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RESEARCH ARTICLE

Factors that Drive the Implementation of Sustainable Land Management (SLM) Practices by Soybean Producers in North Benin (West Africa)

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ABSTRACT

Sustainable Land Management (SLM) practices not only increase the soil's water conservation capacity and restore degraded soils but also increase the availability of microelements essential for soybean productivity improvement. However, despite the degradation of agricultural lands, their low fertility, and the sustained efforts of development agencies, the adoption or continued use of these SLM practices is not widespread. This study identified the socioeconomic factors influencing the adoption of SLM practices on soybean farms. Data collected on 200 soybean producers and analysed using a probit model showed that producers living close to markets were likelier to adopt SLM practices than those living far from them. Off-farm activities, education, and the availability of labour foster the adoption of SLM practices. Producers' technical training and access to extensions improve their information and knowledge of SLM practices and optimise their efficiency in using these technologies through learning. Adopting technologies such as livestock parking and spreading animal droppings has contributed to improving neighbourhood relations between farmers and transhumant breeders and, to a certain extent, reducing tensions between these two communities. This study suggests that the promotion of technical training for producers, improvement in their access to the market, and advice on SLM practices are necessary to boost the adoption of SLM practices.

INTRODUCTION

As in most West African countries, land degradation in Benin is one of the major problems affecting agricultural land productivity. Indeed, a study carried out by the Soil Laboratory of the National Institute of Agricultural Research of Benin (INRAB) in three of the country's twelve departments revealed that 90% of the land has a low to deficient level of fertility and 2.2 million hectares of agricultural land have degraded in 10 years, i.e. 19% of the national territory (ProSol, 2018). This situation is exacerbated by the fact that agriculture faces climate change and variability.

Land degradation is mainly due to natural factors (biophysical, topographic, and climatic conditions) and anthropogenic factors, such as the massive use of chemical fertilisers, increasing population pressure, and unsustainable cultivation practices (e.g. slash-and-burn cultivation, vegetation fires, etc.) (FAO, 2017; Etsay et al., 2019). Thus, producers have virtually depleted the nutrient reserves in their agricultural lands, resulting in soils with very low fertility and productivity (Verbree et al., 2015; Baba et al., 2016). Land degradation reduces the capacity of land resources, disrupts ecosystem integrity and services, and undermines the ability of farms to adapt to climate variability (Dallimer et al., 2018; Mersha et al., 2022)

To help rural producers overcome this situation and produce sustainably, several projects and programs (e.g. ProSOL, ProCIVA, ProSAR, and ProPFR) have promoted Sustainable Land Management (SLM) practices such as technologies and "best measures" to address land degradation problems. These SLM practices include organic fertilisation, integrated soil fertility management technologies, incorporation of residues, water and soil conservation, agriculture/livestock integration, agroforestry, and climate change adaptation measures, such as tillage perpendicular to the slope (Baba et al., 2016; Birnholz et al., 2017; ProSol, 2018).

The main goal of these SLM practices is to protect agricultural land or rehabilitate degraded soil while promoting the long-term productivity of this land (Branca et al., 2013). SLMs are an effective technique for improving soil physicochemical properties, maintaining the quality of cultivable soils, and positively restoring soil ecosystems (Terefe et al., 2020; da Silva et al., 2021). It also increases soil carbon sequestration, restores degraded soils and improves crop productivity, which is essential for reducing food insecurity and enhancing the incomes of smallholder farmers (Branca et al., 2013; Diogo et al., 2021).

In Benin, however, despite the degradation of agricultural lands, their low fertility, and the sustained efforts of development agencies, the adoption or continued use of these SLM practices is not widespread. The low level of information among decision-makers and extension agents on the factors determining the adoption of these SLM practices could, among other things, explain this situation. The lack of capacity and awareness of SLM practices among rural farmers is a serious obstacle to implementing these technologies (Wairiu, 2017).

This study aimed to fill this gap by targeting soybean-producing farms. The choice of soybeans is justified by the fact that this crop often suffers from water stress caused by the low water retention capacity of the land, which obliges producers to harvest their soybeans early to reduce losses in the field (Zhai et al., 2021). Soybean plants also suffer from soil deficiency in certain microelements, such as Mn, Fe, and possibly Mo and B, in particular soils (Chaney, 1986). This is one of the causes of Benin's low soy productivity. Indeed, soy productivity remains far from expectations because the potential yield estimated at three tons per hectare (for the soy varieties promoted in Benin) is far from being achieved. Indeed, soybean yield is currently estimated to be 1,247 kg/ha in Benin and 1,135 kg/ha in the country's northeast (DSA, 2022). Using SLM practices increases the soil's water conservation capacity and the availability of microelements essential for soybean growth (Bechtaoui et al., 2021).

Thus, the main objective of this study is to investigate the factors that affect the adoption of SLM practices in soybean farms in the semi-arid region of northeastern Benin.

MATERIALS AND METHODS

Theoretical framework

Technology adoption is when a producer decides whether to adopt or reject a technology. This adoption generally occurs when the producer has sufficient knowledge of the technology. This is rational behaviour because the producer prefers the technology that offers the most utility (Rogers, 2003; Mounirou, 2015). Thus, the rational producer prefers the SLM practice, which provides him with the highest utility compared to an alternative technology. In other words, let U_1 be the utility provided by a given SLM practice and U_0 be the utility provided by the old or alternative technology. The producer will adopt the SLM practice if $U_1 > U_0$; that is, a given soybean producer I will adopt the SLM practice if the difference in utility (U_1-U_0) is greater than zero.

This difference in utility can be written as a function of factors that affect the adoption of the technology considered (Verbeek, 2004). This equation can be written as follows (Greene, 2012):

$$y^* = U_{i1} - U_{i0} = X_i\beta + \varepsilon_i \quad (1)$$

where y* is the utility difference (U_1-U_0) which is not observable and is often referred to as the latent variable, X_i are observable factors and ε_i non-observable factors that can influence the adoption of a given SLM technology. In this study, adopting a given SLM practice is considered binary, with 1 when the producer adopts the measure and 0 otherwise. The factors influencing technology adoption can be analysed using binary models, such as logit and probit models. These two models lead to the same conclusions. In this study, we used a probit model.

Data used

The data used in this study were collected for 2022 in the Borgou Region (northeastern Benin) using qualitative and quantitative approaches. Qualitative approaches included semi-structured interviews with key informants (extension agents, managers of cooperatives working on soy, etc.) and focus group discussions in the study villages. Interview guidelines were used for this purpose.

The quantitative approach was based on a questionnaire implemented in KoBoCollect and administered to soybean producers selected using a multistage sampling technique. Interviews with key informants helped identify the main soy-producing villages in which SLM practices have been disseminated over the last two decades. Five villages were selected randomly. A census of soybean producers was conducted in the selected villages to obtain the sampling frame. In each village, 40 soybean producers were selected using systematic random sampling, yielding 200 producers for the study.

The collected data included the different SLM practices used by soybean producers, their sociodemographic characteristics (age, education, literacy, household size, etc.), technical training in the agricultural field, access to credit, area sowed, experience in soybean production, membership of an organisation or cooperative, contact with an extension agent, and distance between the village and the nearest town.

Data analysis

The data analysis methods used depended on the type of data collected. Thus, content analysis was used for the qualitative data. Descriptive statistics (mean, standard deviation, percentage, and frequency) were used to describe the study sample and SLM practices for the quantitative data. The probit model used to identify the factors influencing the adoption of SLM practices is as follows:

$$y_i = \beta_0 + \beta_1 DISTVIL + \beta_2 GENDER + \beta_3 INSTRC + \beta_4 EXTRG + \beta_5 HHSIZE + \beta_6 COOPR + \beta_7 CVULG + \beta_8 FORMG + \beta_9 ACRED + \beta_{10} DTERR + \beta_{11} SUPD + \beta_{12} EXSOJ + \beta_{13} DISTCV + \beta_{14} FERTCL + \varepsilon_i \quad (2)$$

with y_i the dependent variable, that is, the SLM practice considered. These include rotation or short-term fallow based on legumes (seed legumes, cover legumes, and fodder plants), crop residue management, the spreading of cattle dung and animal droppings, parking of animals (sheep or cattle) on agricultural plots, and ploughing perpendicular to the slope. Table 1 presents the independent variables included in the probit model are Table 1.

Distvil: Distance (km) between villages and the nearest urban area. In the literature, proximity to urban areas has often favoured innovation adoption. For example, Sodjinou et al. (2015) and Hinnou et al. (2018) note that the proximity of producer villages to urban areas encourage the adoption of agricultural innovation. Thus, we hypothesised that DISTVIL would have a negative sign, indicating that producers living close to urban areas would be more likely to adopt SLM practices.

Table 1: Description of dependent and independent variables used in the probit model

Variable	Type of variable	Label	Expected sign
Independent variables			
DISTVIL	Continuous	Distance from producer's house to the nearest urban area (km)	-
GENDER	Binary	Gender of the producer (1 = male, 0 = female)	±
INSTRC	Continuous	Schooling of the producer (year)	+
EXTRG	Binary	Have an off-farm activity (1 = yes)	±
HHSIZE	Continuous	Household size (number of person)	+
COOPR	Binary	Member of cooperative (1 = yes)	+
CVULG	Binary	Contact with extension services (1=yes)	+
FORMG	Binary	Technical training in soybean production (1=yes)	+
ACRED	Binary	Access to credit (1=yes)	+
DTERR	Binary	Have sufficient land for agriculture (1 = yes)	+
SUPD	Continuous	Total agricultural area available (ha)	+
EXSOJ	Continuous	Experience in soybean production (year)	+
DISTCV	Continuous	Distance between producer's home and the farm (km)	-
FERTSL	Ordinal	Farmer perception of the fertility status of the soil (1=very infertile, 2=infertile, 3=fertile, 4=very fertile)	-
Dependent variables			
PLANTM	Binary	Rotation or short-term fallow based on legumes (1 = yes)	
GRESIRE	Binary	Adoption of Crop residue management (1=yes)	
EPANFIN	Binary	Cattle dung and animal droppings spreading (1=yes)	

PARCBT	Binary	Parking of animals (sheep or cattle) on agricultural plots (1=yes)	
LABPEP	Binary	Ploughing perpendicular to the slope (1=yes)	

Gender: Gender of the producer, with 1 for male and 0 for female. We assume that the effect of gender on the adoption of SLM measures could be positive or negative. The effect of gender on technology adoption is controversial. Thus, according to Stiem-Bhatia et al. (2017), the small area of land women cultivate limits the adoption of SLM practices based on fallow, such as fallowing with legumes such as Mucuna pruriens. However, female farmers were likelier to adopt compost, cattle dung, and animal droppings than male farmers, who often have large farms. Mersha et al. (2022) also noted that being female reduces the probability of adopting new agricultural technologies, as they have less access to productive resources and are physically weaker than men.

Instrc: Producers' level of education (in years) Most socioeconomic studies identify education as a crucial element in farmers' decisions to adopt agricultural innovations (Carlisle, 2016). Education allows producers to communicate with extension agents and read and understand extension documents (Sodjinou, 2024). Accordingly, we expect the coefficient of this variable to have a positive sign.

Extrg: The practice of off-farm activities, with 1 if the producer has off-farm activities and 0 otherwise. Off-farm activities, including SLM practices, are sources of additional resources that can be reused to implement innovation. Carlisle (2016) showed that off-farm activities are among the primary drivers of farmers' adoption of conservation SLM practices. However, under certain circumstances, if they flourish, off-farm activities can lead the producer to acquire new land and, in turn, neglect SLM practices. Thus, the influence of this variable on the adoption of SLM practices can be either positive or negative.

Hhsize: Size of the producer's household (number of people living in the household). Producers often rely on family labour for agricultural production in the study area. Thus, the more family labour the producer has, the more inclined he will be to adopt technologies requiring more labour. Indeed, according to Moumouni et al. (2013) and Tede et al. (2023), the producer could initially try the technologies, but his decision to adopt them will depend on the availability of labour, since SLM practices increase the demand for labour. Therefore, the expected sign for this variable is positive;

Coopr: Membership in a cooperative, with a value of 1 if the producer is a cooperative member and 0 otherwise. The effect of this variable on the adoption of SLM practices is assumed to be positive. Indeed, several authors (e.g., Raga et al., 2024; Assogba et al., 2017) have shown that membership in producer cooperatives influences the adoption of innovations, notably organic fertilisers and soil fertility management technologies.

Cvulg: Contact with extension agents, with a value of 1 if yes and 0 otherwise. In agroeconomic literature, most authors conclude that contact or access to information benefits farmers' adoption of agricultural innovations and technologies. For example, Masangano and Miles (2004) showed that producers' contact with extension agents positively affects the adoption of improved cowpea varieties. According to Kaweesa et al. (2020), the two main reasons producers adopt agricultural technologies, notably conservation agriculture, are access to information and dissemination strategies. This is consistent with the findings of Chang et al. (2024), who reached a similar conclusion in their review of the determinants of sustainable agricultural practices for rice cultivation in Southeast Asia. Thus, we assume this variable would have a positive sign coefficient; for example, producers in contact with extensions are likelier to adopt SLM practices.

Formg: Training the producer in agricultural production techniques, especially soybeans, with a value of 1 if yes and 0 otherwise. According to Tede et al. (2023) and Teno et al. (2018), a trained and monitored producer changes their decisions in favour of using technologies. Assogba et al. (2017) also noted that technical training influences the adoption of innovations, such as improved seed and compost application. In their review of sustainable crop farming practices in South Asia, Begho et al. (2022) found that training positively influenced producers' decision-making. Thus, we assume that producers benefit from technical training are more likely to adopt SLM practices.

Acred: Access to credit, with 1 if the producer obtains credit and 0 otherwise. It is essential to enable producers to purchase legume seeds, transport animal droppings, and address other financial constraints. Thus, as Feder et al. (1985) and Teno et al. (2018) note, credit is a key driver of adopting agricultural technologies. Sodjinou (2024) obtained similar results when identifying the determinants of village poultry technologies. Therefore, this variable is expected to have a positive sign, indicating that producers with greater access to credit are more likely to adopt SLM practices.

Dterr: The availability of sufficient land for agricultural production, with 1 if the producer feels that he has sufficient land and 0 otherwise. According to Raga et al. (2024), land availability positively affects ALM technology adoption. This can be explained by the SLM technology requiring more space. Thus, the variable was expected to have a positive sign.

Supd: Total amount of available agricultural land (ha). Several studies (for example, Raga et al., 2024; Adekambi et al., 2021) have shown that planted area has a positive effect on the adoption of technologies, particularly soil and water conservation practices. Thus, we hypothesised that producers with large land areas would be more likely to adopt SLM practices.

Exsoj: Experience in soybean production (years). According to Sall et al. (2000), knowledge gained from working in an uncertain production environment can help evaluate information, affecting farmers' adoption decisions (Sodjinou 2011; Sodjinou 2024). Producer experience can influence the decision to adopt sustainable agricultural land practices. Therefore, we hypothesise that this variable positively influences the adoption of SLM practices.

Distcv: distance (km) between the producer's house and the farm. The closer a producer's farm is to his house, the more likely he is to adopt SLM technologies. Adekambi et al. (2021) found that the distance of farms from producer villages positively affect their decision to adopt technologies requiring maintenance and close monitoring. Accordingly, it is expected that the sign of this variable will be negative, meaning that producers with farms closer to their homes will be more favourable to the adoption of SLM practices.

Fertsl: The peasant's assessment of the soil fertility in his plot, with 1 if the producer finds the plot very infertile, 2 if the plot is not very fertile, 3 if he considers the soil fertile, and 4 if the soil is very fertile. The farmer's perception of the fertility of his plot is an essential element in his decision-making. Indeed, according to Tede et al. (2023), a producer who considers his land's fertility level unacceptable is likelier to adopt SLM practices. Consequently, this variable was expected to have a negative sign.

The coefficients of the probit model were estimated using the maximum likelihood method (MMV) in Stata/SE 15.1 software for Windows (StataCorp, 2017). A likelihood ratio test was used to test the null hypothesis that all coefficients associated with the explanatory variables were simultaneously equal to zero. The significance level of the coefficients of the independent variables, H0: $\beta_k = 0$, is tested using the z statistic, which is equal to the ratio of the coefficient and its standard error: $\beta_k/\hat{\sigma}_{\beta_k}$ (Wooldridge, 2013). Furthermore, in addition to the β_k coefficients, the marginal effects of the independent variables were estimated since β_k are not directly interpretable in terms of probability. The marginal effects are *ceteris paribus*, which is the change in the dependent variable for a slight change in the independent variable.

RESULTS AND DISCUSSION

Description of SLM practices used by soybean farmers

Five main SLM practices were identified at the interviewed soybean farms: legumes, crop residue management, spreading animal droppings, livestock parking (cattle, sheep, etc.), and ploughing perpendicular to the slope. In the sample, 87% of interviewees adopted at least one of the five SLM technologies (Figure 1). As shown in Table 2, the five main reasons for adopting SLM practices were their ability to increase soil fertility (91% of the producers) and provide fodder (29% of respondents), availability of family labour (23%), their ability to improve soybean productivity (18%), and to provide edible seeds (20% of interviewees).

Table 2: Reasons for adopting different SLM practices (in percentage of adopters)

Reasons for adopting SLM	Legumes	Crop residues management	Spreading animal droppings	Livestock parking	Ploughing perpendicular to the slope	At least one of these technologies
Improves yield	20,4	14,5	33,3	7,5	9,1	17,8
Provides fodder	0,0	56,6	0,0	2,2	0,0	28,7
Provides edible seeds	79,6	0,0	0	0,0	0,0	19,5
Generates money/better income for the producer	18,5	0,0	0,0	0,0	0,0	5,2
Improves soil fertility	72,2	60,2	79,2	95,5	13,6	90,8
Reduces soil erosion	0,0	1,2	0,0	0,0	100,0	12,6
Controls weeds	24,1	0,0	0,0	0,0	0,0	7,5
Reduces the number of weeding	11,1	0,0	0,0	0,0	0,0	3,4
Availability of family/less demanding labour	11,1	0,0	0,0	28,4	13,6	23,0

Maintain soybean quality	0,0	1,2	16,7	0,0	0,0	2,9
Readily available	0,0	1,2	0,0	0,0	0,0	0,6

The identified legume-based SLM practices included short fallow based on cover legumes (Mucuna pruriens), and fodder plants (Gliricidia sepium and Aeschynomene histrix), rotation and intercropping techniques based on seed legumes (Cajanus cajan). These legume-based SLMs were adopted by 27% of interviewees (Figure 1). In the study area, Mucuna pruriens was used for short-term fallow (7–12 months) in rotation on leached soils or in association with soya or cereals (maize, millet, and sorghum). Adopted by 12.5% of soybean producers surveyed, this technology helps prevent soil erosion and improves soil fertility because of its potential for nitrogen fixation. According to Maliki (2013) and Kouelo et al. (2022), covering legumes enhances the availability of organic matter and nitrogen in the soil, controls weeds, and reduces the risk of runoff and erosion. The utilisation of this technology is not widespread among the surveyed producers for three main reasons: (i) peasants do not have enough land for Mucuna pruriens cultivation as short fallow; (ii) in associated cultivation, peasants think that Mucuna pruriens suffocates the field too much; and (iii) the wandering of animals sometimes prevents its development. This aligns with the findings of Moore et al. (2016), who noted that the most significant challenges to cover crop adoption include short planting windows for cover crops and the extra time required to manage cover crops.

Cajanus cajan (or pigeon pea), a drought-tolerant plant capable of regenerating or improving soil fertility, is adopted by 18% of the soy producers surveyed. Producers combine it with soybeans to benefit simultaneously from several products on the same plot. Pigeon pea is a multi-annual crop (with several harvest possibilities) with high biomass productivity that can be used in animal feeding (Odeny, 2007; Ayena, 2017). Constraints to adopting pigeon peas include the additional cost necessary for cultivation and the risk of destruction by transhumants or wandering animals.

The producers studied used improved fallows based on Gliricidia sepium to restore the fertility of degraded lands or limit soil water erosion. Only 1.5% of soy producers surveyed have adopted this technology. Aeschynomene histrix, a herbaceous legume, was adopted by 5% of interviewed producers. This plant's advantage is that producers use it as fodder for animal feeding, particularly ruminants, rabbits, and even poultry. Destruction by animals is the primary constraint limiting the adoption of this plant improver.

Table 2 indicates that the main reasons for adopting legumes by the producers surveyed included their ability to provide edible seeds (80% of interviewees), to better increase soil fertility (72% of cases), and to reduce the number of weddings (11% of cases). Other reasons that producers mentioned included the ability of these legumes to control weeds (24% of farmers), to improve soybean yield (20%), and to generate money or more income for the producer (19 %).

Crop residue management (or mulching with crop residues) consists of letting harvest residues degrade on the plots or incorporating them during ploughing to stimulate their biodegradation, contrary to the common practices of burning these residues. The degradation of these residues allows for organic fertilisation of the soil. Nearly 41.5% of the producers studied have adopted this technology. To achieve this, these producers avoid burning harvest residues and use them partially as fodder (57% of cases). According to Badou et al. (2013), soybean residues rarely return to the soil because of the traditional harvesting practices of burning or removing them from the field. The two main reasons for adopting this technology were its ability to improve soil fertility (60% of adopters) and crop yield (15% of interviewees). Other reasons (1% of adopters) included the possibility of residues to reduce soil erosion, to maintain the quality of soybeans, or the fact that this technology is readily available. According to the interviewed peasants, the excess work generated, vegetation fires, and termites that degrade the residues were the main constraints to adopting SLM. For other peasants, crop residues are not incorporated into the soil or used as mulch because they are increasingly used or marketed as hay. Mersha et al. (2022) reported the results for northwest Ethiopia, where crop residues and cow dung were used as household energy sources.

The spreading of animal droppings involves spreading over plots or incorporating animal droppings into the ground during land ploughing. This technology improves soil fertility and water retention capacity, enhancing crop productivity. According to the producers interviewed, the constraints to adopting this technology were the high transport cost and difficulty finding droppings. Approximately 12% of soy producers surveyed used this technology because it improves yield (33% of adopters), improves soil fertility (79% of cases), or enhances soy quality (17% of adopters).

Livestock parking involves immobilising animals (generally cattle and sheep) on agricultural plots overnight during the dry season. This technique is performed in a rotating manner in which the farmer's field is subdivided into several plots. Thus, for a maximum of 15 days, animals stationed in one plot were transferred to another plot to distribute their droppings. According to Baco et al. (2003), animals are parked with the farmers' animals or based on contracts with transhumant herders (mainly Fulani). Before the Fulani agree, they must guarantee remuneration in kind or cash (Baco et al., 2003). Used by 67% of the producers interviewed, this technology promotes soil fertilisation but requires perfect collaboration between farmers and breeders. Their use can lead to soil compaction if the number of animals exceeds the required number. However, producers mainly adopt it to increase soil fertility (96% of cases) because of the availability of family labour (28%), to improve soybean yield (8%), and to allow animals to use pasture and harvest residues available on the plot (2%). These results align with Kasse (2019), who, in a study in Mali, found that 57.8% of the farms surveyed practised nighttime parking of cattle. According to this author, constraints on this practice are mainly linked to a lack of water points, insecurity, and device rotation.

The key informants and resource persons interviewed appreciated soil fertility management technologies, particularly animal manure and livestock penning. Indeed, they believe that adopting these technologies improves cohabitation and neighbourliness between farmers and breeders. When the contracting farmer's farm is located on the edge of a watercourse, the animals benefit from grazing and have easy access to water. These positive effects of SLM practices highlight the importance of agricultural–livestock integration in northern Benin, which has undergone two significant changes in recent decades: an increase in the need for animal products and the expansion of cultivated land, leading to a reduction in access to fodder resources and water, greater mobility of herds, and more frequent conflicts between mobile farmers and breeders (Sounon et al. 2019). Livestock parking practices have contributed to implementing the Beninese Government's policy to settle mobile livestock breeders. A study based on simulations allowed Sounon et al. (2019) to show that the practice of sedentarisation would improve the annual numerical production of animals.

Ploughing perpendicular to the slope involved orienting sowing lines perpendicular to the slope. Adopted by 11% of soy producers surveyed, this technology allows water to be conserved in the soil and used later by the plants. The arduousness of this work is a major constraint associated with this technology (Stiem-Bhatia et al., 2017). People using this technology do so because they have sufficient family labour (14% of cases), it reduces soil erosion (100% of cases), improves soil fertility (14%) and soybean yield (9%).

Finally, traditional fallow, the practice of not cultivating agricultural plots for several years (2 to 10 years, depending on the case), was only used by 5% of the soy producers surveyed. According to these producers, this centuries-old practice maintains soil fertility and conserves soil moisture and is recommended for producing good-quality yams with a high yield. This result confirms the findings of other authors, notably Eneyew (2022), who showed that endogenous techniques for managing soil fertility have been abandoned in Ethiopia in favour of chemical fertilisers. According to the author, the reasons justifying this situation include small landholdings, the prevalence of field-crop pests, late-onset and early cessation of rainfall, and the neglect of traditional practices by extension agents that promote introduced alternatives. In Benin, Badou et al. (2013) stated that traditional fallow abandonment is due to increasing demographic pressure, which reduces agricultural land areas and the possibility of long-term fallow land.

Characteristics of adopters of SLM practices

Table 3 indicates that adopters of the different SLM practices are closer to urban areas than non-adopters, except for the spread of poultry and animal droppings and perpendicular ploughing, where the opposite situation is noted.

Table 3: Characteristics of producers according to GDT practiced

Characteristic		Legumes		Crop residues management		Spreading animal droppings		Livestock parking		Ploughing perpendicular to the slope		All (n=200)
		No (n=146)	Yes (n=54)	No (n=117)	Yes (n=83)	No (176)	Yes (n=24)	No (n=63)	Yes (n=134)	No (n=178)	Yes (n=22)	
Distance between village and commune capital (km)		20.6 (6.7)	19.9 (7.0)	20.5 (6.4)	20.4 (7.2)	20.3 (6.7)	21.4 (7.7)	25.4 (6.4)	18.0 (5.5)	20.2 (6.6)	22.6 (7.6)	20.4 (6.8)
Gender of producer (%)												
	Male	72.6	75.9	76.9	68.7	72.2	83.3	68.2	76.1	71.9	86.4	73.5
	Female	27.4	24.1	23.1	31.3	27.8	16.7	31.8	23.9	28.1	13.6	26.5
Age of producer (year)		40.0 (12.0)	43.3 (12.0)	40.9 (12.2)	40.8 (12.0)	41.6 (12.4)	35.8 (8.2)	39.9 (10.4)	41.4 (12.8)	41.2 (12.0)	38.7 (12.8)	40.9 (12.1)
Producer education level (%)												
	None/kindergarten	74.7	66.7	77.8	65.1	76.7	41.7	72.7	72.4	75.3	50.0	72.5
	Primary	3.4	3.7	1.7	6.0	3.4	4.2	1.5	4.5	3.4	4.6	3.5
	Secondary	16.4	29.6	16.2	25.3	17.1	41.7	22.7	18.7	16.9	45.5	20.0
	Superior	5.5	0.0	4.3	3.6	2.8	12.5	3.0	4.5	4.5	0.0	4.0
Practice of extra-agricultural activity (% of yes)		39.7	57.4	36.8	55.4	43.8	50.0	51.5	41.0	41.6	68.2	44.5
Household size (number of people)		5.8 (3.0)	7.7 (4.5)	6.4 (3.8)	6.1 (3.1)	6.4 (3.6)	5.5 (3.5)	5.8 (2.7)	6.5 (3.9)	6.3 (3.5)	5.8 (3.7)	6.3 (3.6)
Belonging to a cooperative (% yes)		19.9	38.9	24.8	25.3	25.0	25.0	19.7	27.6	24.7	27.3	25.0

Contact with extension (% yes)		4.1	16.7	4.3	12.0	7.4	8.3	3.0	9.7	5.6	22.7	7.5
Training in the agricultural field (% of yes)		20.5	59.3	23.9	41.0	29.0	45.8	30.3	31.3	29.8	40.9	31.0
Access to credits (% of yes)		30.8	29.6	29.9	31.3	30.1	33.3	34.8	28.4	32.6	13.6	30.5
Availability of land (% of yes)		26.7	35.2	25.6	33.7	25.6	54.2	27.3	29.9	28.7	31.8	29.0
Total available agricultural area (ha)		6.4 (5.7)	13.2 (37.0)	6.7 (6.4)	10.4 (29.9)	8.0 (21.0)	10.2 (8.2)	6.1 (5.2)	9.3 (24.0)	6.8 (6.5)	19.9 (57.0)	8.3 (19.9)
Experience in soybean production (year)		5.5 (3.0)	6.2 (3.9)	5.3 (2.8)	6.2 (3.8)	5.5 (3.1)	6.8 (4.0)	5.8 (2.9)	5.6 (3.4)	5.8 (3.3)	4.7 (2.8)	5.7 (3.3)
Distance from producer's home to farm (km)		6.7 (5.8)	5.3 (4.0)	6.6 (5.3)	5.9 (5.6)	6.3 (5.2)	6.5 (7.1)	6.1 (4.8)	6.4 (5.8)	5.9 (4.7)	9.4 (9.1)	6.3 (5.4)
Soil fertility (%)												
	Very infertile	23.3	44.4	24.8	34.9	27.8	37.5	13.6	36.6	27.0	45.5	29.0
	Not very fertile	34.9	37.0	35.0	36.1	34.7	41.7	34.9	35.8	36.0	31.8	35.5
	Fertile	39.0	16.7	38.5	25.3	34.7	20.8	48.5	25.4	34.8	18.2	33.0
	Very fertile	2.7	1.9	1.7	3.6	2.8	0.0	3.0	2.2	2.3	4.6	2.5

( ): Numbers in parentheses are standard deviations

Table 3 also shows that the average age of the producers surveyed is 41 years, and those adopting "ploughing perpendicular to slopes", animal droppings, or crop residues are relatively younger than those not adopting these practices. The adopters were older than the non-adopters regarding livestock parking and legumes. This can be explained by the fact that these two technologies (livestock parking and legumes) require producers to have sufficient land. However, in the study area, older people own more land and should be more inclined to adopt SLM practices. Moreover, this assessment confirmed the respondents' perceptions. Indeed, adopters of SLM practices believe they have more land than non-adopters. For example, 30% of livestock housing adopters indicated they had sufficient land compared to 27% of non-adopters in this SLM practice (Table 3). The agricultural area available to adopters was greater than that available to non-adopters, regardless of the SLM measures considered (Table 3).

However, this result contradicts those obtained by Miheretu and Yimer (2017), who found that younger farmers are relatively more open to adopting SLM practices than older farmers. This reflects that younger farmers may have a longer planning horizon and, therefore, be more flexible in adopting SLM technologies (Miheretu and Yimer, 2017).

More men than women adopted the different technologies, except for crop residue management (Table 3). This could be explained by the fact that men have much more access to land than women do. In addition, most producers surveyed (73% of cases) have no level of education. The same situation is noted for all the SLM practices studied, with adopters being more educated than non-adopters, regardless of technology. For example, for legumes, 33% of adopters were educated (3.7% had completed primary school and 29.6% secondary school), compared to 25% of non-adopters. These results agree with the findings of Adekambi et al. (2021), who argued that educated producers are more likely to adopt organic manure.

Adopters were more involved in off-farm activities than non-adopters, except for animal parking, where non-adopters (approximately 52%) were more involved than adopters (41%) (Table 3). This could be explained by the fact that income from off-farm activities is essential for using plants to improve soil fertility.

The average household size of the producers was six (Table 3). Households of non-adopters with perpendicular ploughing, animal droppings, and crop residues had relatively more members than non-adopters. The opposite situation is noted for livestock parking and legumes, where adopter households have more members than non-adopters.

As shown in Table 3, a quarter of the producers interviewed were members of cooperatives or farmer organisations. Adopters of SLM practices tend to be members of cooperatives rather than non-adopters. Similarly, the adopters of SLM practices have more contact with extension agents. The same trend was observed for the training in agricultural techniques. In other words, producers who adopted SLM practices seemed to have participated much more in training in various fields related to agriculture (e.g. production techniques, access to credit, and marketing).

Adopters of SLM practices have lower access to credit than non-adopters, except for crop residues and the spread of animal droppings (Table 3). The average number of years of experience in soybean production was six, and adopters of legumes, crop residue management, and animal droppings had relatively more experience in soybean production than non-adopters. For livestock parking and ploughing perpendicular to the slope, non-adopters were more skilled in soya production.

Legume adopters and crop residue management appear closer to their farms than non-adopters. The opposite situation was noted for other GDT practices. Finally, most adopters had low fertility levels before using GDT measures.

Factors determining the adoption of SLM practices

Table 4 presents the probit model results for the factors influencing the adoption of SLM practices. This Table shows that the distance between the producer's village and the urban area significantly influences (at a 1% level) the adoption of livestock parking. The probability that a soy producer will adopt livestock parking increases, ceteris paribus, by 4.3 percentage points when the producer moves approximately one kilometre closer to an urban area. This is because development agencies and extension services are generally located in urban areas. Thus, producers close to urban areas have greater information access than those further from the urban areas. This agrees with the findings of Belay and Bewket (2013), who stated that the proximity of villages to urban areas, improves the adoption of SLM technologies. Another factor that could explain this finding is that urban areas generally have livestock markets. Therefore, these markets are places of concentration and interaction among producers from various villages. Producers near these locations have more access to information than those far from periodic markets. As per Tede et al. (2023), this could encourage the dissemination of technology and lead producers to try or even adopt it. This finding aligns with that of Hinnou et al. (2018), who found that a short distance between the rice market and the producer's household gives them confidence in adopting technologies to improve crop production. In short, access to information and technology is decisive in adopting SLM practices.

Table 4: Determinants of the adoption of SLM practices: results of the probit model

Variable	Description	Legumes		Crop residues management		Spreading animal droppings		Livestock parking		Ploughing perpendicular to the slope	
		Coef.	Marg. Eff.	Coef.	Marg. Eff.	Coef.	Marg. Eff.	Coef.	Marg. Eff.	Coef.	Marg. Eff.
DISTVIL	Distance between village and nearest urban area (km/10)	-0.229 (0.193)	-0.068 (0.058)	-0.207 (0.166)	-0.080 (0.064)	-0.062 (0.214)	-0.010 (0.033)	-1,382*** 0.214	-0.434*** 0.069	0.290 (0.250)	0.036 (0.031)
GENDER	Gender of the producer (1=male)	-0.071 (0.286)	-0.021 (0.087)	-0.348 (0.250)	-0.137 (0.098)	0.067 (0.366)	0.010 (0.054)	0.064 0.293	0.020 0.094	0.252 (0.387)	0.029 (0.040)
INSTRC	Producer education level (in %)	0.101 (0.144)	0.030 (0.043)	0.135 (0.118)	0.052 (0.046)	0.414*** (0.143)	0.064*** (0.023)	0.255* 0.140	0.080* 0.043	0.117 (0.166)	0.014 (0.021)
EXTRG	Practice of extra-agricultural activity (1=yes)	0.408* (0.241)	0.123* (0.073)	0.435** (0.211)	0.169** (0.081)	0.023 (0.283)	0.004 (0.044)	-0.147 0.243	-0.046 0.077	0.498* (0.303)	0.065 (0.043)
HHSIZE	Household size (number of person)	0.074** (0.034)	0.022** (0.010)	-0.044 (0.034)	-0.017 (0.013)	-0.030 (0.044)	-0.005 (0.007)	0.031 0.044	0.010 0.014	-0.053 (0.061)	-0.007 (0.008)
COOPR	Peasant cooperative membership (1=yes)	-0.567* (0.323)	-0.149** (0.074)	-0.731** (0.300)	-0.263*** (0.097)	-0.497 (0.388)	-0.065 (0.044)	-0.285 0.342	-0.093 0.116	-0.442 (0.386)	-0.046 (0.036)
CVULG	Contact with extension (1=yes)	0.962** (0.416)	0.348** (0.161)	0.782* (0.399)	0.303** (0.142)	0.096 (0.513)	0.016 (0.089)	0.912* 0.551	0.204*** 0.077	0.929** (0.466)	0.196 (0.139)
FORMG	Training in the agricultural field (1=yes)	1,171*** (0.312)	0.387** (0.104)	0.771*** (0.284)	0.299*** (0.106)	0.349 (0.362)	0.059 (0.068)	0.096 0.326	0.030 0.100	0.112 (0.382)	0.014 (0.051)
ACRED	Access to credits (1=yes)	-0.082 (0.247)	-0.024 (0.072)	-0.073 (0.214)	-0.028 (0.083)	0.011 (0.280)	0.002 (0.044)	-0.208 0.253	-0.067 0.083	-0.276 (0.365)	-0.032 (0.039)
DTERR	Availability of land (1=yes)	-0.081 (0.357)	-0.024 (0.104)	0.308 (0.277)	0.121 (0.109)	0.640** (0.305)	0.119* (0.067)	-0.456 0.416	-0.151 0.140	-0.024 (0.464)	-0.003 (0.057)
SUPD	Total agricultural area available (ha/10)	0.195 (0.256)	0.058 (0.077)	0.078 (0.161)	0.030 (0.063)	-0.043 (0.091)	-0.007 (0.014)	0.746* 0.394	0.234** 0.113	0.270 (0.322)	0.033 (0.042)
EXSOJ	Experience in soy production (year/10)	0.112 (0.381)	0.033 (0.113)	0.394 (0.334)	0.153 (0.130)	0.315 (0.411)	0.049 (0.064)	0.348 0.408	0.109 0.129	-1,298* (0.693)	-0.161** (0.082)
DISTCV	Producer's home-farm distance (km/10)	-0.450* (0.242)	-0.134 (0.072)	-0.237 (0.188)	-0.092 (0.073)	-0.152 (0.237)	-0.024 (0.037)	0.078 0.218	0.025 0.069	0.150 (0.226)	0.019 (0.028)
FERTSL	Soil fertility	-0.412*** (0.149)	-0.122*** (0.043)	-0.179 (0.124)	-0.069 (0.048)	-0.316* (0.183)	-0.049* (0.028)	-0.318** 0.145	-0.100** 0.046	-0.392** (0.191)	-0.049** (0.023)
_cons	Constant	-0.275 (0.520)		0.515 (0.470)		-0.915 (0.593)		3,173*** 0.595		-0.922 (0.725)	

Variables marked * are significant at 1%; ** Significant at 5% and * Significant at 10%**

( ): Standard errors

The producer's education level determines the adoption of the animal dropping (at 1% level) and the livestock parking (at 10% level). Increasing the producer's educational level by one unit improved the probability of adopting animal droppings by 6.4 percentage points and that of livestock parking by 8 percentage points, ceteris paribus. Education also had a positive but insignificant influence on adopting other SLM practices. These results could be explained by the fact that educated producers can read extension manuals and interact with extension agents and researchers. Accordingly, they can better appreciate the importance of SLM practices and may be more likely to adopt these technologies than their less-educated peers. This is consistent with the findings of Adekambi et al. (2021), who reported that the level of education positively affects the adoption of SLM practices, mainly organic manuring. According to Miheretu and Yimer (2017), education is believed to enhance the reasoning capability of farmers, as well as their capability to recognise the risks associated with land degradation. Thus, improving farmers' educational status enhances their adoption of land management practices (Miheretu and Yimer, 2017). Conversely, Tede et al. (2023) found that education had no significant effect on adopting sedentary yam practices, particularly fertility-improving crops.

The practice of off-farm activity positively and significantly influenced the adoption of legumes (at 10% level), crop residue management (at 5% level), and ploughing perpendicular to slopes (at 10% level). This means that producers practising off-farm activities have a relatively higher probability of adopting legumes, crop residue management, and ploughing perpendicular to slopes, ceteris paribus, at 12.3 percentage points, 16.9 percentage points, and 6.5%, respectively than producers who do not practice off-farm activities. This suggests that producers practising off-farm activities use part of their profits to cover the costs of adopting SLM technologies. This aligns with the findings of Eneyew (2022), who noted that rural dwellers' involvement in off-farm activities could create a labour shortage for better-off farmers who usually hire daily labour during peak weeding and harvesting periods.

Household size, used as a proxy for labour availability, significantly influenced (at a 5% level) the adoption of legumes. The probability of adopting legumes increases by 2.2 percentage points when the household size increases by one unit. This suggests that farmers with more family labour tend to use labour-intensive SLM practices. This could be explained by the fact that using legumes requires additional labour. These results are in line with Tede et al. (2023), for whom legumes, also used as a yam cultivation sedentarisation technology, are labour-demanding (particularly for installation, maintenance, and monitoring) and are out of reach of small producers with small household sizes. Miheretu and Yimer (2017) and Etsay et al. (2019) reached the same result in Ethiopia, reporting that the presence of more family labour favoured the adoption and continued use of labour demanding SLM technologies, such as stone terraces, conservation tillage, and soil bundles. For these authors, farmers endowed with family labour could efficiently allocate sufficient labour to sustain SLM measures by carrying out maintenance work.

The adoption of legumes and crop residue management was negatively influenced by membership in a cooperative or farmer organisation at 10% level and 5% level, respectively. Thus, ceteris paribus, cooperative member producers are 14.9 percentage points and 26.3 percentage points less likely to adopt legume and crop residue management, respectively. These results differ from the expected positive signs in that cooperatives are often the first entry points for extension projects and services in rural areas. These results are also inconsistent with the findings of Dovonou et al. (2021) and Oduniyi (2022), who argued that belonging to a peasant organisation positively affects the adoption of SLM techniques, including Mucuna pruriens and Aeschynomene histrix. The adverse effect of membership in cooperatives suggests that soybean farmers' cooperatives do not share information related to SLM practices. Woldegebrial et al. (2018) found that formal peasant organisations and other community groups stimulated smallholder farmers to adopt SLM practices.

Contact with extension services positively and significantly affected the adoption of SLM measures, except for animal droppings (Table 4). In other words, soybean producers with contact with extension agents tend to adopt SLM. The probability that a soybean producer adopts SLM practices increases, ceteris paribus, from 20 percentage points (case of animal parking and ploughing perpendicular to slopes) to 38 percentage points (case of legumes) when he has contact with extension agents compared to those without contact with extension agents. This indicates that extension agents play a significant role in disseminating and adopting SLM to ensure sustainable soybean production. These results are consistent with the findings of Adekambi et al. (2021) and Dovonou et al. (2021), who showed that extension improves the adoption of SLM measures, particularly soil regeneration with legumes and soil fertility management techniques based on Mucuna pruriens and Aeschynomene histrix. This extension allows soybean producers to acquire new skills and knowledge related to SLM practices and sometimes benefits from close supervision (Miheretu and Yimer, 2017; Sodjinou et al., 2015; Tede et al., 2023).

As shown in Table 4, technical training in agricultural production techniques positively influenced (at a 1% level) the adoption of legumes and crop residue management. Soybean farmers' participation in training, ceteris paribus, increases the probability of legume adoption by 38.7 percentage points and the probability of crop residue adoption by 29.9 percentage points. This suggests that training increases producers' awareness and adoption of SLM practices. This agrees with the findings of Assogba et al. (2017), who showed that technical training allows producers to acquire skills to adopt innovations, particularly SLM technologies. This suggests that the government and extension agencies should intensify the technical training of producers because trained farmers acquire adequate and relevant information and technical skills on how to apply SLM practices, notably legumes and crop residue management, which consequently increases their level of participation (Mersha et al., 2022). According to Miheretu and Yimer (2017), the knowledge soybean farmers gain through technical training enables them to be equipped with the technical knowledge required to implement SLM practices. This also makes farmers seek the long-term benefits of SLM practices through sustainable soybean production rather than the immediate benefits obtained at the expense of soil quality (Miheretu and Yimer, 2017).

Table 4 indicates that the availability of sufficient land has a significant and negative effect (at a 5% level) on the adoption of animal droppings spreading. In other words, peasants with more available land were less likely to adopt animal droppings. This could be explained by the fact that the quantity of manure required to cover a large area of land is enormous compared with small-area farms, where the farmer can quickly mobilise the necessary manure. This result is consistent with the findings of Etsay et al. (2019), who argued that peasants who operate on considerable farmlands need time to maintain the introduced SLM measures and improve the fertility status of farmlands. These activities may demand a significant labour force and burden farm households greatly (Etsay et al., 2019).

Similarly, the total amount of developed agricultural land significantly affected the adoption of livestock parking. Producers with large agricultural land areas tended to accept livestock parking unlike those with small areas. The probability of adopting livestock parking increases by 23.4 percentage points when the available area increases by 1%. This result is consistent with the findings of Mersha et al. (2022).

The producer's experience in soybean production has a positive but non-significant effect (at a 10% level) on the adoption of legumes, crop residue management, spread of animal droppings, and livestock parking. This factor, however, negatively affects (at a 10% level) the adoption of perpendicular ploughing. The less experience a producer has in soybean production, the less they adopt ploughing perpendicular to the slope. This result is consistent with the findings of Nambima et al. (2023), in which rural farmers acquired significant experience and deep knowledge of their environment, allowing them to appreciate the richness and diversity of SLM techniques. This has improved the propensity to adopt these technologies.

Table 4 shows the positive and significant relationship between farmers' perceptions of the fertility level of the soil and the adoption of SLM measures. Thus, producers who perceive that the fertility of their soil is low tend to adopt SLM measures more often than those who perceive that their soil is fertile. This agrees with producers' appreciation presented in Table 2, in which 91% argued that the main reason for adopting SLM measures was that they significantly improved soil fertility. This result agrees with the findings of Woldegebrial et al. (2018), who noted that farmers' attitudes and perceptions are crucial in their decision to adopt SLM technologies to the extent that producers with positive attitudes are more inclined to adopt these technologies.

CONCLUSION AND IMPLICATION

The soybean farmers adopted five SLM practices: legumes, crop residue management, spreading animal droppings, livestock parking, and ploughing perpendicular to the slope. The five main reasons for adopting SLM practices are their ability to increase soil fertility, the possibility of providing fodder, the availability of family labour, their ability to improve soybean productivity, and their ability to provide edible seeds (pigeon pea). Men are much more likely to adopt these practices than women, mainly because men are more endowed with land and productive resources than women. Producers living near urban areas were more inclined to adopt SLM practices than those far from them. This is explained by the fact that producers residing close to these places have much more access to information, given that urban areas are home to projects, extension services, and livestock markets, which are places of concentration and, therefore, interactions between producers from various localities. Educated producers and those practising off-farm activities have a higher propensity to adopt SLM practices than uneducated producers and those not practising off-farm activities. Labour availability positively influences the adoption of SLM practices. Producers' training and access to extensions improve their information and knowledge of SLM practices and optimise their efficiency in using these technologies through learning. Thus, providing technical training to soybean producers and enhancing their access to information (notably through close advisory support and raising awareness) and the market are crucial for fostering the adoption and dissemination of SLM practices.

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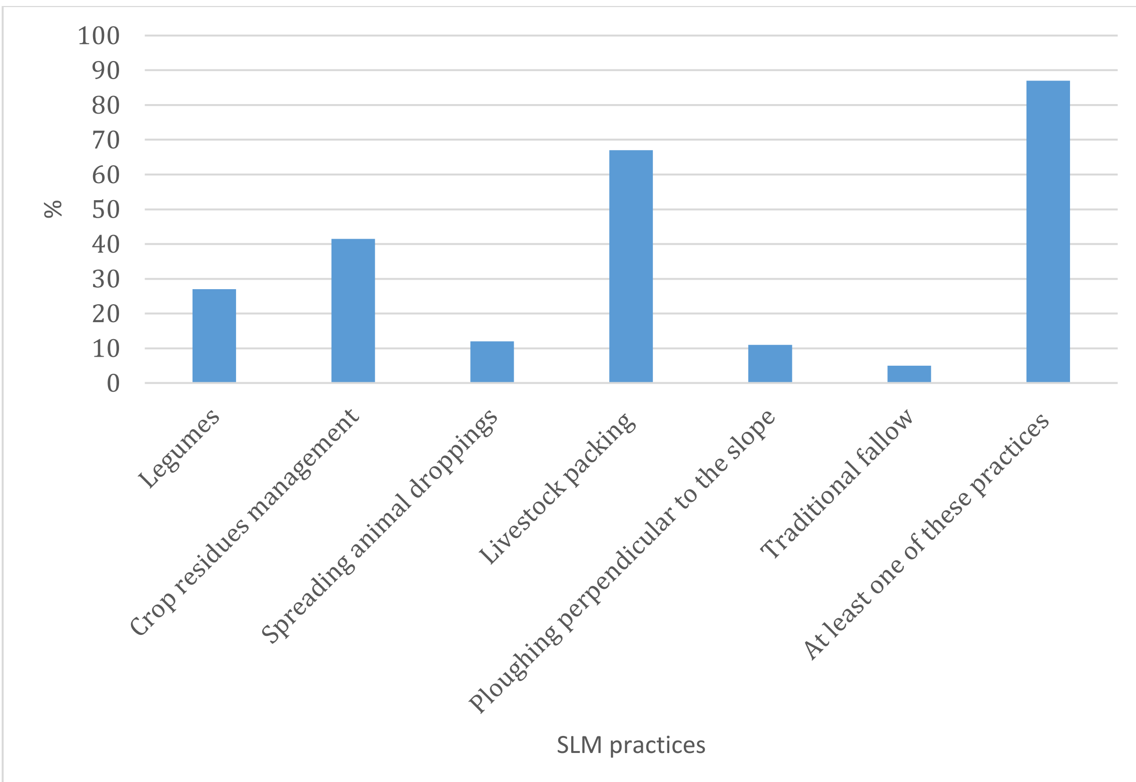

Figure 1: SLM measures identified in the study area