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Drivers of Land Degradation in Trays Ecosystem as Modulated under a Changing Climate: Case Study of Côte d'Ivoire

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***Abstract*—**Land degradation is a serious problem in developing countries including Cote d'Ivoire, which has its economy focused on agriculture. It occurs in all kinds of ecosystems over the world. However, the drivers of land degradation vary from one region to another, and from one ecosystem to another. Thus, identifying these drivers is an essential prerequisite to develop and implement appropriate policies to reverse the trend of land degradation in the country, especially in the trays ecosystem. Using the binary logistic model with primary data obtained through 780 farmers surveyed, we analyze and identify the drivers of land degradation in the trays ecosystem. The descriptive statistics show that 52% of farmers interviewed have stated facing land degradation in their farmland. This high rate shows the extent of land degradation in this ecosystem. Also, the results obtained from the binary logit regression reveal that land degradation is significantly influenced by a set of variables such as sex, education, slope, erosion, pesticide, agricultural activity, deforestation, and temperature. The drivers identified are mostly local, as a result, the government must implement some policies and strategies that facilitate and incentive the adoption of sustainable land management practices by farmers to reverse the negative trend of land degradation.

***Keywords*—**Drivers, land degradation, trays ecosystem, sustainable land management.

I. Introduction

LAND is a vital resource providing the primary basis for human livelihood and well-being, food supply, freshwater, and many other ecosystem functions. Its degradation is a global ecological problem [1]. It has a direct impact on the livelihoods of millions of people, especially the farmers and the most vulnerable people living in the world's drylands. It also hurts the ability to increase global food production [2], which is necessary to meet the food needs of a rapidly growing population that is projected to exceed 9.2 billion in 2050 [3]. Land degradation is increasing significantly in the world covering around 23% of the global land [4]. It is more pronounced in developing countries [5], [6], especially in Sub-Saharan Africa where the economy is focused in the majority on agriculture [5], [7]. Indeed, agricultural productivity in this region has declined because of poor inherent soil fertility, biophysical factors, and climate changes.

Cote d'Ivoire, one of the Sub-Saharan African countries has its economic foundation in agriculture. Agricultural productivity is declining despite the increase in the production of some crops due to extensive agriculture. This decrease in agricultural productivity is partially due to climate change, land degradation, and unsustainable land management [8]. Despite the country being endowed with enormous biophysical potential, it needs to have healthy soil for sustaining its economy and people's livelihoods above all its economy is focused on agriculture [8].

Closely interwoven with climate change, land degradation has given rise to a multitude of policy responses across the world [9]. However, it still increases and its impacts are several for developing countries precisely those located in Sub-Saharan Africa including Cote d'Ivoire.

Understanding and identifying the drivers of land degradation are necessary for the implementation of policies and measures that will help to reduce their negative trends to have more social and environmentally friendly outcomes [10]. The drivers of land degradation are complex and diverse and they vary from one region to another, and across the region [6], [9], [11], [12]. Their impact on natural resources includes functions and services of soil that affect biodiversity, environmental health, and closely human welfare [11].

In Cote d'Ivoire, despite the lack of the assessment of relevant drivers of land degradation, the causes are essentially anthropogenic including urbanization, overgrazing, mining and quarrying activities, intensive agriculture, deforestation, etc. even if sometimes it is due to natural causes such as drought, landslide, flood, and water erosion. Erosion resulting from the threshing of water drops and the transport of solid particles by runoff is the most serious form of soil degradation in the country [13].

General objective of this paper is to analyze the drivers of land degradation in trays ecosystems in Cote d'Ivoire. As specific objective, it is to identify the key drivers of land degradation in trays ecosystems in Cote d'Ivoire. The hypothesis on which this study is focused is that the decreasing precipitation and/or the increasing temperature have a positive effect on land degradation.

The study uses logit regression to achieve our objectives. It is structured as follows: Section II presents the literature review. Section III deals with the materials and methods. Section IV presents the results and discussion while Section V concludes the study.

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II. Literature Review

Drivers of land degradation encompass the external factors that can act directly or indirectly to result in declines in biodiversity, and quality of life [14]. They can be classified into direct and indirect drivers [1], [14], [15]. Direct drivers can be also natural or anthropogenic and they have an impact on the implementation of ecosystems [14]. Natural drivers are those that are beyond human control whilst anthropogenic drivers are the result of human decisions and actions. Direct drivers explaining land degradation are multiple [16]. They are classified into subgroups which are agricultural expansion, infrastructure expansion, and wood extraction denoted deforestation.

Concerning indirect drivers of land degradation, they are underlying causes and act on the direct drivers of land degradation. They act from the way humans manage and interact with their ecosystem [14]. They are subdivided into five categories that are:

- Demographics include population growth rate, migration and population mobility, density of population, and age structure.
- Economy is focused on poverty, demand and consumption, commercialization and trade, labor market, prices, and finance.
- Science, knowledge, and technology concerns education, indigenous and local knowledge, taboos, research and development investments, access to technology, innovation, and communication.
- Institution and governance include public policy, property rights, customary laws, certifications, international agreements and conventions, informal institutions, and competencies for formal institutions.
- Cultural aspects: they are focused on values, religion, worldviews, consumer behaviour, and diet.

Natural drivers of land degradation include earthquakes, volcanic eruptions, landslides, floods, droughts, hurricanes, typhoons, and periodic outbreaks of pests and pathogens. The frequency of their appearance varies from years to millennia and contributes to land degradation, biodiversity, and ecosystem function and services loss. The anthropogenic drivers of land degradation are essentially focused on the misuse of land. Some examples include bush burning, overstocking of herds, cultivation on steep slopes, land clearing, pollution of land and water sources [17]. According to [9], nine variables can account for anthropogenic drivers of land degradation. These are the distance to the nearest urban center, the distance to the nearest rural settlement, the distance to the nearest mining area, the distance to the nearest road, the distance to the nearest surface water body, the human population density, the livestock density, the mean growing season temperature, and the annual sum of precipitation. For [18], the drivers and the causes of land degradation are the same. According to the authors, agricultural activity is the most important direct driver of land degradation followed by deforestation, road network development, urbanization, and bushfire. All these drivers are considered anthropogenic drivers. For indirect drivers of land degradation and deforestation, [18] has found five socioeconomics and political factors that can influence the change in the vegetation cover. Poverty and population growth are the main factors that drive land degradation and deforestation in the study area. These drivers are followed by shortage of off-farm employment, weak policy in favor of forest, and subsidies on farm input.

Land degradation is also classified into two categories that are proximate and underlying causes [6], [19]. According to [16], proximate causes are human activities or immediate actions at local level (agricultural expansion) that originate from intended land use and directly impact forest cover while underlying causes are fundamental social processes such as human population dynamics or agricultural. For [6], proximate drivers of land degradation include biophysical factors and unsustainable land management practices while underlying drivers are social, economic, and institutional factors that lead to unsustainable land management practices. As proximate causes, climatic conditions, topography [15], unsustainable land management [20], infrastructure development [16], deforestation [21], timber and charcoal extraction, and uncontrolled fires play an important role in the process of land degradation. Concerning the underlying causes, we can quote population density [22], land tenure [23], and poverty [24], [25].

With the complexity of the topic and the fact that the drivers of land degradation can change from one place to another one, several studies have been carried out at different regional scales with different methods. For instance, [26] using improved DISMED methodology in the southern and central southeastern areas of Europe have found that over 400.000 km^2 (around 25% of the total area of 1.700 km^2) of lands had high and very high sensitivity to land degradation compared to the initial DISMED methodology. Reference [9] from their side using partial ordered ranking of land degradation and Hasse Diagram during 1975-2000 found that livestock density and population are the main dominant drivers in Xilingol (China). Focusing on water conditions, the authors found three levels and three isolated elements corresponding to the counties meaning that there is no spatial pattern in the impact of water conditions on land degradation. Reference [19] used binary logit regression model with NDVI data between 1982 and 2006 to assess the relevant drivers of land degradation in Ethiopia, Malawi, and Tanzania. The results have shown that biophysical, demographic, plot level, and socioeconomic characteristics influence significantly land degradation and focusing on the regional characteristics, land degradation is significantly higher in Malawi and lower in Ethiopia taking as basis country Tanzania in the combined model.

Reference [6] used the ordered probit model to identify the drivers of land degradation in their study titled “Global Drivers of Land Degradation and Improvement”. The authors found that higher population density and intense night-time lighting intensity that is a proxy for higher socioeconomic development are positively associated with land degradation. Also, they associated areas with severe concerns over land tenure with land degradation.

Reference [27], using boosted regression trees in the

Amudarya River delta (between Uzbekistan and Turkmenistan) has found that near the Aral Sea in the downstream areas, some lands were severely degraded and water withdrawal availability and decreased precipitation were the factors that explained land degradation of cropland, sparse vegetation, and grasslands from 1990 to 2000. For the period 2000-2015, the authors found salt discharge as the major force causing land degradation in different vegetation types. Other studies have reported that anthropogenic factors increase land degradation [28], [29].

The diversity of the methods used and the results obtained imply that targeting anthropogenic factors are not sufficient to address land degradation. A set of natural and anthropogenic factors need to be taken into account when designing policies to prevent or mitigate land degradation.

III. Material and Method

A. Study Area

The study was conducted in Cote d'Ivoire, a West African country located between 4°39' and 10° of latitude North and 2°30' and 8°30' of longitude West with an area of 322,462 km^2 [42]. The tray ecosystem is located in the central-eastern and the northern part of the country. For our study area in this ecosystem, we have considered the "Iffou region" which is located in the central-eastern part. The region covers an area of 8955.05 km^2 and its population is estimated at 311,642 inhabitants. The climate in this region is of the baouleen type. It is hot and humid and alternates four seasons divided into two rainy seasons and two dry seasons. The great rainy season extends from March to mid-July to cope with the small dry season which lasts from September to October. As for the great dry season, it begins in November and ends in March interspersed by an unstable period of harmattan. The region possesses two types of vegetation namely grassy savannah in the west and the degraded forest in the east, north, and south. It is crossed by two principal rivers "Comoe" and "N'zi" which are permanent regimes. The others are seasonal. Among them, we can quote, "Ifou" which is the name of the region. For the potential economy, it is focused on agriculture which is of the itinerant type. This kind of agriculture has caused the reduction of the forest giving way to many fallows. The most common crops cultivated are cash crops (coffee, cocoa, rubber, palm, cashew, etc.), which are combined with food crops (yam, cassava, etc.). Fig. 1 locates the study area.

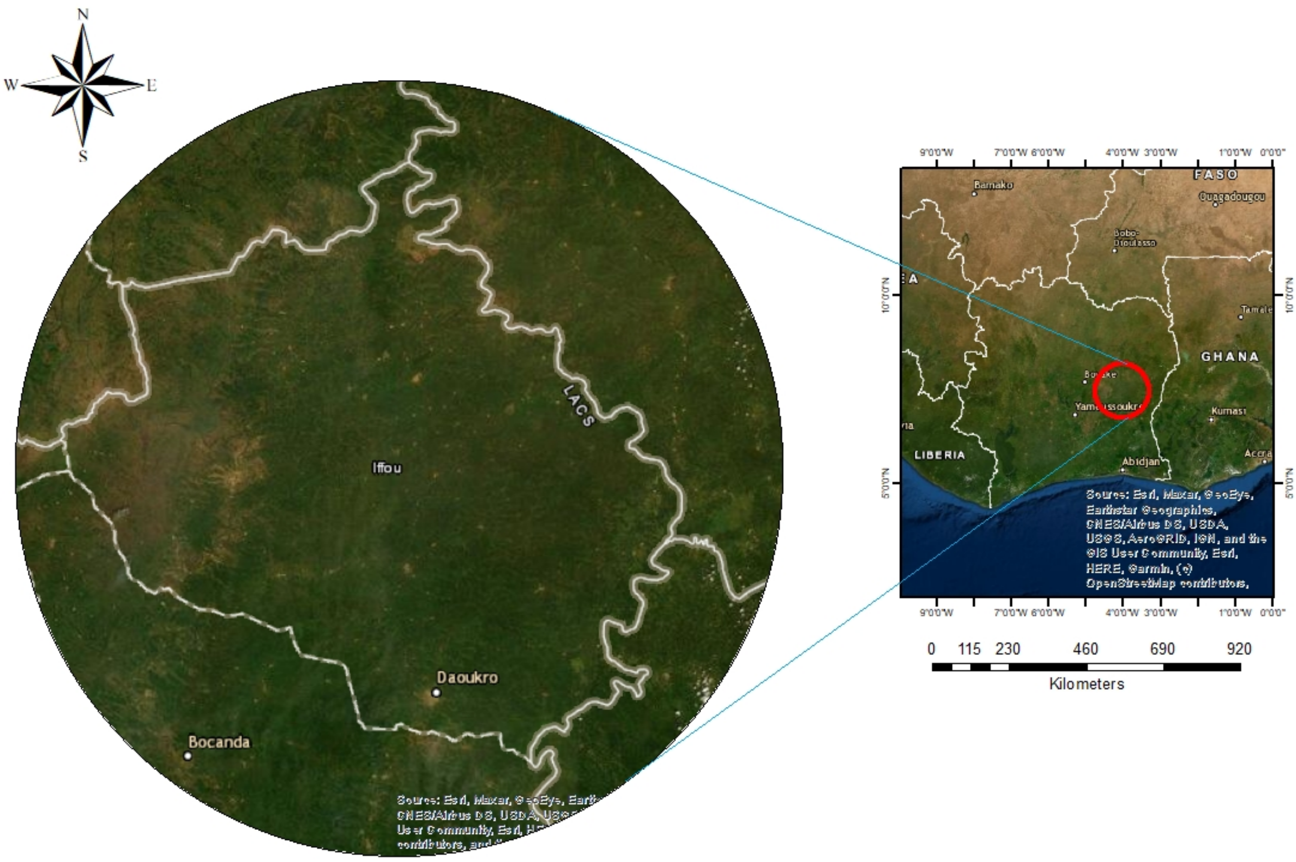

Fig. 1 Study area, computed by the author using ArcGIS, 2022

B. Data Source and Sampling Procedure

The data used for this study are primary data based on household surveys conducted in trays ecosystems. In this ecosystem, a two-round survey was conducted. The first one was to test the questionnaire to improve its quality. The second one officially collected the information needed to do the study. The sample size was determined using the Cochran equation that is: $n_0 = \frac{Z^2PQ}{e^2}$ where n_o is the sample size, z is the z-score which is equal to 1.96 with 95% confidence level, P is the population proportion set at 0.5, Q is equal to 1-P, and e is the desired margin error equal to 0.05 [30]. The minimum sample size is estimated at 384. However, to increase the quality of the study, 780 farmers were invited for interview in the trays ecosystem. A multi-stage sampling procedure has been employed to obtain the data. Firstly, the trays ecosystem was purposively selected because it is severely affected by land degradation. Secondly, four villages in the ecosystem were randomly selected. Thirdly, the respondents who are farmers were randomly selected using a simple random technique. The data include some socioeconomic (level of education, age, gender of the household), climate data (temperature and precipitation), and institutional characteristics data (land tenure, credit access).

TABLE I
THE SAMPLE SIZE IN TRAYS ECOSYSTEM

Ecosystem	Region	Name of village	Farmer sampled	Total population	Total farmer sampled
Trays	Iffou	Adikro	82	777	780
		Akanangbo	80	508	
		Donguikro	101	850	
		Koffi Amonkro	130	2500	
		Nafana	113	1598	
		Tetesi	97	1056	
		Ahouan	85	843	
		Koffi-Akakro	92	1447	

C. Model Specification

To achieve the general objective of this work which is to analyze the drivers of land degradation in the tray ecosystems in Cote d'Ivoire and deal with the specific objective which is to identify the key drivers of land degradation in trays ecosystems in Cote d'Ivoire, we used the Logit regression model. According to [19], the choice to use the Logit regression model is informed by the nature of the assessment and the kind of data available. The Logit model can be easily applied in cases where the dependent variable is nominal or ordinal and also in the case where it has two or more levels. Logistic regression has been used particularly to investigate the relationship between binary or ordinal response probability and explanatory variables. Theoretically, the Logit model can be specified as:

$$Y_i = \beta X_i + u_i \tag{1}$$

where Yi is a dummy variable that is defined as 1 and 0. In this study, Y is 1 if land is degraded and 0 if land is not degraded or improved. X_i is a vector of exogenous factors that influence Y, β are unknown parameters and u_i is an error term. The probability that a land falls under one of Y is given as:

$$(Y = 1|X) = (X, \beta) \tag{2}$$

$$(Y = 0|X) = 1 - (X, \beta) \tag{3}$$

The logistic function can therefore be defined as:

$$(Y = 1|X) = e^{X'} = \Phi\ (X'\beta),\ 1 + e^{X'} \tag{4}$$

where Φ denotes the logistic cumulative function. Given this formulation, the equation is given as follows:

$$LD_i = \boldsymbol{\beta_0} + \boldsymbol{\beta_1} X_i + u_i \tag{5}$$

where LD is land degradation and Xi represents the independent variables used in the study.

Xi is a set of variables including climate factors, demographic characteristics factors, socioeconomic and institutional characteristics factors. u_i is the error term. Table II summarizes and defines the variables used in the study.

TABLE II
DEFINITION OF ALL VARIABLES USED IN THE MODEL

Variables	Description
	Dependent variable
LD	Land degradation that takes 0 if the land of farmer is degraded; 1 otherwise
	Independent variables
Age	Age of respondent in year.
Sex	Gender of the farmer; 1 male, 0 otherwise
Education	Literacy of the respondent; 1 if the respondent is literate, 0 otherwise
Propright	Property right; 1 whether a farmer has property right of his land, 0 otherwise
Erosion	Erosion of soil; 1 if farmer constated erosion of soil in his plot, 0 otherwise
Pesticid	Pesticide use; 1 if farmer use pesticide in the plot, 0 otherwise
Slope	Slope of the plot; 1 if the field is on slope, 0 otherwise
Agriact	Agricultural activity; 1 if farmer perceives agricultural activities as responsible of LD, 0 otherwise
Defor	Deforestation; 1 if farmer perceives Deforestation as responsible for LD
Temp	Daily temperature in (°c)
Preci	Daily precipitation in (mm)

IV. RESULTS AND DISCUSSION

A. Descriptive Statistics

In this subsection, the results of the descriptive statistics are discussed. Table III pointed out the results of the mean and standard deviation of the variables used in the regression model. From farmers interviewed, about 65% were men, while the remaining 35% were women. The results observed reveal that men were the most implicated in agriculture than women. Concerning the demographic characteristics, 33% of farmers were educated while the average age of farmers was 49 years. The mean household size is estimated at 7.42 people showing that this ecosystem is densely populated exacerbating pressure on land.

Focusing on plot characteristics, plot on slope accounted for around 11.2%. Land degradation, according to farmers interviewed, is estimated at 52.4%. The trays ecosystem's historical focus on cocoa production dating back to independence, is the reason for its high rate of land degradation.

Regarding erosion, the proportion of farmers who stated facing soil erosion in their plots was about 41%. According to them, deforestation is the main cause of soil erosion above all the scarce rainfall can fall during some days creating floods that are harmful to land. For pesticides use, the main pesticides used were herbicides because they have no money to hire labor above all the cost of one labor per day was around 2000 fcfa[1]. Around 39% of farmers use pesticides in their fields to fire grass in order to clean their fields. According to climate change characteristics, results indicated that the temperature is about 25 °C while for the precipitation, the daily quantity was around 6 mm on average. The scarcity of the precipitation combined with the high temperature plays an important role in the decision of farmers to have off-farm employment. For agricultural activities, 65% of the farmers stated that agricultural activities are responsible for land degradation. Deforestation accounted for 72% according to farmers interviewed.

TABLE III
DESCRIPTIVE STATISTICS OF ALL VARIABLES USED IN THE STUDY

Variable	Mean	Std. Dev.
LD	0.524	0.500
SEX	0.646	0.478
AGE	49.221	13.625
EDUCATION	0.327	0.469
HHSIZE	7.423	3.648
SLOPE	0.112	0.315
EROSION	0.409	0.492
PESTICID	0.387	0.487
AGRIACT	0.650	0.477
DEFOR	0.721	0.449
TEMP	25.379	1.666
PRECI	5.955	9.990

B. Logistic Regression Results

The logistic regression model is used to address the objective of the study that is to identify the drivers of land degradation in the study area. Table IV presents the results of Logit regression for the study areas. The model is globally significant because the log-likelihood value was statistically significant at 1% level of significance indicating that the hypothesis that all the coefficients except the intercept are equal to zero was rejected [(Trays: $Chi^2(11) = 75.20$, Prob = 0.000)]. Concerning the validation tests of the model, we used the prediction power test, the discriminating power test: the ROC curve, and the Hosmer-Lemeshow goodness of fit test. The fit test of the model to the data is good because the following Prob > chi2 = 0.4754 is greater than the pvalue = 5%, of this fact, the model is performant to data in our study. The predictive power of the model is perfect in the study area. The percentage obtained after running the test was estimated at 60.51% showing that the logit model is correctly classified.

About the ROC (Receiver Operating Characteristic) curve concerning the power of the discrimination test, it is low because the value (0.66) is comprised between 0.6 to 0.7. In addition, the Variance Inflation Factor (VIF) which detects multicollinearity in a set of variables has shown that there is no multicollinearity because all values of VIF (< 2) were under the value "5" [31].

The result of binary logit regression shows that 8 out of 11 variables included in the model significantly affect land degradation in the study area (Table IV). These are sex, education, slope, erosion, pesticide, and temperature. Apart from sex and education which negatively affect land degradation respectively at 1% and 5% level of confidence, slope, agricultural activity, deforestation, and temperature positively affect land degradation at 1% while erosion and pesticide use positively influence it at 5% and 10% level of confidence respectively. Our interest variable "temperature" as mentioned above has a positive effect on land degradation. For instance, an increase in the daily temperature of 1% may increase land degradation by 5.3% holding other factors constant. This finding is consistent with [19], [27], [32], [33], who argued that increasing temperature accelerates land degradation. The hypothesis on which this study is focused is that the decreasing precipitation and/or the increasing temperature have a positive effect on land degradation is verified. Conversely to our finding, [34] found that increasing temperature showed less influence on land degradation. The variable sex which takes 1 if the farmer is a male and 0 otherwise is less likely to experience land degradation. When holding all other variables constant, the presence of one male farmer results in a reduction of 0.314 units of degraded land. This is consistent with the result found by [35] who argued that cultural and social setups dictate access to control land and external inputs (fertilizers and seeds), and their controls are considered discriminatory against women. Therefore, farmers who are males are more likely to take care of their land by investing in SLM practices than females.

TABLE IV
RESULTS OF THE LOGIT REGRESSION

LD	Odds Ratio	Std. Err.	P>z	dy/dx
SEX	0.265	0.06	0.000	-0.314***
AGE	0.998	0.006	0.722	-0.001
EDUCATION	0.695	0.124	0.042	-0.091**
HHSIZE	1.014	0.021	0.513	0.003
SLOPE	2.642	0.69	0.000	0.225***
EROSION	1.399	0.236	0.046	0.083**
PESTICID	1.308	0.209	0.093	0.067*
AGRIACT	1.978	0.461	0.003	0.169***
DEFOR	1.575	0.277	0.01	0.113***
TEMP	1.236	0.062	0.000	0.053***
PRECI	1.01	0.008	0.202	0.002
_cons	0.004	0.006	0.000	

***, **, and * denote significance at 1%, 5% and 10% respectively. The dependent variable – LD is binary (1 = degraded, 0 = otherwise)

Education influences land degradation negatively and significantly at 5% level of significance. This implies that an increase of 1% of the farmers who are educated may decrease land degradation by 9% keeping other factors constant. This is because educated farmers are able to obtain, interpret, and respond to new information about sustainable land management practices. The result is in line with [4], [19], [36], [37].

Slope had a positive and significant influence on land degradation. An increase of slope of 1% accentuates land degradation by 22.5% keeping the other variables constant. This could be explained by the fact that the plot on the slope is

[1] Local Currency

more vulnerable to soil erosion than other flat plots. This result is in agreement with the findings of [38] who pointed out that plot on the slope coupled with the nature of tillage practices create a suitable condition for soil erosion. Other studies found a positive influence of slope in the process of land degradation [39], [40].

Erosion has positive influence on land degradation and was significant at less than 5% level of significance. Holding other variables in the model constant, a change in the erosion by 1% will increase land degradation by 8.3%. The results found by [41] corroborated our findings.

Consistent with the findings of [40] agricultural activity had a positive and significant influence on land degradation at 1% level of significance. This means that when agricultural activity increases by 1% land degradation could increase by 16.9% keeping the other regressors in the model constant. One explanation could be the way land is used and the inputs use on it. The positive and significant influence of agricultural activity on land degradation is in line with the findings of [18].

Another variable playing a positive and significant influence on land degradation is deforestation. It is significant at 1%. The positive influence implies that when deforestation increases by 1% land degradation could be increased by 11.3%, all other things being equal. This is because deforestation reduces the recharge of groundwater and nutrient cycling, leads to desertification of the land, and has a direct link to soil erosion.

V. Conclusion and Recommendations

Land degradation is a serious threat for developing countries, particularly those located in Sub-Saharan Africa because their economy is mainly focused on agriculture. It is an important subject due to the increasing number of causes as well as its consequences. This study used surveys from farmers in the trays ecosystem and applied the binary logit regression method to analyze and identify the drivers of land degradation in this ecosystem. Descriptive data analysis showed that on average 52% of farmers have stated facing land degradation in their fields. The binary logit regression results show that sex, education, slope, erosion, pesticide, agricultural activity, deforestation, and temperature all have a significant impact on land degradation. Thus, the hypothesis we formulated in this study, which states that decreasing precipitation and/or the increasing temperature have a positive effect on land degradation, is accepted. The diversity of the drivers of land degradation across the trays ecosystem is due to differences in economic, social, cultural, plots, and climate characteristics meaning that the problem of land degradation must be treated in holistic ways if the country wants to continue to take advantage of the agricultural sector. Therefore, immediate actions are required to reverse the negative trend of land degradation, particularly in the study areas where land degradation increases. Of this fact, improving farm management skills and making information available on SLM practices could help farmers which are already suffering from the consequences of land degradation to improve their management of land. This study that mainly analyzed and identified the drivers of land degradation in trays ecosystems may still not be adequate to explain the exhaustive land degradation in the country. Future research must attempt to analyze and identify the drivers of land degradation in all ecosystems of the country to have a better overview of the drivers of land degradation.

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Appendix

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. summarize LD SEX AGE EDUCATION HHSIZE SLOPE EROSION  PESTICID AGRIACT DEFOR TEMP PRECI
```

Variable	Obs	Mean	Std. Dev.	Min	Max
LD	780	.524359	.4997267	0	1
SEX	780	.6461538	.478469	0	1
AGE	780	49.22051	13.62519	20	91
EDUCATION	780	.3269231	.4693899	0	1
HHSIZE	780	7.423077	3.647917	1	25
SLOPE	780	.1115385	.3149998	0	1
EROSION	780	.4089744	.49196	0	1
PESTICID	780	.3871795	.4874178	0	1
AGRIACT	780	.65	.4772756	0	1
DEFOR	780	.7205128	.4490352	0	1
TEMP	780	25.37905	1.666057	21.23	31.13
PRECI	780	5.955167	9.990464	.01	98.18

Fig. 2 Descriptive statistics of all variables used in the model

```
. logit LD SEX AGE EDUCATION HHSIZE SLOPE EROSION PESTICID AGRIACT DEFOR TEMP PRECI

Iteration 0:   log likelihood = -539.72879
Iteration 1:   log likelihood = -502.17761
Iteration 2:   log likelihood = -502.12901
Iteration 3:   log likelihood = -502.12901

Logistic regression                               Number of obs     =        780
                                                  LR chi2(11)       =      75.20
                                                  Prob > chi2       =     0.0000
Log likelihood = -502.12901                       Pseudo R2         =     0.0697
```

LD	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
SEX	-1.328429	.2269398	-5.85	0.000	-1.773223	-.8836355
AGE	-.0021751	.0061179	-0.36	0.722	-.014166	.0098157
EDUCATION	-.3633103	.1790237	-2.03	0.042	-.7141903	-.0124303
HHSIZE	.0137065	.0209379	0.65	0.513	-.0273311	.0547441
SLOPE	.9713713	.2612769	3.72	0.000	.459278	1.483465
EROSION	.336055	.1685656	1.99	0.046	.0056724	.6664375
PESTICID	.2686747	.1599263	1.68	0.093	-.044775	.5821244
AGRIACT	.6821691	.2332871	2.92	0.003	.2249348	1.139403
DEFOR	.4541994	.1757476	2.58	0.010	.1097404	.7986583
TEMP	.2121315	.0500233	4.24	0.000	.1140878	.3101753
PRECI	.0100244	.0078617	1.28	0.202	-.0053841	.025433
_cons	-5.469058	1.305823	-4.19	0.000	-8.028423	-2.909692

Fig. 3 Logit regression results

```
. mfx compute

Marginal effects after logit
      y  = Pr(LD) (predict)
         =  .52805794
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
SEX*	-.3137488	.04869	-6.44	0.000	-.409173	-.218325	.646154
AGE	-.0005421	.00152	-0.36	0.722	-.00353	.002446	49.2205
EDUCAT~N*	-.0905237	.04443	-2.04	0.042	-.177606	-.003441	.326923
HHSIZE	.0034158	.00522	0.65	0.513	-.006812	.013643	7.42308
SLOPE*	.2251886	.05341	4.22	0.000	.120515	.329862	.111538
EROSION*	.0833929	.04154	2.01	0.045	.001977	.164809	.408974
PESTICID*	.0667293	.03952	1.69	0.091	-.010725	.144183	.387179
AGRIACT*	.1689038	.05669	2.98	0.003	.057803	.280005	.65
DEFOR*	.1130602	.0434	2.61	0.009	.027999	.198121	.720513
TEMP	.0528659	.01246	4.24	0.000	.028437	.077295	25.3791
PRECI	.0024982	.00196	1.28	0.202	-.001342	.006338	5.95517

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Fig. 4 Marginal effect results

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. vif
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Variable	VIF	1/VIF
AGRIACT	1.98	0.504869
SEX	1.81	0.552731
AGE	1.24	0.805741
EDUCATION	1.23	0.815568
EROSION	1.19	0.839748
TEMP	1.14	0.879198
DEFOR	1.07	0.931457
PRECI	1.07	0.935510
PESTICID	1.06	0.938997
SLOPE	1.06	0.939241
HHSIZE	1.05	0.956620
Mean VIF	1.26	

Fig. 5 Result of Vif test

```
. lstat

Logistic model for LD
```

Classified	True D	~D	Total
+	256	155	411
-	153	216	369
Total	409	371	780

Classified + if predicted Pr(D) >= .5
True D defined as LD != 0

Sensitivity	Pr(+| D)	62.59%
Specificity	Pr(-|~D)	58.22%
Positive predictive value	Pr(D| +)	62.29%
Negative predictive value	Pr(~D| -)	58.54%
False + rate for true ~D	Pr(+|~D)	41.78%
False - rate for true D	Pr(-| D)	37.41%
False + rate for classified +	Pr(~D| +)	37.71%
False - rate for classified -	Pr(D| -)	41.46%
Correctly classified		60.51%

Fig. 6 Results of the prediction power test

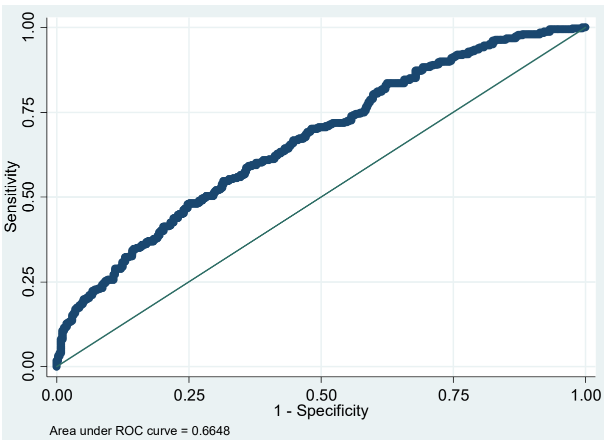

Fig. 7 The discriminating power test- the ROC curve: lroc: number of observations = 780

```
. estat gof, group(10)table
```

Logistic model for LD, goodness-of-fit test

(Table collapsed on quantiles of estimated probabilities)

Group	Prob	Obs_1	Exp_1	Obs_0	Exp_0	Total
1	0.3282	15	20.9	63	57.1	78
2	0.3943	32	28.6	46	49.4	78
3	0.4381	38	32.6	40	45.4	78
4	0.4720	37	35.7	41	42.3	78
5	0.5120	41	38.4	37	39.6	78
6	0.5605	40	42.0	38	36.0	78
7	0.6133	44	45.9	34	32.1	78
8	0.6640	47	49.7	31	28.3	78
9	0.7207	50	53.9	28	24.1	78
10	0.9575	65	61.5	13	16.5	78

```
      number of observations =       780
            number of groups =        10
     Hosmer-Lemeshow chi2(8) =         7.58
                 Prob > chi2 =         0.4754
```

Fig. 8 The results of the Hosmer-Lemeshow goodness fit test

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