 3.9 (1.3) [b] |
| Off-farm income | 0.32 (0.50) | 0.49 (0.50) | 0.75 (0.43) |
| Landholding size | 23.8 (21.1) [a] | 34.7 (25.4) [b] | 74.3 (36.7) [c] |
| Livestock herd size (LSU) * | 2.9 (1.9) [a] | 3.7 (2.6) [b] | 6.7 (2.8) [c] |
| Extension service | 0.80 (1.1) [a] | 3.2 (2.2) [b] | 5.5 (1.7) [c] |
| Distance from home to nearest government forest | 4.2 (2.7) [a] | 9.0 (5.6) [b] | 9.3 (5.5) [b] |
| Transport (tractor, bullock cart) | 0.6 (0.51) | 0.4 (0.51) | 0.3 (0.48) |
| Irrigation | 0.35 (0.48) | 0.46 (0.50) | 0.63 (0.49) |
| Membership | 0.25 (0.43) | 0.51 (0.50) | 0.73 (0.45) |
| Origin | 0.41(0.49) | 0.40 (0.49) | 0.58 (0.50) |
| Risk taking attitude | 2.4 (0.80) | 1.71 (0.77) | 1.52 (0.74) |
| Awareness | 0.28 (0.45) | 0.51 (0.50) | 0.69 (0.47) |

Note: Figure in the parenthesis is the standard deviation. Means in a row with different superscripts are significant at 0.05 level, and with similar superscripts are insignificant. CAS: Conventional agricultural system; ACS: Alley cropping system and AFS: Agroforest system. *: adult buffalo = 1 LSU.

Farmland is the primary livelihood asset of Nepalese farmers. The survey results indicate that the average landholding size of the sample farm households was 1.16 hectares (ha), slightly above the national average, which is 0.8 ha [48]. However, the group-wise distribution of landholding was different: the AFS farmers had the highest average. The livestock herd size was measured in terms of livestock standard unit (LSU). Only the young and adult buffaloes and cattle were considered while estimating the LSU. The average LSU of sample farm households was 3.8 with the highest average LSU in the AFS group. The study area community is composed of both native and migrant people. Out of the total sample households, 56% were migrants. The migrants included people coming from both the hilly regions of Nepal and northern India.

### 3.2. Determinants of AFS and ACS Adoption

The determinants of agroforestry adoption were examined using the multinomial logit (MNL) model. Since conventional agriculture is the base category, two models were estimated: one is for agroforest/woodlot adoption relative to conventional agriculture and the other is for alley-cropping adoption relative to conventional agriculture. The relative risk ratio (RRR), coefficients and significance levels are presented in Table 3. The model is good-fit, as it was significant at the 1% level. The RRR shows the relative risks/likelihood/chances of AFS and ACS adoption relative to CAS.

**Table 3.** Parameter estimates and RRR of a multinomial logistic model for AFS and ACS.

| | **AFS ($n$ = 48)** | | | **ACS ($n$ = 60)** | | |
|---|---|---|---|---|---|---|
| **Independent Variables** | **Coefficient** | **RRR** | ***p* Value** | **Coefficient** | **RRR** | ***p* Value** |
| Years of schooling (education) | 0.159 | 1.172 | 0.247 | 0.114 | 1.121 | 0.194 |
| Age of household head | −0.048 | 0.953 | 0.315 | −0.008 | 1.008 | 0.753 |
| Sex of household head | 0.280 | 1.323 ** | 0.044 | 0.202 | 0.823 | 0.714 |
| Household size | −0.618 | 0.539 ** | 0.041 | −0.078 | 0.925 | 0.580 |
| Off-farm income | 1.083 | 2.954 ** | 0.023 | 0.148 | 1.159 | 0.262 |
| Landholding size | 0.123 | 3.130 *** | 0.000 | 0.095 | 1.099 *** | 0.003 |
| Livestock herd size | 0.555 | 1.742 *** | 0.003 | 0.178 | 1.195 | 0.179 |
| Extension service | 1.064 | 2.910 *** | 0.000 | 0.529 | 1.697 *** | 0.003 |
| Distance from home to government forest | 0.376 | 1.457 *** | 0.001 | 0.322 | 1.380 *** | 0.000 |
| Transport | −0.682 | 0.506 *** | 0.005 | −0.172 | 0.842 * | 0.086 |
| Irrigation | 0.549 | 1.732 ** | 0.042 | 0.302 | 0.352 | 0.571 |
| Membership | 0.217 | 1.242 ** | 0.038 | 0.115 | 1.122 ** | 0.019 |
| Origin | 1.215 | 3.371 | 0.188 | −0.336 | 0.714 | 0.551 |
| Risk averse [a] | −2.134 | 0.118 ** | 0.041 | −1.208 | 0.299 | 0.123 |
| Risk neutral [a] | −1.049 | 0.350 | 0.326 | −0.384 | 0.681 | 0.577 |
| Awareness | 0.189 | 1.208 * | 0.058 | 0.821 | 2.273 | 0.122 |
| Constant | −10.110 | 0.00004 *** | 0.004 | −5.213 | 0.0054 *** | 0.002 |
| **Diagnostics** | | | | | | |
| Base category | | CAS ($n$ = 162) | | | | |
| Number of observations | | 270 | | | | |
| LR chi-square | | 373.13 *** | | | | |
| Log likelihood | | −93.45 | | | | |
| Pseudo $R^2$ | | 0.67 | | | | |

[a] risk loving is the reference category. AFS: Agroforest system, ACS: Alley cropping system, CAS: Conventional agricultural system. RRR: Relative risk ratio. * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$.

The analysis of the MNL model showed that the adoption of AFS and ACS was influenced by several factors. AFS adoption was influenced by eleven variables including the sex of household head, household size, off-farm income, landholding size, livestock size, extension service, distance from home to government forest, transport, irrigation, membership and risk-taking. Out of eleven, the influence of three variables, household size, transport and risk-taking was negative. The adoption of ACS was influenced by five variables only. They included landholding size, extension service, distance from home to government forest, transport and membership (Table 3).

The sex of household head had a positive and significant effect on the adoption of AFS. This implies that the relative risk/chance of adopting this practice would be 1.32 times more likely when the household head were males. In other words, if the household head was a male, we would expect him to be more likely to prefer AFS over conventional agriculture.

The negative and significant sign of household size indicates that larger families were less likely to adopt agroforest/woodlot. In other words, if household size increased, we would expect farmers to be more likely to prefer conventional agriculture over agroforest/woodlot. Landholding size positively and significantly influenced the adoption of AFS and ACS. In other words, if farmers held larger landholdings, we would expect them to be more likely to prefer AFS and ACS over conventional agriculture.

Livestock herd size (expressed in terms of LSU) is positively and significantly associated with the adoption of AFS, which means if the herd size is increased by one unit, the relative risk of AFS adoption relative to conventional agriculture would be expected to increase by a factor of 1.742. The positive association and the significance of extension service revealed that training for farmers and visits by extension officials are important for the adoption of both practices.

The negative and significant sign of transport indicated that when a farmer had a means of transport, the farmer would be expected to be less likely to adopt agroforest/woodlot and alley cropping. Farmers' association with farmer groups and agricultural organizations positively and significantly affected the adoption of these agroforestry practices. The risk-taking farmers and those living farther from the government forest were more likely to adopt AFS. The distant farmers also preferred alley cropping to conventional agriculture.

## 4. Discussion

The cereal-based farming practice (conventional agriculture) is the most dominant in the study area. However, the continuation of the practice is uncertain given the shortage of labor/workforce. Farmers are forced to grow one or two field crops only and even some farmlands are left all barren. A large section of the workforce is now in gulf countries for jobs, which has dropped farming activities considerably in Nepal [49]. A tree-based farming practice, which could be a viable alternative to conventional agriculture, is slow-growing in the study area. Although it holds the potential of enhancing the household economy and contributing to climate change mitigation and biodiversity conservation, the uptake of the practice by farmers is at a snail's pace. We attempted to address the slow-uptake issue through this study by analyzing the adoption factors using the MNL model.

The role of gender in agroforestry adoption is vividly discussed in the literature. Both men and women have influenced the adoption decisions depending on their circumstances. For example, in Malawi, male-headed households are more likely to adopt agroforestry in patrilocal societies, while in matrilocal societies, it is the female-headed households who are more interested in the adoption [21]. In another study from the Rulindo district of Rwanda, men were found to be reluctant regarding agroforestry adoption. The reason for this is attributed to the agroforestry trees, which lack commercial values such as timber and only have subsistence uses such as fodder, firewood and soil fertility improvement. However, many other studies claimed that agroforestry adoption has been the male-headed households' preference [50–52]. A study by Catacutan and Naz [26] in Vietnam highlights the reasons for women's reluctance towards the adoption being a lack of knowledge, low education level and poor access to extension. In line with the above studies, our finding also reinforces that the adoption of agroforest/woodlot is the male-headed households' affair. The reasons for this can be attributed to the commercial values of agroforest/woodlot in the study area, and lower education level of female heads, which might have limited their access to extension officials. In the study area, the agroforest is composed of commercially important multipurpose tree species while fuelwood and fodder species are preferred for alley cropping [11,30].

Access to land and land tenure security are considered two important determinants of agroforestry adoption [53,54]. However, for the kind of agroforestry we have in the study area, more important is landholding size. Our result suggests that the adoption of AFS and ACS is dependent on farm size: the larger the farm size is, the greater the chance of adoption is, and the result was as expected. To better understand why the large farmers are likely to favor agroforest/woodlot, we need to know the very nature of these practices. AFS is different from ACS. Farmers are required to have allocated parts of their farmland and wait for at least 10 years for returns if they want to grow trees as an agroforest [11]. The reduction in farmland after land-sparing decreases annual food production, which might fall short of fulfilling the annual food demand of the family and livestock. Since large landholding guarantees food security, farmers are willing to allocate parts of their farmlands for long-term investments such as AFS [55]. Ahmed et al. [56] argue that farmers with more farmland are less risk-averse, and therefore tend to and are more willing to try new technologies. In the case of ACS, land allocation is not required since the trees are grown on farm bunds. However, there exists competition between tree crops and agricultural crops for light, water and nutrients, thus increasing the risk of a decrease in food production. Therefore, smallholder farmers are less likely to shift from conventional agriculture to any of the two agroforestry practices. Our finding is supported by previous studies [24,28,57,58] which found that farm size is the significant factor positively influencing the adoption of agroforestry.

Agroforest/woodlot and alley cropping are new practices in the study area. Early adopters of such new practices tend to be the better-off households [11,24]. In rural Nepal, land, livestock and off-farm income are the measure of wealth. Just as more farmland, we hypothesized off-farm income of farm households positively influences the adoption of both practices. The influence of the variable was found to be positive but not significant for ACS adoption. Alley-cropping is in practice in the study area, mainly for subsistence uses such as fodder and firewood. This might be the reason why farm households with a good source of off-farm income are not interested in ACS adoption. A study by Kassie [59] carried out in northwest Ethiopia revealed that agroforestry adopters tend to have more off-farm income diversification than non-adopters. Off-farm source of income acts as a safety net and helps solve the cash constraints of the farm households, thus inducing them to perform long-term investments, which are expected to yield higher returns in the future [59]. Financial security backs them up to take risks and they tend to try technologies such as agroforest/woodlot [56]. Studies from Swaziland [60] and Indonesia [61] are some examples supporting the hypothesis that off-farm sources of income positively influence agroforestry adoption. Our finding that risk-averse farmers are less likely to adopt AFS also reinforces the argument that agroforestry adopters are less risk-averse.

Irrigation and livestock are two important endowments (inputs) for agriculture. These inputs contribute to enhancing farm productivity. Our result reveals that these endowments are positively associated with AFS adoption. Studies by Sood and Mitchell [62] in Himachal, India and Pingale et al. [63] in Pantnagar, India report that having a source of irrigation favors agroforestry adoption. These are interesting results because farmers generally use irrigated farmlands for field crop and cash crop production. Our finding agrees with these studies too. To understand why the farmers of the study area prefer agroforest/woodlot to conventional agriculture when irrigation is available, we need to see the physical properties of soil of the study area. The study area falls in the Bhabar zone of Nepal. The Bhabar is characterized by the low water holding capacity and high rate of infiltration and percolation [64]. These characteristics favor tree plantations. In the study area, *Eucalyptus camaldulensis* is the most preferred agroforestry species because of its high-value poles that are used as utility poles [11]. Farmers have experienced faster growth of the species when grown in the irrigated fields. The harvest cycle of the species for pole production is considered 10 years. However, Dhakal [16] reported the harvest cycle to be seven years in the irrigated farmlands. A similar result is reported by Pingale et al. [63] from India, that farmers preferred woodlots of *Populus deltoides* and *Eucalyptus camaldulensis* in the irrigated fields for their high industrial values. Likewise, livestock is a good source of farmyard manure to improve farm production and an agroforest is a good source of feed to livestock as it provides fodder. Therefore, our finding that there exists a positive association between livestock herd size and AFS adoption was as expected. However, this is not true for ACS adoption. This is because farmers' choice of tree species for farm bunds are mostly fodder species (medium-sized trees with minimum shading effects), which cannot fulfill both needs: commercial (timber and pole) as well as subsistence (fodder and firewood) like the agroforest does. Similar results are reported by Neupane et al. [27] and Oli et al. [25] from the studies carried out in the mid-hills districts of Nepal.

Labor is one of the major factors of a production system. In recent years, Nepalese farmers have witnessed a shortage of workforce. Family labor is the main source of the workforce in Nepal. The shortage of labor has resulted in low-intensity farming. Since cereal-based farming is a labor-intensive activity, many farmers are forced to leave their farmlands barren [65]. Our finding that an agroforestry practice such as agroforest/woodlot is favored when the workforce is not enough holds great significance in the present Nepalese farming context. However, there is no consensus on whether an agroforestry practice is less labor-intensive. Depending on the types and objectives of agroforestry, it can be either less or more labor-intensive. For example, coffee-based agroforestry and cocoa-based agroforestry are more labor-intensive than conventional agriculture [26,66] while timber/fuelwood-based agroforestry such as agroforest is less labor-intensive [16,19]. A study by Kassie [59] reveals that farmers are shifting to timber-based agroforestry when they found food crop farming is more labor-intensive. In a timber/fuelwood-based agroforestry such as agroforest, no labor is required after the second year of establishment until the harvest year. A recent study by Cedamon et al. [67] from Nepal's mid-hills also reinforces our findings. They argue that the emerging remittance economy of the country has increased the outmigration of Nepalese youths, resulting in a short supply of labor force, which made the Nepalese farmers adopt less labor-intensive cultivation practices such as agroforestry with multipurpose tree species.

Training and farmers' field visits are two important extension services, widely used to transfer knowledge and skills about agricultural innovations such as agroforestry to farmers [68]. These services not only assist farmers in gaining skills on nursery techniques, tree planting and raising and tree harvesting but also provide opportunities to establish a good rapport with extension workers and extension offices/agents, which may increase their access to information and keep them abreast of the latest developments in agroforestry [69]. Against this backdrop, our finding that extension services positively influence the adoption of AFS, and ACS was as expected. Our result is supported by previous studies which proved that provision of training and contact with extension workers are the significant factors positively affecting the uptake of agroforestry [28,55,68–71].

As hypothesized, membership in farmer groups and local agricultural organizations had a positive and significant sign, which implies that the farmers, who are affiliated to a group/organization, were more likely to prefer AFS and ACS to CAS. This is because being in the group provides farmers with opportunities to share information, knowledge, and experiences about the new technologies and learn from one another, which positively influences the adoption behavior of individual farmers [70,71]. Our finding is supported by previous studies, which documented the significant and positive influence of group membership on the adoption behavior of farmers [55,67,70–72].

The influence of forest distance from home was positive and significant. This implies that the chance of adopting AFS and ACS increases when farmers live at a distant location from the nearest forest. Our finding was as expected. This is because the distant farmers may find it difficult and time-consuming to go to the forest very often for grazing their livestock and collecting fodder and fuelwood. Having a private source of fodder and fuelwood such as AFS and ACS would save time and labor, which farmers could utilize in other farming activities. Our finding corroborates with previous studies [28,31,73].

There is a wealth of literature that describes the environmental benefits of agroforestry including biodiversity conservation, climate change mitigation and carbon sequestration. We attempted to examine whether Nepalese farmers are aware of these benefits and their awareness positively influences the adoption of AFS and ACS. Our finding that awareness increased farmers' willingness to adopt AFS was expected. This is because, in recent years, peoples' awareness of environmental issues such as climate change and the role of trees in climate change mitigation has increased [74]. Last but not least, our finding that having a private transport (bullock-cart) decreases farmers' willingness to adopt AFS and ACS seems to be unexpected, as we see from the result of a study [60] that documented that bullock-carts are used to carry timber and fuelwood to the proximate market centers and there exists a strong and positive relationship between transport means and timber/fuelwood-based agroforestry adoption. In the study area, however, bullock-carts are used mainly to carry food crops (food grains) and sell them at the farmer markets. Even though AFS is a timber/fuelwood-based agroforestry, carts are not needed; the sale of agroforestry products (timber, poles and fuelwood) is managed by the local contractors who transport the products to the market centers by using their transport means [16]. ACS is mainly a fodder-based agroforestry practice and there exist no formal markets for fodder. Based on the current practice in the study area, our result was as expected.

## 5. Conclusions

The study indicates that landholding size, extension services, distance from home to forest, and membership in farmer groups have positive impact on selecting both agroforestry systems over conventional farming. This clearly suggests that agroforestry can be promoted with less effort in the communities, that are distantly located. In addition, well-off households (i.e. having more farmlands) can be the entry point of agroforestry promotion program compared to their smallholder neighbors as the former are less risk averse. However, extension services and the formation of farmer groups are essential conditions for information sharing and learning about these agroforestry systems.

The results also show that male-headed households having large livestock herd and small working family size with irrigated land preferred AFS over conventional farming system. In the context of growing labor shortage for farming activities in rural areas, there is a huge scope and potential for farmers to utilize agroforest/woodlot as a viable strategy to address the 'land fallow' issue. While the labor constraint is a favorable condition for AFS promotion, farm size is the major challenge to the wider uptake of this practice.

These results clearly suggest that the agroforestry program should not be considered as a poverty reduction strategy. This is because smallholders may not be able to afford the initial production loss due to a shift from conventional farming to agroforestry. For this, a policy intervention is imperative to involve smallholders in agroforestry promotion. The interventions may include provisioning public land to smallholder farmers under a legal framework and organizing them to initiate collective farming through a cooperative approach both in private as well as public land [75]. However, these interventions are to be supported by some other programs such as extension services and off-farm income-generating activities.

Nepal has recently adopted an agroforestry policy, the impact of which has yet to be realized at farmers' level. The policy might bring changes in the perception and adoption behavior of farmers, which could be the future agenda of research in the field of agroforestry adoption in Nepal.

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