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Determinants Of The Adoption Of Sustainable Agricultural Land Management Practices In The Municipality Of Bassila, Benin

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Resumé – Declining soil fertility is one of the problems currently facing agriculture in Benin. In order to meet the challenge of sustainable management of natural resources, it is necessary to apply good sustainable land management (SLM) practices. The aim of this study is to analyse the determinants of SLM practices in the municipality of Bassila. To this end, a survey was conducted among 363 farmers.

Analysis of the results using logistic regression showed that several factors influence the adoption of a SLM practice by a producer. Land tenure, especially land donation and land lease, had a negative but significant impact on the adoption of SLM practices at the 5% and 1% thresholds, respectively. Level of education and availability of land also have a negative and significant impact on the adoption of SLM practices at the 5% threshold. Gender, on the other hand, had a positive but insignificant effect on the adoption of SLM practices. Income level had a negative but insignificant effect on the adoption of SLM practices. Ethnicity of the producer significantly determines the adoption of SLM practices at the 1% threshold, and 'knowledge of SLM practices' significantly determines the adoption of these practices by producers in the commune at the 5% threshold.

Improving farmers' knowledge, supporting them with appropriate materials and equipment, and building their capacity in the different SLM practices by increasing the involvement of women farmers could increase the adoption rate of these practices.

Keywords – Soil fertility - Sustainable land management practices - Logistic regression - Bassila Municipality

1. INTRODUCTION

Sub-Saharan Africa is particularly vulnerable to the threats of natural resource degradation and poverty. The main causes are high population growth rates and increasing population pressure, dependence on agriculture that is vulnerable to environmental change, fragile natural resources and ecosystems, high rates of soil erosion and degradation, low yields and post-harvest losses [1].

In West Africa, agriculture contributes 30% of GDP and employs more than 50% of the labour force [2] [3]. However, it is essentially rain-fed and subsistence agriculture, characterised by low soil fertility [4] [5] [6] [7]. In Benin, 55% of the population depend on agriculture for their livelihoods [8]. One of the major problems currently affecting agriculture in northern Benin is the decline in soil fertility [9]. In Benin, more than 40% of agricultural land is degraded and about 75,000 hectares of forest are lost every year. This loss is estimated to reduce GDP by 8% per year [10]. Given this trend, soil restoration and protection is a major challenge to achieving sustainable development and food security. Important measures are being taken by both public and non-governmental actors to encourage producers to adopt sustainable land management (SLM) practices.

This is the case in the municipality of Bassila, where agriculture is the main economic activity of the population. It employs about 62.8% of the working population. It provides more than 80% of the population's income and is the main source of employment [11]. There are 13,983 agricultural households in the municipality, of which 13,851 are involved in crop production and 8,737 in livestock production [12]. According to the data collected in the PDC (2024-2028), the main assets of agriculture in the commune of Bassila are the availability of fertile arable land, valued at 196,253.484 ha, as well as climatic conditions, especially rainfall [11]. However, agriculture is hampered by major constraints, including poor soil fertility management.

According to the same source, the municipality of Bassila has soils with fairly well-developed humus horizons, which are very rich in nutrients. They are very favourable for almost all crops. However, due to a combination of human and natural factors, these soils are being severely degraded and are becoming increasingly poorer as a result of overuse, leading to a decline in agricultural yields. Between 2018 and 2020, the yield of the main agricultural crops in the commune fell from 2,731 tonnes to 2,079 tonnes per hectare. Faced with this land degradation, which does not guarantee an increase in agricultural activity in the commune, we are entitled to wonder about the practices adopted by those involved in agricultural production to mitigate land degradation, on the one hand, and to preserve it in order to improve production yields, on the other. This study responds to the need for farmers to improve the organic status of their soils by adopting sustainable land management practices. It aims to analyse the determinants of the adoption of SLM practices in the municipality of Bassila.

2. MATERIALS AND METHODS

2.1. Study area

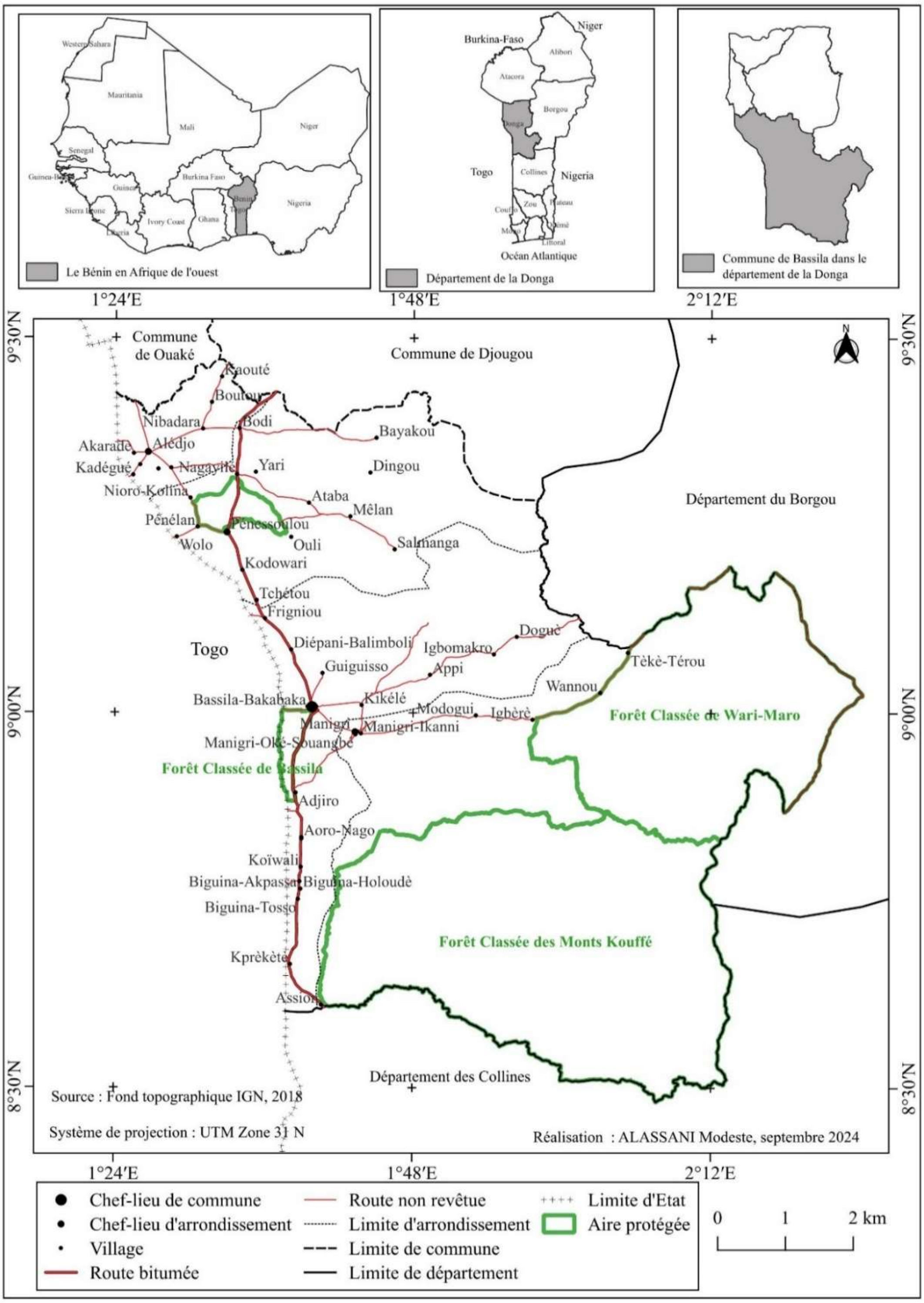
The study was carried out in the community of Bassila in central western Benin. It is located in the Donga department and covers an area of 4,900 km². It is one of the four communes that make up the Donga department in northwestern Benin and lies between latitudes 9°37 and 8°50 north and longitudes 1°40 and 2°50 west (Figure 1). The commune of Bassila is located in the Sudano-Guinean climate zone, with a dry season (mid-October to mid-April) and a rainy season (mid-April to mid-October). The

average annual rainfall, based on a 30-year climatic normal, is 1,277.6 mm and can reach 1,800 mm, with a minimum of 900 mm. The monthly average is 106.5 mm for the whole year and 175.8 mm during the rainy season. The average temperature is around 30°C. Agriculture is the main economic activity of the population. It employs about 62.8% of the working population. It provides over 80% of the population's income and is the main source of employment. There are 13,983 agricultural households in the municipality, of which 13,851 are involved in crop production and 8,737 in animal production.

The main advantages of agriculture in the municipality of Bassila are the availability of fertile arable land, estimated at 196,253.484 ha, and the climatic conditions, especially rainfall. It is a major producer of soya, yams and cashew nuts. In addition to these flagship crops, other no less important crops are grown. These include maize, rice, sorghum, cassava, cowpeas, peanuts, tomatoes and cotton. Despite these strengths in agricultural production, this community was chosen for the following reasons:

- The municipality is experiencing accelerated demographic growth. Between 2002 and 2013, its population almost doubled, rising from 71,711 to 130,091. It is estimated to reach 2,264 in 2023 [1]. As a result of heavy human pressure and unsuitable farming practices, these soils are being severely degraded and are becoming increasingly impoverished due to overuse.
- Minimum temperatures have increased. They increased from 21.1°C to 22.95°C at Bassila (Savè synoptic station) between 1961 and 2009, an overall increase of 1.85°C over the period. Maximum temperatures rose from 32.03°C to 34.43°C between 1961 and 2009, for an overall increase of +2.40°C over the period. Agriculture remains the sector most affected by climate change. For example, the yield of the main agricultural crops in the municipality of Bassila has decreased from 2,731 tons in 2018 to 2,079 tons in 2020 [13].

Figure 1: Presentation of the municipality of Bassila



2.2. SAMPLING AND WORKING TOOLS

The sample consisted of farmers and resource persons. The commune of Bassila has 16,927 households, of which 9,873 are agricultural households [14]. The sample size n was determined using the formula of Dagnelie (1998) [15]. **$n = [(U_{1-\alpha/2})^2 p(1-p)] / d^2$**.

Where $U_{1-\alpha/2} = 1.96$ (value of the normal distribution for $\alpha = 0.05$) and d is the marginal sampling error, here set at 0.05. The value of p is the proportion of the agricultural population in the municipality of Bassila (66.22%) according to the RPGH4. Therefore, according to this formula, a sample of 343 farmers should be considered. However, for the purposes of our study, we went beyond this and took a sample of 363 farmers. This sample is distributed proportionally according to the number of farmers per district. According to the data collected by the Direction Nationale des Statistiques Agricoles, the commune of Bassila had 13851 farmers in 2022, of which 1847 were in the arrondissement of Alédjo, 5568 in Bassila, 2874 in Manigri and 3562 in the arrondissement of Pénessoulou. The sample by arrondissement is as follows:

Table 1: Distribution of the sample by arrondissements

Arrondissement	*Number of farmers*	*Sample*
ALEDJO	*1 847*	*45*
BASSILA	*5 568*	*148*
MANIGRI	*2 874*	*92*
PENESSOULOU	*3 562*	*78*
TOTAL	*13 851*	*363*

Sources: Based on the number of farmers per arrondissement provided by the RPGH4.

The survey units were selected randomly, taking into account the criteria of representativeness in the different districts. They were selected from villages with high agricultural production, identified with the support of the Communal Unit of the Territorial Agricultural Development Agency. These are the villages of Adjiro (4), Appi (24), Biguina (24), Diepani (11), Doguè (41), Frignon (13), Guiguisso (9), Igbomacro (8), Kikélé (14) in the Bassila district; Bayakou (7), Bodi (5), Kodowari (4), Nagayilé (3), Nioro (1), Pénélan (6); Pénéssoulou (40), Salimanga (4), Talou (6) and Tchétou (2) in the district of Penessoulou; Igbèrè (37), Modogui (25), Wannou (30) in the district of Manigri and Alédjo (11), Boutou (13), Kadegué (5), Partago (10), Tchimberi (6) in the district of Alédjo, i. e. a total of 26 administrative villages. In other words, 26 of the 31 administrative villages in the commune.

Primary data were collected through questionnaires and interview guides sent to 363 sample farmers and resource persons identified for the purpose of this study.

2.3. DATA PROCESSING AND ANALYSIS OF RESULTS

Logistic regression was used to process the data obtained with STATA 15 software. The aim was to analyze the influence of certain socio-economic and cultural factors on the adoption of Sustainable Land Management (SLM) practices by farmers in the commune of Bassila.

The variables studied are:

- **Independent variables:**

- Level of education: A measure of people's level of education, which can influence their ability to adopt sustainable agricultural practices.
- Land tenure status: The legal status of land ownership and use, which can affect access to and willingness to adopt SLM practices;

- Gender: male or female characteristics of producers that may influence resource management behaviors and choices;
- Origin: the geographical or cultural origin of farmers, which may influence their farming practices and their openness to innovation;
- Knowledge of SLM practices;
- Income level;
- Number of dependents living in the household;
- Ethnicity;
- Religion;
- Marital status.

According to our explanatory model, if the coefficient of a variable is positive (+), it means that this variable positively determines SLM practices. This variable therefore promotes the adoption and implementation of SLM practices. If the coefficient is negative, this variable negatively determines SLM practices. This variable therefore discourages the adoption of SLM practices.

- **Dependent Variable:**

The dependent variable examined is the availability of sufficient arable land. This dichotomous variable indicates whether farmers have enough arable land to adopt SLM practices. It is coded as follows: 0 for 'no' and 1 for 'yes'.

Modelling using logistic regression made it possible to explore the relationships between socio-economic and cultural factors and the decision of Bassila farmers to adopt sustainable land management practices. The model is as follows:

$pi = prob(yi/xi)$

$Pi = F\ (Xi\ ;\ \beta)$

where the function F follows a logistic distribution

$$F(\omega) = \frac{e^w}{1 + e^w}$$

$$F(\omega) = \frac{e^w}{1 + e^{-w}}$$

Note that the β parameters have been estimated using the **maximum likelihood method**. This method consists of maximising the log-likelihood function.

Thus the logit model defines the probability associated with the event y=1 (y=0 otherwise) as the value of the logistic distribution function at the point xiβ.

Xi being a matrix of the model's explanatory variables. Thus, the model is specified as follows:

Pro (adoption_measure_GDT) = F (**Education level, Land tenure status, Gender, Origin; β**)

where:

- *P(Y=1)* is the probability that the dependent variable ('sufficient availability of land for cultivation') is equal to 1 (i.e. that producers have sufficient land available for cultivation).
- *β0* is the model intercept.

- *β (β1,β2,β3,β4)* are the coefficients associated with each independent variable, representing the effect of each factor on the probability of having sufficient land available for cultivation.

3. RESULTS

3.1. Sociodemographic and economic characteristics of respondents

The majority of producers surveyed were male (94.5% compared to 5.5% female). Of these, 7.71% were single and 92.29% were married. 52.34% of these producers are uneducated, 22.04% have primary education, 23.42% have secondary education and 2.20% have higher education. 70.25% of these producers are indigenous and 29.75% are non-indigenous. They come from different ethnic groups: the Anii (15.98%), the Ditamari (7.44%), the Kotocoli (13.77%), the Lokpa (36.91%), the Nagot (22.59%) and the Yom (3.31%). They all have different land tenure status. The majority are landlords (65.84%), 22.87% received their land by gift, 3.58% by purchase, 2.75% by lease and 4.96% are sharecroppers. 50.96% have more than 5 hectares of land, 33.1% have between 2 and 5 hectares and 13.5% have less than 2 hectares. Islam is the religion most commonly practised by the target producers (60.88%), 38.57% of them practise Christianity and a minority of 0.55% are animists (see table below).

Table 2: Sociodemographic and economic characteristics of respondents

Variables	Size	Frequency (%)
Gender		
Female	20	5,5
Male	343	94,5
Marital status		
Single	28	7,71
Married	335	92,29
Level of education		
Primary	80	22,04
No_education	190	52,34
Secondary	85	23,42
University	8	2,20
Origin		
Allochthone	108	29,75
Autochthone	255	70,25
Ethnicity		
Anii	58	15,98
Ditamari	27	7,44
Kotocoli	50	13,77
Lokpa	134	36,91
Nagot	82	22,59

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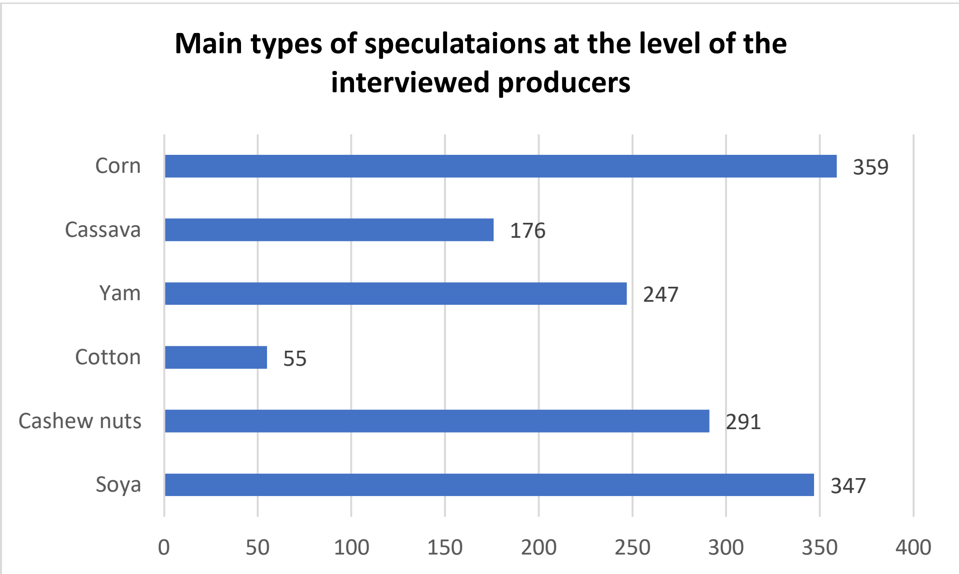
Yom	12	3,31
Land tenure status		
Purchase	13	3,58
Donation	83	22,87
Rental	10	2,75
Sharecropping	18	4,96
Landowner	239	65,84
Religion		
Animist	2	0,55
Christianism	140	38,57
Islam	221	60,88
Area of available land		
Less than 2 ha	49	13,50
Between 2 et 5 ha	120	33,1
More than 5 ha	185	50,96

Several types of crop are produced by these farmers. The main ones are summarized in the following graph.

Figure 1: Types of crops produced by the producers interviewed



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3.2. Determinants of the adoption of SLM practices in the municipality of Bassila

The analysis of the determinants of the adoption of SLM practices reveals several factors that influence this decision to varying degrees.

According to the explanatory model obtained, summarised in the tables below, we find that :

- The adoption of SLM practices is significantly influenced by the **donation and rental of land**, which have a negative but significant influence on the adoption of SLM practices at the 5% and 1% thresholds respectively. Female gender has a positive but insignificant impact on the adoption of SLM practices.
- Level of education (primary) has a negative and significant impact on the adoption of SLM practices at the 5% threshold in our study.
- Land availability has a negative and significant impact on the adoption of SLM practices at the 5% threshold.
- Income level has a negative but insignificant effect on the adoption of SLM practices.
- Ethnicity of the farmer significantly determines the adoption of SLM practices at the 1% threshold.
- Knowledge of SLM practices significantly influences the adoption of SLM practices at the 5% threshold.

Table 3: Logit regression model

Log likelihood= **-110.95791**	Number of obs	=	356
	LR chi2 (22)	=	147.28
	Prob> chi2	=	0.000
	Pseudo R2	=	0.3989

dispst2	Coef.	std.Err	Z	P>|z|	[95% conf. Interval]	
Purchase	-1.237908	.9433833	-1.31	0.189	-3.086905	.6110895
Donation	-1.57079	.4965166	-3.16	0.002	-2.543944	-.597635
Rental	-2.835967	1,245427	-2.28	0.023	-5.27696	-.3949744
Female	.7854031	.7127475	1.10	0.270	-.6115564	2.182363
Primary	-1.123567	.5146718	-2.18	0.229	-2.132306	-.1148293
Fallows	1.254131	.4734692	2.65	0.008	.32614487	2.182114
Cultural_Association	-.989884	.7155077	-1.38	0.167	-2.392253	.4124854
crop_succession	-.5186903	.6238817	-0.83	0.406	-1.741476	.7040953
crop rotation	1.153888	.6273095	1.84	0.066	-.0756159	2.383392
animal_fertilization	.2342427	.6339749	0.37	0.712	-1.008325	1.476811

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fertilizing_plant_culture	-.4576014	.7226322	-0,63	0.527	-1.873935	.9587317
agroforestry	.4510293	.4318004	1.04	0.296	-.395284	1.297343
crop_residue_management	-.71655	.7247097	-0,99	0.323	-2.136955	.7038549
organic_chemical_fertilizer	-1.320934	.6835997	-1.93	0.053	-2.660765	.0188964
land_status	.330961	.4578763	0.72	0.470	-.5664601	1.228382
improvement_income	-1.377501	1.153984	-1.19	0,233	-3.6392268	.884266
equipment_availability	-1.213631	.5011863	-2.42	0.015	-2.195938	-.2313243
income_level	-.3131311	.7143779	-0.44	0.661	-1.713286	1.087024
possibility_of_diversifying crop	-2.759721	.6038755	-4.57	0.000	-3.943295	-1.576147
type_culture	-.1956212	.590898	-0.33	0.741	-1.35376	.9625176
knowledge_practice GDT	1.389308	.6015802	2.31	0.021	.2102325	2.568383
ethnicity	2.277905	.7732193	2.95	0.003	.7.624227	3.793387
_cons	4.572422	1.507241	3.03	0.002	1.618284	7.526559

Variable	**Active**
Purchase	**-1.238**
Donation	**-1.571****
Rental	**-2.836***
Female	**0.785**
Primary	**-1.124***
Fallows	**1 .254****
Cultural_Association	**-0.990**
crop_succession	**-0.519**
crop rotation	**1.154**
animal_fertilization	**0.234**
fertilizing_plant_culture	**-0.458**
agroforestry	**0.451**
crop_residue_management	**-0.717**
organic_chemical_fertilizer	**-1.321**
land_status	**0.331**
improvement_income	**-1.378**

equipment_availability	**-1.214***
income_level	**-0.313**
possibility_of_diversifying crop	**-2.760*****
type_culture	**-0 .196**
knowledge_practice GDT	**1.389****
ethnicity	**2.278**
_cons	**4.572****
N	**356**
11	**-110.958**
Chi2	**147.281**
Df_m	**22.000**
aic	**267.916**
Legend : *p<0.05 ; ** p<0.01 ; *** p<0.001	

Analysis of these tables enables us to assess the influence of each of the variables on the adoption of practices.

First of all, the variable 'Availability of suitable agricultural equipment' has a negative coefficient of -1.214, suggesting that the lack of suitable equipment may be a major obstacle to the adoption of SLM, thus limiting farmers' options. On the other hand, the negative coefficient associated with 'ability to diversify crops' (-2.760***) indicates that farmers who perceive constraints to diversification are less likely to adopt sustainable practices. This highlights the importance of crop diversity in optimising sustainable farming practices.

Knowledge of sustainable land management practices' is also crucial, with a positive coefficient of 1.389*, meaning that greater knowledge of SLM encourages farmers to adopt them. This highlights the role of awareness and education in promoting sustainable farming practices. With regard to ethnicity, a positive coefficient of 2.278** indicates that certain ethnic groups may have cultural practices that are more aligned with sustainability principles, favouring their adoption of SLM.

In addition, the negative coefficient for the 'Donation' variable (-1.571) shows that those who depend on external aid are less likely to adopt these practices, while land tenure status, with a positive coefficient of 0.785, indicates that those who rent land are more supportive of SLM adoption. Gender' is also an important factor, with a positive coefficient of 0.785, underlining the active role of women in sustainability decision-making. Income level had a negative, but not significant, influence on SLM adoption. This shows that the higher the income, the lower the adoption of SLM practices.

The level of education was also significant; a negative coefficient for those with only primary education (-1.236*) shows that education is a determining factor in SLM adoption.

Finally, the perception of an improvement in the situation, with a negative coefficient of -1.378, indicates that those who do not see any concrete benefits from adopting SLM are less inclined to make the change.

The pseudo R^2, which represents the proportion of variance explained by the model, as well as the AIC of 267.916, reinforce the validity of this model, indicating a good fit and highlighting the complexity of the determinants that influence the adoption of SLM practices. These results highlight the need for targeted and tailored approaches to encourage the adoption of sustainable practices in various socio-economic contexts.

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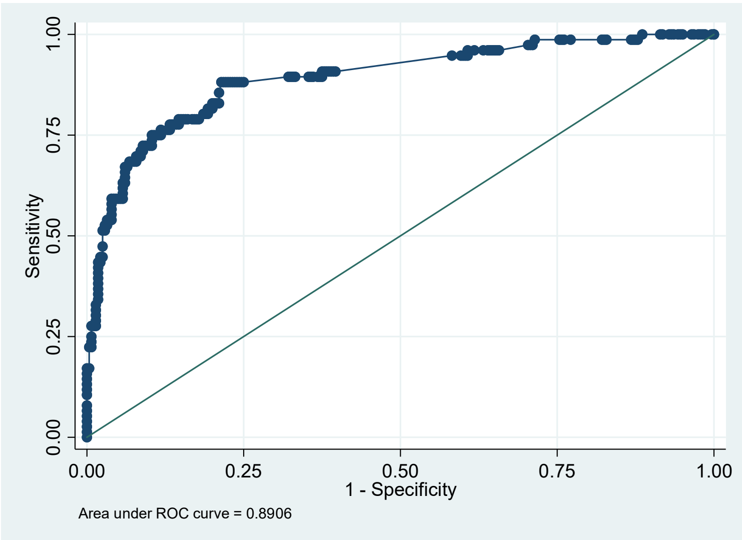
. estat classification

Logistic model for dispst2

              ———————— True ————————
Classified |         D            ~D  |      Total
-----------+--------------------------+-----------
     +     |        45            15  |         60
     -     |        31           265  |        296
-----------+--------------------------+-----------
   Total   |        76           280  |        356

Classified + if predicted Pr(D) >= .5
True D defined as dispst2 != 0
--------------------------------------------------
Sensitivity                     Pr( +| D)   59.21%
Specificity                     Pr( -|~D)   94.64%
Positive predictive value       Pr( D| +)   75.00%
Negative predictive value       Pr(~D| -)   89.53%
--------------------------------------------------
False + rate for true ~D        Pr( +|~D)    5.36%
False - rate for true D         Pr( -| D)   40.79%
False + rate for classified +   Pr(~D| +)   25.00%
False - rate for classified -   Pr( D| -)   10.47%
--------------------------------------------------
Correctly classified                        87.08%
--------------------------------------------------
```

Post-estimation tests are generally carried out after the regression model has been estimated in order to assess its quality. In our case, we carried out a post-estimation test to examine the explanatory power of the model by analysing the agreements and disagreements between the estimated values and the observed values. In the first table, the number of correct predictions is on the diagonal (45 + 265), corresponding to a success rate of 310 out of 356, or 87.08%.



Note that the area under the ROC curve plotted by lroc is an estimator of the overall effectiveness of the test. If the test is informative, the area is ½. If the test is perfectly discriminating, the area will be 1. Graphically, the further the curve deviates from the bisector, the better the discrimination and therefore the better the model. In our case, we have good discrimination because Area under ROC curve= 0.8906.

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4. DISCUSSION

Several authors have concluded that the factors determining the adoption of an innovation introduced in a rural environment are linked not only to the technology but also to the socio-economic and cultural conditions of the producer. However, the importance of this influence varies from topic to topic and from context to context.

Giving and renting land has a negative but significant influence on the adoption of SLM practices. This is because farmers' land tenure status does not guarantee them any degree of security. As a result, many farmers see little point in adopting agroecology and other sustainable land management practices. These are all missed opportunities for transition to sustainable and resilient farming systems. Yet there is a strong correlation between land security and real environmental progress, particularly in the adoption of sustainable practices. For example, increasing soil fertility and combating erosion require long-term planning, for which secure land tenure is an essential prerequisite [16]. This trend is confirmed by [17], who found that the formalisation of land access rights has a positive impact on the level of investment in SLM.

Female gender has a positive but insignificant impact on the adoption of sustainable land management practices. This result is not consistent with the findings of some authors. The adoption of new technologies in agriculture is sometimes influenced by gender, especially when they are energy intensive [18] [19]. In particular, author [20] finds that being male has a positive effect on the likelihood of weeding a plantation, pruning trees and protecting them from insects. In his study in Malawi, author [21] found that female-headed households did not adopt the new technologies proposed to them, which is consistent with the results of the present study. The insignificance of this result may be related to the low number of women in agriculture.

The level of education (primary) has a negative impact on the adoption of SLM in our study. This is the lowest level of education, highlighting the importance of education in agricultural development. Farmers with higher levels of education are more likely to adopt SLM practices. In his results, author [20] finds that farmers with a high level of education are more aware of the tangible, positive and recurring effects of good agricultural practices. Several other authors have obtained the same results, showing that education level is a determining factor in technology adoption [22, 23, 24, 25].

Land availability has a significant negative impact on the adoption of SLM practices. This can be explained by the fact that 77% of respondents still have sufficient arable land. The adoption of SLM is motivated by the search for arable land. In order to limit increasing soil degradation, rehabilitate degraded soils and thus contribute to improving crop productivity, several sustainable land management approaches have been promoted at farm level [26].

Income level has a negative but insignificant effect on the adoption of SLM practices, which is consistent with the work of [27], who conclude that income level has no significant effect on the adoption of the proposed technology package. This conclusion is contrary to that of [28], who argue that the prices of production factors and products on the market are strong economic signals that can influence the adoption of new technologies.

The ethnicity of the producer significantly determines the adoption of SLM practices. In fact, ethnicity gives the producer the status of native or non-native. In the commune of Bassila, inheritance is the main means of access to land. Non-natives who do not have enough land adopt SLM practices to make the most of what little they have by sharecropping, renting or even buying.

Finally, ‘Knowledge of SLM practices’ significantly determines the adoption of SLM practices. This result corroborates the findings of [4], who found that improving the contact of supervisory structures with farmers in order to increase their knowledge of the use of organic manure could increase the rate of adoption of this strategy. This is also the case with those of [29] who show through the calculation of marginal effects that a farmer who is in contact with extension agents and who participates in demonstrations organised by them has a greater probability of adopting the extension technical package than his peers.

5. CONCLUSION

The present study is a contribution to the analysis of the determinants of sustainable land management practices by producers in the municipality of Bassila. In order to cope with the effects of climate change and to ensure soil sustainability, farmers are increasingly adopting sustainable land management practices. The study revealed that several factors influence the adoption of sustainable land management practices in Bassila municipality. These include the farmer's land tenure status (lease or gift), education level (primary), income level and the farmer's ability to diversify crops, all of which have a negative impact on the adoption of SLM practices by farmers. On the other hand, the farmer's gender, ethnicity and knowledge of sustainable land management practices positively influence the adoption of SLM practices by farmers. In order to facilitate the adoption of SLM practices by farmers, and taking into account the factors identified above, we recommend that:

- Encourage collaboration: Promoting a network between producers and support structures to share best practices and successful experiences, thus strengthening the sense of belonging to a community committed to SLM.
- Strengthen producers' knowledge of SLM practices.
- Strengthening producers' capacity in terms of materials and equipment adapted to the implementation of SLM practices;
- Strengthening producers' skills in different types of SLM practices, increasingly including women producers;

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