FUZZY INDICATOR OF SUSTAINABLE LAND MANAGEMENT AND ITS CORRELATES IN OSUN STATE, NIGERIA

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Abstract

Sustainable land management is one of the major issues of concern to Nigerian policy makers. This study applies fuzzy set method to compute composite indicator of unsustainable land use (IULU) from 31 selected plot-level indicators, based on the Framework for Evaluating Sustainable Land Management (FESLM). 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 (-0.0230), household size (-0.0120), access to credit (-0.7808), access to extension (-0.1163), per capita farm income (-4.04e-08), farming experience (0.0060), erosion problem (0.1218) and inadequate land problem (0.2673) significantly influence IULU (p<0.10). The study notes that efforts to promote soil conservation technologies through extension services and ensuring availability of credits, among others, will go a very long way in addressing land degradation.

Keywords: Sustainable land management, land degradation, fuzzy, Indicator, Nigeria

Introduction

Agriculture, where more than 70 percent of the 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 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 development.

Furthermore, 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 concentrating among farming households. These problems are further compounded by constraints such as low financial status of the peasant farmers, information asymmetry in relation to soil properties, suitability and capabilities, 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 up-scaling sustainable land management (SLM) approaches. This study seeks to construct indicator of unsustainable land use indices (IULU) and determine its correlates. In the remaining parts of the paper, the conceptual issues and literature review on SLM, the methods of data collection and analysis, results/discussions and conclusion have been presented in that order.

Conceptual Issues and Literature Review

The Boserup's hypothesis on the theories of induced technical and institutional innovation in agriculture explained changing land management systems in terms of changing microeconomic incentives facing farmers as a result of changing relative factor endowments (Boserup, 1965). It was noted that as population grows, land and other natural resources become scarce relative to labour and access to markets improves. Therefore, agricultural intensification occurs, relative prices change and food prices increase as demand for food rises. This process induces institutional innovations such as private property rights, which then facilitate the use of soil conservation technologies that help reverse the onset of diminishing factor marginal productivity (Kabubo-Mariara, 2007).

SLM is an off-shoot of the broad discussion of sustainable agriculture. It is a complex concept, although many attempts have been made to define it. It incorporates a number of common elements such as efficient use of inputs, enhancement of environmental quality, maintenance of the natural resource base, adequate supply of human food and fibre needs, enhancement of the quality of life, and assurance of profitability. Although it has different meanings to different people, SLM refers to practices that do not degrade the soil or contaminate the environment while providing support to human life (Greenland, 1994). The major concerns in the analysis of SLM border on the need for spatial and temporal cut-off points, as well as the selection of indicators to evaluate sustainability in a given locality. However, considerable achievements have been made in the assessment of sustainable land management in the tropics, but most studies refer to subsistence agriculture where low crop yields and soil degradation have formed a formidable vicious cycle.

Furthermore, SLM is a knowledge-based procedure that helps to integrate land, water, biodiversity, and environmental management to meet the rising food and fiber demands, while sustaining ecosystem services and livelihoods (World Bank, 2006). Smyth and Dumanski (1993) submitted that SLM combines technologies, policies and activities that are aimed at integrating socioeconomic principles with some environmental concerns. This is to ensure that agricultural production system simultaneously fulfils the five pillars of the Framework for Evaluation of Sustainable Land Management (FESLM) which are to maintain or enhance production/services (productivity), reduce the level of production risk (security), protect the potential of natural resources (protection), be economically viable (viability) and be socially acceptable (acceptability).

Furthermore the FESLM provides a logical pathway analysis procedure that is able to guide evaluation of land use sustainability through a series of scientifically sound steps (Dumanski and Smyth 1994). It is made up of three main stages which are identification of the purpose of evaluation (specifically land use systems and management practices), definition of the process of analysis (consisting of the evaluation factors, diagnostic criteria, indicators and thresholds to be utilized) and an assessment endpoint that identifies the sustainability status of the land use system under evaluation (Gameda *et al,* no date).

Indicator is a number or other descriptor that represents a set of land use conditions. It should also be able to convey meaningful information about a change or trend in those conditions over time. It can also represent in summarized form the total effect of many variables, as in the use of crop yield as an indicator of soil fertility. Indicators can be derived from qualitative and quantitative measurements. However, they become standardized and comparable only when they are transformed into a numerical form (Pieri *et al.*, 1995). The purpose of indicators is to guide policy changes and management decisions at all levels, from the farm to the national and even global level. They are sometimes needed to monitor the effects of agricultural policies on soil fertility.

Indicators are already in regular use in some areas, especially at a farm level. Indicators to evaluate changes in the quality of land resources at a national or district level still need to be developed. We particularly need indicators for evaluating the sustainability of land management systems. In the development of land quality indicators, Dumanski and Pieri (1997) recognized the application of the pressure-state-response (PRS) framework. This is because land quality should be viewed, not only in terms of the physical condition, but also in terms of how the land is being managed, and the political and social environment for instituting improvements. The framework is a convenient representation of the linkages among the pressures exerted on the land by human activities, changes in the quality of resources, and the response to these changes as society attempts to release the pressure or to rehabilitate land which has been degraded.

Southorn (no date) submitted that there is substantial effort applied to the generation of soil quality models. A model of soil quality could be applied to the assessment of land management practices, development of land management policies, rating of land for production or conservation purposes, and for allocation of financial resources (Parr *et al*., 1992). The integration of soil quality into economic models would be useful in economic analysis of agricultural systems and related policy (Jaenicke and Lengnick 1999).

Jaenicke and Lengnick (1999) summarized some of the research into soil quality models and categorized them into two types which are those where individual soil quality attributes are aggregated into a soil quality index to model soil quality at a single point in time, and those which attempt to model the change in soil quality under some management regime over time. They highlighted the need to apply some value weighting to the component attributes, and that this has been a weakness in such approaches applied to soils. They attempt to merge these research efforts with research into economic models of system productivity and efficiency, with initial soil quality as an input and final soil quality as an output. In this case, indices of sustainability can be decomposed into various component contributors. This provides an interesting perspective, and it is based on some statistical and economic theories and procedures. Furthermore, some authors advocated the use of a single index for soil quality that will permit a numerical comparison and dynamic analysis. Granatstein and Bezdicek (1992) described the use of an integrating index, to help evaluate the interactions between physical, chemical and biological parameters that determine soil quality. Larson and Pierce (1994) described the possible application of statistical quality control procedures.

Braimoh *et al* (2004) applied fuzzy set and interpolation techniques for land suitability evaluation for maize in Northern Ghana. Results showed that interpolated land suitability shows a high correlation (R^2 = 0.87) with observed maize yield at the village level. Membership functions were also used to assess the degree of limitation of land characteristics to maize. Sixty percent of the data has membership functions ranging from 0.23-1.00 for drainage. It was noted that the use of the fuzzy technique is very helpful for land suitability evaluation, especially in applications in which subtle differences in soil quality are of a major interest.

The factors influencing sustainable land management had been studied by many authors. A host of factors including the biophysical nature of the farm, population density, access to markets, the state of rural infrastructure, access to markets, local commodity and factor prices, access to extension programs and services, households' endowments of physical assets, human capital factors (farmer's education, farming experience, and training), "social capital" (assets embodied in social relationships, such as through participation in organizations or informal networks), "financial capital" (access to liquid assets, including credit and savings), and natural capital (quantity and quality of land) have been suggested by Kabubo-Mariara and Linderhof (no date).

Rahji (2005) analyzed the factor influencing adoption of soil conservation in Oyo State, Nigeria. Results show that the level of awareness of the farmers about soil conservation practices was high for most of the soil conservation practices. Parametric analysis was done using the Truncated Negative Binomial Count Data Model. It was found that adoption of soil conservation practices was significantly influenced by farm size, land tenure, extension contact, household net worth, awareness, perceived benefits.

Also, Fakoya *et al.* (2007) analyzed the attitudes of women farmers to sustainable land management practices in southwestern Nigeria. The results revealed a strong positive correlation between the attitude score and land management practices adopted by the women farmers. It was recommended that there should be increase in awareness campaigns on land use fertility and management practices.

Junge *et al.* (2009) analyzed the factors influencing farmers attitudes towards erosion and the adoption of appropriate soil conservation technologies (SCTs) in Osun State, Nigeria.. The result showed that to some extent, soil erosion was a problem confronting agricultural production. Also, the adoption rate of SCTs was low, as only mulching, cover cropping, contour tillage and cut-off drainage were practiced and often rejected. Costs of application, labour requirements, ease of practice and compatibility with the existing farming were considered as important factors driving use of soil conservation methods. Also, education, knowledge of appropriate technologies, farming experience show positive correlation with the number of SCTs adopted by the farmers.

Materials 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 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, Oshogb, 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 suitability analysis by some authors (Braimoh *et al*., 2004; Tang and van Ranst, 1992). It was proposed that in a population A of n households [$A = a_1, a_2, a_3, \ldots\ldots a_n$], 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: $\mu_B [X_j (a_i)] = x_{ij}$, $0 \le x_{ij} \le 1$. 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 (e.g. 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:

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

where $1 \leq c_i \leq C$. Therefore, x_{ij} needs not to be compulsorily 0 or 1, but $0 \leq x_{ij} \leq 1$ 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, $\mu_B(a_i)$, is defined as the weighted average of x_{ij},

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

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:

$$w_j = \log[\sum_{i=1}^{n} g(a_i) / \sum_{i=1}^{n} x_{ij} g(a_i)] \geq 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots.. \qquad (3)$$

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, $g(a_i)/\sum_{i=1}^{n} g(a_i) > 0$ and $g(a_i)/\sum_{i=1}^{n} g(a_i)$ is the relative frequency represented by the sample observation a_i 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 $\mu_B(a_i)$

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

Similarly,

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

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

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

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:

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

Where ϖ is the constant term and λ_j s 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 cropping 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 (₦). Multicollinearity among the independent variables was tested by examining the correlation matrix of the independent variables. Suspected collinear variables were replaced.

Results and Discussions

Description of Farmers' Socioeconomic 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 N113,025.00. 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.

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

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 0.25<0.50 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 that 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 indices. 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).

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 and Otsuka, 2000; Kebede, 2002; 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).

Recommendations and Conclusion

The findings of the study are to guide policy statements for ensuring sustainability of the agricultural production systems in Osun state. First, the study reveals that the farming population in Osun State is ageing and that is adversely affecting sustainable land use. The State Government needs to intensify efforts at integrating more young school leavers into agricultural production within the currently institutionalized poverty alleviation programmes. Such programmes, if designed for each of the local government areas will not only go a long way in ensuring that vibrant youths gradually replace the old farmers, it will ensure conservation of natural resources because of the higher level of education already attained by these youths. Educational attainments become an importance issue here because the study shows that it enhances farmers' ability to use their land in a much more sustainable manner.

Second, the study reveals that improvement in farm income holds some potentials for sustainable land use. Conventionally, farm incomes can increase by getting better price for the produce or getting higher yields. Efforts by the State Government to enhance productivity of the farmers will go a long way in ensuring environmental conservation. This can be channeled through intensification of research efforts into development of sustainable land use technologies and promotion of usage of existing environment-friendly cultural practices and hybrid varieties among the farmers. It should be noted that inability to use hybrid seeds is one of the indicators with highest contributions to IULU.

Third, agricultural extension activities in the state should focus more on sustainable land management. The study already reveals that contacts with extension agents facilitate sustainability of land use by the farmers. Agricultural extension programmes in the state should be strengthened for more impact on sustainability of existing farming systems. Regular radio agricultural extension programmes should be organized in order to reach more farmers.

Fourth, the study finds that access to credit is an important factor for ensuring sustainability of the agricultural production system in the state. There is need to ensure that agricultural credit schemes in the state are well targeted and adequately managed. The farmers in the state should be encouraged to participate in the GEF-components of Fadama III project, which is mainly targeting sustainable land management.

In conclusion, this study assessed sustainability of land use in Osun state with the FESLM. This is a worth-while 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.

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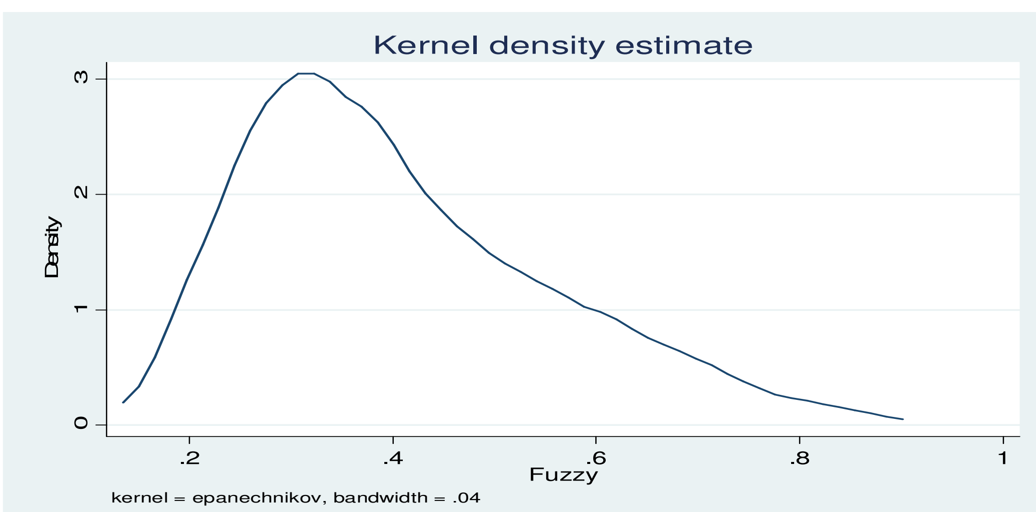

Figure 1: Kernel Density Graph of the Fuzzy IULU.

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	

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

Table 3: Descriptive Statistics of Fuzzy Unsustainability Indices Across Some Demographic Groups

Group	Frequency	Mean	Std Deviation	ANOVA F Test
<0.25	7	0.8069	0.0362	
$0.25 \leq 0.50$	61	0.5961	0.0680	
$0.50 \leq 0.75$	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	ANOVA
Ilesha Zone	120	0.5198	0.1383	F=241.35***
Age				

<40	15	0.2651	0.0799	
40<50	33	0.4072	0.1506	ANOVA
50<60	111	0.4326	0.1435	F = 4.733***
60<70	91	0.4030	0.1534	
≥ 70	20	0.3781	0.1251	
Sex				
Female	20	0.4848	0.1024	ANOVA
Male	250	0.3999	0.1494	F = 6.21**

Table 4: Contributions of SLM Indicators to Unsustainable Land Use in Southwestern Nigeria

SLM Indicators	Absolute Contribution	Relative Contribution
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

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		
chi2(13) = 214.54***		

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

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