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Drivers of farmers' decisions to adopt agroforestry: Evidence from the Sudanian savanna zone, Burkina Faso

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Abstract

In most developing countries, there has been a long-standing conflict of interest between using land for agriculture and the conservation of biodiversity. This paper reports on a study of factors influencing farmers' decisions to integrate trees into their agricultural practice. We also discuss the possibility of protecting and managing planted and naturally regenerating trees on farmland in order to restore degraded land and improve biodiversity. Data were collected from interviews with farmers in the Center-West region of Burkina Faso and analyzed using Principal Component Analysis, multiple linear regression and binary logistic regression. The results show that farmers' decisions to incorporate trees into their farmland were mainly influenced by silvicultural knowledge and skills, participation in farmers' groups or other social organizations with an interest in tree conservation, the social value of biodiversity in the rural landscape, and the perceived economic benefits of trees on farmland. The most important factors associated with variation in levels of motivation to conserve trees on farms included household wealth, gender, age, education level, marital status, residence status, farmland size, household size and technical support. We conclude that an agroforestry project will be more successful if the local biophysical conditions and diversity of smallholder socio-economic characteristics and their perceptions, needs and preferences are considered in its design. There is also an immediate need for coordinated development of information and training to raise local community awareness of the potential of agroforestry as well as to disseminate information about adding value to tree products in order to encourage farmers to protect on-farm trees.

Key words: agroforestry parkland, climate smart agriculture, farmers' perceptions, multiple linear regression, principal component analysis, West Africa

Introduction

In the second half of the 20th century, the West African Sahel and dry savanna region experienced a dramatic change in climate. The rainfall pattern changed from abundant rains in the 1950s and 1960s to progressively drier conditions in the 1970s and 1980s (Hulme, 1996; Giannini et al., 2008). This change led to recurrent droughts which have contributed to a reduction in the region's agricultural production potential (Sissoko et al., 2011). For this reason, farmers in the Sahel and dry savanna region often expand their agricultural lands, and cultivate marginal areas in attempts to reduce the ever-growing yield gap. This has led farmers to abandon traditional practices especially bush fallow that allows farmland to rejuvenate.

Many areas of Sub-Saharan Africa that were previously arable land are becoming infertile or deprived of nutrients, thereby jeopardizing the region's long-term prospects for agricultural productivity (Bationo et al., 2006). Thus, the decline in soil fertility, extreme climatic shocks, the high cost of agricultural inputs and insecurity of rural household livelihoods are widely recognized as the main factors contributing to rural poverty and a decrease in farming productivity (Franzel, 1999). These factors paint a dismal picture for the ability of Sub-Saharan Africa to achieve food security for its teeming population (Lugandu et al., 2012). Further, many regions are facing severe shortages of fuelwood, fodder and food (FAO, 2003; De Leeuw et al., 2014). This situation can be explained by the pressure on these resources caused by population growth, climate variability, overgrazing, the use of outdated farming techniques and equipment, and poor pest and disease control. However, nurturing trees on farmland can contribute to building resilience to climate change and increasing food security and farmers' incomes (Bayala et al., 2011).

Agroforestry practices among subsistence West African farmers

The integration of trees into farming systems is a traditional land-use developed by subsistence farmers throughout much of Sub-Saharan Africa to deliver multiple socio-economic and environmental outcomes (Ndayambaje, 2013). Trees contribute to the needs of rural households such as firewood, construction materials and non-timber forest products (NTFPs) for human and animal consumption. Thus, trees are often retained during land clearance for agriculture in order to sustain their valued provision of goods and services for rural farming households (Arnold and Townson, 1998; Kristensen and Balslev, 2003). Trees can also serve as a 'savings account', providing a livelihood safety net including to buffer against the shocks experienced during periods of food scarcity (Wunder et al., 2014). Trees are therefore especially important for the rural poor who are particularly vulnerable to the adverse impacts of climate change.

Sub-Saharan farmers' association of trees and annual crops has created the concept of 'parkland systems' around villages throughout the region (Grolleau, 1989). The parkland system is based on the selection of desirable woody plants, which includes preferred species and preferred individuals within a species (Maranz and Wiesman, 2003). The parklands that form the most widespread farming systems in the savanna zone of West Africa are those in which annual crops are grown under scattered remnant trees that were preserved by farmers during the initial woodland clearing (Bayala et al., 2015). Activities in these parklands indicate that the ultimate management goal is the diversification of the production system to increase farmland productivity (Boffa, 2000; Bayala, 2002). The parkland systems are a recognized agroforestry approach that helps to increase productivity and sustain food security, while also preserving the biophysical environment (Fig. 1).

The current adoption of tree conservation on farmland in Sub-Saharan Africa is driven by considerable decreases in timber and other tree-based resources as a result of the dwindling size of natural vegetation stands in the region (Oino and Mugure, 2013). This decrease is strongly linked to the fact that rural and urban households use wood as their primary source of energy because they lack the funds to purchase alternative fuels such as electricity, butane gas and certain renewable energies (Karekezi and Majoro, 2002; Dovies et al., 2004). The high pressure exerted on the forest resource is the origin of deforestation, and forest and land degradation (Mekonnen and Köhlin, 2009). Agroforestry systems play an important role in the production of biomass to satisfy the daily energy (firewood, charcoal), construction material and NTFP needs of households while also providing important environmental services (Oino and Mugure, 2013; Bayala et al., 2014).

Besides timber and NTFPs, important environmental services provided by trees on farms in Sub-Saharan Africa include shelter, soil enrichment and erosion prevention, watershed protection, rehabilitation of degraded lands and reducing the ecological risks associated with high climatic variability in the region (Bayala et al., 2014). Agroforestry as a land-use system also provides other benefits such as carbon sequestration and biodiversity conservation (Acharya, 2006; Garrity and Stapleton, 2011). This provides opportunities for payments for environmental services, including through the Reducing Emissions from Deforestation and Forest Degradation (REDD+) program advocated by the United Nations.

Determinants of agroforestry adoption

The promotion of agroforestry must be sensitive to the socio-economic conditions of households and the characteristics of their physical environment in order to meet local needs and preferences (Ndayambaje, 2013). Such a targeting will help to create and promote locally-acceptable and sustainable agroforestry projects. Many studies have focused on the socio-economic factors that motivate farmers to engage in the planting and conservation of trees in their fields (e.g. Salam et al., 2000; Mahapatra and Mitchell, 2001). For example, Pattanayak et al. (2003) reviewed 120 articles on the adoption of agricultural and forestry technology by smallholders and concluded that five categories of factors explain technology adoption. The factors include household preferences, resource endowments, market incentives, biophysical factors and risk and uncertainty. Furthermore, studies have shown that the age of the household head, education level, gender, household wealth, household size, farmland size and access to agricultural inputs all influence farmers' adoption of agroforestry technologies (Omuregbee, 1998; Ndayambaje, 2013). In a study of patterns of tree adoption on farms in Ethiopia, Iiyama et al. (2017) found that favorable climatic conditions and institutional arrangements to control free grazing influence adoption. Jerneck and Olsson (2013) found that in Kenya,

Figure 1. Pictorial representation of typical agroforestry system; (a) *Vittelaria paradoxa* parkland associated with sesame; (b) *Faidherbia albiba* parkland associated with millet.

food-secure and opportunity-seeking farmers are more likely to adopt agroforestry. Scherr (1992) found that in Kenya, a community-based approach to extension services is more suitable for local conditions than a commodity-based approach.

Achieving successful promotion and widespread adoption of innovative technologies regarding the retention of trees in cropping systems requires paying particular attention to the socio-economic attributes of rural communities and farmers (Buyinza and Ntakimanyire, 2008). Therefore, it is important to have a better understanding of farmers' decisions to adopt agroforestry technologies. In most Sub-Saharan African countries, efforts to promote tree conservation practices have not been very successful in achieving sustained or widespread adoption. This situation highlights the need to better understand the influences of participation in on-farm conservation in Sub-Saharan Africa. The conceptual framework of this study relates to the factors that interact to influence farmers' decisions to undertake tree conservation on farmland, considering the spillover effects on livelihoods (Fig. 2).

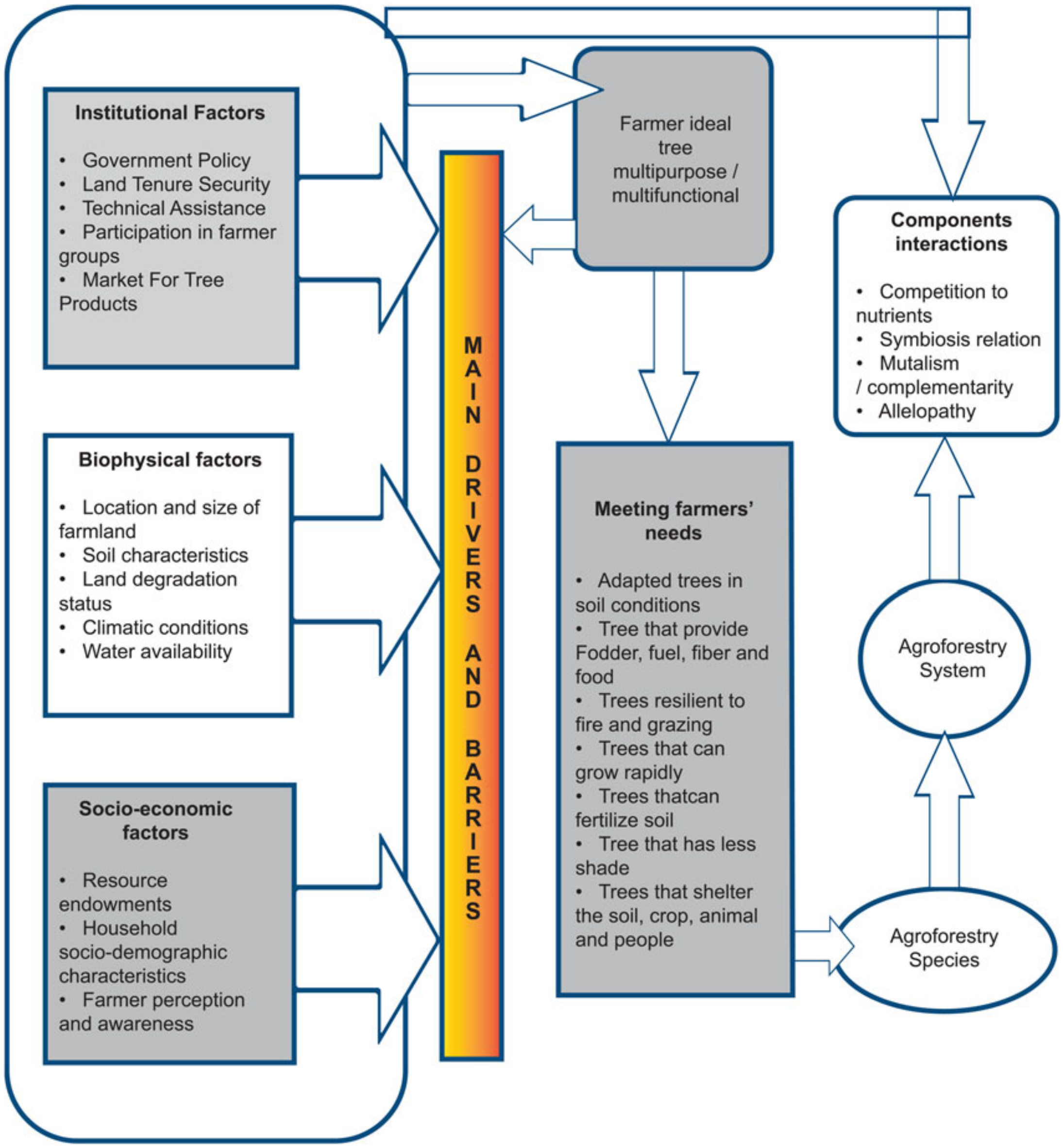

Figure 2. Conceptual framework for the conservation of trees on farmland, adapted from Hachoofwe (2012).

We assume that certain factors serve as drivers of adoption. Farmers' adoption of tree conservation on farmland is determined by a combination of household socio-economic characteristics, resource availability, environmental factors, biophysical characteristics of the land and institutional support. It is important to understand the relationship between these factors and the process of adoption of new technology to improve farm production and sustainable land management.

Food security and protection of the environment in Burkina Faso

In Burkina Faso, several conventions such as the National Program of Land Management (PNGT), the National Program for Adaptation to Climate Change (PANA) and the United Nations Convention to Combat Desertification (UNCCD) have been signed by the government in order to support the protection and sustainable management of the environment. Furthermore, efforts have been made by the government and various technical and financial partners to support research into the development and implementation of technologies to enhance soil and water conservation. These technologies include 'zaï', 'half-moon', mulching and tillage methods (Zougmoré et al., 2000; Kagambega et al., 2011; Sop et al., 2012), which can be used to improve soil productivity and fertility, and enhance the restoration of degraded land. Zaï refers to small planting pits that typically measure 20–30 cm in width, are 10–20 cm deep and spaced 60–80 cm apart, and are used for collecting water and nutrients from compost. Half-moon basins are dug on bare and crusted soil with a

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gentle slope of less than 3% to form a half-circle. They act as micro-water catchments, and can hold as much as four times the amount of water that normally runs off the land (Zougmoré et al., 2003).

Frameworks for the conservation of protected areas and the participatory management of forest resources have been established in Burkina Faso (Coulibaly-Lingani et al., 2010). Farmer-managed natural regeneration (FMNR) is being promoted to restore tree cover in the agricultural landscape. FMNR is a simple, low-cost forest restoration method that can be used to convert degraded areas into productive farmland (Shono et al., 2007). More precisely, instead of clearing all farmland during sowing, farmers are encouraged to select stems sprouting from living stumps of previously felled trees, and to actively manage their regeneration by pollarding or various forms of coppice management (Reij and Garrity, 2016). Despite these efforts, the problems associated with land degradation and insufficient food production in Burkina Faso have not been resolved. This could be because most farmers in the country have insecure land tenure, use little agricultural inputs, which promotes shifting cultivation, and have not received a formal education (Etongo et al. 2015). Although parkland management practices and FMNR are important activities for promoting the conservation and sustainable management of natural regrowth/revegetation, the widespread adoption beyond certain localities in Sahelian countries is yet to be achieved (Reij and Winterbottom, 2015; Reij and Garrity, 2016). While technical issues related to FMNR practice can be easily overcome by farmers, it remains a challenge to induce institutional innovations to enable communities to agree on enforceable social contracts to protect tree regrowth and to respect the regrowth on their neighbors' land (Iiyama et al., 2017). For these reasons, it is important to increase our knowledge of the biophysical, policy, institutional and socio-economic determinants of adoption of sustainable agroforestry practices by rural communities in Burkina Faso.

Objective of the study

This study sought to examine factors influencing farmers' decisions to incorporate trees into their farmlands. We also aimed to identify natural resource management strategies that could be used to promote tree cover on farmlands to enhance biodiversity conservation, support climate change adaptation and sustain food security. The findings can provide agricultural policy-makers and planners with a greater understanding of the drivers of agroforestry adoption by farmers and appropriate agricultural management strategies for promoting the integration of trees into farming systems. The findings also provide guidelines for developing an agroforestry system that meets farmers' needs and preferences.

Study site

This study was conducted in four villages (Negarpoulou, Kyon, Tialgo and Tiogo) located in Sanguie Province (12.13′N, 2.42′W), Burkina Faso (Fig. 3). All four villages are located within close proximity of the Tiogo State Forest. The choice of the villages was based on the presence of agricultural land-uses, which integrate trees and crop production. We also took into account the proximity of the villages to the Tiogo State Forest, where various projects dealing with sustainable forest management have been undertaken along with the promotion of agroforestry buffer zones as a conservation and productive land-use strategy. We assumed that the closer a village is to the forest the greater the interaction between locals and State Forest officials, which may increase the potential to influence locals' decisions to adopt agroforestry (Ezebilo, 2012).

The Tiogo State Forest was designated by the colonial French administration in 1940 and covers an area of approximately 30,000 ha. It is located along Burkina Faso's only permanent river (The Mouhoun River, formerly known as The Black Volta). Phyto-geographically, Tiogo State Forest is situated in the Sudanian regional center of endemism in the transition from the north to the south Sudanian zone (Fontès and Guinko, 1995). The Sudanian savanna is an area stretching across the African continent from Senegal in the west to the Ethiopian highlands in the east. It is characterized by a 6–7-month dry season and a mean annual rainfall of between 700 and 1200 mm (Breman and Kessler, 1995).

The total population of the studied villages is approximately 45,506 (INSD, 2007). The main livelihood activities of the residents include extensive livestock grazing and harvesting of fuelwood, poles for construction and various NTFPs such as thatching materials and edible and medicinal plants. The main crops grown are *Sorghum bicolor*, *Panicum miliaceum*, *Zea mays*, *Arachis hypogaea*, *Vigna unguiculata* and *Gossypium hirsutum*. The people mainly engage in subsistence agriculture, which is entirely rainfall-fed (Sawadogo, 2009). Farmers typically retain some trees when clearing land for agriculture. Species commonly found on farms include: *Adansonia digitata*, *Bombax costatum*, *Detarium microcarpum*, *Eucalyptus camaldulensis*, *Lannea microcarpum*, *Mangifera indica*, *Moringa oleifera*, *Parkia biglobosa*, *Sclerocarya birrea*, *Tamarindus indica*, *Gmelina arborea* and *Vitellaria paradoxa*.

Research method

Survey design and data collection

Data were collected by means of household surveys using personal interviews. Prior to the household survey, focus group discussions and interviews with key informants were held. The focus group participants and key informants

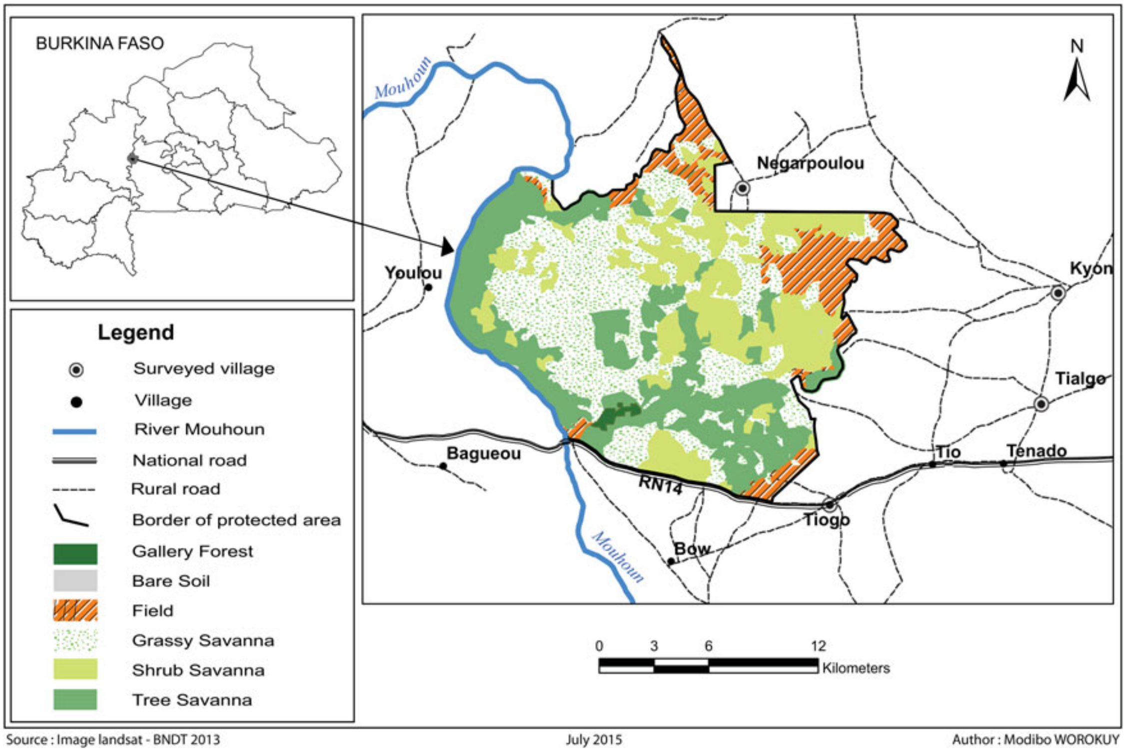

Figure 3. Location of the study site.

included leaders of the local forest management cooperatives, local chiefs, government officials and members of local non-governmental organizations (NGOs) and other special interest groups. The primary aim of the discussions was to obtain a background understanding of the local practice of tree conservation on farmland (qualitative data) and to compile a list of farmers for further investigation. Information acquired during these discussions allowed us to identify key drivers of tree conservation in the villages (Table 1). Knowledge of these drivers was used in the design of the questionnaire.

Initial farmer wealth ranking was also conducted in order to include a representative number of farmers from different wealth categories in the sample. The Participatory Analysis of Poverty and Livelihood Dynamics method was used to rank each farming household according to their wealth status using a stratified sampling approach (Krishna et al., 2004; Phiri et al., 2004). To do this, household wealth status was ranked based on criteria determined by key informants (see Supplementary Data in Appendix 1). The order of rankings that emerged was poor, moderate and wealthy.

A total of 300 household heads were randomly selected (i.e. 75 in each village) after taking into account the wealth status of households. In order to have an equal representation of wealth status groups in each of the villages, 25 household heads from each of the wealth categories were selected. The survey focused on household heads because in the study area, they make decisions on major issues, including land management and agriculture. Although men are more likely to be household heads in Burkina Faso, their decisions on agricultural production are often shaped by the views of their wives and children. For this reason, the opinion of all members of a household is to a greater extent captured by a household head's decisions.

Prior to the interviews, each of the household heads was asked whether he/she was willing to participate in the interview. The household heads were interviewed after giving their consent. All the household heads that were selected for the interviews agreed to be interviewed. Interviews were conducted at farmers' homes to avoid the influence of other farmers, and were carried out by a trained enumerator. The main researcher was also present during all interviews to verify the accuracy of questionnaire completion. A pre-tested semi-structured questionnaire was used for gathering information, and each interview lasted about 1 h.

After explaining the purpose of the interview (i.e. adoption of agroforestry to help mitigate the adverse effects of climate change) and assuring the interviewees about the confidentiality of their responses, they were asked to rate the drivers of tree conservation on farmland and whether they have adopted agroforestry practices on their farmland. The interviewees were asked about their selection of tree species, and their silvicultural knowledge and practices utilized on their farmland including any strategies for improving tree planting and conservation activities. Demographic and socio-economic questions related to their household size, level of education, gender, age, residence and land tenure status and their forest-based income generating activities. The interviewees were also asked whether they had received any technical assistance from the State Forest service or NGOs.

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Table 1. Names, abbreviations and scales of the variables included in the factor analysis.

No	Names of the variables	Label	Scale
1	Access to credit and loans	ACCE	[1–4]
2	Other peoples' attitudes towards tree conservation/Social pressure	ATTI	[1–4]
3	Firewood need	BOIS	[1–4]
4	Characteristics of the farm (land area, tenure & location)	CARA	[1–4]
5	Silvicultural knowledge & skills (including species selection)	CONN	[1–4]
6	Delimiting the agricultural space/securing its land (Land boundary/land for security)	DELI	[1–4]
7	Low labor requirements	FAIB	[1–4]
8	Training received from technical partners (Research institutes, NGOs, Forest Officer)	FORM	[1–4]
9	Need for fodder	FOUR	[1–4]
10	Need for tree products: FRUIT	FRUI	[1–4]
11	Governance. policies & institutions	GOUV	[1–4]
12	Hobby/satisfaction	HOBB	[1–4]
13	Disadvantages related to tree planting and management	INCO	[1–4]
14	Market availability & information & price of wood	MARC	[1–4]
15	Incentives received (financial, seedlings & fertilizers & extension/training)	MOTI	[1–4]
16	Need for shade	OMBR	[1–4]
17	Perception of the opportunities and future returns of tree conservation activities on the farm	OPPO	[1–4]
18	Participation in farmers' group & other social organizations /Following other farmers	PART	[1–4]
19	Need for tree products: MEDICINE (Pharmacopoeia)	PHARM	[1–4]
20	Land policy of the government (for land and cropland tree tenure)	POLF	[1–4]
21	Participation in an environmental program	PROG	[1–4]
22	Need for protection (backup) of the landscape and diversity for future generations	PROT	[1–4]
23	Site quality and climatic conditions	QUAL	[1–4]
24	Environmental reasons (erosion control, rehabilitation)	RAIS	[1–4]
25	Household land tenure status (e.g. landowner)	SITU	[1–4]

For the drivers of tree conservation on farmland, the interviewees were asked to rate them on a 4-point Likert-type scale (Clason and Dormody, 1994) as 1: not important, 2: moderately important, 3: important and 4: very important. Interviewee adoption of agroforestry on their farm took a 'yes' or 'no' answer. An unbalanced Likert-type scale was used in this study in order to reduce the tendency of interviewees to choose the middle point scale. This is a means of reducing potential biases in the results of this study.

Data analysis

Drivers of tree conservation on farmland. Descriptive statistics were first used to summarize the profile of the interviewees and information related to the conservation of trees on farms. Factor analysis was employed to identify latent dimensions underlying indicators that determine the conservation of trees on farms (Table 1). This statistical approach involves finding a way to condense information about a number of original variables into a smaller set of dimensions (factors) with minimum loss of information (Hair et al., 1998). Each factor is interpreted according to its loadings, i.e. the strength of the correlations between the factor and the original variables (Tabachnick and Fidell, 1996). Creating a small set of factors can reveal 'latent' patterns in the relationships between the variables. Principal Component Analysis (PCA) was used to extract factors using Varimax rotation to ensure that the extracted factors were independent and unrelated to each other, and to maximize the loading on each variable and minimize the loading on other factors (Bryman and Cramer, 2005).
To test the relevance of factor analysis for the dataset, the Bartlett Test of Sphericity and the Kaiser–Meyer–Olkin (Kaiser, 1974) measure of sampling adequacy were applied. Kaiser–Meyer–Olkin's overall measure of sampling adequacy for our dataset (0.886) was well above the recommended threshold value of 0.5 (Kaiser, 1974). This indicates that patterns of correlation in the dataset are relatively compact and that factor analysis can therefore be applied. The results of the Bartlett Test of Sphericity were also highly significant ($\chi^2 = 2658.145$, df = 190, $P < 0.0001$), which further suggests that factor analysis can be applied to the dataset, and supports the factorability of the correlation matrix.

Factors with eigenvalues exceeding 1.5 were considered significant following Kaiser's criterion. The number of factors that were retained was guided by three decision rules: Kaiser's criterion, inspection of the screeplot and Horn's parallel analysis (Horn, 1965). Parallel analysis is one of the most accurate approaches to estimating the number of components. The size of eigenvalues obtained from PCA is compared with those obtained from a randomly generated dataset of the same size. An inspection of the screeplot revealed a clear break after the third

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component; therefore, three components were retained for further analysis (Pallant, 2013). This was further supported by the results of parallel analysis, which showed only three components with eigenvalues exceeding the corresponding criterion value for a randomly generated data matrix of the same size (25 variables × 300 respondents).

Multiple linear regression analysis was used to explore the association between participation indicators and interviewees' socio-economic and demographic characteristics. In order to estimate the subject score for each factor, the Anderson-Rubin approach (Tabachnick and Fidell, 1996) was applied. This is a method for estimating factor score coefficients, which ensures orthogonality of the estimated factors. The resulting scores have a mean of 0.0 and a standard deviation of 1.0 and are uncorrelated. The following model was developed using Ordinary Least Squares (OLS) regression:

$$\begin{aligned}\text{Factor}_i = {} & \text{Constant} + \beta_1\text{HHW} + \beta_2\text{GDE} + \beta_3\text{ETH} \\ & + \beta_4\text{AGE} + \beta_5\text{EDL} + \beta_6\text{MAS} + \beta_7\text{RES} \\ & + \beta_8\text{TIM} + \beta_9\text{LAN} + \beta_{10}\text{HHS} + \beta_{11}\text{PFM} \\ & + \beta_{12}\text{TEA} + \varepsilon \end{aligned} \tag{1}$$

where Factor_i represents the factors found from the factor analysis, β_1 to β_{12} represent the coefficients of the socio-economic, demographic and policy-related variables (see Table 2 for details of the explanatory variables) and ε is the error term, which is independently and identically distributed. Tests of features of the dataset that could impair the reliability of estimates (including specification, multi-collinearity and spatial autocorrelation) indicated that OLS regression assumptions have not been violated.

Determinants of the adoption of tree conservation practices on farmland. The binary logistic regression model was used to examine the socio-economic and demographic determinants with respect to the retention of trees on farmlands. The logistic regression model is written as:

$$\begin{aligned}&\text{Choice to adopt conservation of trees on farm:} \\ &P(y) = \exp(\beta_0 + \beta_x)/(1 + \exp(\beta_0 + \beta_x))\end{aligned} \tag{2}$$

where β_0 and β_1 are coefficients estimated based on the data: $P(y)$ = probability of the event y coded with 1 when happening and otherwise 0.

A logistic regression is the logit, the natural logarithm (ln) of an odds ratio (Agresti, 1996; Peng et al., 2002). The odds of y represent the likelihood of it occurring. The odds are the ratio of the probability of y, i.e. $P(y)$, occurring versus the probability of y not occurring $(1 - (P(y))$. The logistic model predicts the logit of the response variable (y) from the explanatory variables (x):

$$\begin{aligned}\text{Logit}(y) &= \text{natural(odds)} = \ln(P(y)/1 - (P(y) \\ &= \beta_0 + \beta_x.\end{aligned} \tag{3}$$

The extension of the logistic regression model incorporating many independent variables, as in our study, is similar to the following model:

$$\begin{aligned}\text{Logit}(y) &= \ln(P(y)/1 - P(y)) \\ &= \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_n x_n\end{aligned} \tag{4}$$

where β_0 is the intercept and $\beta_1, \beta_2 \ldots \beta_k$ are the coefficients of the independent variables $x_1, x_2 \ldots x_n$.

Initially, the models contained 18 explanatory variables that were introduced simultaneously, and stepwise linear regression was used to select the best combination of variables based on the most significant ones. Before performing the logistic regression, correlations between the explanatory variables were explored. We found that correlation between the variables did not exceed 0.40, which implies that collinearity is not a serious problem in the estimated model. The significance of the logistic regression parameters was assessed by χ^2 likelihood ratio and deviation tests, and Hosmer–Lemeshow's and Wald's statistics (Tabachnick and Fidell, 1996). SPSS 20 software (SPSS for Windows, Release 2013 Chicago: SPSS Inc.) was used for all statistical analyses.

Table 2. Name, abbreviations and scales of the variables in the regression equation model.

No	Names of the variable	Abbreviations	Scale
1	Household wealth	HHW	[1–3]
2	Gender	GDE	[0–1]
3	Ethnic group	ETH	[1–4]
4	Age class	AGE	[1–5]
5	Education level	EDL	[1–6]
6	Marital status	MAS	[1–3]
7	Residence status	RES	[1–2]
8	Duration of occupancy	TIM	[1–5]
9	Land area	LAN	[1–4]
10	Household size	HHS	[1–5]
11	Proportion of females/males in the household	PFM	[0–5]
12	Technical assistance	TEA	[1–3]

Results and discussion

Profile of respondents

The frequencies of respondents in each class with respect to the socio-economic and demographic variables are shown in Table 3. Most of the respondents (91%) were men, with 40% aged 20–40 years. In addition, more than half of the respondents (54%) had between five and ten persons in their household. Most of the respondents were from the Gourounsi ethnic group (91%). Most (65%) do not have a formal education and only a few had completed secondary school education (5%). The respondents' major sources of income were agriculture (79%) and the selling of NTFPs (79%), whereas 21% generated their income through other activities. Most of the

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Table 3. Profile of the respondents.

Variables (abbreviation)		Frequencies	Percentage
Gender	Male	273	91
	Female	27	9
Age	[20–30]	32	10.67
	[30–40]	89	29.67
	[40–50]	92	30.66
	[50–60]	62	20.66
	[60–70]	25	8.34
Ethnic group	Gourounsi	274	91.33
	Mossi	12	4.00
	Peulh	14	4.67
Education	Illiterate	196	65.33
	Primary school	68	22.67
	Secondary school	16	5.33
	Religious education	6	2.00
	Adult education	9	3.00
	Agricultural training	5	1.67
Marital status	Married	280	93.33
	Single	13	4.34
	Widowed	7	2.33
Residence status	Native	274	91.33
	Migrant	26	8.67
Duration of occupancy	[20–30]	45	15.00
	[30–40]	90	30.00
	[40–50]	77	25.67
	[50–60]	60	20.00
	[60–70]	28	9.33
Religion	Religious	220	73.33
	Non-religious	80	26.67
Number of household members	<5	33	11.00
	[5–10]	162	54.00
	[10–15]	72	24.00
	[15–20]	24	8.00
	≥20	9	3.00
Household wealth	Poor	100	33.33
	Moderate	100	33.33
	Wealthy	100	33.33
Cropping system	Intensive	27	9.00
	Extensive	215	71.67
	Semi-extensive	58	19.33
Size of farm (ha)	<1	42	14.00
	[1–2]	132	44.00
	[2–4]	112	37.33
	[4–10]	14	4.67
Acquisition of land	Inheritance	163	54.33
	Loan	24	8.00
	Gift	113	37.67
Tools for cultivation	Daba	297	99.00
	Plow/tractor	3	1.00
Harvest of crop	Increasing	36	12.00
	Decreasing	230	76.67
	Stable	34	11.33
Livestock	Increasing	66	22.00
	Decreasing	169	56.33
	Stable	65	21.67
Number of livestock	[0–10]	134	44.67
	[10–20]	106	35.33
	[20–30]	41	13.67
	≥30	19	6.33

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Table 3. (*Cont.*)

Variables (abbreviation)		Frequencies	Percentage
Source of income	ASP	236	78.67
	AGR	64	21.33
Technical support	Yes	60	20.00
	Yes in part	50	16.67
	No	190	63.33
Number of planted trees	[1–10]	148	49.33
	[10–30]	95	31.67
	[30–50]	30	10.00
	≥50	26	8.67
Source of energy	Fuelwood	291	97.00
	Butane gas	9	3.00

Note: ASP: selling of NTFPs cash crop and livestock; AGR: small trades.

farmers (72%) practice an extensive cropping system whereby they use small inputs of labor, fertilizer and capital relative to the land area being farmed. Only a few practiced more intensive cropping systems.

Almost all the respondents used fuelwood as their main source of energy. The high use of fuelwood is one of the factors that encourages the preservation of trees on farmland throughout the study site. Indeed, the results revealed that during recent years all respondents had retained some trees on their farmland for future firewood use. This finding is consistent with previous research in Africa (Pearce, 2001; Buyinza and Ntakimanyire, 2008; Coulibaly-Lingani et al., 2010). For example, in a Burkinabe study of factors influencing people's participation in a forest management program, Coulibaly-Lingani et al. (2010) found that biomass fuel is the principal energy source for household needs and farm-grown trees provide approximately 96% of the studied villagers' energy requirements.

Factors influencing farmers' decisions to protect and manage trees on their farmland

The results of the correlation matrix revealed that many coefficients had the value of 0.3 and above. The Kaiser–Meyer–Olkin value was 0.7, which exceeds the recommended level of 0.6. The Bartlett Test of Sphericity was statistically significant, which supports the factorability of the correlation matrix ($\chi^2 = 2658.145$, df = 190, $P < 0.001$). The three-component solution explained a total of 45% of the variance, with components 1–3 contributing 22, 12 and 11%, respectively (Table 4). The total explained variance is not high, which is typical for studies involving cross-sectional data of this nature. To make the interpretation of these three components easier, Varimax rotation was applied. The rotated solution revealed the presence of a simple structure, with three components showing a number of strong loadings and all variables loading substantially on only one component. There was a weak positive correlation between the three factors ($r^2 = 0.4$). Factor analysis summarized the original 25 indicators within three factors that accounted for 45.3% of the total variance (Table 4). This may simply illustrate the diversity of respondents. The communalities (loadings) representing the overall importance of each variable in the PCA as a whole was low (<0.5 i.e., variables for which the common factors explain little variance) for disadvantages related to tree planting and management (INCO), low labor requirements (FAIB), training received from partners (forest and agriculture service, NGOs etc.) (FORM) and tree products needed for medicine (PHARM). The reasons why communalities for measured variables are low is that these variables are unrelated to the factors influencing farmers' decisions, and thus share little in common with other measured variables in that domain. These results showed that these indicators accounted for little of the common variability among the variables and contributed little to the PCA solution.

The relatively high values for the other communalities indicated that the factors explained most of the variation in the original variables. A variable with a high communality of 0.7, for example, indicated a significant correlation between that variable and other variables contributing to a common factor. The dominant variables for skills and participation in a tree conservation program explained 22% of the variation. This first factor is constituted by 14 indicators (Table 4). The high importance placed the variable ATTI, which suggests peer/social pressure could play an important role for agroforestry adoption in this region (0.734). These indicators also include incentives received such as finance, seedlings, fertilizers and extension/training. Others are access to credit and loans, participation in an environmental program, governance, policies and institutions, delimitation of agricultural space/securing land (border zones/land for security), and land-use policy of the government (for land and cropland tree tenure). Participation in farmers' groups and other social organizations/following other farmers silvicultural knowledge and skills (including species selection), along

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Table 4. Pattern and structure for PCA with Varimax rotation of three factors solution of indicators of participation in tree conservation on farmland.

Description	Factor 1	Factor 2	Factor 3	Communality
Skill and participation in tree conservation program				
Attitudes towards tree conservation	**0.734**	−0.085	0.146	0.567
Incentives received	**0.686**	0.219	0.031	0.519
Hobby/satisfaction	**0.683**	−0.090	0.226	0.526
Participation in an environmental program	**0.680**	0.119	0.120	0.490
Access to credit & loans	**0.666**	0.045	0.041	0.448
Governance, policies & institutions	**0.642**	0.328	0.073	0.525
Delimitation of land	**0.630**	0.016	0.170	0.426
Land policy	**0.593**	0.383	0.083	0.505
Participation in farmers' group	**0.548**	0.131	0.232	0.371
Silvicultural knowledge	**0.524**	−0.011	0.156	0.300
Site quality and climatic conditions	**0.519**	−0.006	0.446	0.468
Disadvantages related to tree planting and management	0.478	0.475	−0.073	0.459
Low labor requirements	0.461	−0.019	0.227	0.264
Training received	0.413	0.134	0.176	0.219
Economic benefits				
Need for tree products : MEDICINE	0.411	0.364	0.215	0.348
Firewood needed	−0.094	**0.805**	−0.020	0.657
Need for fodder	−0.057	**0.745**	0.032	0.560
Market availability	0.040	**0.582**	0.102	0.350
Characteristics of the farm	0.117	**0.578**	0.121	0.362
Household land tenure status	0.260	**0.532**	0.008	0.351
Conservation of biodiversity				
Environmental reasons	0.163	−0.095	**0.754**	0.604
Need protection	0.278	−0.057	**0.743**	0.633
Need shading	0.314	0.179	**0.626**	0.522
Need for tree products : FRUIT	0.107	0.100	**0.601**	0.382
Perception of the opportunities	0.045	0.332	**0.598**	0.469
Eigenvalue	6.927	2.596	1.801	11.324
Variance explained (%)	21.906	12.202	11.189	45.297

Note: Rotation method: Varimax with Kaiser normalization. Rotation converged in five iterations ($N = 300$) and major loadings (with a value larger than 0.50 in absolute terms) for each variable item are highlighted in bold. The communality measure is the squared multiple correlation coefficient (SMC). 'Skill and particatipion in tree conservation, 'economic benefits', and 'Conservation of biodiversity' are names that the researchers developed based on interpretation of the loadings in each factor.

with disadvantages related to tree planting and management, site quality, climatic conditions, low labor requirements and other people's attitudes towards tree conservation/social pressure had the highest loading (0.7).

Our findings are consistent with previous research such as that by Allendorf et al. (2006) and Vodouhê et al. (2010). These authors found that people's positive response to natural resources management influences their attitude towards conservation. Furthermore, Coulibaly-Lingani et al. (2010) found that participation in decision-making and economic benefits strongly influence participation in forest management in rural Burkina Faso. If the intention of policy-makers and planners is to stimulate farmers to embrace biodiversity conservation, more effort should be geared towards involving farmers in decision-making in the design of agroforestry programs such as FMNR.

Farmers should be trained in natural resource management. This training needs to emphasize the benefits of agroforestry especially the roles it can play for food security, poverty alleviation and climate change adaptation. Our findings show that there was a lack of farmer training from technical partners (State Forest service and NGOs). Such training added little to the PCA solution and was allocated a low loading (0.413). This suggests that inadequate training could lead to low adoption of agroforestry by farmers, and especially if the training does not incorporate local knowledge and farmer innovation (Sinclair and Walker, 1998; Meijer et al., 2015). Environmental education should build on positive perceptions that people already hold, and work towards mitigating negative perceptions wherever possible. This could be an important way to motivate people to develop or reinforce positive perceptions about biodiversity conservation, as reported by Vodouhê et al. (2010). Our findings are consistent with those of Ezebilo (2012) who found that in rural Nigeria, locals with primary and high school levels of education perceived community forestry positively. This suggests that environmental education will play a key role in encouraging farmers to adopt agroforestry on their farms. Agroforestry produces several ecosystem services that some farmers are not very familiar with, such as carbon sequestration, water and air purification and recreational experience. Environmental education is required to reveal the benefits of these services to farmers, which should help to encourage their support for and participation in agroforestry projects.

The dominant variables for the second factor, which explained 12.20% of the variation, were firewood requirement, need for fodder, market availability information including the price of wood, characteristics of the farm (land area, tenure and location), and household land tenure status (e.g. landowner). This indicates that farmers preserved trees on farms in order to obtain economic benefits (goods and services) such as windbreaks, fodder, fuelwood, a source of income, soil improvement, medicines, shade and construction materials, as also reported by several other authors (Franzel, 1999; Adewuyi, 2006; Jamala et al., 2013). Our findings confirm those of Etongo et al. (2015) who found that insecurity of land tenure contributes to deforestation in Burkina Faso. They are also consistent with the findings of Ezebilo and Mattsson (2010) who found that NTFPs contribute significantly to household livelihoods in villages around the Cross River National Park, Nigeria. This suggests that an agroforestry strategy focusing on the provision of NTFPs that will generate a sustainable income for farmers, has the potential to encourage farmers to adopt agroforestry. To this end, it is important for policy-makers and planners to design and implement agroforestry pilot farms, which farmers could then visit, learn from and emulate on their own properties.

The third factor explained 11.19% of the variation. Five indicators (environmental reasons, need to protect the landscape and diversity for future generations, perception of the opportunities and future returns from tree conservation activities on the farm, need for tree products e.g. fruit, and need for shading). These results are consistent with Coulibaly-Lingani et al. (2009), Vodouhê et al. (2010) and Jamala et al. (2013), who found that economic benefits of tree products represent a strong incentive for people to undertake conservation measures. In order to encourage farmers to embrace agroforestry, the government, through agricultural extension agents, should provide farmers with access to affordable trees species that are resistant to diseases, pests and adapted to the changing climate. Furthermore, there is need for more effective agricultural extension services in Burkina Faso, especially in terms of the dissemination of information to farmers. The extension services should be more farmer-centered, and periodically evaluated to identify areas that require more attention, as advocated by Franzel et al. (2004). It is important to note that farmers often differ in terms of their preferences and demands for tree species to plant on their farms. For this reason, it is important to provide farmers with opportunities to access seeds of a range native and exotic economic tree species. For example, in an Ethiopian study, Iiyama et al. (2017) found that farmers often integrate several species of native and exotic trees on their farms to meet variable farm conditions, needs and asset profiles. This suggests that if the intention of the government is to encourage farmers to embrace agroforestry, tree promotion efforts in Burkina Faso should focus on the provision of native and exotic tree species that match the varying ecological conditions throughout the country.

Does farmer participation in tree conservation programs depend on their socio-economic and demographic attributes?

The multiple regression models developed to examine the relationships between socio-economic and demographic attributes of respondents and their potential to participate in agroforestry programs revealed that variables such as household wealth, ethnic group and age class were statistically significant for all three participation indicators (Table 5). Other variables include residence status, household size and the proportion of female/male household members. The adjusted R square values for the socio-economic and demographic attributes were low: 0.016, 0.054 and 0.011 for skill development and participation in tree conservation programs, economic benefits and the conservation of biodiversity, respectively. This indicates that the model explains little of the variability of the response data around its mean. The household size and ethnic group were both significant with respect to the decision to participate in skill development and tree conservation programs (Factor 1). Individuals with larger families greatly depend on forest resources to diversify household livelihoods, as they may find it difficult to access alternative sources of subsistence (Coulibaly-Lingani et al., 2009). According to Oino and Mugure (2013), farmers engage in agroforestry practices of various types and characteristics that fit their individual-household situations.

A significant relationship between household wealth, age, residence status and economic benefits (Factor 2) was found, indicating that these variables are important in land and forest management programs that generate income for households in the West-Center region of Burkina Faso. The objective pursued by farmers is to improve their livelihood. Thus, farmers with poor or moderate household wealth are motivated to participate in any programs and activities that facilitate them achieving these objectives.

For the conservation of biodiversity, significant relationships were only found between the ratio of women to men (Factor 3). Male and female respondents experience different situations that influence their participation in forest management programs. Indeed, women's personal and household activities constrain their participation in community organizations in southern Burkina Faso (Coulibaly-Lingani et al., 2010). Thus, norms shape the

Table 5. Estimated regression standardized beta coefficients () of the latest variable equation for participation in tree conservation programs.

	Factor 1		**Factor 2**		**Factor 3**	
	***t*-values**		***t*-values**		***t*-values**	
Constant		0.559		0.278		−2.332
Household wealth	−0.035	−0.577	−0.118**	−1.997	0.052	0.852
Gender	0.053	0.824	0.004	0.056	0.067	1.045
Ethnic group	−0.131**	−2.199	0.029	0.506	−0.003	−0.049
Age	0.052	0.514	−0.235**	−2.351	0.024	0.232
Education level	−0.025	−0.431	−0.071	−1.229	0.051	0.86
Marital status	−0.005	−0.075	−0.037	−0.624	0.05	0.823
Residence status	−0.02	−0.346	0.185***	3.21	0.024	0.406
Duration of occupancy	0.121	1.181	0.084	0.838	0.072	0.703
Land area	−0.032	−0.514	−0.015	−0.236	0.065	1.026
Household size	−0.137**	−2.007	0.023	0.348	−0.006	−0.089
Proportion of females/males in the household	0.062	1.059	−0.036	−0.631	0.141**	2.39
Technical assistance	0.014	0.24	−0.011	−0.191	−0.005	−0.089
Adjusted R^2	0.016		0.054		0.011	

Note: Statistically significant estimates are indicated by asterisks **$P < 0.05$; ***$P < 0.005$.
Factor 1: Skill and participation in tree conservation program; Factor 2: Economic benefits; Factor 3: Conservation of biodiversity.

division of labor between the genders, and the role of women as care-givers and nurturers often prevents them from sparing time from domestic duties to participate in forest management activities (Nuggehalli and Prokopy, 2009). Social organization among the Gourounsi (ethnic group), where woman are occupied with farm and household activities (child care, fetching water, cooking food and farming), prevents them from attending meetings related to decision-making concerning the conservation of forest resources (Coulibaly-Lingani et al., 2010). Thus, understanding the various factors that influence farmers' decision to participate in tree conservation programs could be used for developing an appropriate strategy for promoting a sustainable agroforestry program, which is acceptable to most farmers in Burkina Faso. As women play an important role in agroforestry, planning and implementation of the strategy must include women. The strategy must be used to promote potential ways that encourages women to access the agroforestry program.

Socio-economic determinants of decisions to protect and manage trees on farmland

Binary logistic regression was used to explore the impact of a number of factors on the likelihood that respondents would adopt agroforestry (Table 6). The model contained 11 independent variables (wealth levels, gender, ethnic group, age, education, marital status, status of residence, duration of residence, farm size, household and technical support). The full model containing all predictors was statistically significant. The overall assessment of the logistic regression model and the Hosmer-Lemeshow goodness-of-fit statistics revealed a fit with the data: χ^2 $(8, N = 300) = 7.116$, $P = 0.524$. The model as a whole explained between 14.40% (Cox and Snell R square) and 20.40% (Nagelkerke R squared) of the variance associated with the decision to adopt agroforestry, and correctly classified 70.7% of the cases. The −2Log likelihood value for the data in the model is 321.575, indicating fitness of the model. Certain variables were positively associated with the conservation of trees on the farm and other variables were negatively associated. The negative β coefficients indicated that those variables reduced the likelihood of adopting agroforestry technologies (Zerihun et al., 2014).

Moderate wealth status of the household had a positive coefficient with an odds ratio of 0.057, which implies that wealthy households are more likely to adopt agroforestry technologies than poor households, although the level of significance is low. Wealth level can influence adoption in several ways: higher income farmers may be less risk averse, have more access to information and have greater capacity to mobilize resources in order to cultivate trees in fallows (Franzel, 1999). Other authors have also suggested that wealthier farmers rather than poor farmers are more likely to create improved fallows (Phiri et al., 2004; Keil et al., 2005). The findings suggest the need to understand the motive of various farmers prior to the design of an agroforestry adoption strategy. For example, in a Kenyan study, Jerneck and Olsson (2013) found that food-secure and opportunity-seeking farmers have the potential to invest in land and labor for tree planting and management. Risk-averse farmers are less likely to invest their time in tree planting and management because they are often constrained by a food production imperative.

Gender-related decision-making, which is often linked to intra-household resource allocation, is an important

Table 6. Binary logistic regression model of the household characteristics influencing adoption of tree conservation on the farm.

	β_i	S.E. β_i	Wald	df	P	Odds ratio ($e\beta$)	95% C.I. for odds ratio	
							Lower	Upper
Household wealth			1.580	2	0.454			
Poor	−0.350	0.349	1.007	1	0.316	0.705	0.355	1.396
Moderate	0.042	0.373	0.013	1	0.909	1.043	0.503	2.166
Gender (male)	0.750	0.540	1.925	1	0.165	2.117	0.734	6.105
Ethnic group			1.494	2	0.474			
Gourounsi	0.086	0.715	0.014	1	0.904	1.090	0.268	4.424
Mossi	−0.794	0.657	1.462	1	0.227	0.452	0.125	1.638
Age class			1.622	4	0.805			
[20–30]	−0.710	0.762	0.867	1	0.352	0.492	0.110	2.190
[30–40]	−0.676	0.850	0.633	1	0.426	0.509	0.096	2.689
[40–50]	−1.187	0.947	1.570	1	0.210	0.305	0.048	1.954
[50–60]	−0.969	1.212	0.640	1	0.424	0.379	0.035	4.079
Education level			4.747	5	0.448			
Iliterate	−0.106	0.382	0.077	1	0.781	0.899	0.426	1.901
Primary school	−0.770	0.624	1.525	1	0.217	0.463	0.136	1.572
Secondary school	−0.478	1.015	0.222	1	0.637	0.620	0.085	4.528
Adult education	−1.302	0.803	2.628	1	0.105	0.272	0.056	1.313
Agriculture training	−1.034	1.116	0.858	1	0.354	0.356	0.040	3.171
Marital status			1.363	2	0.506			
Married	1.063	0.938	1.283	1	0.257	2.894	0.460	18.209
Single	−0.323	1.058	0.093	1	0.760	0.724	0.091	5.762
Residence status (Native)	−0.169	0.485	0.122	1	0.727	0.844	0.326	2.183
Duration of occupancy			6.243	4	0.182			
[20–30]	0.884	0.601	2.164	1	0.141	2.421	0.745	7.866
[30–40]	1.032	0.731	1.995	1	0.158	2.807	0.670	11.760
[40–50]	1.905	0.850	5.027	1	0.025**	6.718	1.271	35.510
[50–60]	2.325	1.122	4.293	1	0.038**	10.227	1.134	92.242
Farmland size (ha)			13.751	3	0.003***			
<1	0.592	0.447	1.756	1	0.185	1.808	0.753	4.341
[1–2]	−0.612	0.452	1.838	1	0.175	0.542	0.224	1.314
[2–4]	−0.821	0.764	1.157	1	0.282	0.440	0.098	1.965
Household size			2.310	4	0.679			
<5	0.061	0.541	0.013	1	0.911	1.062	0.368	3.069
[5–10]	0.408	0.619	0.434	1	0.510	1.504	0.447	5.065
[10–15]	−0.103	0.750	0.019	1	0.891	0.902	0.207	3.924
[15–20]	1.318	1.283	1.056	1	0.304	3.737	0.302	46.184
Technical support			0.048	3	0.997			
High technical support	−0.091	0.480	0.036	1	0.850	0.913	0.357	2.340
Low technical support	−0.075	0.370	0.041	1	0.839	0.927	0.449	1.916
Constant	0.016	1.000	0.000	1	0.987	1.016		

Note: Statistically significant estimates are indicated by asterisks**$P < 0.05$; ***$P < 0.005$; Hosmer & Lemeshow Test: $\chi^2 = 7.116$. df = 8. $P = 0.524$; −2Log likelihood = 321.575; Cox & Snell $R^2 = 0.144$ and Nagelkerke $R^2 = 0.204$; Overall percentage of correct prediction = 70.7%.

determinant of the adoption of agroforestry technologies by both men and women (Kiptot and Franzel, 2012). Our results show that men are more positively associated with the conservation of trees on the farm. Buyinza and Ntakimanyire (2008) reported that men are more likely to establish plantations on their fields than women. According to Thangata (1996), the probability of agroforestry adoption was higher for men than women. Women are less likely to test and adopt improved fallows by planting trees for social reasons and because of their lower wealth levels (Franzel, 1999). Other reasons, such as inheritance systems, the lack of rights for women to grow trees and less access to credit and land for exploitation (secure land and tree tenure) can also explain this situation (Kiptot and Franzel, 2012; Bourne et al., 2015). However, women must be engaged in the development and promotion of agroforestry programs because they are often the primary users of tree resources and obtain substantial benefits from them, in terms of food, fuelwood and other products and services, and particularly in times of need. They are also more informed and concerned by the lack or abundance of these resources that they depend on for their daily needs. Coulibaly-Lingani et al. (2010) recommended that increasing women's participation and more equitable benefit-sharing among user groups are essential in improving the success of participatory forest management programs. Kiptot and Franzel (2012) proposed various technological, policy and institutional recommendations (access to extension services and market information, improving women's access to financial resources, land tenure reforms etc.) to promote more active participation of women in agroforestry development to ensure greater benefits can accrue to them. It is important to note that only a small number of women participated in our study, which makes it difficult to draw exhaustive conclusions about gender-related issues for agroforestry adoption in the Burkina Faso context. We therefore advocate for more research on the influence of gender on the adoption of agroforestry in Burkina Faso.

Our results show that local people's perceptions of conservation of trees on farms were influenced by their origin (ethnic group), age, education level, farm size and technical support. These results are consistent with those of Vodouhê et al. (2010). Other authors have suggested that indigenous people may express anti-environmental attitudes for a variety of reasons, including low education levels, lack of awareness about environmental issues and a lack of engagement within their new community (Sah and Heinen, 2001; Allendorf et al., 2006). According to Buyinza and Ntakimanyire (2008), technical support (environmental education) could play an important role in adoption of new and innovative technologies by the public. In addition, our results also concur Jamala et al. (2013) who reported that technical assistance is needed to facilitate the spread of agroforestry practices. However, it is similar to the results of Coulibaly-Lingani et al. (2009) in the same region of Burkina Faso as our study. The period of residence is an important factor in participation in programs that contribute to the development of a village. Thus, the fact that migrants spend a long time in a locality encourages them to work to improve their livelihoods, and they therefore feel that they belong to the people of their village.

Farmers' silvicultural practices and suggested strategies for improving tree conservation on farmland

There were five main silvicultural practices utilized by the farmers on their farmland. These were the protection of seedlings against fire (94%), wood cutting (93%) and fodder harvesting (77%), enrichment planting (85%), FMNR (87%) and direct seeding of tree seeds (66%). The following quote from one interviewed farmer reflects the practices adopted by most farmers in the study site: '*for the protection of young plants against grazing and bushfires, we surround young plants* (with) *thorny branches cut from other shrubs. During the plowing, we avoid to damage young preferred plants. At the end of the rainy season, crop residues are piled up in one place in order to avoid the expansion of accidental fires. When we have the fund, we buy at the market the multipurpose plants that we plant in our farmland. We keep in the farmland only the dominant stems of the resprout and also carry out direct seeding'*.

The main strategies suggested by the farmers for improving tree conservation activities were facilitating targeted incentive programs (84%) and extension in the form of silvicultural training/environmental education (80%) and on-ground technical assistance (75%), and flexibility for land tenure and tree ownership security (73%). One of the interviewed farmers in Negarpoulou village commented on the need for an improved availability of extension and incentives: '*awareness and incentives for tree conservation in the farmland is an effective way for many people to know the importance of promoting tree conservation on farmland. Here, there is long time that we have not received technical assistance. Environmental education for adults and our children at school could benefit us*'. Another non-landowning farmer's comments reflected the general opinion of many of this type of interviewee: '*if the land tenure and tree secure were flexible, they would be motivated to invest in their restoration because most of the loaned land is generally unsuitable for cultivation. But, when the rights to used land and tree are not equitably arranged, the owners are capable to ask you to return land, once you invested to restore through plantation lands'*.

Concluding remarks

This study provides insights into farmers' decisions to incorporate trees into agricultural land-use systems in the Center-West region of Burkina Faso. In order to improve the adoption of agroforestry by farmers in this region, the government and their rural development NGO partners could empower farmers with forest management skills and provide measures that encourage their participation in tree conservation programs. These measures may include a more effective agroforestry extension service, and the provision of locally-suitable tree seeds and simple agricultural equipment for working the soil. Agroforestry extension services should be designed to match local biophysical and socio-economic conditions. This will ensure the local farmers' immediate needs and preferences are understood and effectively addressed. It is also important for different categories of farmers to be actively involved in the design of agroforestry programs such as Farmer-Managed Natural Regeneration. This is important to improve these programs' relevance to and acceptance by all types of farmers. The government of Burkina Faso and their NGO partners could encourage and stimulate the promotion of agroforestry technologies by helping local communities to resolve the constraints to improved tree conservation on farms. The promotion of agroforestry can be used as a toolkit to fight rural poverty, food insecurity, desertification and the negative impacts of climate change. The findings from this study should contribute to the design and delivery of agroforestry projects that address farmers' needs and preferences, thus helping improve community food security and adaptation to climate change.

Supplementary material

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References

Acharya, K.P. 2006. Linking trees on farms with biodiversity conservation in subsistence farming systems in Nepal. Agroforestry and Biodiversity conservation: Traditional practices, present dynamics, and lessons for the future. Biodiversity and Conservation 15(2):631–646.

Adewuyi, H.G. 2006. Agroforestry practices and species preference in Kano State. Potentials for improvement. Production Agriculture and Technology (PAT) 2:2–4.

Agresti, A. 1996. An Introduction to Categorial Data Analysis. 2nd ed. Wiley-Interscience a John Wiley & Sons, Inc., Publication, New Jersey, United States. 392 p.

Allendorf, T., Swe, K.K., Oo, T., Htut, Y., Aung, M., Aung, M., Allendorf, K., Hayek, L.A., Leimgruber, P., and Wemmer, C. 2006. Community attitudes toward three protected areas in Upper Myanmar (Burma). Environmental Conservation 33(4):344–352.

Arnold, M. and Townson, I. 1998. Assessing the potential of forest product activities to contribute to rural incomes in Africa. Natural Resource Perspectives no 37, November 1998. Overseas Development Institute, London, UK.

Bationo, A., Hartemink, A., Lungu, O., Naimi, M., Okoth, P., and Thiombiano, L. 2006. Africa soils: Their Productivity and Profitability of Fertilizer Use. Background paper prepared for the African Fertilizer Summit, Abuja, Nigeria.

Bayala, J. 2002. Trees crown pruning as management tool to enhance the productivity of parkland in West Africa. PhD thesis, School of Agricultural and Forest Sciences, University of Wales, Bangor, UK. 207 p.

Bayala, J., Kindt, R., Belem, M., and Kalinganire, A. 2011. Factors affecting the dynamics of tree diversity in agroforestry parklands of cereal and cotton farming systems in Burkina Faso. New Forests 41:281–296.

Bayala, J., Sanou, J., Teklehaimanot, Z., Kalinganire, A., and Ouédraogo, S.J. 2014. Parklands for buffering climate risk and sustaining agricultural production in the Sahel of West Africa. Current Opinion in Environmental Sustainability 6: 28–34.

Bayala, J., Sanou, J., Teklehaimanot, Z., Ouedraogo, S.J., Kalinganire, A., Coe, R., and Van Noordwijk, M. 2015. Advances in knowledge of processes in soil-tree-crop interactions in parkland systems in the West African Sahel: A review. Agriculture, Ecosystems and Environment 205:25–35.

Boffa, J.M. 2000. Les parcs agroforestiers en Afrique de l'Ouest: clés de la conservation et d'une gestion durable. Unasylva, 51:11–17.

Bourne, M., Kimaiyo, J., Tanui, J., Catacutan, D., and Otiende, V. 2015. Can gender appreciation of trees enhance landscape multifunctionality? A case of smallholder farming systems on Mount Elgon. International Forestry Review 17(4):33–45.

Breman, H. and Kessler, J.J. 1995. The Role of Woody Plants in Agro-Ecosystems of Semi-arid Regions: With an Emphasis of the Sahelian Countries. Advanced Series in Agricultural Sciences, vol. 23. Springer-Verlag, Berlin.

Bryman, A. and Cramer, D. 2005. Quantitative Data Analysis with SPSS *12* and *13*. A Guide for Social Scientists. Routledge, East Sussesx.

Buyinza, M. and Ntakimanyire, A. 2008. Rotational Woodlot Technology in Kigorobya Sub-County, Hoima District, Uganda. Botany Research Journal 1(2):36–42.

Clason, D.L., and Dormody, T.J. 1994. Analyzing data measured by individual Likert-type items. Journal of Agricultural Education 35:31–35.

Coulibaly-Lingani, P., Tigabu, M., Savadogo, P., Oden, P.C., and Ouadba, J.-M. 2009. Determinants of access to forest products in southern Burkina Faso. Forest Policy and Economics 11:516–524.

Coulibaly-Lingani, P., Savadogo, P., Tigabu, M., Odén, P.C., and Ouadba, J.M. 2010. Factors influencing people's participation in forest management program in Burkina Faso, West Africa. Forest Policy and Economics 13:292–302.

De Leeuw, J., Njenga, M., Wagner, B., and Iiyama, M. 2014. Treesilience: An Assessment of the Resilience Provided by Trees in the Drylands of Eastern Africa. ICRAF, Nairobi, Kenya. 166 pp.

Dovies, D.B.K., Witkowski, E.T.F., and Shackleton, C. 2004. The fuelwood crisis in southern Africa – relating fuelwood use to livelihoods in rural village. Geographical Journal 60:123–133.

Etongo, D., Djenontin, I.N.S., Kanninen, M., and Fobissie, K. 2015. Smallholders' tree planting activity in the Ziro Province, Southern Burkina Faso: Impacts on Livelihood and Policy Implications. Forest 6:2655–2677.

Ezebilo, E.E. 2012. Community forestry as perceived by local people around Cross River National Park, Nigeria. Environmental Management 49:207–218.

Ezebilo, E.E. and Mattsson, L. 2010. Contribution of non-timber forest products to livelihoods of communities in southeast Nigeria. International Journal of Sustainable Development & World Ecology 17:231–235.

FAO 2003. Wood energy. Unasylva Series No.211:53. Food and Agriculture Organisation of the United Nations, Rome, Italy. p. 60.

Fontès, J. and Guinko, S. 1995. Carte de la végétation et de l'occupation des sols du Burkina Faso. Ministère de la Coopération Française : projet campus (88 313 101), Toulouse, France. p. 67.

Franzel, S. 1999. Socioeconomic factors affecting the adoption potential of improved tree fallows in Africa. Agroforestry Systems 47:305–321.

Franzel, S., Denning, G.L., Lillesø, J.P.B., and Mercado, A.R., Jr 2004. Scaling up the impact of agroforestry: Lessons from three sites in Africa and Asia. Agroforestry Systems 61:329–344.

Garrity, D.P. and Stapleton, P. 2011. More trees on farms. Farm Matters 27(2):8–9.

Giannini, A., Biasutti, M., and Verstraete, M.M. 2008. A climate model-based review of drought in the Sahel: Desertification, the re-greening and climate change. Global and Planetary Change 64:119–128.

Grolleau, A. 1989. Contribution à l'étude de la multiplication végétative par greffage du karité (Vitellaria paradoxa Gaertn. f.=Butyrospermum paradoxum Hepper). Bois et Tropiques 222:38–40.

Hachoofwe, E.M. 2012. Local ecological knowledge of trees on farms, constraints and opportunities for further integration in Tigray Region, northern Ethiopia: A case study of smallholder farmers in Abreha Wa Atsbeha and Adi gudom. Master of Science (Msc) in Agroforestry, School of Environment, Natural Resources and Geography Bangor University, Wales. 72p.

Hair, J.F.J., Anderson, R.E., Tatham, R.L., and Black, W.C. 1998. Multivariate Data Analysis, 5th ed. Prentice Hall, Upper Saddle River, NJ.

Horn, J.L. 1965. A rationale and test for the number of factors in factor analysis. Psychometrika 30:179–185.

Hulme, M. 1996. Recent climatic change in the world's drylands. Geophysical Research Letters 23:61–64.

Iiyama, M., Derero, A., Kelemu, K., Muthuri, C., Kinuthia, R., Ayenkulu, E., Kiptot, E., Hadgu, K., Mowo, J., and Sinclair, F.L. 2017. Understanding patterns of tree adoption on farms in semi-arid and sub-humid Ethiopia. Agroforestry Systems 91:271–293.

INSD 2007. Résultats préliminaires du recensement général de la population et de l'habitatde 2006. In: Institut National des Statistiques et de la Démographie (INSD). Direction de la démographie, Ouagadougou, Burkina Faso.

Jamala, G.Y., Shehu, H.E., Yidau, J.J., and Joel, L. 2013. Factors influencing adoption of Agro-Forestry among Smallholder Farmers in Toungo, Southeastern, Adamawa State, Nigeria. Journal of Environmental Science, Toxicology And Food Technology 6:66–72.

Jerneck, A. and Olsson, L. 2013. More than trees! Understanding the agroforestry adoption gap in subsistence agriculture: Insights from narrative walks in Kenya. Journal of Rural Studies 32:114–125.

Kagambega, F.W., Thiombiano, A., Traoré, S., Zougmoré, R., and Boussim, I.J. 2011. Survival and growth responses of Jatropha curcas L. to three restoration techniques on degraded soils in Burkina Faso. Annales of Forest Science 54(2):171–184.

Kaiser, H. 1974. An index of factorial simplicity. Psychometrika 39:31–36.

Karekezi, S. and Majoro, L. 2002. Improving modern energy services for African's urban poor. Energy Policy 30:1015–1028.

Keil, A., Zeller, M., and Franzel, S. 2005. Improved fallows in smallholder maize production in Zambia: Do initial testers adopt the technology? Agroforestry Systems 64: 225–236.

Kiptot, E. and Franzel, S. 2012. Gender and agroforestry in Africa: A review of women's participation. Agroforestry Systems 84:35–58. DOI: 10.1007/s10457-011-9419-y.

Krishna, A., Kristjanson, P., Radeny, M., and Nindo, W. 2004. Escaping poverty and becoming poor in twenty Kenyan villages. Journal of Human Development 5:211–226.

Kristensen, M. and Balslev, H. 2003. Perceptions, use and availability of woody plants among the Gourounsi in Burkina Faso. Biodiversity and Conservation 12(8):1715–1739.

Lugandu, S., Dulla, H., Ngotio, D., and Mkomwa, S. 2012. The extent of adoption of conservation agriculture with trees by smallholder farmers in Tanzania. Working paper adoption. p. 40.

Mahapatra, A.K. and Mitchell, C.P. 2001. Classifying tree planters and non-planters in subsistence farming system using a discriminant analytical approach. Agroforestry Systems 52(1):41–52.

Maranz, S. and Wiesman, Z. 2003. Evidence for indigenous selection and distribution of the Shea tree, Vitellaria paradoxa, and its potential significance to prevailing parkland savanna tree patterns in sub-Saharan Africa north of the equator. Journal of Biogeography 30:1505–1516. doi: 10.1046/j.1365-2699.2003.00892.x.

Meijer, S.S., Catacutan, D., Ajayi, O.C., Sileshi, G.W., and Nieuwenhuis, M. 2015. The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. International Journal of Agricultural Sustainability 13:40–54.

Mekonnen, A. and Köhlin, G. 2009. Determinants of household fuel choice in major cities in Ethiopia. Working papers in Economics Numero399, Department of Economics, Göteborg University, Göteborg, Sweden.

Ndayambaje, J.D. 2013. Trees and woodlots in Rwanda and their role in fuelwood supply. PhD thesis, Wageningen University, Wageningen.

Nuggehalli, R.K. and Prokopy, L.S. 2009. Motivating factors and facilitating conditions explaining women's participation in co-management of Sri Lankan forest. Forest Policy and Economics 11:288–293.

Oino, P. and Mugure, A. 2013. Farmer-oriented factors that influence adoption of agroforestry practices in Kenya: Expériences from Nambale District, Busia County. International Journal of Science and Research 450–456.

Omuregbee, F.E. 1998. Communication of improved farm practices to rural women farmers in Benue State, Nigeria. Outlook on Agric. 27:53–56.

Pallant, J. 2013. SPSS Survival Manual: A Step by Step Guide to Data Analysis using IBM SPSS, 5th ed. The McGraw Hill companies, England p. 353.

Pattanayak, S.K., Mercer, D.E., Sills, E., and Yang, J.-C. 2003. Taking stock of agroforestry adoption studies. Agroforestry Systems 57:173–186.

Pearce, D.W. 2001. The economic value of forest ecosystems. Ecosystems Health 7(4):284–296.

Peng, C.J., Lee, K.L., and Ingersol, G.M. 2002. An introduction to logistic regression: Analysis and reporting. Journal of Educational Research 96:1–14.

Phiri, D., Franze, L.S., Mafongoya, P., Jere, I., Katanga, R., and Phiri, S. 2004. Who is using the new technology? The association of wealth status and gender with the planting of improved tree fallows in Eastern Province, Zambia. Agricultural Systems 79:131–144.

Reij, C. and Garrity, D. 2016. Scaling up farmer-managed natural regeneration in Africa to restore degraded landscapes. Biotropica 48:834–843.

Reij, C. and Winterbottom, B. 2015. Scaling Up Regreening: Six Steps to Success. World Resources Institute, Washington DC, United States, p. 66, ISBN 978-1-56973-861-0.

Sah, J.P. and Heinen, J.T. 2001. Wetland resource use and conservation attitudes among indigenous and migrant peoples in Ghodaghodi Lake area, Nepal. Environmental Conservation 28:345–356.

Salam, M.A., Noguchi, T., and Koike, M. 2000. Understanding why farmers plant trees in the homestead agroforestry in Bangladesh. Agroforestry Systems 50:77–93.

Sawadogo, L. 2009. Influence de facteurs anthropiques sur la dynamique de la végétation des forêts classées de Laba et de Tiogo en zone soudanienne du Burkina Faso. Thèse d'Etat, Université de Ouagadougou, Burkina Faso. p. 142.

Scherr, S.J. 1992. The role of extension in agroforestry development: Evidence from western Kenya. Agroforestry Systems 18:47–68.

Shono, K., Ernesto, A., Cadaweng, E.A., and Durst, P.B. 2007. Application of assisted natural regeneration to restore degraded tropical forestlands. Review. Restoration Ecology, 620–626.

Sinclair, F.L. and Walker, D.H. 1998. A utilitarian approach to the incorporation of local knowledge in agroforestry research and extension. In L.E. Buck, J.P. Lassole and E.C.M. Fernandes (eds.). Agroforestry in Sustainable Agricultural Systems. Lewis Publishers, New York, USA. p. 245–278.

Sissoko, K., van Keulen, H., Verhagen, J., Tekken, V., and Battaglini, A. 2011. Agriculture, livelihoods and climate change in the West African Sahel. Regional Environmental Change 11:119–125.

Sop, T.K., Kagambega, F.W., Bellefontaine, R., Schmiedel, U., and Thiombiano, A. 2012. Effects of organic amendement on early growth performance of *Jatropha curcas* L. on a severely degraded site in the Sub-Sahel. Agroforestry Systems 86:387–399.

Tabachnick, B.G. and Fidell, L.S. 1996. Using Multivariate Statistics. Harper Collins College Publishers, New York.

Thangata, P. 1996. Resource poor farmers perception of agroforestry practices – a case study of Malawi. MSc dissertation, University of Edinburgh, Scotland, UK.

Vodouhê, F.G., Coulibaly, O., Adégbidi, A., and Sinsin, B. 2010. Community perception of biodiversity conservation within protected areas in Benin. Forest Policy and Economics 12: 505–512.

Wunder, S., Börner, J., Shively, G., and Wyman, M. 2014. Safety nets, gap filling and forests: A global-comparative perspective. World Development 64(Suppl. 1):S29–S42.

Zerihun, M.F., Muchie, M., and Worku, Z. 2014. Determinants of agroforestry technology adoption in Eastern Cape Province, South Africa Development Studies Research: An Open Access Journal 1(1):382–394. DOI:10.1080/21665095.2014.977454.

Zougmoré, R., Guillobez, S., Kambou, N.F., and Son, G. 2000. Runoff and sorghum performance as affected by the spacing of stone lines in the semi-arid Sahelian Zone. Soil and Tillage Research 56:175–183.

Zougmoré, R., Zida, Z., and Kambou, N.F. 2003. Role of nutrient amendments in the success of half-moon soil and water conservation practice in semi-arid Burkina Faso. Soil & Tillage Research 71:143–149.