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Farm Level Indicators of Sustainable Land Management: Effect on Agricultural Production in Oyo State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author IOO designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors JOO and AAA managed the analyses of the study. Authors IOO and MOR managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Farmland sustainability and increased agricultural production have been a major concern of average farmers in Nigeria especially in South Western part of the Country. The study examines the farm level indicators and their effects on agricultural production among rural farmers. Multi-stage methods of sampling technique were used to select fifty respondents for this study using a well-structured questionnaire. Data collected were analyzed by the use of descriptive such as means, percentage, standard deviation and fuzzy logic analysis. The result shows that average age of farmer, farm size, household size and farming experience are 52.28 years, 2.072 hectare, 6.80 and 29.42 years of farming experience respectively. The fuzzy logic method was used to compute

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the composite indicator of sustainable land use (ISLU) which was 0.2843 indicating that farmers' land management practices in the study area are generally sustainable with the current application of the indicators. Land fallowing, trends of vegetative cover, irrigation, pesticide used among others contributed a higher percentage of land use sustainability with about 3.8% each, while minimum tillage, cover crops, crop rotation and cassava cutting use had no contribution to land use sustainability. The study recommends that rural water should be made available and that informal training through extension services should be conducted to educate farmers on sustainable land management (SLM) practices in order to have a better environment and improve production in the study area.

Keywords: Farm level; indicators; sustainable; land managements; fuzzy; cassava; Oyo State.

1. INTRODUCTION

The agricultural sector has always been an important component of the Nigerian economy. The sector is almost entirely dominated by small scale resource-poor farmers living in the rural areas, with farm holdings of 1-2 hectares, which are usually scattered over a wide area [1]. The size distribution of these holdings as defined by previous studies and evidenced in the literature by many researchers [2,3] as small-scale farms, ranges from 0.10 to 5.99-hectares, medium scale, 6.0-9.99 and large scale above 10 hectares. These classes constituted 84.49 percent, 11.28 percent and 4.23 percent respectively in 2004 [4]. According to Oksana [5], about 75% of southwestern Nigeria's land is under arable cultivation with a land-human ratio of 58 persons per square kilometre in southwestern Nigeria. Sustainable agriculture has been defined variously by different authors [6]. However, FAO [7] defined sustainable agriculture as one, which involves the successful management of resources for agriculture to satisfy human needs, while maintaining or enhancing the quality of the environment and conserving natural resources. Sustainable land management (SLM) is defined as a knowledge-based procedure that helps integrate land, water, biodiversity, and environmental management (including input and output externalities) to meet rising food and fiber demands while sustaining ecosystem services and livelihoods. Sustainable land management (SLM) has been defined as the adoption of appropriate land management practices that enables land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources [8].

Traditionally through time, farmers have developed different soil conservation and land management practices of their own. With these practices, farmers have been able to sustain their production for centuries thus the determined effects of resource exploitation have become widespread, there has been growing awareness that productive lands are getting scarce, land resources are not unlimited, and that the land already in use needs more care. As a result of the increase in world population, other non-agricultural activities are demanding for land space, hence there is a progressive loss of land for food production. At the same time, demand for food and other agricultural products is increasing, requiring for more land which is not available since the earth's land area is finite.

The extent of land degradation in Nigeria is presently alarming. This occurs in different scales and dimensions and no part of the country can be entirely excluded. Also, compared with some other African countries, the country is blessed with abundant land resources, which are capable of indefinite regeneration over a given period of time where the prevailing management practices are conducive. Management issue cannot be taken for granted, given that these resources constitute the productive base for the Nigerian agriculture, upon which the livelihoods of many rural and urban households depend on [9]; moreover, poor incentives for natural resource conservation, among other socioeconomic problems, have subjected the soil's nutrients to serious exploitation and depletion. The diminishing worldwide availability of productive land is such that continued degradation of such land is a clear threat to the survival of the human race. Hence, this raises the research objectives which are to (i) describe the socio-economic characteristics of the farmers in the study area (ii) analyse the effect of sustainable land management indicators to land use among the farmers as to whether or not the forces driving improved management practices are fully understood and construct an index of sustainable land use indicators.

2. MATERIALS AND METHODS

2.1 The Study Area

This study was carried out in Oyo State (Nigeria), located in the Southwestern part of the country. Oyo State consists of 33 local government areas grouped under four agricultural zones of Oyo State Agricultural Development Programme (OYSADEP). The zones are Ibadan-Ibarapa, Oyo, Saki and Ogbomoso Zones. Oyo State covers a total land area of about 27,249,000 km^2 with a total population of about 5.6 million [10]. It is situated between Latitude 7^o N and 19^o N and Longitude 2.5^o E and 5^o E of the meridian. The state is predominantly agrarian, annual mean rainfall is above 1000 mm with the rainy season average eight months in a year. Rain starts in Oyo state during the first week of March with storms. Mean temperature varies from a daily minimum of 18.9 ^{0}C to a daily maximum of 35 ^{0}C. Humidity is quite high in Oyo state; relative humidity is 70% with a maximum of about 60% in the evening and a maximum of around 80% in the morning.

2.2 Sampling Technique and Sample Size

Multi-stage sampling technique was used to obtain data for this study through the use of structured questionnaires. The first stage was the choice of choosing the existing four Agricultural zones, namely, Ibadan-Ibarapa, Oyo, Saki and Ogbomoso zones. The second stage involved purposive selection of the respondents under Oyo agricultural zone where these farmers are concentrated. In the third stage 10% of the respondent (50) were selected according to the population of the registered cassava farmers from the list of the Nigeria Cassava Growers Association (NCGA). Lastly, 50 respondents were selected at random for this study. The study used data obtain mainly from the primary source.

2.3 Analytical Techniques

Descriptive statistics were used to analyse the socio-economic characteristics of the farmers while the fuzzy set theory was used to analyse the contribution of the indicators to land management used.

The fuzzy set was proposed by Tang and Van Ranst [11]. This approach had been applied to land suitability analysis by many authors [12,13,9]. It was proposed that in a population A of n households [A = a1, a2, a3, ……an], the subset of households using land unsustainably B includes any household $ai_{\in}B$. These farmers present some degree of sustainability in some of the m land indicators (X). The degree of sustainability by the ith farmer (i=1,….,n) with respect to a particular attribute (j) given that (j = 1,……,m) is defined as: μB [Xj (ai)] = xij, 0 < xij < 1. Specifically, xij = 1 when the farmer's use of land depicts sustainability and xij = 0 otherwise. Betti et al. [14] noted that putting together categorical indicators of deprivation for individual items to construct composite indices requires decisions about assigning numerical values to the ordered categories and the weighting and scaling of the measures. Farm-level indicators of sustainable land use often take the form of simple 'yes/no' dichotomies. In this case xij is 0 or 1. However, some indicators may involve more than two ordered categories (for example, discrete categorical variables and continuous categorical variables), reflecting the different degree of deprivation. Consider the general case of c = 1 to C ordered categories of some deprivation indicator, with c = 1 representing the most deprived and c = C the least deprived situation. Let ci be the category to which individual *i* belongs. Cerioli and Zani [15], assuming that the rank of the categories represents an equally-spaced metric variable, assigned to the individual a deprivation score as: xij = (C-ci)/(C-1) (1) where 1 < ci < C by summarizing the key notions about sustainable land management based on the theory of fuzzy sets, and in particular on the work of [16]

i. sustainable land management indicators in the given space (a_1)

$$A=\{a1........ai............\}; \quad (1)$$

and

ii. A vector to the order of m for socio-economic attributes (X_1) for studying the state of sustainable land management for

$$A:X=\{X1............Xj............Xm\} \quad (2)$$

The choice of the set of socio-economic attributes in relation to sustainable land management will consist, for each set in a selection of socio-economic sets the absence or partial possession of which contributes to the state of farmers' sustainable land management. They are calculated using a vector X of the order m: X = (X_i.....X_j.......X_m), X includes economic, social, and family attributes represented by (discrete and continuous) quantitative variables and/or qualitative variables. Let us call B a subset of A such that each $a_i \in B$ represents a degree of deprivation in at least one of the attributes included in X.

The function of the i-th farmer (i = 1.........n) belonging to the fuzzy subset B in relation to the j-th attribute (j =1......m) is defined as follows

$$X_{ij}=U_{\beta}\ (X_1(a_1)),\ 0 \leq 1 \quad (3)$$

In this case:

Xij = 1, if the i-th farmer does not have the j-th attribute;

Xij = 0, if the i-th farmer possesses the j-th attribute;

0 < xij < 1, if the i-th farmer has the j-th attribute with an intensity between (0, 1).

The function of the i-th farmer (i = 1.... n) belonging to the fuzzy subset B can be defined as the average weight of xij;

$\mu_{\beta}\ (a_i)$ = equation $\mu_{\beta}\ (a_i)$ measures the ratio of the sustainable land management of the i-th farmer, where w_i is the weight attached to the j-th attribute and where

$0 \leq \mu_{\beta}\ (ai) \geq 1$

The behaviour of the function of belonging (to a fuzzy subset) is the following:

$\mu B\ (a_i) = 0$, if ai possesses the m attributes;

$\mu B\ (a_i) = 1$, if ai is totally deprived of the m attributes;

$0 < \mu B\ (a_i) < 1$, if ai is partially or totally deprived of some attributes, but not completely deprived of all attributes.

Weight wj represents the intensity of deprivation linked to attribute Xj. It is an inverse function of the degree of deprivation of this attribute for the farmer population. The smaller the number of households with attribute Xj is, the bigger the weight wj will be; [15] define a weight that verifies this property, namely:

$$Wj = \log[\textstyle\sum_{j=1}^{n} g(a_i) / \sum_{j=1}^{n} x_n\, g(a_i)] \quad (4)$$

$\sum_{j=1}^{n} x_n\, g(a_i) > 0$

where $g(a_i)$ refers to the frequency (weight) with which respondent a_i of the population was observed; $g(a_i)\ \sum_{j=1}^{n} x_n\, g(a_i)$ is the relative frequency with which sample ai of the population observed, g(ai) is equal to n times the relative frequency of farmers in the total population.

Therefore, when everybody possesses an attribute or nobody has it, the attribute should be removed because it is of no serious relevance to the sustainability of land use. In equation (4), the denominator of the logarithm is always positive. If the value Xij = 0 was part of the possible sets, that would mean there would be no deprivation in Xj. The fuzzy index of sustainability of set A is a weighted mean of $\mu_B\ (a_i)$ given by formula (4).

In addition to determining the multidimensional sustainable land management for the i-th farmer and that for the overall populat ion, the use of the theory of fuzzy sets makes it possible to calculate a uni-dimensional index for each one of the j attributes considered

$$\mu_{\beta}\ (X_j) = \textstyle\sum_{j=1}^{n} x_n g(a_i) / \sum_{j=1}^{n} g(a_i) \quad j = 1, 2,.....\ n \quad (5)$$

where $\mu_{\beta}\ (X_j)$ defines the degree of deprivation of the jth attribute for the population of the respondent. The overall fuzzy index of sustainable land management can also be defined as a weighted average of uni-dimensional indices for each attribute

$$\mu_{\beta} = \textstyle\sum_{j=1}^{m} \mu_{\beta}(X_j) W_j / \sum_{j=1}^{m} \quad w_j = 1, 2,...\ m \quad (6)$$

The analysis of the results obtained in (5), for j=1 ...m, offers to the decision makers the possibility to identify the causes of unsustainable land management and to intervene structurally in order to reduce it.

3. RESULTS AND DISCUSSION

3.1 Socio-economic Characteristics of the Respondents

Table 1 revealed that the average age of the farmers was 52.8 years, average farming management experience was 18.32 years, implies that the farming system in the study is becoming ageing. This is in line with findings of [17] which says that cassava-based farming in Oyo State was in the hands of elderly people who may not have the required labour by themselves 38% of the farmers were female, this shows that male farmers were the majority involved in cassava farming in the study, 1.12% were single, average farm size owned by the farmer was 2.07 hectares which implies that farmers were operating on a small scale farming system, mean household size was 6.80 persons

Table 1. Socio-economic characteristics of the farmer

Socio-economic characteristics	Means	Standard deviation
Age	52.8	13.310
Gender (% female)	38	
Marital status (% single)	1.12	0.480
Educational level	1.48	0.953
Household size (n. Person)	6.80	1.829
Hired labour (%)	82	
Rain-Fed agriculture (%)	80	
Mode of cultivation % mechanization)	18	
Average farm size (hectare)	2.07	1.485
Land use duration (year)	15.86	7.895
Farm management experience (year)	18.32	8.353
Gross income (Naira)	295400	

Table 2. Effect of SLM indicators to sustainable land use in the study area

SLM indicators	Absolute contribution	Relative contribution (%)
The vigour of crop yield	0.0095	3.32840342
Trend of vegetative covers	0.0108	3.78987618
Residue cover	0.0107	3.77705761
Crop yield	0.0084	2.94250896
Labour productivity	0.0100	3.53044691
Profit per hectares	0.0080	2.82105708
Organic matter contents	0.0090	3.15403524
Drainage/infiltration of water	0.0102	3.58372123
Water holding capacity	0.0095	3.34660207
Aggregation of soil	0.0108	3.78993742
Earthworm/ soil life	0.0084	2.96773692
Compaction and rooting	0.0107	3.77711864
Crusting/ emergency	0.0102	3.58372123
Tilth / workability	0.0108	3.79068973
Wind or water erosion	0.0106	3.73488028
Salinity	0.0106	3.73488028
Plot level application fertilizer	0.0080	2.82105708
Addition of organic manure	0.0098	3.45054330
Mulching of crops	0.0063	2.20416883
Minimum tillage	0.0000	0.00000000
Cover crops	0.0000	0.00000000
Rotation of crops	0.0000	0.00000000
Land fallowing	0.0108	3.80332494
Irrigation water level	0.0108	3.80332494
Irrigation water quality	0.0090	3.15403524
Use of pesticide	0.0094	3.80332494
Use of herbicide	0.0108	3.80332494
Use of chemical poison	0.0084	2.94255651
Industrial discharges	0.0099	3.49803877
Land use intensity	0.0099	3.49803877
Labour use intensity	0.0082	2.89541341
Type of seeds	0.0082	2.88541341
Seed use intensity	0.0066	2.32205584
Total computed (ULUI)	0.2843	100

which is fairly large and can be useful for family labour, average educational level was 1.48, indicating that average farmers could not go beyond secondary education, 82% of the farmer used hired labour, 80% rely on rain-fed agriculture, 18% used mechanical mode of cultivation while 82% made use of the crude/manual mode of cultivation, average years of land use duration was 15.86 years. This may cause soil nutrients lost because of its long term use which may lead to a poor yield of crops if not properly managed while average farm income was =N=295,400.00k, 80% of the farmer have an absolute right to their farmland. This may enhance the farmer to embark on extensive sustainable land management practices without any fear.

3.2 The Contribution of SLM Indicators to Sustainable Land Use and Index of Sustainable Land Use

Results are reported in Table 2 It shows that land following contributes relatively 3.8% to sustainability because same pieces of farm land were used periodically for agricultural activities which may serve as a cause of soil nutrients loss and degradation without allowing the land to rest. Trends of vegetative cover have a relative contribution of 3.78% to sustainability because farmers clear and fell forest trees but are unable to replace them thereby led to land degradation and deforestation. Irrigation water level also contributes 3.8% to sustainability because the water level annually reducing because the farmers solely depend on rainfall for irrigation; also pesticide application contributes 3.8% to sustainability because pesticides applied may have contaminated water and were not applied in a right manner. This is in conformity with the findings of [9]. All the indicators mentioned above contribute to land been sustainable, and these can reduce the level of crop production in the study area. However, Stem use intensity, minimum tillage, cover crops and crop rotation contributed 0% to land sustainability. This implies that all these indicators contribute relatively to land sustainability which can influence crop output positively in the study area because the closer the fuzzy value is closer to zero the better the sustainability.

4. CONCLUSION AND RECOMMENDATIONS

The study examines the farm level indicators and their contributions to sustainable land management practices among rural farmers in Oyo agricultural zone. It considered different production objectives in farmers land use system using fuzzy sets. This allows the integration of different properties of a particular land into a composite index that captures the extent of degradation to the farm land. It was discovered that majority of the farmer are male and they are operating on a small scale farming system. Also, trends of vegetative cover, land fallowing, irrigation, pesticide used among others contribute higher percentage to land use sustainability with about 3.8% each, while minimum tillage, cover crops, crop rotation and cassava cutting use intensity have no contribution to land use sustainability respectively in the study area.

Based on the result and findings of the study the following are therefore recommended.

- Informal training can be conducted to educate the farmers on sustainable land use practices that can deplete soil through extension officers.
- The government agencies saddled with the responsibility of disseminating information to farmers through extension service departments should step up their efforts in creating awareness through mass orientation in the study area.
- Small scale farmers should form agricultural societal group in order to have access to micro credit which can result in environmental conservation through access to formal credit.
- Farmers should be encouraged to replace back the trees that were cleared/ felled from the farmland in order to discourage deforestation and exposure of the soil to erosion and thereby enhancing agricultural sustainability in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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