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Modelling Indices of Efficiency and Sustainable Land-use and Management Among Migrant Farmers in a Farm Settlement of Cross River State, Nigeria

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ABSTRACT

This paper employed a cross sectional data set to assess how sustainable land use and management practices of migrant farmers are in typical farming settlement. Through stochastic frontier modelling both indices of inefficiency and land use and management were estimated. Empirical result revealed mean level of inefficiency in resource use of 23%. The result also showed that about 72% of the farmers adopted land use and management practices that impaired land productivity. On the short-run therefore, the study revealed that only about 29% of the farmers improved crop productivity in the context of efficient use of inputs and proper use and management of land. The study recognised the importance of large-scale adaptive research and extension services in educating farmers of the suitable practices that would ensure sustainable use of agricultural land.

Key Words: Migrant farmers; Efficiency; Sustainable land use; Stochastic frontier; Nigeria

INTRODUCTION

The practice of agriculture depends on land use and resource allocation. Land utilization and management practise by peasant farmers with limited resources focus on practices aimed at achieving farm level objectives in term of economic viability, food security and risk aversion (Pinstrup-anderson & PandyaLorch, 1995; Krusemen *et al.*, 1996; Udoh *et al.*, 2002). The framework of land use is viewed therefore to have a short-term planning horizon as little attention is paid to the status and management of the land. (Thapa, 1996; Udoh *et al.*, 1999). Seemingly, inter-related objectives of increasing productivity, income and short-term food security have been partially addressed, but the achievements may have come at the expense of long-term sustainability in agricultural production.

In Nigeria, greater proportions of farmers practise low-external-input agriculture (LEIA). On the faces of demographic and environmental pressures and changes in social and political circumstances, this traditional systems are being disrupted (Udoh *et al.*, 2002). There are reported cases of considerable degradation of the natural resource-base, particularly when its use is intensified and indiscriminate (NEST, 1991). Under LEIA, the choice of land use, allocation and management may not necessarily reflect proper and adequate practices. This problem is further compounded by constraints such as financial status of the farmers, information asymmetry as regards soil properties, suitability and capabilities etc (Udoh, 2000). This situation has culminated in persistent food crisis in Nigeria as gap between population and food production continue to widen (Igben & Banwo, 1982; World Bank, 1992). In an effort to increase food production, LEIA depends primarily on expansion of cultivated area at the expense of restorative bush fallow, thereby causing a considerable decline in the length of the cultivation cycle in slash and burn cultivation (Spencer, 1990; Manyong & Degand, 1995; Tisdell, 1996). In densely populated areas, marginal lands and forest reserves are encroached for crop cultivation. Besides, soils in the tropics have low productivity due to lack of trace elements as they are fragile, loosing organic matter and nutrient quickly (Spencer, 1989). Consequently, LEIA in most cases is always not sustainable and certainly not economical.

Within the context of sustainability, land use and management must aim at addressing the simultaneous aspects of production and conservation. This involves combine technologies, policies and activities aimed at integrating socio-economic principles with environmental concern (CGIAR, 1988; IITA, 1992; Smyth *et al.*, 1993; NRC, 1993). This paradigm of evaluating economic returns and environmental characteristics becomes necessary in order to reframe the neo-classical optimization in light of objectives other than profit-maximising that farmers may express (Ikerd, 1990; Hewitt & Lohr, 1995). Therefore improving farm productivity, efficiency and combating land degradation problems are the key issues in sustainable agricultural production. In this regard, consideration is given to land resource quality maintenance and resource-use efficiency (Ali, 1996; Udoh & Akintola, 2001a & b; Udoh, 2005).

Within the foregoing context, certain questions become fundamental: if the productivity of the farm is high and the farmers are efficient in use of inputs, can land management practices of the migrant farmers be capable of maintaining the economic benefits over the subsequent years? Also, are the management practices adequate to improve the state variables and enhance sustainable production in every cultivation cycle? Answers to these questions would involve identification and measurement of land use and management indices and thresholds of migrant farmers in a typical farming settlement. This paper then seeks to meet the following objectives:

- Evaluate pattern of land use and management; and
- Evaluate whether the system of cropping pattern is sustainable.

MATERIALS AND METHODS

Area of study. The study was conducted in three locations of Odukpani Local Government Area of Cross River State. The area became accessible due to the highway, which was constructed in the early 1970's, and since then there has been high land-use intensity for agricultural production by predominantly migrant farmers, who moved from hinterland and neighbouring states to settle for crop production. The area is basically a farm settlement with little government presence. It has an evolving village structure with line settlement along the highway. Farming activities continue throughout the year in the area.

Data collection and sampling technique. A cross sectional data from 180 sample farming household were collected with the aid of pre-tested, structured questionnaires administered by trained enumerators. The baseline survey covered information on household characteristics, land holding, land-use and crop production factors and their respective prices, crop combination and diversification and land management systems etc.

Two-stage sampling technique was employed in selecting the sample needed. First, three villages that are located along the major highway were randomly selected. These are Okoyong Usang Abasi, Okurikan and Usung Odot. The second stage of sampling was the selection of the farming households. This was done purposively to ensure that migrant farming households were selected. Specifically, sixty migrant farmers were sampled from each of the location.

Analytical framework. A combination of analytical tools was used to investigate the state objectives of the study.

Land use pattern analysis. This was investigated by measuring the index of crop diversification and index of nutrient intake. Entropy index formulated by Hackbart and Anderson (1975) is used.

Entropy index is given as:

$$CDI_e = \sum_{i=1}^{n} P_I \log P_i^{-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where

CDI_e is the crop diversification index; P_i = Proportion of net income from ith crop. The Diversification index is optimal when $0 < 1/N.CDI_e \leq 1$.

Nutrient intake index is a customised measure developed to empirically capture how different crop geometry can affect land nutrient quality. It is measured as a ratio of crop configuration to number of crops in combination. Crop configuration is derived by assigning different weights to different crops in a combination and summing the weighted values for each farm and then dividing the value by the number of crops in such combination. In this study, four major classes of crops were identified, viz -

(i) Root and tuber crops: Example, Cassava, Yam and Cocoyam. This class is assigned the highest weight of 4; (ii) Cereals: Example, maize and rice, assigned with weight 3; (iii) Vegetables: Example okra, pepper and fluted pumpkin, assigned with weight 2; and (iv) Legume: Examples, beans, and melon, assigned with weight 1.

The assigned weights to the respective classes are based on nutrient depletion ability of crops in an environment where nutrient-augmenting input like fertiliser is absent. Agronomists and soil scientists have found that root-tuber crops are heavier nutrient eater than grain cereals and that geometry of crop combination can affect land degradation (Mandal & Mitra, 1990).

However, the nutrient intake index is given as:

$$NII = \frac{1}{n} \sum_{i-1}^{n} WiTi \quad I = (1, 2, \ldots, n) \ \ldots\ldots\ldots\ldots (2)$$

Where,

n = number of crops in a combination; W_i = Particular weight attached to ith class of crop; T_i = Type of crop planted.

Nutrient intake index is meant to capture the vulnerability of farm total output (or gain equivalent) to different crop combination on a farm and is expected to be negatively associated with output level.

Sustainability analysis. This involves 2-step approach measurement. First, estimation of farm specific inefficiency index (RUI). Secondly, estimation of farm specific index of sustainable land use and management (ISM), and summing both indices. Generally, these two indices depend on a stochastic frontier specification that is transcendental logarimthic in form. This is given as:

$$LnQ_j = a_o + \sum_{i=1}^{n} a_i lnX_{ij} + \frac{1}{2}\sum_{i=1}^{n}\sum_{g=1}^{n} b_{ig} (\ln X_{ij} \ln X_{ij}) + \sum_{k=1}^{o} c_K R_{kj} + \sum_{t=1}^{m} d_t lnC_{tj}$$

$$+ \sum_{i=1}^{n} b_{ii}(lnX_{ii})^2 + \frac{1}{2}\sum_{i=1}^{n}\sum_{r=1}^{p} f_{ir} (\ln X_{ij} \ln l_{rj}) + \sum_{r=1}^{p} e_r \ln l_{rj} + \frac{1}{2}\sum_{i=1}^{n}\sum_{t=1}^{m} h_{it} (lnX_{ij} \ln C_{tj}) +$$

$$\frac{1}{2}\sum_{r=1}^{p}\sum_{r=1}^{p} j_{rr}(\ln l_{rj} \times \ln l_{rj}) + \frac{1}{2}\sum_{k=1}^{q}\sum_{0\neq k}^{q} r_{ko}(R_{kj} R_{oj}) + \frac{1}{2}\sum_{t=1}^{m}\sum_{k=1}^{q} w_{tk}(lnC_{ij} R_{kj}) + \frac{1}{2}\sum_{t=1}^{m}\sum_{r=1}^{o} S_{tr}(lnC_{tj} \ln l_{rj})$$

$+U_j + V_i$ .... (3)

Where,

j = 1, 2, …, 300 farms; i, g = 1, 2, …, n are physical inputs; Q represents grain equivalent (kg); X represents conventional variables; R represents land quality variables; L represents land management variables; C represents land use variables; V_j is the symmetric error component and U_j is a one sided error component that measures technical efficiency. Further, a_o = parameter of intercept; a_i = parameters of physical inputs and migrant status; b_{ig} = parameters for interaction across ith and gth physical inputs; c_k = parameters for dummy variable on land resource quality; d_t = parameters for land management variables; b_{ii} = parameters for square terms of physical inputs; f_{ir} = parameters for interaction between the ith physical inputs and land use variables; j_{rr} = parameters for interaction among land use variables; e_r = parameters for land use variables; h_{it} = parameters for interaction between ith physical inputs and land management variables; r_{ko} = parameters for interaction across kth and oth dummy variables on resource quality; w_k = parameters for interaction between land management variables and land resource quality; and S_{tr} = parameters for interaction between land management variables and land use variables.

It should be stated that, X_i are the conventional inputs that are normally considered in transformation process. But R, L and C are conditioning variables, whose inclusion into the model is to capture the effects of land use and management practices on the farm output. The physical inputs considered include land, labour, capital and cost of planting. Land use variables include crop diversification index and nutrient intake index. Land management variables include level of tillage, length of fallow and fertilisation. Land resource quality variables include drainage and terraces.

Specifically, RUI is evaluated by maximising the log-likelihood of the equation (3). This involves the conditional distribution of U given e expressed as:

$$E(U_i/e_i) = \mu_i + \sigma^* \{f(-\mu_i/\sigma^*) [1-F(-\mu_i/\sigma^*)]^{-1}\} \quad (4)$$

Where

$\sigma^* = (\sigma_v^2\sigma_u^2/\sigma^2)^{1/2}$; $u_i = (-\sigma_u^2 e_i)/\sigma_2$, and f = the standard density function. Similarly, average technical efficiency for all the firms in a sample is derived by evaluating equation 5 at $e = N^{-1}\Sigma e_i$.

ISM is also estimated at equation (4) with respect to all the agronomic practice (i.e. land use & management practices), evaluated at different level of output and resource quality. This is given as:

$$ISM = \sum_{t=1} d_t + \sum_{r=1} e_r + ½ \sum_{t=1}\sum_{r=1} s_{tr} + ½ \sum_{i=1}\sum_{r=1} f_{ir} (\ln X_{ij}) + ½ \sum_{i=1}\sum_{t=1} h_{it} (\ln X_{ij}) + ½ \sum_{t=1}\sum_{k=1} W_{tk} (R_{kj}) \quad (5)$$

Where,

All notations are as previously defined and ISM measures the land use and management index. Inferentially, if the value of ISM is zero, the land use and management practices give no change in land quality; if it is positive, then there has been improvement in the use and management of the land; and if it is negative, then land use and management practices have adverse effects on the land resources.

Then, the summation of the index of sustainable land use and management and resource use inefficiency index gives the measure of short-run sustainability index (SRSI) given as:

$$SRSI = 1 – [(X_i . p)(X_a .p)^{-1}] + \sum_{t=1} d_t + \sum_{r=1} er + ½ \sum_{t=1}\sum_{r=1} S_{tr} + ½ \sum_{i=1}\sum_{r=1} f_{ir} (\ln X_{ij}) + ½ \sum_{i=1}\sum_{t=1} h_{it} (\ln X_{ij}) + ½ \sum_{t=1}\sum_{k=1} W_{tk} (R_{kj}) \quad (6)$$

Where,

All notations are as previously defined and when SRSI is positive, this indicates that the production process of the farmer is sustainable in terms of resource use and environmental management and vice versa if it is negative.

RESULTS AND DISCUSSION

Land use pattern analysis. This involves evaluating cropping pattern, index of crop diversity and index of nutrient intake.

Cropping pattern. Discussions concerning the choice of cropping pattern by the migrant farmers are made based on their priorities and primary thrust of cultivation. Table I shows the distribution of the sampled farmers on the bases of cropping pattern.

Majority of the farms have crop mixed together, which is an indication that each farmland cultivated were adequately utilised (Table I). But in situation of improper combination, the productivity of the crops would be adversely affected and land use would be un-sustainable. On the issue of crop mix, the most popular crops were cassava, maize, melon and okra that appeared in over 89% of the sampled farms. This mode of mixture may not be un-connected to the easy adaptation of these crops and the migrant's interest on the crops for income generation and food security of their households.

Index of crop diversification. A 0.26 E-index is evident for two-crop mixture and 0.51 E-index for five or more crop mixture (Table II). The sample mean (0.28) shows that on the average, majority of the migrant farmers cultivated two to three crops. When two or more crops are grown in a field, each crop uses the fertility of the soil in its own particular way especially when the rooting systems of the crops differ (Dupriez & De Leaner, 1988). The mixed cropping could be three to four times higher in yield than that of sole cropping on a per hectare basis. However, the benefits depend on proper management of the land and the type of crop mixture. Where the rooting system of the combined crops is concentrated on a particular horizon, the combination might be bad for the combined crops. To further highlight this point, nutrient intake index is evaluated.

Index of nutrient intake. The advantages of multiple cropping can only be achieved when the combined crops have been grown in such a way that each crop uses the fertility of the soil in its own particular way so as to eliminate the risk of competition for the available soil nutrients. It is expected that the yield of crops in combination would be affected if the combined crops are similar. For instance, a combination of maize-cassava and melon would not deplete soil nutrients as the case of cassava-yam and cocoyam mixture. Therefore, combining crops that would deplete soil nutrients heavily does not show sustainable land use practice (Table III).

About 58% of the sampled farmers combined crops that have nutrient intake index of 3.6 and above and only negligible number of the farmers (3%) have nutrient intake index within the 1 - 2 class interval. Since the index measures the intensity of likely nutrient depletion by the combined crops, it can be seen from the table that majority of the farmers combined crop that has greater tendency to deplete soil nutrient. This is not un-connected to the fact that all the crop combinations observed in the area have or two root tuber crops (Table III). Furthermore, beside melon, there is no other crop that could be grouped under leguminous crop. Therefore, the distribution of nutrient intake index among the sampled farmer indicates the risk of competition among the crops grown for the available soil nutrient. In such a situation the nutrient available is not sufficient, the crop nutrition would be adversely affected, which would be translated into poor crop yield, below sustainable and economic threshold.

Sustainability Analysis

Resource-use inefficiency. The frequency distribution of RUI showed a sharp rise from left to highest, and then a gradual falling to lowest distribution (Table IV). This distribution reveals a mean inefficiency index of 0.23 with a mode of 0.16. This means that about 23% higher production could be achieved without additional resources. Therefore this suggests a rather high degree of technical efficiency among the migrant farmers. This distribution agrees with previous works carried out in other peasant farming environments (Ali & Byerlee, 1991; Parikh, *et al.*, 1995; Coelli & Battesse, 1996).

Index of sustainable land use and management. The distribution of ISM at farm level presented in Table V shows the accumulated marginal effect of the land use and management practices on land resource quality. From the table, about 72% of the migrant farmers adopted land use and management practices that impaired land quality, while only 27% of them adopted practices that improved the land quality. It is specified that the farms with negative values of ISM impaired land productivity and vice versa. Specifically, on the top of the ISM table is the (0.7 - 0.09) interval class with about 51.67% of farmers falling into this class.

Short-run sustainability index (SRSI). Table VI

Table I. Description of cropping pattern in the area

Cropping Pattern	Frequency	%age
Sole Cropping	32	17.78
Inter Cropping	30	16.67
Mixed Cropping	118	65.55
Total	180	100

Source: Field survey, 2000

Table II. Entropy Index of Crop Diversification

Description	Frequency	Combination
Sole	32	0
Two-crop combination	30	0.26
Three-crop combination	67	0.40
Four-crop combination	41	0.48
$\geq$ Five-crop combination	10	0.51
Sample Mean	180	0.28

Table III. Distribution of nutrient intake index among the sampled farmers

Nutrient intake index	Frequency	%age
1-2	6	3.00
2.1-2.5	24	13.00
2.6-3.0	10	6.00
3.1-3.5	36	20.00
3.6-4.0	74	41.00
$\geq$4.1	30	17.00
Total	180	100

Source: Field survey, 2000

Table IV. Distribution of farm-specific Resource-use inefficiency indices among farms

Class interval of inefficiency indices	Frequency	%age
0.01-0.10	9	5.00
0.11-0.20	80	44.44
0.21-0.30	51	28.33
0.31-0.40	19	10.55
0.41-0.50	10	5.55
0.51-0.60	5	2.77
0.61-0.70	3	1.67
0.71-0.80	1	0.56
0.81-0.90	1	0.56
0.91-1.00	1	0.56
Total	180	100

Mean = 0.23; Mode = 0.16; Standard Deviation = 0.14; Minimum value = 0.01; Maximum value = 0.98; Skewdness = -0.50

Table V. Distribution of farm specific sustainable land use and management index (ISM)

Class interval	Frequency	%age
(2.3-1.6)	5	2.78
(1.5-0.8)	21	11.67
(0.7-0.09)	93	51.67
(0.08-0.01)	12	6.67
0.01-0.08	9	5.00
0.09-0.7	26	14.44
0.8-1.5	8	4.44
1.6-2.3	6	3.33
Total	180	100

Values in parentheses are negative values

Table VI. Distribution of farm specific short run sustainability index

Class Interval	Frequency	%age
(3.3-2.8)	1	0.55
(2.7-2.2)	3	1.67
(2.1-1.6)	5	2.78
(1.5-1.0)	15	8.33
(0.9-0.4)	24	13.33
(0.3-0.07)	38	21.11
(0.06-0.01)	42	23.33
0.01-0.06	25	13.89
0.07-0.3	14	7.78
0.4-0.9	5	2.78
1.0-1.5	6	3.33
1.6-2.2	2	1.11
Total	180	100

Values in the parenthesis are negative values.

apparently shows a normal distribution of the indices with the majority of the farmers falling into the – 1.5 to – 0.3 class interval. Specifically, about 71% of the farmers fall within the class (i.e. – 0.01 to – 3.3) while about 29% fall within the 0.01 to 2.20 class interval. The result therefore showed that 71% of the farmer's land productivities declined owing to the net balance effect of the resource-use inefficiency and effect of land use and management practices. On the contrary, about 29% of the farmers improved their land productivity on the context of efficient use of inputs and proper use and management of land. In essence, considering the level of input combination and utilisation by the farmers, only 29% of them undertook sustainable crop production processes.

CONCLUSION

The central issue this paper focussed was to evaluate land use and management practices of migrant farmers within the paradigm of sustainable crop production. On the basis of analysis, the system of crop production shows low level of crop diversity and some remarkable signs of un-sustainability in the area of resource use efficiency and land resource maintenance. The findings of this study and their implications have brought to fore a number of issues that needs to be addressed. Therefore, the study suggests large-scale adaptive research and extension programme that would assist and educate farmers on sustainable land use and management pattern.

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