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Wiley Blackwell
2018-08

Etongo, D, Epule, T E, Djenontin, I N S & Kanninen, M 2018, 'Land management in rural Burkina Faso: the role of socio-cultural and institutional factors', Natural Resources Forum, vol. 42, no. 3, pp. 201-213. https://doi.org/10.1111/1477-8947.12153

http://hdl.handle.net/10138/316303
10.1111/1477-8947.12153

acceptedVersion

Land management in rural Burkina Faso: the role of socio-cultural and institutional factors

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Abstract

Farmers in the Sahel have been acknowledged for reclaiming degraded lands and improving food security by ingeniously modifying traditional agroforestry, water, and soil management practices. Despite the advantages offered by this range of farming techniques, their adoption rate is influenced by several factors. Using multivariate probit models and a correlation coefficient, this article examines the factors influencing the adoption of five land management practices based on 220 household and 40 farm surveys in four adjacent rural communities in southern Burkina Faso. The model results indicate that household labor force, education of household head, land tenure security, livestock holding, and membership in farmers' groups influence the adoption of zaï practice, composting, improved fallow, stone bunds, and life hedges. However, two of the surveyed factors - number of farms and visit by agricultural extension staff during the twelve months prior to the survey - were not significant. Furthermore, a significant correlation was found between different land management practices, e.g., the decision to practice zaï is significantly linked to that of live hedges and composting. Zaï practice and stone bunds are considered labor intensive, which explains their significant correlations with household labor force at the 1% and 5% level of significance, respectively.

***Keywords*:** Smallholder farmers; sustainable agricultural practices; land tenure; food security; multivariate probit model; southern Burkina Faso.

Introduction

Scholars have predicted that the world will need to produce 70–100% more food by 2050 than at present to meet anticipated demands (Godfray *et al.* 2010). This is because of global population growth, urbanisation, and rising wealth that have created new patterns of consumption, including a surging demand for food, raw materials, and energy. While global agricultural production has increased — expanding at an estimated 2% per year since 2000, land productivity seems to have reached a plateau as the rate of growth in major crops has declined (Tully *et al*., 2015). A major factor for such a decline, especially in Africa's agriculture, and particularly in sub-Saharan Africa (SSA), is attributed to low inputs that have affected farm productivity, especially among smallholder farmers, for decades (DFID, 2004). The soils in Africa are the most degraded in the world (Koning and Smaling, 2005; Tully *et al*., 2015) and dominated by farmlands that suffer from intense land fragmentation (Gray, 1999).

As such, ensuring food security for an increasing global population and at the same time promoting the use of soil fertility and land management techniques (Barrett *et al.*, 2001), have become a critical issue of concern, particularly in the era of the Sustainable Development Goals (SDGs). Relying solely on a "new green revolution", based on the use of improved seed varieties, has its shortcomings in fragile ecosystems such as the Sahel (Gubbels and Brescia, 2017). Notwithstanding, different land management interventions have been developed, tested, and promoted across Africa, with the aim of increasing agricultural production under sustainable farming systems. Therefore, the potentials of sustainable land management (SLM) practices to reconcile and achieve concomitantly food security and environmental protection underpins its acknowledgement by scientists, policymakers and development practitioners, especially with the challenges posed by climate change, land scarcity, and land degradation (Nkonya et al., 2012). This is because land degradation at the global level has led to a net loss of croplands at an average rate of 0.2% per year, with a projected 12% decrease in food production in the next 25 years (Tully *et al*., 2015).

Despite these challenges, the agricultural sector plays a central role in the economy of most, if not all, African countries. In Burkina Faso, it accounts for 35% of the Gross Domestic Product (GDP), while employing approximately 85% of the population (FIP, 2012). The southern region, characterized by a Sudanian agro-ecological zone, offers better opportunities for rain-fed agriculture and livestock, with over 50% of the suitable arable land located in the

region (Ouedraogo et al., 2015). However, this region has been subjected to human migration catalysed by the harsh biophysical conditions of the central and northern regions of the country, which are affected by drought and desertification. Field expansion of crops into forest areas have been identified in the southern region (Ouedraogo *et al*., 2009) as driven by low farm productivity and poor monitoring of community forests (Reenberg *et al*., 2003; Gray, 2005). The consequences of such activities are intense degradation and deforestation (DD) in the southern part of the country (Etongo et al., 2015), consistent with the general trends observed in SSA (Barrett *et al*., 2001; Niemeijer and Mazzucato, 2002). Although estimates of the extent and rate of land degradation lack consistency, some studies in the Sahel have shown the dynamics of land degradation over different periods and how it affects farm and forest areas (Ouedraogo *et al*., 2014; Mbow *et al*., 2015).

Local knowledge-based innovations were rediscovered and enhanced in simple, low-cost ways by innovative farmers and non-governmental organizations (NGOs) through a range of farming techniques to mitigate the effects of DD while improving food security. Some of these land management practices are common among farmers in SSA, while others are indigenous to the Sahel because they have been developed to suit local biophysical and climatic conditions (Howorth and O′keefe, 1999). For instance, the implementation of a range of farming techniques in the Central Plateau of Burkina Faso is said to have reclaimed 200,000-300,000 ha of degraded lands (Lenhardt *et al*., 2014). Based on this evidence, the implementation of farmer-led innovation techniques, especially in southern Burkina Faso, has the potential not only to improve food security and reclaim degraded lands (Reij *et al*., 2009), but also to further reduce field expansion into forest areas. Therefore, the adoption of SLM practices no longer seems to be an option in Burkina Faso and as such, the Ministry of Agriculture and Food Security of Burkina Faso has the mandate to support and promote SLM practices with funding from both the government and NGOs.

There are a number of land management practices — such as zaï[1] (Roose *et al*., 1999; Kaboré and Reij, 2004; Biazin *et al*., 2012), composting (Ouédraogo *et al*., 2001; McClintock

[1] Zaï pits, also known as planting pits, is a term that farmers in northern Burkina Faso use to refer to small planting pits that typically measure 20-30 cm in width, are 10-20 cm deep, and are 60 by 60 cm apart (Biazin *et al*., 2012).

and Diop, 2005), stone bunds[2] (Gebrernichael *et al*., 2005), live hedges[3] (Ayuk, 1997), and improved fallow[4] (Buresh and Tian, 1998; Ajayi *et al*., 2003; Mando *et al*., 2005) — that have been tested and been proven to be sustainable. Despite their availability in Burkina Faso, farmlands are still undergoing degradation (Batta and Bourgou, 2017) because of the differences in household and farm characteristics and local institutions that have not allowed farmers to effectively engage in these practices (Etongo *et al*., 2016a). Socioeconomic, farm characteristics, and institutional factors that have been documented to influence smallholders' adoption of land management practices include farmer's age, farm age (years of operating the present farm), household labour force, education, size of farm, land and tree tenure security, technical and financial assistance received by farmers, and membership in a farmers' group (Aklilu and de Graff, 2007). Tenure security is very important and in Burkina Faso, two studies indicated that customary land tenure security acted as an incentive to land investment (Brasselle *et al*., 2002; Gray, 2005).

Therefore, the aim of this study is to assess the factors that influence the adoption of improved fallows, zaï (planting pits), stone bunds, composting, and live hedges among 220 farm households across four villages in Southern Burkina Faso. These five SLM practices are considered in this study because they were identified in an earlier study conducted in the study area (Etongo et al., 2016a; p. 14). A major novelty of this paper is that it deals with a variety of land-related aspects affecting the adoption of SLM. These various aspects are discussed in some detail in the following sections.

Conceptual perspectives of factors influencing the adoption of SLM practices

Several explanations have been offered as to why farmers' land management practices vary from one place to another - or even among farm households within a community. These

[2] Stone bunds, usually 0.4-meters-wide, are constructed along contour lines to slow down, filter, and spread out runoff water, thereby increasing infiltration and reducing soil erosion (Gebrernichael *et al*., 2005).

[3] Live hedge (as distinct from live fence) refers to one or more rows of trees closely planted (25 cm or 50 cm fence) to form a continuous barrier around the desired area. The rows may contain one or several types of species, and the entire hedge is usually cut at an appropriate barrier height (Ayuk, 1997; p. 191).

[4] It involves fast-growing, high-quality-biomass-producing multi-purpose tree (MPT) species (*in situ*) as short (three to four years) fallows and incorporating their biomass into the soil before planting the crops (Kaya and Nair, 2001; p. 2).

divergent views illustrate the underlined rationale as to why land use decision making in SSA, and in Burkina Faso in particular, might not follow a 'silver bullet' approach. Despite the difference in the explanations on the adoption of SLM practices, reoccurring factors that are common in most literature could be summarized as socio-cultural, economic, institutional, and environmental (Adesina and Baidu-Forson, 1995; Sidibé, 2005; Yila and Thapa, 2008; Okuthe *et al*., 2013). From a cultural ecologist lens, land management practices at a given time and place are a function of constraints imposed by the physical environment and technological capabilities to reduce and modify those constraints (Ali, 1995).

Therefore, farmers' land management practices are driven by several factors that affect farmers differently. These include the availability of resources (natural, human, technological, capital), the existence of constraints (biophysical, socioeconomic), and the policy environment such as land rights, land and tree tenure, and subsidies, which are considered invaluable in the adoption of SLM practices (Baidu-Forson, 1999; Rasul, 2003). Teshome *et al.* (2016) reinforces such arguments based on their findings that land quality, land fragmentation, and tenure arrangements in Ethiopia influence farmers' adoption of SLM practices. On the other hand, Tiffen *et al.* (1994) found that population pressure on land resources stimulated farmers' adoption of SLM practices that increase production per hectare. However, according to an earlier study, population pressure in our case study area is a threat to environmental sustainability through the conversion of forests to farmlands (Ouedraogo *et al*., 2009). Alternate options such as field expansion into poorly monitored forests areas with fertile soils are likely to weaken the potential of population pressure as a driver of agricultural intensification. Thus, it is appropriate to start the investigation from the micro-level factors comprising farmers' socioeconomic and institutional characteristics, as well as the physical attributes of landholdings (Lefroy *et al*., 2000; Paudel and Thapa, 2004).

Indeed, the decision on how to manage the land depends on smallholders' perceptions of land degradation as well as other factors that are specific to households and their landholdings. For example, access to land does not automatically mean ownership or the right to transfer land in the context of customary systems in rural Burkina Faso (Ouédraogo, 2002). Moreover, farmers' levels of education and exposure to society and local institutions such as land and tree tenure security and membership in a farmers' group are likely to influence the adoption of SLM practices (Teshome *et al*., 2016; Brasselle *et al*., 2002). Additionally, some land management practices are labour intensive -e.g. construction of planting pits, stone bunds

and composting, and as such household labour force can enhance the adoption of such practices. Besides, households whose primary source of income is not agriculture are likely to be less concerned about SLM practices compared to others that derive their livelihood mainly from agriculture (Mehta and Kellert, 1998). Though this is true for other regions, over 97% of the four studied communities depend on crop and livestock farming as their main source of income and livelihoods (FIP, 2012).

Furthermore, support services such as agricultural credit, training, and extension services influence the adoption of SLM practices, at least initially, and could become less effective if farmers do not receive such support regularly (Adesina *et al*., 2000). Visits by agricultural extension staff to provide technical assistance and financial support to facilitate access to agricultural inputs e.g. fertilizers and soil inputs received by farmers during the 12 months prior to the survey were considered in this study. The logic here was to capture those farmers who received such support, where it be in the form of advice or agricultural inputs in a year and not how many times in a year.

Materials and methods

1.1 Study area

This study was conducted in the Ziro province of the southern region of Burkina Faso. It is located between 11˚35′-12˚00′ N and 01˚30′-2˚03′W (Figure 1) and covers an estimated area of 5291 km². Located 150 km from Ouagadougou - the nations' capital - this region falls within the south-Sudanian phytogeographical zone (Fontes and Guinko, 1995). The relief is low, with an average altitude of 300m above sea level. This region experiences the highest amount of annual rainfall, which ranges from 800-1000 mm, with temperatures between 30-35ºC (Ingram *et al*., 2002). The main soil types are silt-clay cambisols, sandy lixisols, and loamy ferric luvisols (Driessen *et al*., 2001).

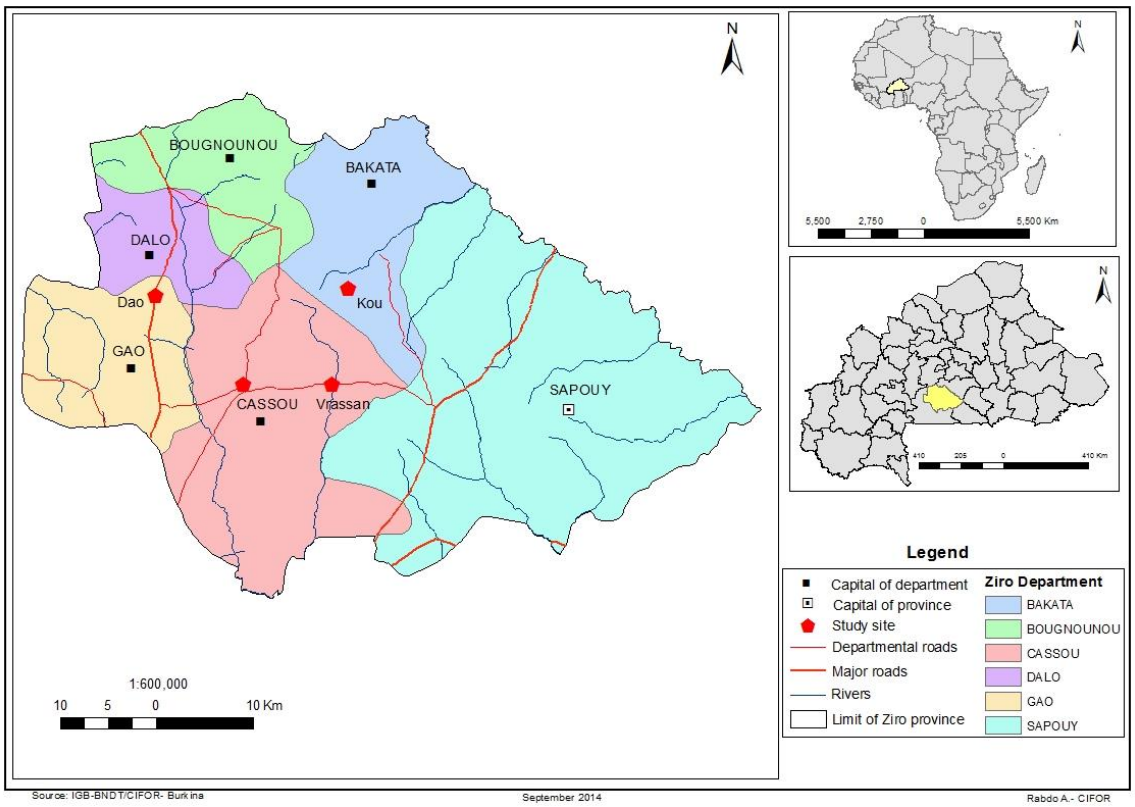

Figure 1. Map of the study area.

The population of the four villages of study (Cassou, Kou, Vrassan, and Dao) consists of three ethnic groups: the Gourounsi, Mossi, and Fulani, with the first group being indigenous, while the last two groups are migrants who originate from the central plateau and northern region of the country. Based on the last population and housing census in Burkina Faso in 2006, the population in the Ziro province was estimated at 40,833 inhabitants, with an average population density of 28 inhabitants/km² (INSD, 2007), which is considered the highest in the country.

In term of biodiversity, the natural flora is dominated by perennial grasses such as *Andropogon gayanus* Kunth, *A. ascinodis* C.B. Clarke, and *Schizachyrium sanguineum* (Retz.) Alston (Fontes and Guinko, 1995). Tree species commonly found in the parklands include *Vitellaria paradoxa* C. F. Gaertn, *Parkia biglobosa* (Jacq.) R. Br. ex G. Don., and *Tamarindus indica* L., amongst others. Forests in the study villages are under one of two management regimes: protected and classified forest. The classified forests, or national parks, (25 percent) are strictly protected from livestock and farming activities, while the protected forests (chantiers d'aménagements forestiers—CAF and forêts villageoises) are subject to

field expansion and managed by local communities in collaboration with the government (Kambire *et al*., 2015).

The farming system is dominated by crops grown under a discontinuous cover of scattered trees that constitutes the so-called "parklands" (Belem *et al.*, 2011). Parklands are considered as agroforestry systems, but their biodiversity depends on the original vegetation cover, the number and type of trees and shrubs spared during conversion to farmland, and the needs of farmers, etc. (Belem *et al*., 2011). Traditionally, the indigenous ethnic group in this region practices a 'gentle' form of agriculture, which is labour intensive with little inputs and relatively low soil usage, and the cultivated area is estimated at 4.5 ha per family. In addition, going by this farming technique in the past, fields/farms were cultivated on an average of four to five years, with fallows traditionally ranging between 20 to 30 years (Howorth and O'Keefe, 1999). However, the fallow period, especially in Southern Burkina Faso, has greatly reduced and, in some cases, no longer exists due to land use pressure and the inheritance system that partitions land among adult males (Kaboré and Reij, 2004). On the other hand, the Mossi ethnic group practices an extensive form of agriculture with almost total field clearing, while the Fulani tend to concentrate their animal herding in the zones of low-intensity agriculture in the periphery/wooded areas of the village's territory (Howorth and O'Keefe, 1999).

The story is different today because activities that induce environmental degradation are not ethnic-specific, but influenced by poverty and land tenure security (Etongo *et al.*, 2016a). In this study, even those who perceive their land tenure as secured were found to have engaged in activities considered environmentally-degrading. The customary tenure arrangement continues to dominate despite the adoption of Burkina Faso's rural land tenure legislation of 2009. Its incomplete application in most rural areas has left ample opportunity for customary practices, which in some cases bring along uncertainties to dominate (Ouédraogo, 2002). Therefore, those who perceive their tenure to land as insecure are likely not to engage in practices that can improve the land, and instead will draw as much as possible from the land with little or no input in return.

In general, subsistence agriculture in this region involves the cultivation of cereals (sorghum, sesame, maize, and millet) and tubers (yam and sweet potatoes) and animal husbandry. The climate and soils in this region favor rain-fed agriculture with little inputs compared to other regions in the country. In addition, 70% of the country's forest is located in

this region. Therefore, a lucrative production system that involves the extraction of fuelwood and non-timber forest products, the cultivation of cash crops (cotton and fruit-tree plantations), and ranching have, over the years, been developed in this region (FIP, 2012; Kambire *et al*., 2015).

However, land degradation due to agricultural expansion driven by the growing population, unsustainable use of fuelwood, and climate variability are the main environmental threats in this region. The practice of shifting cultivation that provides the latitude for bush fallow with the potential of improving soil fertility is fast disappearing due to population pressure on land. Additionally, low farm productivity on relatively older fields/farms has been identified among the drivers of land and soil degradation in southern Burkina Faso (Etongo *et al*., 2015). According to this study, field expansion into forest areas was one of the options adopted by farmers to augment farm productivity. To improve on their local livelihoods while protecting the environment, farmers in the southern region of Burkina Faso, just like those in the north and central regions, also engage in land management practices such as improved fallow, planting pits, composting, stone bunds, and live hedges (Etongo *et al*., 2016; p. 14).

1.2 Data collection

The entry point for this study was contact with a key informant in each of the study villages. The key informants in this case were the village chief and youth leaders, who helped in identifying respondents to be included in the focus group discussions (FGDs). Four FGDs were conducted in each of the four study villages with participants from the three ethnic groups who were identified by the key informants. Fifteen small-scale farmers attended, comprising of six females and nine males in Cassou, seven females and eight males in Dao, and nine females and six males in Vrassan and Kou, respectively. Focus group discussions (FGDs) were conducted by the researcher and a research assistant during which all the research questions were read out and explained to all the participants. Some of the questions discussed during the FGDs included, among others: (i) SLM practices commonly adopted in the community; (ii) land and tree tenure security in relation to the adoption of SLM practices; and (iii) different forms of support (financial and technical) received in promoting these practices during the 12 months prior to the survey.

This was followed by the administration of a survey that enlisted and surveyed 220 households based on a random selection of 55 households from each of the four villages. A

justification of the sample population is rooted in previous studies and information, indicating that at least 98% of the population in the study sites are small-scale farmers engaged in crop production and livestock herding. In addition, 40 farm households with 10 from each study village were randomly selected for the farm survey. The purpose of conducting the farm survey was to assess the current land management practices to validate the interview results. The portfolio of SLM practices in this study is guided by the hypothesis that the factors that influence their adoption differ across the 220 surveyed households.

The questionnaires were pre-tested with participants in the FGDs, and clarifications and improvements were made based on the following themes: (i) respondents' age, gender, ethnic group, education, household labor force, number of farms, farm size (ha), farming years, livestock holding, and land tenure security; (ii) respondents' adoption or non-adoption of planting pits, improved fallow, stone bunds, composting, and life hedges; and (iii) visit to farmers by agricultural extension staff and financial support received during the 12 months prior to the survey, and membership in a farmers' group. It is expected that the adoption of SLM practices varies from one farm household to another due to household-specific, farm-specific, and institutional factors (Table 1). Household labor force was derived from the following categories: family members <15 years old were considered children while those ≥15≤64 years old were considered adults. The relative work force contribution of men, women, and children was weighted by a factor of 1, 0.7, and 0.5, respectively, and the household work force was computed. This method is adopted from a study conducted in Benin Republic (Yabi *et al.*, 2012).

1.3 Data analytical framework

We use a mixed-method analytical approach made of an econometric estimation of the adoption factors complemented by the explanatory qualitative data and information collected from the FGDs.

1.3.1 Specification of the econometric model

Guided by the conceptual perspective along with the potential factors of influence (Section 2), we consider the following Multivariate Probit model (mvprobit) to represent farmers' choices to develop either one or more of the five SLM practices and the factors leading to or influencing such choices and adoption. The M equation multivariate probit model (mvprobit) is:

$$y_{im}^{*} = \beta_{m}' X_{im} + \varepsilon_{im}, \qquad m = 1, 2, 3, 4, 5$$

With- $y_{im} = 1 \; if \; y_{im}^{*} > 0 \; and \; 0 \; otherwise$

To achieve this, we assume that the disturbance terms of the five SLM practices equations are correlated with ρ representing the correlation coefficient and that these disturbance terms are distributed as multivariate normal and independent of the explanatory variables (Wooldridge, 2002: 570). Mathematically, this translates that:

ε_{im}, $m = 1, 2, 3, 4, 5$ are error terms distributed as multivariate normal, each with a mean of zero, and variance-covariance matrix *V*, where *V* has values of 1 on the leading diagonal and correlations $\rho_{jk} = \rho_{kj}$ as off-diagonal elements.

The model stands as an extension of the univariate probit model to allow more than one equation of land management practice. Under the null hypothesis that a correlation equals zero, or that there is no correlation among the land management practices along with the various drivers of their adoption, the model consists of five independent probit equations, which can be estimated separately with a Simulated Maximum Likelihood (SML) (Greene, 2000; Wooldridge, 2007). Each of the five SLM practices, as a dependent variable, is binary, and there is no need to have the same set of explanatory factors in every equation. As such, each of the five SLM practices with its equation, and correlation of disturbances between the four equations, are explored.

As such, based on these assumptions and following Greene (2008: 896), the log-likelihood function for our sample of *220* independent observations is defined as follows:

$$L = \sum_{i} w_i \log \Phi_5(\mu_I; \Omega)$$

With: w_i is an optional weight

$\Phi_5(\mu_i; \Omega)$ is a standard multivariate normal cumulative distribution function, where

$$\mu_i = (K_{i1}\beta_1' X_{i1}, \quad K_{i2}\beta_2' X_{i2}, \quad K_{i3}\beta_3' X_{i3}, \quad K_{i4}\beta_4' X_{i4}, \quad K_{i5}\beta_5' X_{i5})$$

With $K_{ik} = 2y_{ik} - 1$, for each *j*, *k* = 1, 2,…, 5

Ω has elements Ω_{jk}, where $\Omega_{jj} = 1$ for *j* = 1, 2,…, 5-;

Log-likelihood function depends on the multivariate standard normal distribution function $\Phi_5(.)$!

The Maximum Likelihood estimates of the parameters are obtained by maximizing, in only one step, the log-likelihood function that stays on the definition of conditional probability. Indeed, each probit equation explains the probability to adopt SLM practices in relation to farmers' household and farm characteristics, as well as institutional factors. A Wald test or a Likelihood ratio test is used for the null hypothesis that ρ equals to zero. The rejection of the null hypothesis implies that the decision associated to the use of the five SLM practices are interrelated, as well as the factors affecting such decision.

1.3.2 Data analysis

The econometric model is estimated, consistently to the equation above, using the mvprobit program (Cappellari and Jenkins, 2003) in STATA 11.2 and its post-estimation prediction program (mvppred), which allows predicting the joint probability of non-practitioners of all and the marginal probability of practicing one of the SLM options — planting pits, life hedge, composting, stone bunds, and improved fallow. The p-values (Table 1) further reaffirm that some socio-cultural and institutional factors are likely to have more influence than others on each of the five SLM practices. These values were relatively lower for household work force and land tenure but much higher for technical support and belonging to a farmer's group.

The complementary qualitative data from the FGDs were analyzed using verbatim transcription and Wordstat 7 content analysis software that enable us to identify the key themes emanating from the discussion. The Wordstat 7 software was used because of its ability to find themes or relationships in verbatim responses, focus group transcripts, or other text sources. It involved four main steps (Adam *et al*., 2015) as follows: (1) identification of the main themes; (2) attributing codes to the main themes; (3) classification of responses under the main themes; and (4) integration of themes and responses into narratives.

Table 1. Summary means for practicing the land management options

Variables	Zai practice				Life hedge				Composting				Full sample (n=220)
	Non-practitioners (n=91)	Practitioners (n=129)	t test	P-value	Non-practitioners (n=188)	Practitioners (n=32)	t test	P-value	Non-practitioners (n=126)	Practitioners (n=94)	t test	P-value	
Age of HH head (years)	41.88 (13.59)	47.22 (14.12)	-2.82	0.0026	45.27 (14.10)	43.5 (14.33)	0.65	0.7391	44.35 (14.02)	45.89 (14.27)	-0.8	0.2123	45.01 (14.11)
Education (dummy)	0.15 (0.36)	0.15 (0.36)	0.13	0.5529	0.13 (0.34)	0.25 (0.44)	-1.43	0.0800	0.14 (0.35)	0.16 (0.37)	-0.34	0.3672	0.15(0.36)
HH work force (count)	9.12 (6.28)	15.06 (7.75)	-6.26	0.0000	12.43 (7.79)	13.63 (7.46)	-0.83	0.2051	10.59 (6.06)	15.31 (8.88)	-4.44	0.0000	12.6 (7.74)
Farm age (years)	19.04 (11.97)	24.42 (11.98)	-2.14	0.0006	22.12 (12.33)	22.63 (11.92)	-0.22	0.4137	21.52 (12.27)	23.1 (12.22)	-0.94	0.1736	22.2 (12.24)
Farm size (ha)	6.07 (5.46)	7.22 (4.63)	-1.65	0.0505	6.58 (4.92)	7.72 (5.51)	-1.1	0.1394	6.02 (4.10)	7.72 (5.91)	-2.4	0.0087	6.75 (5.01)
Number of farms	1.78 (1.20)	2 (1.04)	-1.41	0.0797	1.89 (1.08)	2 (1.27)	-0.45	0.3287	1.97 (1.15)	1.83 (1.05)	0.93	0.8223	1.91 (1.11)
Land tenure (dummy)	0.48 (0.50)	0.45 (0.50)	0.49	0.6891	0.44 (0.50)	0.63 (0.50)	-2	0.0257	0.56 (0.50)	0.34 (0.48)	3.25	0.0007	0.46 (0.50)
Number of cattle (count)	4.54 (10.97)	11.7 (22.82)	-3.09	0.0011	8.53 (18.87)	9.97 (20.91)	-0.37	0.3583	1.41 (1.43)	18.55 (26.26)	-6.32	0.0000	8.74 (19.13)
[a]Financial support (dummy)	0.44 (0.50)	0.51 (0.50)	1.05	0.1470	0.49 (0.50)	0.44 (0.50)	0.54	0.7035	0.44 (0.50)	0.53 (0.50)	-1.28	0.1006	0.48 (0.50)
[a]Technical support (dummy)	0.27 (0.45)	0.26 (0.44)	0.18	0.5724	0.28 (0.45)	0.22 (0.42)	0.71	0.7602	0.25 (0.44)	0.29 (0.45)	-0.55	0.2930	0.27 (0.44)
Belong to farmers' group (dummy)	0.16 (0.37)	0.25 (0.43)	-1.52	0.0647	0.21 (0.41)	0.22 (0.42)	-0.07	0.4704	0.19 (0.39)	0.24 (0.43)	-0.95	0.1704	0.21 (0.41)

SD in brackets

Table 1. Continued

Variables	Stone bunds				Improved fallow				Full sample (n=220)
	Non-practitioners (n=162)	Practitioners (n=58)	t test	P-value	Non-practitioners (n=162)	Practitioners (n=58)	t test	P-value	
Age of HH head (years)	43.66 (13.86)	48.78 (14.27)	-2.36	0.0101	45.69 (13.87)	43.89 (14.53)	0.9	0.8161	45.01 (14.11)
Education (dummy)	0.14 (0.35)	0.17 (0.38)	-0.53	0.2976	0.08 (0.27)	0.27 (0.44)	-3.42	0.0004	0.15 (0.36)
HH work force (count)	11.14 (6.51)	16.71 (9.33)	-4.19	0.0000	12.8 (8.12)	12.29 (7.11)	0.48	0.6859	12.6 (7.74)
Farm age (years)	20.7 (11.68)	26.38 (12.89)	-2.95	0.0020	21.96 (11.86)	22.58 (12.92)	-0.35	0.3624	22.2 (12.24)
Farm size (ha)	6.22 (3.83)	8.21 (7.21)	-1.99	0.0249	6.53 (5.29)	7.11 (4.52)	-0.87	0.1931	6.75 (5.01)
Number of farms	1.88 (0.97)	2 (1.43)	-0.61	0.2719	1.86 (1.13)	1.99 (1.09)	-0.83	0.2049	1.91 (1.11)
Tenure security (dummy)	0.46 (0.50)	0.48 (0.50)	-0.34	0.3682	0.29 (0.46)	0.75 (0.44)	-7.36	0.0000	0.46 (0.50)
Number of cattle (count)	6.01 (10.13)	16.34 (32.20)	-2.4	0.0097	10.42 (21.37)	5.96 (14.43)	1.84	0.0334	8.74 (19.13)
[a]Financial support (dummy)	0.5 (0.50)	0.43 (0.50)	0.9	0.8152	0.51 (0.50)	0.43 (0.50)	1.11	0.8659	0.48 (0.50)
[a]Technical support (dummy)	0.28 (0.45)	0.24 (0.43)	0.54	0.7000	0.28 (0.45)	0.25 (0.44)	0.4	0.6538	0.27 (0.44)
Belong to farmer group (dummy)	0.22 (0.42)	0.19 (0.39)	0.53	0.7015	0.23 (0.42)	0.18 (0.39)	0.95	0.8273	0.41)

SD in brackets

[a]Visit by agricultural extension staff and financial support received during the 12 months prior to the survey

1.4 Use of the SLM practices by farmers

Patterns of the use of the SLM practices considered vary among the farm households. Given that the 220 farm-households interviewed had the latitude to provide multiple responses about the different SLM practices they applied, this results in a total of 371 practitioners put together across the five SLM practices considered in this study (see Table 1). Based on that figure, zaï pits were used by 34.77% of the surveyed farm households in the case study areas. This is followed using composting (25.3%), stone bunds (15.6%), improved fallows (15.6%), and life hedges (8.6%). Furthermore, the different SLM options applied by each of the farm households were later summed up to provide information on the total number of SLM they adopted. According to Figure 2, 16.4% of the surveyed households used none of the five SLM practices. But, farm households that implemented SLM practices often apply a certain combination of them. Indeed, while 22.3% of the farm households applied only one SLM practice, 25.5% used two practices, and 28.2% used three practices altogether. Fewer households were found to have combined four and all five SLM practices, as reported by a minuscule 6.4% and 1.4%, respectively (see Figure 2).

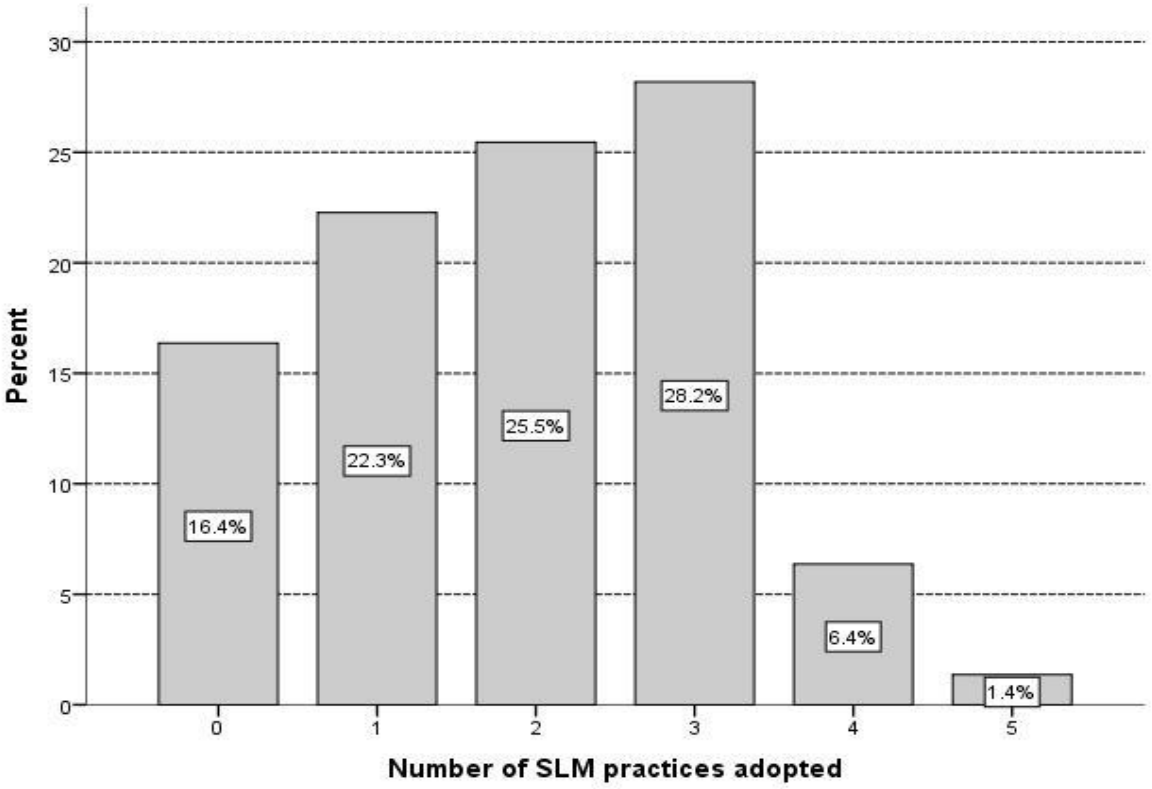

Figure 2. Total number of SLM practices used by surveyed farm households.

1.5 Model results

The Wald tests statistic results presented at the bottom of Table 2 for the overall multivariate model indicate that the null hypothesis — according to which there are no correlations among the land management practices along with the various factors of their adoption — is rejected at the 1% significance level. Accordingly, this attested for significant correlations among the decisions to adopt the SLM options. Such results reveal, as supposed, that the multivariate probit model is appropriate to estimate consistently the factors affecting the adoption of the SLM practices and the ways in which the choices of these practices are interconnected. In addition, the farm household variables in each equation of land management practices contribute significantly as a group to explain the adoption or not of the SLM practices. In other respects, the correlation coefficient ρ among the equations of land management practices is significantly different from zero at the 1% critical level.

1.5.1 Factors influencing the adoption of SLM practices

Results of the multivariate analysis revealed that the adoption of SLM practices is significantly influenced by the following variables: education of the household head, household labour force, land tenure security, livestock holdings, and membership in a farmers' group (Table 2). Farm size and farm age are marginal factors affecting the implementation of SLM practices. Education of the household head is significant at the 10% level for the practice of composting and improved fallow. Coupled with the fact that farm age is also proven significant at the 10% level, this implies educated farmers engage in the use of compost, especially when farmlands are likely to loose soil fertility as the age of the cultivated land increases.

Aside from education, another significant variable is household labor force for zaï (at the 1% level) and stone bunds (at 5% level). Zaï is a traditional practice that requires digging of pits on farmland that are 60 x 60 cm apart. Though the dimension of pits may vary, information from the FGDs supported the fact that this practice is considered labor-demanding and is influenced by household labor force due to the low level of mechanization of smallholder agriculture in the Sahel. Such labor demand supports the fact that the farm size negatively affects the practice of zaï at the 1% level of significance.

In addition, land tenure security influences both improved fallow and live hedges at the 1% and the 10% level of significance, respectively. The factor of livestock holdings is significant at the 1% level for households engaged in composting, and at the 5% level of significance for practitioners of stone bunds. Membership in farmers' groups is significant for households that adopted the use of zaï, and improved fallow at the 1% and the 10% levels, respectively (See Table 2). Though two of the variables used in the model were not significant; (i) the number of farm holdings by farmers; and (ii) visits to farmers by agricultural extension staff during the 12 months prior to the survey, all the other variables were significant at least in one of the five SLM practices.

Table 2. Multivariate probit results of practice of zai, life hedge, composting, stone bunds, and improved fallow on farms as SLM options

	Practice of land management									
	Zai practice		Life hedge		Composting		Stone bunds		Improved fallow	
Variables	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
Age of HH head	0.0038	0.719	-0.0210*	0.073	-0.0220	0.138	-0.0072	0.532	-0.0086	0.426
Education	0.1426	0.559	0.3625	0.143	0.4990*	0.084	0.0895	0.747	0.4265*	0.073
HH work force	0.1172***	0.000	0.0140	0.373	0.0168	0.528	0.0373**	0.039	0.0084	0.645
Farm age	0.0084	0.466	0.0172	0.193	0.0352*	0.062	0.0201	0.144	0.0035	0.770
Farm size	-0.1000***	0.003	0.0301	0.256	-0.0284	0.427	0.0184	0.499	0.0223	0.375
Number of farms	0.0637	0.631	0.0077	0.945	0.1059	0.398	0.0030	0.974	-0.0126	0.908
Tenure security	0.2791	0.190	0.4628*	0.054	0.4454	0.101	0.3714	0.105	1.1284***	0.000
Number of cattle	0.0150	0.169	0.0046	0.446	0.4461***	0.000	0.0183**	0.015	0.0007	0.917
Technical support	0.1845	0.432	-0.3785	0.149	0.0597	0.840	-0.3490	0.171	-0.3201	0.205
Member of farmer group	0.7932***	0.005	-0.3388	0.262	0.3070	0.371	-0.3001	0.306	-0.5179**	0.039
Constant	-1.4324***	0.002	-1.1145**	0.017	-2.2611***	0.000	-1.6036***	0.000	-0.7135*	0.090

Estimated correlations: Rho between Life hedge and Zai= 0.2879** (p=0.034); Rho between Composting and Zai = 0.6943*** (p=0.000); Rho between Stone bunds and Zai = 0.0729 (p=0.572); Rho between Improved fallow and Zai = 0.1365 (p=0.304); Rho between Composting and Life hedge = 0.1940 (p=0.244); Rho between Stone bunds and Life hedge = 0.0683 (p=0.601); Rho between Improved fallow and Life hedge = 0.9355*** (p=0.000); Rho between Stone bunds and Composting = 0.1591 (p=0.413); Rho between Improved fallow and Composting = 0.1469 (p=0.339); Rho between Improved fallow and Stone bunds = -0.1866 (p=0.157)

Likelihood ratio test for all null correlations (rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0): chi2(10) = 59.4261 (p= 0.0000)

Number of observations = 220 Wald chi2(10) = 213.28*** (p=0.000) Log pseudo-likelihood = -465.864

***Significant at 1% level of significance **Significant at 5% level *Significant at 10% level

1.5.2 Association between SLM practices

The other results of the model (Table 2), explicitly displayed in Table 3, indicate that the decision to practice zaï is significantly linked to that of live hedges (rho=0.2879), and composting (rho=0.6943) at the 5% and the 1% levels of significance, respectively. Hence, to some extent, zaï practitioners are not tied to a single land management practice, but also adopt other SLM interventions. The FGDs data indicate that the use of compost in planting pits (zaï) explains the reason for the significant relationship at the 1% level of significance for farmers' decision to adopt composting and zaï.

Similarly, for farm households that adopted life hedges, a correlation does also exist with improved fallow (rho=0.9355) at the 1% level of significance, in addition to the previous mentioned correlation with zaï practice (rho=0.2879) at the 5% level (Table 3). This implies that practitioners of live hedges are likely to practice zaï and improve their fallow because trees constitute an important component in these practices. Security of land tenure concourses in explaining the practice of both live hedges and improved fallow — two likely combinations of SLM practices. The zaï pits are filled with compost, and this facilitates the natural regeneration process of indigenous tree species in the Sahel[5].

On the other hand, practitioners of stone bunds and composting did not show any significant relationship with live hedges. Zaï and stone bunds did not reveal any significant association (see Table 3). Although stone bunds showed significance for household labor force and those holding cattle at the 5% level, no association was found between stone bunds practice and any of the other SLM practices. The lack of association between stone bunds and live hedges, between stone bunds and composting, and between improved fallow and stone bunds (Table 3) indicated that farm households adopt different portfolios of SLM practices, and therefore are likely to promote those practices that complement each other, as shown above.

[5] Natural regeneration is a key characteristic of indigenous tree species in the Sahel. Some examples of these species include, among others, *Vitellaria paradoxa*, *Parkia biglobosa*, and *Adansonia digitata* (Ky-Dembele *et al.*, 2007).

Table 3. Correlation matrix between the different SLM practices used

Rho & sign. level	Zaï	Life hedge	Composting	Stone bunds	Improved fallow
Zaï	1				
Life hedge	0.2879**	1			
Composting	0.6943***	0.1940	1		
Stone bunds	0.0729	0.0683	0.1591	1	
Improved fallow	0.1365	0.9355***	0.1469	-0.1866	1

***Significant at 1% level of significance **Significant at 5% level *Significant at 10% level

Discussion

Results indicated that the adoption of SLM practices in the study area is influenced by several factors ranging from household socioeconomic, farm-specific, and institutional factors. The following sections discuss, in detail, how these factors have influenced the adoption of SLM practices by smallholder farmers.

1.6 Household socioeconomic factors

The level of education of the household heads is an important social factor that influences the adoption of SLM practices. In the context of farm households in rural Burkina Faso, household heads are the ones who make the decision on behalf of the household on major issues, including land use decision making and management. Farm household heads who are educated have the capability to seek information and get necessary support from the government and NGOs. In addition, their analytical capabilities are strengthened, which explains why composting and improved fallow were significant at the 10% level. Our findings are consistent with those of another study conducted in northern Burkina Faso, in which education influences the adoption of planting pits (Sidibé, 2005). Two studies further indicated that farmers in Burkina Faso have developed traditional land management practices — for close to a century — that have the potential of sustaining crop yields under a changing climate (Howorth and O'Keefe, 1999; Mortimore and Adams, 2001).

Household labor force is another factor that influences the adoption of SLM practices, and it is significant for planting pits and stone bunds (Table 2). These two land management practices are both labor-demanding and require a larger labor force or the financial capability to hire such labor (Schuler *et al*., 2016). According to the FGDs, it requires the labor force of two adult males over a one-month-period while working five to seven hours a day, six days a week, to construct planting pits on a hectare. Two studies in Burkina Faso arrived at similar estimates that installing planting pits in just one hectare of land requires six to twelve weeks of one person working every day, depending on soil conditions (Ndiaye and Zoungrana, 2010; Lenhardt *et al.*, 2014). Furthermore,

the FGDs indicated that compared to other SLM practices, planting pits are one of the best and effective techniques in land rehabilitation. Previous scholarly empirical studies have concluded that planting pits can rehabilitate land within three to five years, while improved fallow will require seven to 10 years to achieve the same results (Schuler *et al*., 2016; Kpadonou *et al*., 2017).

Household livestock holdings influence the adoption of SLM practices, especially composting and stone bunds. The dung from cattle and donkeys provides material for compost, which is mixed with crop residues to produce manure, thus explaining its influence on composting. The dung is mixed with crop residue in a pit and allowed to decompose. As such, the availability of compost material by farm households influences their adoption – a finding that corroborates an earlier study conducted in central Burkina Faso (Ouédraogo, 2005). Kpadonou et al. (2017) found out that stone bunds are labor-intensive. In Burkina Faso, donkeys are used in a cart-driven system call '*charet'* to transport fuelwood, harvested crops, water, and other household items (Etongo *et al*., 2016a). This means of transportation is used during the construction of stone bunds to transport stones from one section of the farmland to another, which in turn can limit the adoption of the practice only to farmers who can afford a '*charet'*. According to Lenhardt *et al*. (2014), a lower rate of adoption of this technology is higher amongst resource-poor households.

1.7 Farm-specific factors

The number of farms owned by farmers did not show any significance on the adoption of SLM practices. However, farm size was found to be negatively significant for farm households engaged in the use of planting pits. Therefore, unlike the other SLM practices, the size of a farm is important in land management decision making, especially for the construction of planting pits that requires a larger work force and is labor-demanding. It already has been found that farm size, the type of farm, and the level of technical assistance affect the adoption of SLM practices (Aklilu and de Graff, 2007). The number of farming years is crucial because soil fertility is expected to decline with an increase in farming years if proper and effective land management interventions are lacking. It stems from the FGDs that the majority of the farms have been cultivated for fifty years or more through shifting cultivation. Another issue raised during the FGDs is that shifting cultivation is almost disappearing, and bush fallows are under intensive threat due to land scarcity.

Given that most of the farmlands have a higher number of years of farming, the use of compost alone and the lack of other SLM practices would produce minimal results. Therefore, little investment to improve the farmland will not only produce any effect to its degradation status, but

also affect crop production in the long run. Though composting has proven to be an important soil fertility management practice in Burkina Faso (Ouédraogo et al., 2001; Gray, 2005) and the Sahel (Osbahr and Allan, 2003; McClintock and Diop, 2005), some of the documented constraints of its adoption (Reij *et al*., 2005; Etongo *et al*., 2015) have led to field expansion. This latter practice is another easier adaptation strategy undertaken by farmers when food production declines (Reenberg *et al*., 2003; DFID, 2004).

1.8 Institutional factors

Extension services in the form of support provided to farmers — be they financial, human, material, or technical — are invaluable factors that influence the adoption of SLM practices. Here, the significant factor of membership in a farmers' group is an example of institutional channel at the local level through which different forms of supports can be provided to farmers; since it is difficult for the extension workers and NGOs to deal with individual farmers. The International Fund for Agricultural Development (IFAD), together with other NGOs and research centers, (TreeAID, Centre for International Forestry Research (CIFOR), and the World Agroforestry Centre (ICRAF)) have been actively involved in Burkina Faso through different programs, trainings and interventions with local farmers (IFAD, 2004; Belemvire *et al*., 2008). Some of these projects have provided farmers with tree seedlings through farmers' groups for improved fallow. According to the FGDs, direct financial support is not provided to the farmers, but in the form of trainings and provision of materials that can improve land management.

On the issues of land and tree tenure security, customary systems still dominate and influence the adoption of SLM practices differently among farmers (Brasselle *et al*., 2002). Sharecropping, the inheritance system, and freehold are the different forms of access to land in rural Burkina Faso (Ouédraogo *et al*., 2001; Etongo *et al*., 2015). Sharecropping occurs at two levels, and each has a different effect on land management as follows: (i) inherited land jointly cultivated by family members, especially adult male children who have started their own families; and (ii) leasing of a portion of the land on a fixed-term to another farmer. In the latter, permission is needed from the landlord before certain practices could be carried out — e.g. a study in Burkina Faso found out that permission is granted to tenant farmers only for the planting of non-economic trees (Etongo *et al*., 2016b). In relation to freehold, the land chiefs assign a portion of land to a migrant household in exchange of gifts, with the condition that local rules must be observed. This form of land tenure is still being contested in rural Burkina Faso given that improving the land is considered a form of secured tenure (Brasselle *et al*., 2002). Based on information during the FGDs, some migrants are

still considered to be borrowers of the land and lack the bundle of rights to own, transfer, and sell land. Those who perceived their tenure of the land as insecure are likely to engage in unsustainable practices, as supported by an early study conducted in Southern Burkina Faso (Ouedraogo *et al*., 2009). Additionally, several studies in SSA also found out that an enabling environment supported by appropriate policies and institutional incentives, especially on land and tree tenure security, are important for the adoption of low-cost land management practices (Lefroy *et al*., 2000; Ajayi *et al*., 2003; IFAD, 2006; Matata *et al*., 2010). Therefore, the issue of 'legality' and 'legitimacy' have attracted attention to the uncertainty in land tenure among farmers and to some extent, influences their land management practices.

Conclusions

This study reveals that socio-cultural and institutional factors influence the adoption of SLM practices by smallholder farmers in southern Burkina Faso. In addition, a significant correlation was found between different SLM practices — e.g. the decision to practice zaï is significantly linked to that of live hedges and composting. Therefore, the adoption of a set of SLM practices that complement each other should be encouraged to ensure long-term sustainability. This study argues that despite the prospect of these land management practices in improving soil and food production, ownership rights over land is a key incentive for investment. The issue of 'legality' and 'legitimacy' over land in Burkina Faso is still contested despite the new land law that was issued five years ago. The monetization of land transactions has acted as a push factor for securing formal land title deeds. Those in possession of such deeds have a 'legal' claim over their land. On the other hand, the customary system is dominant in most rural communities in Burkina Faso, which also provides them with 'legitimate' claims to the land. In the context of this study, 'legitimacy' is linked to the following: (i) land acquired through inheritance; (ii) land acquired by belonging to an indigenous group whose ancestors were the first to occupy the land; and (iii) land that has been improved by an individual, irrespective of his or her residential status. Such agreement is largely dominated by customary arrangements without formal documentation. Given that improving the land in the context of Burkina Faso is considered a sense of ownership, the adoption of SLM practices is likely to be influenced by tenure security in addition to other factors at the household level.

The study also contributes to highlighting detailed farmer-level and institutional-related factors that need consideration in achieving the sustainable development needs through the promotion of SLM practices. It provides ground in support of the political will and ministerial mandate that underscores such desire of scaling up and out SLM practices. However, to capture the global picture

that will further inform the successful promotion of SLM practices, future emphasis and further research are needed on approaches and policies that can drive a change in behavior among smallholder farmers, thereby facilitating the promotion of already tested and proven SLM practices in the Sahel and SSA in general.

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