Agroforestry

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Agroforestry is recognized as a sustainable land use practice that creates more integrated, diverse, productive, profitable, healthy, sustainable land-use systems. 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

1. Introduction

1.1. 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 1). 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 [1]. 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 1). 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 1). 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 1. 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]

Variables.	Mean Values of the Variables		
	CAS (*n* = 162)	ACS (*n* = 60)	AFS (*n* = 48)
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)**

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 [2]. 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.

1.2. 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 2. 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 2. Parameter estimates and RRR of a multinomial logistic model for AFS and ACS.

Independent Variables	AFS (*n* = 48)			ACS (*n* = 60)		
	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**

Independent Variables	AFS (*n* = 48)			ACS (*n* = 60)		
	Coefficient	RRR	*p* Value	Coefficient	RRR	*p* Value
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					

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 2).

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.

2. 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 [3]. 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 [4]. 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 [5][6][7]. A study by Catacutan and Naz [8] 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 [9][10].

Access to land and land tenure security are considered two important determinants of agroforestry adoption [11][12]. 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 [9]. 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 [13]. Ahmed et al. [14] 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 [15][16][17][18] 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 [9][15]. 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 [19] 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 [19]. Financial security backs them up to take risks and they tend to try technologies such as agroforest/woodlot [14]. Studies from Swaziland [20] and Indonesia [21] 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 [22] in Himachal, India and Pingale et al. [23] 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 [24]. 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 [9]. 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 [25] reported the harvest cycle to be seven years in the irrigated farmlands. A similar result is reported by Pingale et al. [23] 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. [26] and Oli et al. [27] 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 [28]. 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 [8][29] while timber/fuelwood-based agroforestry such as agroforest is less labor-intensive [25][30]. A study by Kassie [19] 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. [31] 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 [32]. 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 [33]. 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 [13][16][32][33][34][35].

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 [34][35]. Our finding is supported by previous studies, which documented the significant and positive influence of group membership on the adoption behavior of farmers [13][31][34][35][36].

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 [16][37][38].

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 [39]. 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 [20] 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 [25]. 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.

3. 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 [40]. 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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