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Fuzzy Indicator of Sustainable Land Management and Its Correlates in Osun State, Nigeria

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ABSTRACT Sustainable land management (SLM) is one of the major issues of concern to Nigerian policy makers due to persistent degradation of land. This study applied the fuzzy set method to compute composite indicator of unsustainable land use (IULU) from selected plot-level indicators. Results show that average IULU is 0.43 with 41.48 percent of the farms having higher values. Trends in vegetation covers, vigor of crop growth, crop yields, organic matter contents and type of seeds grown have highest contributions to IULU. Also, estimated parameters with Tobit regression show that education, household size, access to credit, access to extension and per capita farm income significantly reduced IULU, while farming experience, erosion problem and inadequate land problem increased it ($p<0.10$). The study noted that efforts to promote soil conservation technologies through extension workers and ensuring availability of credits, among others, will go a very long way in addressing land degradation.

INTRODUCTION

Agriculture, where more than 70 percent of Nigerian labour force is engaged contributed 42.07 percent to the Gross Domestic Product (GDP) in 2008 and 45.35 percent as at the third-quarter of 2009 (National Bureau of Statistics 2009a). Given its direct relevance in foreign exchange earnings and provision of raw materials for industrial growth, the sector will for a very long time remain the mainstay of the nation's economy. Therefore, despite the neglect of the sector by some past administrations because of the 1970s' oil-boom, the Nigerian agriculture still occupies a prime place as a strong pillar for economic growth and national development.

Nigerian agriculture provides the long-term resource base for the direct and indirect support of plant and animal resources, which man uses. However, the performance potential of the sector is still very much under-utilized because of several socio-economic, environmental and political constraints {Federal Government of Nigeria (FGN) 2004}. Specifically, increasing demographic and environmental pressures have subjected the prevailing traditional farming systems to several internal and external disruptions. The consequences are that soil resources are degrading, crop yields are reducing and poverty is concentrated among farm households. These problems are further compounded by constraints such as low financial status of the peasant farmers, information asymmetry in relation to soil properties, among others {Federal Government of Nigeria (FGN) 2004}. However, although outputs in some basic staple crops have recently increased, most of these increases were as a result of agricultural land area expansion (Flake 2009). Therefore, given the long-term consequences of some environmental concerns that the current farming system poses, sustainability of the current agricultural production system is highly questionable,

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 if the prevailing management practices are conducive. The 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. Moreover, poor incentives for natural resource conservation, among other socio-economic problems, have subjected the soils' nutrients to serious exploitation and depletion. Nigerian policy makers have now come to understand that sustainable management of land is a prerequisite for providing enabling environment for agricultural development, which is pivotal towards ensuring that the basic need of man (food) is adequately available, accessible and affordable for the growing populations {Federal Government of Nigeria (FGN) 2004}.

It should be noted that given some critical ecosystem considerations, the implementation of some agricultural development projects has conscientiously taken some environmental issues into consideration. This is in line with international standard practice. However, since the time Nigerian government signed the United Nations Convention to Combat Desertification (UNCCD), the call for actions to support efforts to combat land degradation has been inadequately fulfilled (USAID 2004). A significant potential for progress now exists by systematically upscaling sustainable land management (SLM) approaches.

Objectives of the Study

The study seeks to fulfill the following objectives:

i. construct indicator of unsustainable land use indices (IULU)
ii. determine the farm-specific and socio-economic factors that influence constructed IULU.

MATERIAL AND METHODS

The Study Area and Sampling Methods

Osun State covers an area of approximately 9026 square kilometers (National Bureau of Statistics 2009b). It lies between longitude 04 00E and 05 05" and latitude 05 558" and 08 07", and is bounded by Ogun, Kwara, Oyo and Ondo States in the South, North, West and East respectively. The population of the state, based on 2006 population census was 3,423,535. Among the states in the southwestern part of Nigeria, Osun has one of the highest population densities (379.29/km sq) due to its small land areas. The state also comprises of 30 local government areas (LGA).

The multi-stage random sampling procedure was used for data collection. At the first stage, two (2) administrative zones were selected from the existing six (6) zones comprising Ilesha, Ife, Oshogbo, Ede, Iwo and Ikirun. The selected zones were Ife and Ilesha from where two local government areas each were selected. The selected local governments were Ife-North LGA and Ife East LGA from Ife zone, and Ilesha West LGA and Ilesha East LGA from Ilesha zone. In all, 270 farm households were interviewed comprising 150 from Ife zone and 120 from Ilesha zone. The total number of respondents from each of the LGAs was proportional to the population of the LGAs during the 2006 population census. Data collected covered indicators of SLM as contained in the FESLM presented in Table 1.

Fuzzy Set Approach for SLM Indicators Aggregation

Fuzzy set was proposed by Zadeh (1965). This approach had been applied to land suit-

Table 1: FESLM in Osun State, Nigeria

Maintenance of production (Productivity)	*Reduction of production risk (Security)*	*Protects potentials of natural resources (Protection)*	*Economically viable (Viability)*	*Socially acceptable (Acceptability)*
Application of fertilizer	Drainage / infiltration of water	Trend of vegetative covers	Land use intensity	Type of seeds
Addition of organic manure	Water holding capacity	Plant residue cover	Labour use intensity	Use of pesticides
Vigor of crop growth	Aggregation of soil	Wind or water erosion	Crop yield	Use of herbicides
	Irrigation water level	Planting of cover crops	Profit per hectares	Use of chemical poison in rivers
	Irrigation water quality	Mulching of soil	Labor productivity	Industrial discharges
	Salinity	Fallowing of land Earthworm/ soil life Tilth/ workability Compaction and rooting Crusting/emergency Organic matter contents	Seed use intensity	

ability analysis by some authors (Braimoh et al. 2004; Tang and van Ranst 1992). It was proposed that in a population A of n households [$A = a_1$, a_2, a_3, ……a_n], the subset of households using land unsustainably B includes any household $a_i \in B$. These households present some degree of unsustainability in some of the m land indicators (X). The degree of unsustainability by the i-th household (i=1,….,n) with respect to a particular attribute (j) given that (j = 1,……,m) is defined as: $[X_j(a_i)] = x_{ij}$, $0 \leq x_{ij} \leq 1$. Specifically, $x_{ij} = 1$ when the household's use of land depicts unsustainability and $x_{ij} = 0$ otherwise. Betti et al. (2005) 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 x_{ij} is 0 or 1.

However, some indicators may involve more than two ordered categories (for example, discrete categorical variables and continuous categorical variables), reflecting 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 c_i be the category to which individual *i* belongs. Cerioli and Zani (1990), assuming that the rank of the categories represents an equally-spaced metric variable, assigned to the individual a deprivation score as:

$$x_{ij} = (C-ci)/(C-1) \quad (1)$$

where $1 \leq c_i \leq C$. Therefore, x_{ij} needs not to be compulsorily 0 or 1, but 0 d" x_{ij} d" 1 when there are many categories of the jth indicator and the household possesses the attribute with an intensity. The unsustainable land management index of an household, (a_i), is defined as the weighted average of x_{ij},

$$= \sum_{j=1}^{m} x_{ij} w_j / \sum_{j=1}^{m} w_j \quad (2)$$

w_i is the weight attached to the j-th attribute. The intensity of deprivation with respect to X_j is measured by the weight w_j. It is an inverse function of the degree of deprivation and the smaller the number of households and the amount of their deprivation, the greater the weight. In practice, a weight that fulfils the above property had been proposed by Cerioli and Zani (1990). This can be expressed as:

$$w_j = \log[\sum_{i=1}^{n} g(a_i) / \sum_{i=1}^{n} x_{ij} g(a_i)] \text{ e" } 0 \quad (3)$$

It should be observed that the weight w_j is an inverse function of the average degree of deprivation in the population based on the given indicator. The arbitrariness in this weight had been somehow reduced by using its logarithmic function. Ideally, $g(a_1)\sum_{i=1}^{n} g(a_i) > 0$ and $g(a_1)/ \sum_{i=1}^{n} g(a_i)$ is the relative frequency represented by the sample observation a_1 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 unsustainability of land use.

The fuzzy set approach allows the decomposition of the unsustainability land use indices based on the contributions of each indicator or attribute. The unsustainability land use ratio of the population μ_B is simply obtained as a weighted average of the unsustainability land use of the i-th household $\mu_B(a_i)$

$$\mu_B = \sum_{i=1}^{n} \mu_B(a_i) g(a_i) / \sum_{i=1}^{n} g(a_i). \quad (4)$$

Similarly,

$$\mu_B(X_j) = \sum_{i=1}^{n} x_{ij} g(a) / \sum_{i=1}^{n} g(a_i) \quad (5)$$

$\mu_B(a_i)$

In this way it is possible to decompose the unsustainability land use ratio of the population μ_B as the weighted average of $\mu_B(X_j)$, with weight w_j.

$$\mu_B = \sum_{i=1}^{n} \mu_B(a_i) g(a_i) / \sum_{i=1}^{n} g(a_i) = \sum_{j=i}^{m} \mu_B(X_j) w_j / \sum_{j=1}^{m} w_j \quad (6)$$

Tobit Regression Model

The Tobit regression method was used to determine the socio-economic factors influencing IULU. This is due to the nature of the data. We censored the data using the median of the IULU computed as 0.3699. Those farmers with IULU less than the median value were given zeros. The estimated Tobit model can be stated as:

$$ULUI_i = \varpi + \lambda_j \sum_{j=1}^{n} X_j + e_i \quad (7)$$

Where ω is the constant term and λ_js are the parameters. The error term is denoted as e_i. The included explanatory variables (X_j) are years of education, land size (ha), household size, farming experience (years), method of land preparation (manual = 1, 0 otherwise), access to credit (yes = 1, 0 otherwise), contact with extension officers (yes = 1, 0 otherwise), organic manure problem (yes = 1, 0 otherwise), continuous crop-

λ_j

ping problem (yes = 1, 0 otherwise), soil erosion problem (yes = 1, 0 otherwise), inadequate farm land problem (yes = 1, 0 otherwise), pest and diseases problem (yes = 1, 0 otherwise), and households' per capita farm income (₦). Multi-collinearity among the independent variables was tested by examining the correlation matrix of the independent variables. Suspected col-linear variables were replaced.

RESULTS AND DISCUSSION

Description of Farmers' Socio-economic Characteristics

Table 2 shows that average age of the farmers is 56.66 years and average farming experience is 25.83 years. These results show that the farming population is already ageing. Also, male farmers constitute 93 percent of the sample, while 83 percent are married. Average year of education is 5.46, showing that an average farmer did not complete primary education, which should have taken six years. Household size is relatively large with an average of 7.03. Average total land area owned by the farmers is 6.13 hectares, while average income per capita is ₦113,025.00. Extension services are received by 91 percent, while 55 percent have access to some form of formal or informal credit. About 31 percent relied on the crude manual methods for land preparation.

Table 2: Descriptive statistics of some farmers' socio-economic characteristics

Socio-economic characteristics	*Mean*	*Standard deviation*
Age	56.66	9.68
Sex	0.93	0.26
Marital status	0.83	0.38
Years of education	5.46	4.35
Land area	6.13	1.60
Household size	7.03	2.88
Farming experience	25.83	11.99
Income per capita	113025.80	163191.30
Manual method of cultivation	0.31	0.46
Access to credit	0.55	0.50
Extension contact	0.91	0.28

SLM Indicator Decomposition

The thirty-one indicators that were identified and for which data were collected are contained in Table 1. The computed average IULU is 0.4062 with a standard deviation of 0.1479. The farm plot with the highest IULU has 0.8577, while the one with the lowest has 0.1781. The computed average IULU is 0.4062 and 41.48 percent of the farms have values above this. Figure 1 shows the distribution of the indicators of unsustainable land use

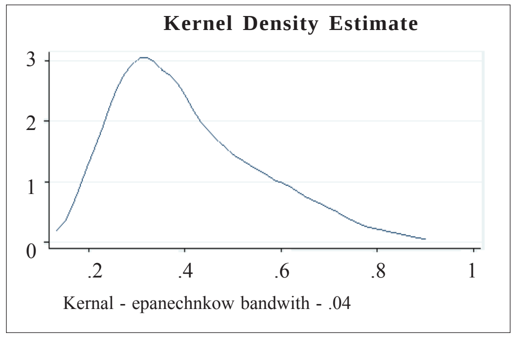

Fig. 1. Kernel density graph of the Fuzzy IULU

Table 3 further shows the frequency distribution of the indices of unsustainability across some demographic groups. It reveals that the highest proportion (63.70 percent) of the farm plots has unsustainability indices 0.50<0.75 with average of 0.3545 and standard deviation of 0.06788. The farm plots from Ilesha have higher average unsustainability index of 0.5198 with standard deviation of 0.1383. There is a significant difference (p<0.01) between the mean unsustainability indices across these two zones.

Across the age groups, those farmers who are less than 40 years of age have farm plots with lowest average unsustainability index of 0.2651, while those between 50-59 years have the highest average value of 0.4326. There is significant difference (p<0.01) in the average unsustainability indices across the different age groups. Across gender, the female farmers have higher average unsustainability index of 0.4848 with standard deviation of 0.1024. There is also significant difference (p<0.05) in the average unsustainability indices across the gender groups.

Table 4 shows that trend in vegetation covers, vigour of crop growth, crop yields, organic matter contents and type of seed grown have the highest relative contributions of 3.78 percent, 3.77 percent, 3.76 percent, 3.74 percent and 3.72 percent respectively to unsustainability in-

Table 3: Descriptive statistics of Fuzzy unsustainability indices across some demographic groups

Variables	*Frequency*	*Mean*	*Std deviation*	*ANOVA F Test*
Groups				
<0.25	7	0.8069	0.0362	
0.25 ≤ 0.50	61	0.5961	0.0680	
0.50 ≤ 0.75	172	0.3545	0.0679	
≥ 0.75	30	0.2824	0.0245	
Total	270	0.4062	0.1479	
Zones				
Ife Zone	150	0.3153	0.0743	ANOVAF=241.35***
Ilesha Zone	120	0.5198	0.1383	
Age				
<40	15	0.2651	0.0799	ANOVAF= 4.733***
40<50	33	0.4072	0.1506	
50<60	111	0.4326	0.1435	
60<70	91	0.4030	0.1534	
≥ 70	20	0.3781	0.1251	
Sex				
Female	20	0.4848	0.1024	ANOVAF = 6.21**
Male	250	0.3999	0.1494	

Table 4: Contributions of SLM indicators to unsustainable land use in southwestern Nigeria

SLM indicators	*Absolute contri-bution*	*Relative contri-bution*
Vigour of crop growth	0.0153	3.77
Trend of vegetative covers	0.0154	3.78
Residue cover	0.0123	3.03
Crop yield	0.0153	3.76
Labour productivity	0.0148	3.66
Profit per hectares	0.0142	3.51
Organic matter contents	0.0152	3.74
Drainage/infiltration of water	0.0151	3.72
Water holding capacity	0.0119	2.92
Aggregation of soil	0.0141	3.47
Earthworm/ soil life	0.0121	2.97
Compaction and rooting	0.0149	3.66
Crusting/emergency	0.0127	3.13
Tilth/ workability	0.0151	3.71
Salinity	0.0153	3.77
Wind or water erosion	0.0147	3.61
Plot level application of fertilizer	0.0146	3.58
Addition of organic manure	0.0129	3.17
Mulching of crops	0.0112	2.76
Cover crops	0.0015	0.37
Fallowing of land	0.0147	3.61
Irrigation water level	0.0133	3.28
Irrigation water quality	0.0123	3.04
Use of pesticides	0.0092	2.26
Use of herbicides	0.0083	2.04
Use of chemical poison	0.0142	3.49
Industrial discharges	0.0140	3.44
Land use intensity	0.0114	2.80
Labour use intensity	0.0113	2.79
Type of seeds	0.0151	3.72
Seed use intensity	0.0139	3.43
All indicators	0.4062	100.00

dices. The implication of these findings is that across the two selected zones, deforestation and inability to grow back the cleared forestland is among the major drivers of land degradation. Similarly, as land is being used continuously for agricultural activities, the land is losing its inherent capacity to support crop and plant growth, resulting in decline the extent of vegetative covers. Declining trends in crop yields and non-usage of organic manure and hybrid seeds have also contributed to unsustainability. Also, planting of cover crops, herbicides, pesticides and mulching contribute least to unsustainability with 0.37 percent, 2.04 percent, 2.26 percent and 2.76 percent, respectively.

Determinants of IULU

The results of the Tobit regression analysis are presented in Table 5. It shows that the Pseudo coefficient of determination is 0.5387, with the Chi-Square value being statistically significant ($p<0.01$). This implies that the model produced a good fit for the data. The same implication can be drawn from the statistical significance of the sigma value. Eight of the included variables in the Tobit regression show statistical significant- four at $p<0.01$, three at $p<0.05$ and one at $p<0.10$. The results indicate that as the years of education increases, unsustainability indices significantly decreases ($p<0.01$). This is expected because education has been found to facilitate adoption of sustainable land management practices among smallholder farmers (Woelcke et al. 2006; Fakoya et al. 2007; Maiangwa et al. 2007).

Table 5: Tobit regression results of the determinants of unsustainable land use indices

Variable	*Parameter*	*t-statistics*
Education	-0.0230***	-3.76
Land size	-0.0024	-0.16
Household size	-0.0120***	-2.68
Farming experience	0.0060**	2.39
Method of land preparation (D)	0.0683	1.08
Credit (D)	-0.7808***	-5.52
Contact with extension officers (D)	-0.1163**	-1.96
Organic manure problem (D)	-0.0586	-0.70
Continuous cropping problem (D)	-0.0642	-0.96
Soil erosion problem (D)	0.1218**	2.01
Inadequate farm land problem (D)	0.2673***	3.61
Pest and diseases problem (D)	0.0953	-0.28
Per capita farm income	-4.04e-08*	-1.67
Constant	0.5563***	3.16
Sigma	0.2943***	
Pseudo R2 = 0.5387		
chi^2 (13) = 214.54***		

(D) ↔ Dummy estimated variables *** implies p<0.01, ** implies p<0.05 and * implies p<0.10

Household size parameter is statistically significant (p<0.01) and with negative sign. This implies that increasing the number of people in the households will reduce unsustainability indices. This is contrary to the findings of Maiangwa et al. (2007). However, Deininger and Jin (2002) and Kabubo-Mariara (2006) noted that family size, especially the presence of more adults can have some positive impacts on farm investments, thereby enhancing conservation. Therefore, the finding that family size reduces unsustainability indices of land supports Tiffen et al. (1994), who used some empirical evidences from Kenya to demonstrate that growing population, in association with market developments, generates new technologies that support increased productivity and improved conservation of land and water resources.

Furthermore, the results show that as the years of farming experience increase, unsustainability land use indices significantly increase (p<0.05). While farming experience is expected to enhance soil conservation, aged farmers with a lot of experience may use the land in an unsustainable manner due to low level of education and immobility as a result of ageing.

The dummy variable that captures access of the farmers to credit shows statistical significance (p<0.01). This implies that those farmers that have access to credit have significantly lower unsustainability land use indices. Many studies (Place et al. 2006) have previously reported that access to credit is one of the major drivers of farmers' investment in sustainable land management technologies.

Those farmers that have contacts with extension officers have significantly lower indices of unsustainable land use. Kabuko-Mariara (2006) already noted that informal education through extension services will enhance sustainable land management practices among peasant farmers. This is due to the role that extension services play in providing informal education to farmers who might be illiterate on different aspects of farming activities. Those farmers that indicated erosion and inadequate land as major problems confronting their land management decision have significantly higher indices of unsustainability (p<0.05) . This is expected because Mohaddes et al. (2008) submitted that erosion and farm yields are among the conflicting objectives influencing sustainable land use planning. Therefore, if a farmer realizes that the land is inadequate in fertility and susceptible to some form of erosion, there will be little incentives to use the land in a sustainable manner. Finally, the parameter of farm income is with negative sign and statistically significant (p<0.10). This shows that as farm incomes increase, unsustainability land use indices decrease. Similar finding had been reported by Brasselle et al. (2002) and Somda et al. (2002).

CONCLUSION

This study assessed sustainability of land use in Osun state with the FESLM. This is a worthwhile effort because FESLM considers different production objectives in farmer's usage of land. This allows integration of different properties of a particular land into a composite index that captures the extent of degradation the land might have suffered. It is a richer way of defining sustainability of land use system because it enables different indicators of land use to be considered at once. However, because of the richness of policy issues that can be derived from this type of study, future studies can explore indicators of sustainable land management in all the LGAs in the state with some introduction of laboratory testing of soil and water for essential parameters and application of the growing technology of Geographical Information Systems (GIS) for vegetation mapping.

The policies that can be derived from the results are discussed as follows: Firstly, there is need to promote some form of informal education among the farmers through extension officers. The researchers found that UILU declined with years of formal education and extension contact. No doubt, present activities of government to promote basic education will have future positive impacts on environmental conservation if rural people are able to explore the opportunities. However, although it is too late for farmers to be enrolled in schools, informal trainings can be explored to educate them on sustainable land use methods and other practices that can be hazardous to soil's health. Secondly, the study also revealed that access to credit reduced UILU. Therefore, activities of the Agricultural Credit Guarantee Scheme (ACGS) if well coordinated and directed at small scale farmers can result in environmental conservation. However, government needs to ensure promotion of small loans to farmers in some organized cooperatives. Lastly, per capita income reduce UILU, implying that on-going programmes by the government to increase farmers' productivity are able to have some positive feedbacks on environmental conservation. Therefore, every avenues and incentives to ensure that benefits of agricultural programmes reach the intended beneficiaries should be ensured.

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