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Adoption of agroforestry in the hills of Nepal: a logistic regression analysis

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Abstract

Widespread deforestation and increasingly intensive use of land to sustain a growing population has increased soil erosion, lowered soil fertility, and reduced agricultural productivity in the hills of Nepal. This has raised concern over sustainability of the hill farming system. There is growing evidence that agroforestry can be a potential solution to above problems. However, the development of agroforestry as a viable alternative for farmers in diverse ecological and socioeconomic conditions has become a very challenging issue. The objective of this paper was to identify factors influencing the adoption of agroforestry by subsistence farmers in the hills, with reference to an agroforestry project initiated by Nepal Agroforestry Foundation (NAF). Necessary information for this study came from a survey of 223 households (82 project and 141 non-project) from Kumpur, Nalang, and Salang villages in Dhading district in 1998. The results showed that male membership in local NGOs, female education level, livestock population, and farmer's positive perception towards agroforestry have significantly positive effects, while the number of children below 5 years of age, number of males aged 10–59 years, male education, female's Non-Governmental Organization (NGO) membership, and respondents' age had significantly negative effects on adoption of agroforestry among project households. Among non-project households, those with more livestock and male membership to local NGOs were found more likely to adopt, while the households headed by males were less likely to adopt agroforestry. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Agroforestry adoption; Hill farming system; Logistic regression; Nepal; Subsistence farm households

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1. Introduction

Hill farmers in Nepal have long been growing a variety of native trees in their farm lands to maintain land productivity and to provide for subsistence needs, such as timber, fodder for livestock and fuel wood for cooking. However, modern agroforestry with exotic fodder and grass species is still a relatively new practice in Nepal. The decline in fodder, fuel wood, and timber production in public and community forests due to widespread deforestation has led farmers in recent years to increase the number of fodder and other trees on their farm lands (Carter and Gilmour, 1989). Several studies indicate improvements in tree growing on the private farm lands to compensate the loss of trees in the forest (Thapa et al., 1994; FSD/FRISP, 1999). The decline in forest cover has been associated with increased soil erosion, lowered soil fertility, and reduced agricultural productivity. There is growing evidence that agroforestry can be a promising solution to these problems (Carter and Gilmour, 1989) and hence a key to the sustainability of the hill farming system.

1.1. The hill farming system

The hill farming system features a complementary relationship among crops, trees and livestock. Assorted species of trees and shrubs grown on farms are an integral component of local economies (Thapa and Paudel, 2000). Besides providing for human needs, crops and trees supply feed, fodder, and bedding materials (litter) to livestock. Animals contribute to the system by providing crops and trees with nutrients via manure. The system is sustained through the recycling of organic materials within the farm as well as through the utilization of forest products. However, there has been a continuous decline in the availability of forest products due to deforestation, especially the clearing of forests for agriculture. According to the recent government statistics, the annual deforestation rate for the whole country is estimated at 1.7% between 1978 and 1996. Similarly, the decrease in forest and shrub cover combined is estimated to be 0.5% per annum. The corresponding figures for the hills are 2.3 and 0.2%, respectively. The forest and shrub cover in the hills has declined from 43 in 1952 to 39% in 1978/1979, and to 37.7% in 1994 (FSD/FRIP, 1999).

The ability of the traditional farming system to meet growing food demands on a sustained basis has decreased over time (Pandey et al., 1995, p. 43). Studies from Nepalese hills indicate a continuous decline in soil fertility due to soil erosion and the depletion of organic matter. Average soil loss of 8–12 t ha^{-1} $year^{-1}$ have been reported (Carson, 1992). The decline in vegetative cover is considered to be the main factor contributing to topsoil erosion. Soil erosion and excess removal of surface cover and crop residues from farm lands pose serious constraints to land management and sustaining agricultural production in the hills (Schreier et al., 1995, p. 249; CBS, 1998, p. 359). Although levels of soil losses from cultivated lands are reported to be much less than previously suggested, they are highly variable over space and time and can be unsustainable (Gardner and Mawdesley, 1997). These problems are likely to be exacerbated unless timely and effective measures are undertaken (Jodha, 1995, p. 142).

Besides for fodder and fuel wood, there is a considerable dependence of hill farmers on common property and public forests for litter for livestock, with its quantity collected varying considerably by location, season and the accessibility to the forest (Khadka et al., 1984; Yadav, 1992). When mixed with livestock waste the litter becomes a valuable source of manure for crops (Gilmour and Nurse, 1991). Thus, the fertility of private farm depends on the nutrient transfer from common property grazing and forest lands (Sinclair, 1999). The desired ratio between agricultural and forest lands to sustain land productivity is 1:3 (APP, 1994). However, given the existing forest cover, it does not seem possible to maintain the desired agricultural and forest land ratio in the hills (Shrestha and Katuwal, 1992).

In the past, farmers gave little or no priority to planting trees on their private lands due mainly to easy access to community and public forests for fodder, fuel wood and timber collection as well as the availability of some naturally grown trees on agricultural lands. Because of widespread deforestation and the transfer of ownership and management of forests to their users under the recent community forestry program, the access to forest resources has been severely curtailed forcing farmers to seek alternatives. One of such alternatives is agroforestry involving both indigenous and exotic fodder tree species in private farm lands. Thus, adoption of agroforestry, which can combine production of crop, livestock and forest in a sustainable basis, should be increased (Robinson, 1987).

1.2. Role of agroforestry in the hill farming system

Agroforestry plays a vital role in achieving sustainability in the hills farming system (Carson, 1992; Yadav, 1992). Agroforestry plays a better role in increasing agricultural productivity by nutrient recycling, reducing soil erosion, and improving soil fertility and enhancing farm income compared with conventional crop production (Kang and Akinnifesi, 2000). Furthermore, agroforestry also has promising potentials for reducing deforestation while increasing food, fodder, and fuel wood production (Benge, 1987; Caveness and Kurtz, 1993; Young, 1997). Amatya and Newman (1993) discuss these potentials in the Nepalese context.

The improvement in vegetative cover through agroforestry in the form of contour hedgerows is reported to be an appropriate innovation for reducing soil erosion on sloping lands (Fujisaka, 1997). In the mountains of Jamaica, hedgerows of *Calliandra calothyrsus* have reduced run-off and soil erosion compared with conventional farmed plots, with a positive effect on crop production (Macdonald et al., 1997). Likewise, live hedges of *Leucaena* and *Calliandra* have resulted in substantial reduction in soil loss in Rawanda (Roose and Ndayizigiye, 1997). Besides counteracting soil erosion and providing a viable alternative to conventional methods of soil conservation (Young, 1997), hedgerows also provide fuel wood and fodder to the rural people (Benge, 1987). Significant reductions in nitrogen and magnesium losses from the soil through hedgerow integration have also been reported (Schroth et al., 1995). Furthermore, several studies have shown that improved agroforestry practices are more productive (Vonmaydell, 1991; Sanchez et al., 1997) and profitable compared with conventional practices over the long run (Kurtz et al., 1991). Combining useful trees and shrubs (Saxena, 1994) and bee keeping and trees (Hill and Webster, 1995) have been reported to increase economic benefits to farmers.

Despite the above potentials, the promotion of agroforestry has never been given high priority in the country's agricultural and forestry development plans (Shah, 1996). However, farmers through experience have developed sophisticated local/indigenous knowledge base about tree–crop interaction (Thapa et al., 1995) and about the nutritive value of local fodder species (Thapa et al., 1997; Walker et al., 1999). In the past, no particular attention was directed toward agroforestry research and innovation, resulting in a lack of appropriate agroforestry practices for farmers (Tamang, 1991; Carson, 1992; Shrestha and Katuwal, 1992). However, in recent years there has been growing concern over the importance of agroforestry to sustaining the hill agriculture and some efforts are being made to promote agroforestry at the farm level.

1.3. Nepal Agroforestry Foundation agroforestry program

Aiming to increase fodder production, Nepal Agroforestry Foundation (NAF) has been engaged in promoting agroforestry in several areas of Dhading district since 1993/1994. Households involved in the NAF project have established a number of exotic fodder and grass species, including ipil ipil (*Leucaena leucocephala* and *Leucaena diversifolia)*, calliandra (*Calliandra calothyrsus*), *bhatmase* (*Flemingia congesta)*, *kimbu* (*Morus alba*), gauzuma (*Gauzuma* ulmifolia), NB 21 (*Pennisetum* sp.), Napier (*Pennisetum purpureum*), and Stylo (*Stylosanthes guianensis*), in addition to local species. Fodder species are planted on terrace risers, edges of farmlands and fallow lands and crops are grown in terraces. Through regular pruning, trees are maintained at breast height ($\sim$1.5 m) to minimize their possible adverse effects on crop yields.

The NAF program has helped strengthen the capacity of local farmers to in adopting agroforestry through the provision of technical know-how, materials support, extension and training. NAF also conducts on-farm trials and farmer-managed agroforestry demonstration plots. Interested farmers from selected communities are taken for field visits to agroforestry farm trials and demonstration plots to provide them with an opportunity of actually seeing the adoption of agroforestry species and practices by fellow farmers. Such visits to nearby villages and districts are arranged every year by NAF to create awareness of and build farmers' confidence in agroforestry. After such visits, interested farmers are organized into groups to initiate desired agroforestry practices and receive NAF support.

1.4. Agroforestry adoption

The process of developing and disseminating agroforestry as a viable alternative for farmers under various ecological and socioeconomic conditions has become a challenging constraint to promote agroforestry. Moreover, as noted by Raintree

(1983), no agroforestry technology, regardless of its ecological and economical soundness, will have significant impacts on land management, productivity and income unless it is adopted by a significant proportion of farmers. Similar to any other new technologies, agroforestry adoption is a complicated process that may be influenced by a number of factors, such as socioeconomic characteristics of farmers, access to and level of resources, provision of extension, infrastructure and market, and other institutional factors. Farm level studies can provide insights into key social and economic factors affecting farmer use and management of agroforestry practices and their effects on household resource base (Scherr, 1990). Despite considerable research directed to the issues of technological adoption in agriculture,[1] except for a very few studies (e.g. Raintree, 1983; Evans, 1988; Caveness and Kurtz, 1993; Alavalapati et al., 1995) very little attention has been given to studying adoption of agroforestry technology, particularly in the Nepalese context. Therefore, there is limited empirical information why some farmers adopt agroforestry and others do not.

Against the above background, the primary objective of this study was to analyze the impacts of various factors on agroforestry adoption by subsistence farm households, with reference to an agroforestry project initiated by NAF in Kumpur, Nalang, Salang VDC villages of Dhading district in Nepal. Information presented in this study is believed to be useful for development agencies involved in the promotion of agroforestry in Nepal.

2. Study area, data, methods and sample characteristics

2.1. Study area

Kumpur, Salang and Nalang VDCs (Village Development Committees) belonging to Dhading district are the focus of this study. Dhading is one of the least-developed mountainous districts in central Nepal with mean annual rainfall of 1819 mm. The altitude varies from 488 to 7500 m, with most of the area lying within the range of 700 to 2000 m (DDP, 1990). More than 90% of farmers in the district practice subsistence agriculture, with average land holding of 0.63 ha (CBS, 1996). The ratio of forest to cultivated land varies from 0.6 to 1.5 (DDP, 1990). The three study villages lie on either side of the 19 km graveled road linking Malekhu in Prithvi Highway to Dhadingbesi, the district headquarters, and extend from Trishuli and Thopal river basins (500 m) up to the middle mountains (1200 m). The study villages are inhabited by various ethnic groups, predominantly Brahmins, Chhetries and Magars. More than 80% of land in these villages is under terrace cultivation, of which more than 60% is leveled terraces.

[1] See Feder et al. (1985) for a survey of literature on adoption of technological innovation in developing agriculture.

2.2. Data and methods

Households for the study were selected in two stages. First, wards were selected from each of the above three VDCs through purposive sampling. Accordingly, wards 3 and 8 of Kumpur VDC, wards 6, 7 and 9 of Nalang VDC, and ward 9 of Salang VDC were selected. The ward selection was based on the motives to cover both households from the NAF project area and those from the non-project area and to compare the situations "with" and "without" project. Second, at least 40% of households were selected at random from each ward selected for questionnaire surveys. Accordingly, a total of 223 households, including 82 project households and 141 non-project ones were surveyed. The sample accounted for about 44% of all households in selected wards and 5% of households in all three VDCs. Since a smaller proportion of households were involved in the NAF project, their representation in the sample was expected to be lower than that of non-project households. The survey was conducted during May 1998 to October 1998 to collect information on various aspects of agroforestry, household characteristics, and the farming system.

The sample households were further divided into two categories depending upon the adoption of exotic species, namely "adopters" and "non-adopters". The "adopter" households had adopted exotic agroforestry species introduced under the NAF project. The "non-adopter" group had not adopted exotic species but followed traditional agroforestry as a supplementary source of food, fodder, fuel-wood and timber by maintaining some naturally grown trees on their farmlands. Despite the NAF project, a sizable proportion (37%) of the sample households from the project villages had not adopted exotic agroforestry species. On the other hand, more than half (51%) of those from non-project areas had adopted promoted agroforestry, i.e. through the process of demonstration effects generated by NAF activities and the adopters in the project area. The adoption of agroforestry practices with exotic species was defined in terms of a dichotomous or binary variable. The variable was assigned 1 if the farmer had adopted new agroforestry practices, and 0 otherwise, and then explained in terms of relevant variables using a logistic regression technique, to be described in the next section of this paper.

2.3. Sample characteristics

Some key characteristics of "adopter" and "non-adopter" households are presented in Table 1. This information is not presented separately for project and non-project households as the differences between project and non-project households were very small. With respect to various socioeconomic characteristics (such as occupational status, landholding, household size and composition, and education level), on average, the "adopter" and "non-adopter" households were quite similar. However, "adopters" and "non-adopters" differed considerably in terms of livestock herd size and the number of exotic fodder trees in their farm lands. For example, the average livestock herd size in terms of livestock units (LSUs) was 4.7 for "adoptors" and 3.7 for "non-adoptors". This difference was significant at the

Table 1
Key characteristics of "adopter" and "non-adopter" households

Characteristics	Adopters	Non-adopters	Both
Population engaged in agriculture (%)	93	91	92
Land holding			
Average total farm size (ha)	0.81	0.73	0.77
Average lowland farm size (ha)	0.21	0.19	0.20
Average upland farm size (ha)	0.60	0.54	0.57
Household size and composition			
Average household size	6.7	6.3	6.5
Children below 5 years of age	0.96	0.99	0.97
Children aged between 5–10 years	0.94	0.96	0.95
Males aged between 10–59 years	2.30	2.10	2.20
Females aged between 10–59 years	2.10	2.00	2.06
Adults aged 60 years and above	0.40	0.33	0.37
Mean education			
Male (years)	3.1	3.1	3.1
Female (years)	1.5	1.3	1.4
Mean livestock herd size (LSUs)	4.7	3.7	4.2
Average number of improved fodder trees	228	71	159
Ethnicity: (%)			
Brahmin/Chhetri (B/C)	29	22	26
Magar/Gurung (M/G)	29	41	34
Majhi/Tamang/Ghale (M/T/G)	17	13	15
Newar/Banda (N/B)	17	16	17
Other castes (Sarki/Kami/Damai)	8	8	8

0.01 level. Similarly, the number of introduced fodder trees (such as *kimbu*, ipil ipil, calliandra, and gauzuma) averaged 228 for "adopters" and 71 for "non-adoptors". This difference was significant at the 0.05 level. Except for a relatively higher proportion of Brahmins/Chhetries among "adopters" and higher proportion of Magars/Ghartis among "non-adopters", the two groups of households had similar ethnic composition (Table 1).

3. Conceptual framework and model specification

3.1. Conceptual framework

Following Rogers (1983), agroforestry adoption can be described as a mental process, commonly knows as the innovation-decision process, farmers go through a stage of being aware or knowledgeable of a new agroforestry technology, to forming positive or negative attitude towards agroforestry, and ultimately to deciding whether to adopt the technology or not. This process can be influenced by a wide variety of factors, including household factors (socioeconomic, resource-base, and outside contacts), community factors (access to extension, education, market, infrastructure, indigenous knowledge and ecological factors), and institutional factors (extension services, training and material support, through government and national/local NGOs). Fig. 1 provides a simple schematic framework for studying agroforestry adoption by farmers involved in this study. This framework has been widely applied to investigate the adoption pattern of various agricultural technologies, especially the adoption of high yielding cereal varieties and related practices (Feder et al., 1985). Raintree (1983), Evans (1988), Caveness and Kurtz (1993), and Alavalapati et al. (1995) have applied this framework for studying adoption of agroforestry. The framework provided in Fig. 1 forms the basis for selecting relevant variables influencing agroforestry adoption.

Previous empirical and theoretical studies indicate that the adoption pattern of new technologies by farmers can be characterized fairly well in terms of the logistic function (Jarvis, 1981; Feder and O'Mara, 1982; Rogers, 1983). Accordingly, when a new technology is first introduced, adoption is slow. Through the process of "demonstration effects" of the early adopters, information, knowledge, and experience of new technology spread to other potential adopters and the rate of adoption increases. This process will continue until all of the potential adopters are exposed to and adopt the new pracice. Given that agroforestry practices with exotic species

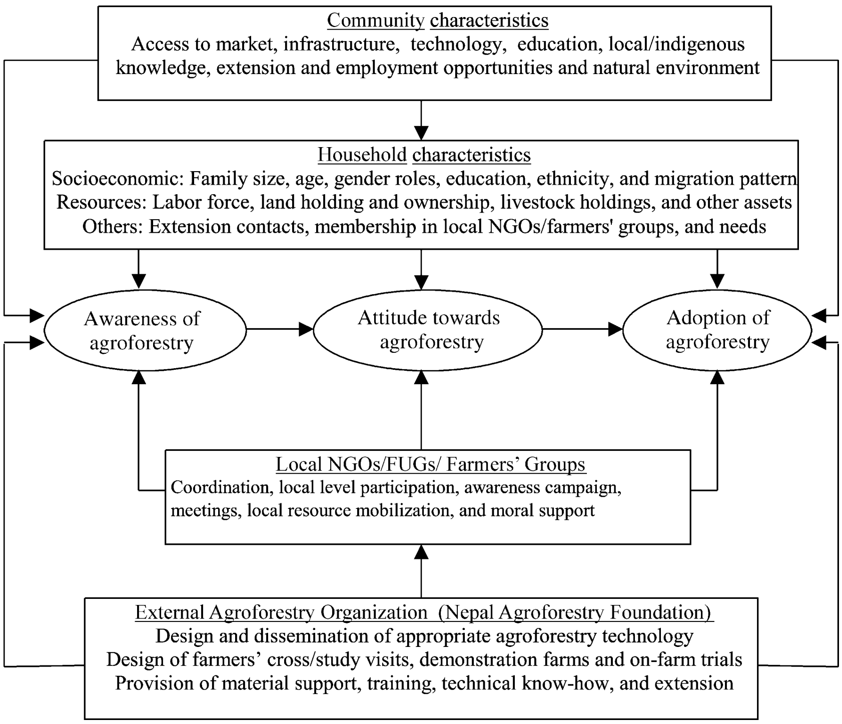

Fig. 1. Agroforestry adoption framework.

were introduced in 1993/1994, and the data were collected in 1998, perhaps most "adopters" were likely to be early adopters and lied on the lower end of the logistic curve.

For empirical analysis it is important to define adoption in terms of an appropriate quantitative measure. For farm-level adoption analysis, adoption is usually defined in terms of a dichotomous (use/no use) outcome. For the purpose of this paper, adoption was defined in terms of a dichotomous or binary variable. The variable was assigned 1 if the farmer had adopted new agroforestry practices, and 0 otherwise. For longitudinal analysis a continuous measure (e.g. the number of improved fodder trees/ha) would perhaps be a more appropriate measure to use.

3.2. Model specification

Logistic regression is a popular statistical technique in which the probability of a dichotomous outcome (such as adoption or non-adoption) is related to a set of explanatory variables that are hypothesized to influence the outcome.[2] The logistic regression model characterizing agroforestry adoption by the sample households is specified as follows:[3]

$$\ln[P_i/(1-P_i)] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki}$$

where subscript i denotes the i-th observation in the sample, P is the probability of the outcome, β_0 is the intercept term, and β_1, β_2, ..., β_k are the coefficients associated with each explanatory variable X_1, X_2, ..., X_k. It should be noted that the estimated coefficients do not directly indicate the effect of change in the corresponding explanatory variables on probability (P) of the outcome occurring. Rather the coefficients reflect the effect of individual explanatory variables on its log of odds $\{\ln[P/(1-P)]\}$. The positive coefficient means that the log of odds increases as the corresponding independent variable increases. However, it is possible to interpret the coefficients in terms of odds $[P/(1-P)]$ or probability (P) of the outcome by observing the relationship between P, $[P/(1-P)]$, and ln[P/(1-btl$P$)]. It can be shown that $[P/(1-P)]$ is a monotonically increasing function of P and ln[P/(1-btl$P$)] is a monotonically increasing function of $[P/(1-P)]$.[4] Consequently, if the log of odds $\{\ln[P/(1-P)]\}$ is positively (negatively) related to an independent variable, both odds $\{[P/(1-P)]\}$ and probability (P) of the outcome are also positively (negatively) related to that variable. The only difference is that this relationship is linear for the log of odds and nonlinear for odds and probability of the outcome. The coefficients in the logistic regression are estimated using the maximum likelihood estimation method.

[2] Another method when the dependent variable is a binary variable is the probit regression model. Unlike the linear probability model, the predicted probabilities under both logistic and probit approaches always lie between 0 and 1. Since both approaches are known to yield similar results, logistic approach is used in this paper.

[3] The underlying mathematical details for the logistic model are presented in Appendix A.

[4] See Rotherford and Choe (1993) for further explanation.

The X-variables involved in the logistic regression model for agroforestry adoption are defined in Table 2 and their summary statistics are presented in Table 3. Most variables are self-explanatory except for extension (X_{20}) and perception towards agroforestry (X_{21}), for which details are given in Appendices B and C, respectively. Among these, the first two are dummy variables accounting for various community factors affecting agroforestry adoption. The next two are also dummy variables representing household ethnicity, which is also hypothesized to influence agroforestry adoption through its effects on farmer's values, beliefs, and socio-economic status. Unlike previous studies, household labor availability is broken down to several components in terms of age and sex of the household members in order to examine possible gender roles in agroforestry adoption. The roles of education and membership to local NGOs have also been analyzed in terms of gender. In view of potentially different patterns of agroforestry adoption between upland and lowland, the amounts of upland and lowland are considered separately instead of using an aggregate landholding as in previous studies on adoption of other agricultural technologies. Since the primary objective of NAF agroforestry project was

Table 2
Description of explanatory variables used in the agroforestry adoption model

Variable name	Description
Kumpur (X_1)	Value 1 if the household is from Kumpur village, 0 otherwise[a]
Nalang (X_2)	Value 1 if the household is from Nalang village, 0 otherwise[a]
Brahmin (X_3)	Value 1 if ethnicity is 'Brahmin' or 'Chhetri', 0 otherwise[b]
Maghtagu (X_4)	Value 1 if ethnicity is 'Magar', 'Majhi', 'Tamang', 'Gurung', and 'Ghale', 0 otherwise[b]
Child: <5 (X_5)	No of children (male + female) aged below 5 years of age
Child: 5–10 (X_6)	No of children (male + female) aged 5–10 years
Male: 10–59 (X_7)	No of males aged 10–59 years
Female: 10–59 (X_8)	No. of females aged 10–59 years
Old: >59 (X_9)	No of old people (male + female) aged 60 years and older
Maledu (X_{10})	Male education (years)
Femedu (X_{11})	Female education (years)
Malmemb (X_{12})	Value 1 if at least one male has membership in local NGO, 0 otherwise
Femmemb (X_{13})	Value 1 if at least one female has membership in local NGO, 0 otherwise
Age (X_{14})	Respondent's age (years)
Sex (X_{15})	Value 1 if the respondent is male, 0 otherwise
Lowland (X_{16})	Amount of lowland (ropanies)
Upland (X_{17})	Amount of upland (ropanies)
Tenant (X_{18})	Value 1 if the farmer is tenant-operated, 0 otherwise
Livestock (X_{19})	Number of livestock units
Extension (X_{20})	Index for extension visits, training, and field visits[c]
Perception (X_{21})	Index for farmer's perception toward agroforestry[d]
Migration (X_{22})	Value 1 if a family member has migrated out for at least 2 months, 0 otherwise

[a] Salang village is treated as the reference village.
[b] Other ethnic group, including Newar, Banda, Sarki, Kami, and Damai is the reference group.
[c] See Appendix B for various components and the procedures involved to derive the extension index.
[d] See Appendix C for various components and the procedures involved to derive the perception index.

Table 3
Descriptive statistics for the explanatory variables involved in estimating the agroforestry adoption model

Variable name	Project households ($n = 82$)		Non-project households ($n = 141$)	
	Mean	S.E.	Mean	S.E.
Kumpur	0.37	0.05	0.36	0.04
Nalang	0.33	0.05	0.28	0.04
Brahmin	0.38	0.05	0.19	0.03
Maghtagu	0.52	0.06	0.48	0.04
Child: <5	0.83	0.10	1.06	0.09
Child: 5–10	0.93	0.10	0.96	0.08
Male: 10–59	2.24	0.15	2.18	0.11
Female: 10–59	1.89	0.11	2.16	0.11
Old: >59	0.33	0.07	0.40	0.06
Maledu	3.54	0.31	2.83	0.23
Femedu	1.69	0.18	1.23	0.14
Malmemb	0.18	0.04	0.12	0.03
Femmemb	0.39	0.05	0.17	0.03
Age	38.50	1.35	41.61	1.06
Sex	0.48	0.06	0.69	0.04
Lowland	4.70	0.50	3.48	0.36
Upland	9.01	0.74	12.72	0.64
Tenant	0.15	0.04	0.06	0.02
Livestock	4.42	0.27	4.15	0.20
Extension	4.84	0.76	1.46	0.26
Perception	−0.06	0.28	−0.62	0.25
Migration	0.29	0.05	0.38	0.04

to increase fodder production, livestock population is included to examine its effect on agroforestry adoption and in turn agroforestry's role in livestock productivity.

4. Results and discussion

Maximum likelihood estimates of parameters in the logistic regression models characterizing agroforestry adoption behavior of project and non-project households are presented in Table 4. Also presented in Table 4 are the effects of independent variables on odds and probability of agroforestry adoption. The log-likelihood ratio (LR) tests showed that for both project and non-project households the estimated models, including a constant and the set of explanatory variables, fit the data better compared with those containing the constant only. In other words, there was a significant relationship between the log of odds and hence odds and probability of adoption of improved agroforestry practices and the explanatory variables included in the model, suggesting that these variables contribute significantly as a group to the explanation of agroforestry adoption behavior of the sample farmers, although several coefficients were not significant individually. The R^2 values and percentages of correct predictions also suggested that the estimated adoption models had a fairly good explanatory power, especially the one for the project households (Table 4).

Table 4
Maximum likelihood estimates of the agroforestry adoption model

Variable	Project households ($n=82$)				Non-project households ($n=141$)			
	β	T-ratio	Exp(β)	Prob (P)	β	T-ratio	Exp(β)	Prob (P)
Kumpur	0.980	0.72	2.666	0.727	1.320**	2.27	3.743	0.789
Nalang	−1.279	−0.87	0.278	0.218	1.730***	2.86	5.639	0.849
Brahmin	−1.430	−1.14	0.239	0.193	−0.489	−0.57	0.613	0.380
Maghtagu	−1.567	−1.12	0.209	0.173	−0.215	−0.37	0.806	0.446
Child: <5	−1.392*	−1.91	0.249	0.199	0.169	0.74	1.184	0.542
Child: 5–10	−0.180	−0.45	0.836	0.455	0.050	0.21	1.051	0.512
Male: 10–59	−0.921**	−2.05	0.398	0.285	0.033	0.16	1.033	0.508
Female: 10–59	0.502	0.96	1.652	0.623	−0.243	−1.11	0.784	0.439
Old: >59	−0.293	−0.40	0.746	0.427	−0.163	−0.48	0.849	0.459
Maledu	−0.398*	−1.92	0.671	0.402	−0.133	−1.30	0.876	0.467
Femedu	0.530*	1.86	1.699	0.629	−0.043	−0.25	0.958	0.489
Malmemb	6.308**	2.21	548.672	0.998	1.570**	2.06	4.806	0.828
Femmemb	−1.470*	−1.77	0.230	0.187	0.355	0.61	1.426	0.588
Age	−0.082*	−1.80	0.921	0.479	0.023	1.28	1.024	0.506
Sex	0.368	0.40	1.444	0.591	−1.086**	−2.13	0.338	0.252
Lowland	0.068	0.72	1.071	0.517	−0.110	−1.63	0.896	0.473
Upland	−0.089	−1.09	0.915	0.478	0.024	0.71	1.024	0.506
Tenant	0.966	0.99	2.628	0.724	−1.354	−1.34	0.258	0.205
Livestock	1.059***	3.08	2.885	0.743	0.361**	2.44	1.434	0.589
Extension	0.042	0.65	1.043	0.511	−0.023	−0.33	0.978	0.494
Perception	0.305*	1.64	1.356	0.576	0.014	0.17	1.014	0.504
Migration	1.543	1.30	4.678	0.824	0.174	0.38	1.190	0.543
Constant	3.698	1.38			−1.792	−1.61		
Maddala R^2	0.434				0.241			
McFadden R^2	0.433				0.198			
LR test[a]	46.73***				38.78**			
No. of correct predictions	70 (85%)				105 (74%)			

[a] Likelihood ratio (LR) test is used to test the null hypothesis that there is no relationship between the log of odds of adoption of improved agroforestry practices and the set of independent variables included in the model (i.e. H_0: $\beta_1=\beta_2=\ldots=\beta_{23}=0$).
*$P<0.10$.
** $P<0.05$.
***$P<0.01$.

Overall, the majority of the variables had expected signs and those with unexpected signs were mostly insignificant. For several variables, the estimated coefficients differed between project and non-project households both in terms of sign and significance. These differences will be discussed next. Of explanatory variables, only livestock population and male membership in a local NGO had a consistently positive and significant effect on agroforestry adoption by both project and non-project households.

For the project households, the number of females aged between 10 and 59 years, male membership in a local NGO, female education level, sex of the head of the household, the amount of lowland, livestock population, and extension, farmer's perception toward agroforestry, and migration of household member were positively associated with the log of odds of adoption of agroforestry, suggesting that these variables were positively associated with agroforestry adoption. Note that, after controlling the effects of other variables, effect of each of these variables on odds of agroforestry adoption is greater than one and in probability terms the effect is more than 50%. Of these variables, the coefficient for livestock population was most significant ($P < 0.01$), followed by male membership in a local NGO ($P < 0.05$), and female education and perception about agroforestry ($P < 0.10$). Thus, the number of livestock kept by the households was found to be the most important determinant of agroforestry adoption. This finding is consistent with NAF's focus on the promotion of fodder trees and grasses in its activities as farmers with higher number of livestock are severely constrained by the shortage of fodder and hence are more likely to adopt the practice. Similarly, the male membership in local NGO may be associated with increased awareness of agroforestry benefits through better access to technical know-how, extension, and training provided by NAF. Educational programs for women could have a positive influence in agroforestry adoption.

Most of the dummy variables associated with VDCs and ethnicity and variables representing household size and composition had negative impacts on the log of odds of agroforestry adoption by project households. Note that, as shown in Appendix A, the effect of each of these variables on odds of agroforestry adoption is < 1 and in terms of probability terms $< 50\%$. Compared with households from Salang VDC, the households from Kumpur were more likely to adopt and those from Nalang VDC were less likely to adopt agroforestry. Likewise, compared with occupational ethnic groups (such as Newar, Banda, Sarki, Damai, and Kami) other ethnic groups were less likely to adopt improved agroforestry practices. However, none of these differences were significant at the 0.10 level. Demographic characteristics such as number of children below 5 years of age, number of males aged 10–59 years, male education, female's NGO membership, and respondents' age had a significantly negative influence on the farmers' decision to adopt agroforestry. While the number of females aged 10–59 years in the family had, although not significant, a positive effect on agroforestry, the number of males aged between 10–59 years had a negative effect. Similarly, unlike the female's educational level, the male's education was negatively associated with agroforestry adoption. These findings are quite expected given the fact that males are likely to out-migrate in search of employment while females are mostly engaged in household and farming activities, including agroforestry. Likewise, compared with educated males educated females are more likely to stay within the village and are likely to contribute more to the adoption of improved technologies. If there are small children in the family, females will have to spend more time in child care and other household production activities and less time in farming activities such as agroforestry. The female membership in the local NGO was negatively associated with agroforestry adoption. This may perhaps be due to the involvement of female NGOs more in non-agricultural activities (such as family planning, health and nutrition) than in farming activities. Moreover, even if females were members in NGOs involved in agroforestry, in the Nepalese context they usually have little influence in the household decision-making process. Consistent with adoption literature, the adoption of agroforestry was negatively associated with the age of the respondent or household head. Older people are generally believed to be more risk averse toward a new technology.

In case of non-project households, farmers from Kumpur and Nalang were more likely to agroforestry than those from Salang and ethnicity had the similar effect on agroforestry adoption as project households. In contrary to project households, the number of females aged 10–59 years had a negative impact on agroforestry adoption, while number of males aged 10–59 years had a positive impact. However, both of these coefficients were not significant at the 0.10 level. Both male and female education years were negatively related to agroforestry adoption, while their membership in the local NGO was positively associated. Only the coefficient associated with male membership was significant at the 0.05 level. This is because local NGOs, community forestry user groups and farmers groups are dominated by men and they are the principal decision makers in the household. Amount of upland was found to be a positive determinant in agroforestry adoption, while lowland affected negatively. This is also expected as farmers under traditional farming condition are more reluctant to plant fodder trees in the lowland because of their perception that trees reduce crop yields. However, it is customary to plant trees in upland to fulfill the subsistence requirements of fodder for livestock and fuelwood for cooking. Although migration and positive perception of agroforestry had positive influence in adoption, the extension was not contributing to the adoption. This was not unexpected that even though farmers had frequent contacts with extension worker they may not have received necessary information and support for agroforestry as most of government extension workers are not knowledgeable in agroforestry and hence not able to deliver the technology and practices suitable for farmers. More importantly, extension department has not given any attention towards agroforestry in their extension program. They are more concerned with cereal crops. Unlike project households, the probability of agroforestry adoption by non-project households was positively associated with the respondent's age and female-headed households were more likely to follow agroforestry.

5. Conclusions and policy implications

In view of agroforestry's potentials for reducing soil erosion, enhancing land productivity, increasing production of fodder and fuel wood for household subsistence, and generating extra income to farmers, recently different government and non-governmental organizations have initiated various programs to promote agroforestry in Nepal. However, the adoption of agroforestry with exotic fodder species at the farm level is too slow and very limited to realize its potential benefits due to farmers' negative perception towards agroforestry, lack of appropriate technologies at farm level, lack of agroforestry extension, and most importantly the need for producing cereal crops to fulfill food demands of the growing population. Given the diverse ecological and socioeconomic conditions and local needs, the design and dissemination of an appropriate agroforestry technology at a large scale is really difficult. Furthermore, the development of an appropriate technology alone does not mean anything unless a significant percentage of farmers are willing to adopt it. The adoption decision by farmers is a function of myriad of factors, such as farm size, local needs, farmer's education, beliefs, and perception, access to market, technology, and so on. The knowledge of the role of each of these factors in adoption of agroforestry at the farm level is indispensable to promoting agroforestry. In these respects, the objective of this paper was to identify important factors associated with adoption of agroforestry by subsistence farm households in the hills of Nepal, with a particular reference to an agroforestry project initiated by NAF in Kumpur, Nalang and Salang vilagges of Dhading district.

The detailed information on agroforestry and household socioeconomic characteristics collected through household survey was analyzed using a logistic regression method. The results showed that male membership in a local NGO, female education level, livestock population, and farmer's positive perception towards agroforestry had significantly positive effects, while the number of males aged 10–59 years, male education, female's NGO membership, and respondents' age had significantly negative effects on adoption of agroforestry by project households. Under non-project conditions, households with more livestock and male membership with local NGO were more likely to adopt, while the households headed by males were less likely to adopt agroforestry.

A significantly positive relationship between livestock population and agroforestry adoption is not only consistent with NAF's emphasis on fodder production, but also shows the importance of agroforestry to livestock productivity. While male membership in local NGO indicated significant influence in the adoption, the education program for women could have strong positive influence on adoption, as females are more likely to remain in the village than their male counterparts and adopt agroforestry practices. Building positive perception about agroforestry through increased awareness of agroforestry among the beneficiaries through better access to technical know-how, extension services and training would increase adoption of agroforestry. As shown in Appendix C, more than 50% of both project and non-project farmers did not believe that agroforestry improves soil fertility and productivity and nearly two-thirds did not think that agroforestry increases crop yields, although these are considered to be positive effects of agroforestry. However, the majority of sample farmers believed on negative effects of agroforestry, which is in conformity with the *rukhopan* concept held by hill farmers (Thapa et al., 1995). Despite negative effects of trees on terrace risers on crop and soil, farmers often tolerate trees because the benefits of fodder outweigh competition with crops.

Contrary to the general belief that agroforestry in the hills is practiced mainly on uplands, as also indicated by a positive association between the amount of upland and agroforestry adoption by non-project households, the results showed that the adoption of agroforestry was positively associated with the amount of lowland for project-households. This has been possible due to improved awareness of agroforestry among project-households through training and extension provided by NAF. However, the amount of lowland was negatively associated with agroforestry adoption by non-project households, perhaps due to their perception that agroforestry reduces crop yields. The results showed that with proper support and extension, agroforestry could be promoted in both lowland and upland conditions. Although the results pertain to the NAF activities in the study areas, the adoption of agroforestry needs to be sensitive not only to the characteristics of the technology and biophysical environment but also to the socioeconomic conditions which is often not given due attention.

Appendix A. Mathematical details of logistic regression

Logistic regression model is derived as follows:

$$P_i = \mathrm{Prob}(Y_i = 1) = \frac{1}{1 + \mathrm{e}^{-(\beta_0+\beta_1 X_{1i}+\ldots+\beta_k X_{ki})}} = \frac{\mathrm{e}^{(\beta_0+\beta_1 X_{1i}+\ldots.+\beta_k X_{ki})}}{1 + \mathrm{e}^{(\beta_0+\beta_1 X_{1i}+\ldots+\beta_k X_{ki})}} \quad \text{(A1)}$$

Similarly,

$$\mathrm{Prob}(Y_i = 0) = 1 - \mathrm{Prob}(Y_i = 1) = \frac{1}{1 + \mathrm{e}^{(\beta_0+\beta_1 X_{1i}+\ldots+\beta_k X_{ki})}} \quad \text{(A2)}$$

Dividing (A1) by (A2) we get

$$\frac{\mathrm{Prob}(Y_i = 1)}{\mathrm{Prob}(Y_i = 0)} = \frac{P_i}{1 - P_i} = \mathrm{e}^{(\beta_0+\beta_1 X_{1i}+\ldots+\beta_k X_{ki})} \quad \text{(A3)}$$

where P_i is the probability that Y_i takes the value 1 and then $(1-P_i)$ is the probability that Y_i is 0 and e the exponential constant.

Now taking natural log in both sides of Eq. (A3) we get

$$\ln[P_i/(1 - P_i)] = \beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki} \quad \text{(A4)}$$

Holding the rest of the variables constant, odds $\{P/(1-P)\}$ and probability (P) of the outcome given the k-th independent variable is equal to e^{B_k} and $1/(1 + \mathrm{e}^{-\beta_k})$, respectively. Hence,

$$\begin{aligned} &\beta_k = 0 \Rightarrow \quad \text{odds} = 1 \quad \text{and} \quad \text{probability} \quad (P) = 0.5, \\ &\beta_k > 0 \Rightarrow \quad \text{odds} > 1 \quad \text{and} \quad \text{probability} \quad (P) > 0.05, \quad \text{and} \\ &\beta_k < 0 \Rightarrow \quad \text{odds} < 1 \quad \text{and} \quad \text{probability} \quad (P) < 0.5. \end{aligned} \quad \text{(A5)}$$

Appendix B. Computation of extension index (extension)[a]

Items included	Project households		Non-project households	
	Mean	Percent[b]	Mean	Percent[b]
No. of agroforestry nursery training (AFNTR)	1.30	72.0	0.60	28.4
No. of agroforestry management training (AFMTR)	1.00	39.0	0.23	12.8
No. of visits by extension workers to the farm (VEWF)	1.50	39.0	0.48	13.5
No. of cross visits made by the farmer (CVF)	0.78	25.6	0.07	6.4
No. of farmer's visits to extension office (FVEO)	0.26	14.6	0.08	4.3

[a] Extension = AFNTR + AFMTR + VEWF + CVF + FVEO.
[b] Percentages of households that had taken at least one training or had at least one extension contact.

Appendix C. Computation of agroforestry perception index (Perception) (Percent of respondents)

Perception	Project households			Non-project households		
	Agree	Disagree	Do not know	Agree	Disagree	Do not know
Positive perception towards agroforestry						
1. Has economic benefits (PPCEPT1)	96.3	1.2	2.4	87.9	7.1	5.0
2. Provides natural beauty (PPCEPT2)	97.6	2.4	0.0	93.6	0.0	6.4
3. Reduces soil erosion (PPCEPT3)	96.3	0.0	3.7	85.8	5.0	9.2
4. Improves soil fertility and productivity (PPCEPT4)	35.4	57.3	7.3	27.7	56.0	16.3
5. Increases crop yields (PPCEPT5)	18.3	65.9	15.9	15.6	66.0	18.4
6. Improves livestock productivity (PPCEPT6)	87.8	9.8	2.4	85.8	7.8	6.4
Negative perception towards agroforestry						
1. Hampers tillage operations (NPCEPT1)	73.2	20.7	6.1	82.3	12.8	5.0
2. Not needed because fodder, fuelwood and grasses are found abundant in the forest (NPCEPT2)	32.9	62.4	4.9	36.9	50.4	12.8
3. Benefits are realized after a long time period (NPCEPT3)	85.4	11.0	3.7	79.4	12.8	7.8
4. Reduces area for cereal crop production (NPCEPT4)	73.2	13.4	13.4	74.5	32.0	3.5
5. Reduces crop yields due to competition for growth factors (NPCEPT5)	92.7	6.	1.	93.	6.4	0.0
6. Harbors crop insects and pests and reduces yields (NPCEPT6)	70.7	13.4	15.9	68.1	13.5	18.4

As shown in the above table, the respondents' perceptions to each statement about agroforestry were recorded as either they "Agree", "Disagree" or "Do not know". These were converted to an index by assigning numerical value of 1, -1 and 0 for "Agree", "Disagree", and "Do not know" responses respectively, for positive statements. For negative statements, the numerical value of -1, 1 and 0 were assigned for "Agree", "Disagree", and "Do not know" responses, respectively. Then the agroforestry perception index was derived as follows:

Perception = Positive perception + Negative perception where Perception = Agroforestry perception index, Positive perception = Agroforestry positive perception index $= \sum_{j=1}^{6} \mathrm{PPCEPT}_j$, and Negative perception = Agroforestry negative perception index $= \sum_{j=1}^{6} \mathrm{NPCEPT}_j$.

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