LAND MANAGEMENT AND RESOURCE-USE EFFICIENCY AMONG FARMERS IN SOUTH-EASTERN NIGERIA

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ABSTRACT

This study examined land management practices and resource-use efficiency among farmers in South-eastern Nigeria within the framework of sustainable crop production.

Two-stage random sampling method was employed to collect primary data from 300 farmers in Odukpani and Itu Local Government Areas of Cross River State and Akwa Ibom State respectively via well structured questionnaires. A combination of tools including descriptive, budgeting, statistical and econometric procedures was used to analyse the data. Specifically, a stochastic production frontier based on transcendental logarithmic model was developed to capture economic and land management variables considered.

The results showed that 70 percent of the farmers were between 20 and 45 years of age, 67 percent were literate and 65 percent took farming as their main occupation. Farming system analysis revealed average farm-size of 2.87 hectares and a labour intensive farming operation. The result also showed that 48 percent and 36 percent of the farmers considered income generation and household food security as the primary reasons for choice of crops respectively. Mixed cropping constituted the major cropping pattern in the area and 78 percent of the farmers grew crops that had greater tendency of depleting soil nutrients. In terms of intensity of cultivation, the Rutherberg value of 0.325 showed that the farming system practised in the area was

moving toward permanent cultivation under the natural fallow management system. Furthermore, Herfindel index of 0.587 and entropy index of 0.288 show low levels of crop diversification.

Budgetary analysis showed that maize-cassava mixture had the highest average net farm income per hectare (N28,851.00). The least average net farm income per hectare came from cassava-okra-yam mixture (N7,071.99). The study showed that the farmers had financial rewards from farming, but there was substantial scope for improvement of productivity as the farmers were operating at stage II of the production process with respect to use of resources.

The maximum likelihood estimation of the stochastic production function revealed the presence of short-run decreasing return to scale. The estimated production frontier fulfilled all the attributes of a well behaved production function and the diagnostic statistics suggested the presence of component error term. The study further revealed mean output-oriented technical efficiency of 0.77 for the farmers; 0.98 for the most efficient farmers (0.67 percent) and 0.01 for the least efficient farmers (5.33 percent). Farmers with efficiency index between 0.01 and 0.69 constituted 10.6 percent while 89.3 percent of the farmers had efficiency index between 0.70 and 0.98. However, it was possible to improve resource-use efficiency in the area to obtain 23 percent higher production at current levels, type and quality of farm resources. The index of land-use and management showed that 66 percent of the farmers impaired land quality while 34 percent of the farmers improved

land quality through their management practices. Again, net effects of resource-use inefficiency and land-use management indices estimated as farm specific short-run sustainability index (SRSI) showed that 73 percent of the farmers impaired farm productivity while 27 percent improved farm productivity and the index was significantly related to crop yield. Cultivating on a poorly drained soil with undulating terrace resulted in less input productivity and lower output level. The result further showed that different land-use and management practices in terms of length of fallow, crop diversification and crop configuration had direct impact on sustainability index of the farms.

Therefore, on the basis of resource-use efficiency and land management practices, the system of farming in the area showed some signs of unsustainable crop production in the short-run. The study therefore, suggested some recommendations to include: soil survey and evaluation by relevant bodies; need for better land use and management practices through adaptive research and extension programmes; and provision and use of land augmenting materials, that would ensure land quality maintenance and input use productivity.

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To God be the Glory, Honor and Power for giving the World Jesus Christ – the High Priest and Saviour of mankind (Hebrews 8). In Him I live, move and have my Being (Act 17:28). Great are the works of His Hands and faithful is He. He has made boundary lines to fall into pleasant places for me and has given me a delightful inheritance (Psalm 16:5-6 NIV). This thesis is a testimony of His goodness and mercies over me.

DEDICATION

I dedicate this thesis to the Almighty God for His Mercies over my life and giving me the grace to know Him.

Also, to the memory of my late father, Elder Joshua Udo Inyang.

CERTIFICATION

I certify that this work was carried out by UDOH, Edet Joshua under my Supervision in the Department of Agricultural Economics, University of Ibadan.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION

Agriculture is the economic mainstay of majority of households in developing economies and will remain so for the foreseeable future. This is largely so since development policy initiative of these economies is very limited in scope to ensure adequate development of non-farming employment opportunities. Therefore maintenance of sustainable productivity in the sector is the pivot of development. But over the past three decades, most developing economies have witnessed substantial decrease in productivity of agricultural sector. This is essentially so as the spectre of hunger, mounting food deficits and widespread rural poverty continue to linger on. Analysis of trade matrix of this region shows trade deficit, thus high dependence on importation. According to FAO (1989) food imports increased sevenfold between 1970 and 1985, and 1980 and 1990. But overall food production, however grew by 26 percent while on a per capita basis, it declined by 5 percent.

Increasing sustainability and targeting small-scale farmers who constitute the bulk of practitioners are the principal policy issues directed toward agricultural development. However, agricultural development policies and programmes aimed at improving the sector directly or indirectly depend on land. Therefore, the availability of land and its productivity has become an area of emphasis. Globally, of the 13,422 million hectares of earth's surface, agricultural land comprises about 4868.3 million hectares (36.3%). The arable land including land under permanent crops is 1444 million hectares (29.7%) of agricultural land (Joshi, 1995). On the world, average arable land per farm is 1.28ha. Specifically, the average arable land per farm in Nigeria is a thing of concern in the face of demographic and environmental pressures. About 36 percent of the land area of the country is devoted to agriculture (NEST, 1991) and the average arable land per farm is about 1.08 hectare (World Bank, 1996).

Recent discussions on agriculture emphasizes sustainable criterion being framed within the context of socio-economic and environmental paradigm. This paradigm is reflected in an emerging consensus on the inextricable link among agricultural production, environmental degradation and demographic trends. That is, agricultural practice must recognise the need to enhance agricultural productivity to meet increased demands created by growing populations and rising incomes at a sustainable rate. Therefore, land use and management should be viewed within this framework. It should enhance the productivity of farm resources with a few (but critical) outside inputs, increase the farmers' income, and improve their living standards .

About 71 percent of Africa's arable land and about 31 percent of its pasture land have already been degraded (Oldema, *et al*, 1991). This becomes even more visible in areas of high population growth as seen in soil erosion, farming on highly erosive and marginal lands, loss of soil fertility, downstream pollution, and deforestation. Nigeria's situation does not differ from the foregoing statement. Demographic and environmental indicators for the country give a clear view.

Table 1.1: **Demographic And Environmental Indicators for Nigeria Indicators Values**

INDICATORS	VALUES
Population density (people 100ha, 1996)	924
Average manual population change (%) (1990-1994)	2.9
Population change in rural area (%) (1990)	2.7
Population in rural area (%) (1990)	77.5
Percentage of total land area:	
* Under cropland (1993)	36
* Under permanent pasture (1993)	44
Percentage change in total forest area (1993-1995)	-88.5
Deforestation per year (%)	3.5
Percentage change in cropland (1993-1995)	5.7

Sources:
1. World Bank,(1989)
2. World Bank,(1989 and 1996)
3. CBN Bulletin,(1996) edition

From table 1.1, the rate at which population is increasing as well as deforestation rate shows the extent to which Nigeria land and forest are endangered. Specifically, the total forest area has been decreasing over the years. In 1993 about 93,345.9 Sq. km of forestland was protected. But as of 1995, only about 10,752.7 Sq. km was left indicating a decline of about 88.5 percent (CBN, 1996). This indicates increasing and perhaps indiscriminate use of forestland. The challenges posed by the indicators presented in table 1.1 require effective allocation, use and management of agricultural land to ensure sustainable agriculture within the framework of small holders' resource endowment and management capacity.

1.1 PROBLEM STATEMENT

The practice of agriculture depends on land use and resource allocation. Land utilization and management practise by subsistence farmers with limited resources focus on practices aimed at achieving farm level objectives in term of economic viability, food security and risk aversion (Scholes *et al*, 1994; Krusemen *et al*, 1996; Pinstrup-Anderson and PandyaLorch, 1995). The framework of their land use is viewed therefore to have a short-term planning horizon as little attention is paid to the status and management of agricultural land which account for a substantial proportion of the total land area (Scholes *et al*, 1994 and Thapa, 1996). Seemingly, it is indicative that the 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 development which include environmental concern.

In Nigeria, subsistence farmers practise low-external-input agriculture (LEIA). In the faces of demographic and environmental pressures and changes in social and political circumstances, this traditional system becomes disrupted. There are reported cases of considerable degradation of the natural resource-base, particularly when its use is intensified and indiscriminate (NEST, 1991).

To a greater extent, farmland is seriously fragmented, especially in southern states of Nigeria where an inheritance tenural arrangement is practised and this process has been going on for generations, leading to individual farm shrinking as the years pass (Adegboye, 1996 and NEST, 1991). The choice of land use, allocation and management by farmers may not necessarily reflect proper and adequate practices. This problem is further compounded by constraints such as financial status of the farmers, lack of relevant information as regards soil properties, suitability and capabilities etc. This situation has culminated in persistent food crisis in Nigeria as gap between population and food production continue to widen (Igben and 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; Tisdell, 1996). In areas where population is quite high, marginal lands and forest reserves are encroached for crop cultivation. Besides, soils in the tropics have low productivity in the absent of fertilizer of trace elements as they are fragile, loosing organic matter and nutrient quickly (Spencer, 1989). Consequently, low-external-input agriculture (LEIA) is always not sustainable and certainly not economical. Unsustainable land use and management is even worsened in situations where most of the practicing farmers are tenants who do not have property rights over the land as is the case of most farmers in the study area. Mining of the land may likely be the common practice by the resident farmers.

Within the context of sustainable agriculture, 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 (Smyth *et al*, 1993; CGIAR, 1988 and IITA, 1992). 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 and Lohr, 1995). Therefore sustainable agriculture must of necessity involve farming practices that enhance productivity of land, labour and other physical resources, and/or improve plant and animal productivity in order to meet present economic needs without compromising the benefits of future generations.

Issues of emphasis in sustainable land use and management within the framework of farming system are considered in respect of land resource quality maintenance and resource-use efficiency (CGIAR, 1988; Ali, 1996). Improving farm productivity, efficiency, and combating land degradation problems are the key issues in sustainable agricultural development. Therefore, within the foregoing context, two questions become fundamental: if the productivity of the farm is high and the farmers are efficient in use of inputs, can land management practices be capable of maintaining the economic benefits over the subsequent years? Are the management practices adequate to improve the state variables-soil fertility, nutrient recycling, etc and enhance sustainable production in every cultivation cycle? To answer these questions modelling approach, and the identification of land use and management indices and thresholds should form the framework of analysis.

1.2 JUSTIFICATION OF THE STUDY

Sustainability as a concept in agriculture transcends practice that involves the successful management of available resources to satisfy identified objectives, while maintaining or enhancing the quality of the environment and conserving natural resources (FAO, 1989; Lynam and Herdt, 1989). Therefore, the paradigm of environmental-economic analysis of sustainable land use and management at farm-level is relevant in assessing, within the framework of sustainability, the extent to which poor resource base farmers allocate, use and manage land.

Farming practices of the area under study are at both subsistence and commercial levels and have evolved over the past three decades since a major highway, "Calabar-Itu" highway was constructed. There have been upsurge of people coming to settle here for farming and other agro-related purposes. This has resulted in horizontal expansion of agricultural land and most of the virgin forest areas have been destroyed. Sequel to the rather intensive and perhaps indiscriminate use of land by the farmers, there is concern as to whether soil have deteriorated, or whether high crop production can be maintained over a longer period. As the area is a food basket to neighboring states with rather overpopulated, overutilised and marginal farmlands, unsustainable use and management of agricultural land in this area would jeopardise food security of the area and the neighbouring states. Therefore, this study would evaluate common crop management options practise, by the farmers toward soil conservation as they aim at meeting their objectives. Further, with better accessibility and proximity of the area to urban areas, even the urban dwellers are engaging in part-time farming in the area. Consequently, indiscriminate use of land in the area without proper land-use planning glean up concern as to whether the land-use and management practices could be sustainable. Furthermore, farm level evaluation of input-output is quite location specific and would provide a veritable information to farmers in assessing the economic rationales for adopting different land management practices in order to maintain the bio-physical condition of the land (Gunatilake and Abeygunawardena, 1993).

Moreso, study on the optimal allocation, use and management of an economically valuable exhaustible resource like land has policy relevance in agricultural development. Furthermore, many studies on peasant agriculture are framed and modeled on the neo-classical economic optimisation without paying adequate attention to the non-economic variables, like land management practices and their marginal effects on the crop productions.

A lack of understanding of the status quo of production system has undermined various development efforts toward agricultural sustainability in the past, and the failure to evaluate and assess the system will inevitably undermine whatsoever efforts of government in the future. A study of land-use and management system from a decision-making viewpoint involves studying the factors which lead to a particular system being chosen and continuing to be used (Tisdell, 1996). There is need to develop a benchmark study of wider dimension that would identify land- use indices and thresholds in a typified small holder farming system.

1.3 OBJECTIVES OF THE STUDY

The main objective of the study is the evaluation of land management and resource-use efficiency among farmers. The specific objectives are to:

i) identify the socioeconomic characteristics of the farmers and the pattern of land-use and management;

ii) measure profitability of the enterprises and resource-use productivity;

iii) measure resource-use efficiency of crop production;

iv) project the resource-use efficiency of the farmers; and

v) evaluate whether the production process is sustainable in terms of resource-use efficiency and land management practices; and to

vi) examine effect of different land condition and management systems on crop production.

CHAPTER TWO

2.1 THEORETICAL FRAMEWORK

This study is conceptualized on the following theoretical constructs.

Efficiency Measurement

Maximum Likelihood Estimation

Sustainability

2.1.1 EFFICIENCY MEASUREMENT

By considering the maximum output that can be produced from a specified set of inputs, given the existing technology available to individual farm involved, the theory of a production function is underscored and the concept of efficiency is defined. Microeconomic theory of production is awash with efficiency measurements and its measurement (technical, allocative and economic) has remained an area of important in economic research.

The concept of efficiency goes back to the pioneering work of Farrell (1957) who drew extensively upon the works of Debreu (1951) and Koopmans (1951) to define a simple measure of firm efficiency which could account for multiple inputs. Farrell's concept of efficiency consist of two components: technical and allocative efficiency, which he termed price efficiency. His idea of technical efficiency reflects the ability of a firm to obtain maximum possible output for a given quantities of inputs, and the ability of a firm to use the inputs in optimal proportions, given their respective prices is the measure of allocative efficiency. These two measures are then combined to provide a measure of total economic efficiency (overall efficiency).

The idea is illustrated in the diagram below:

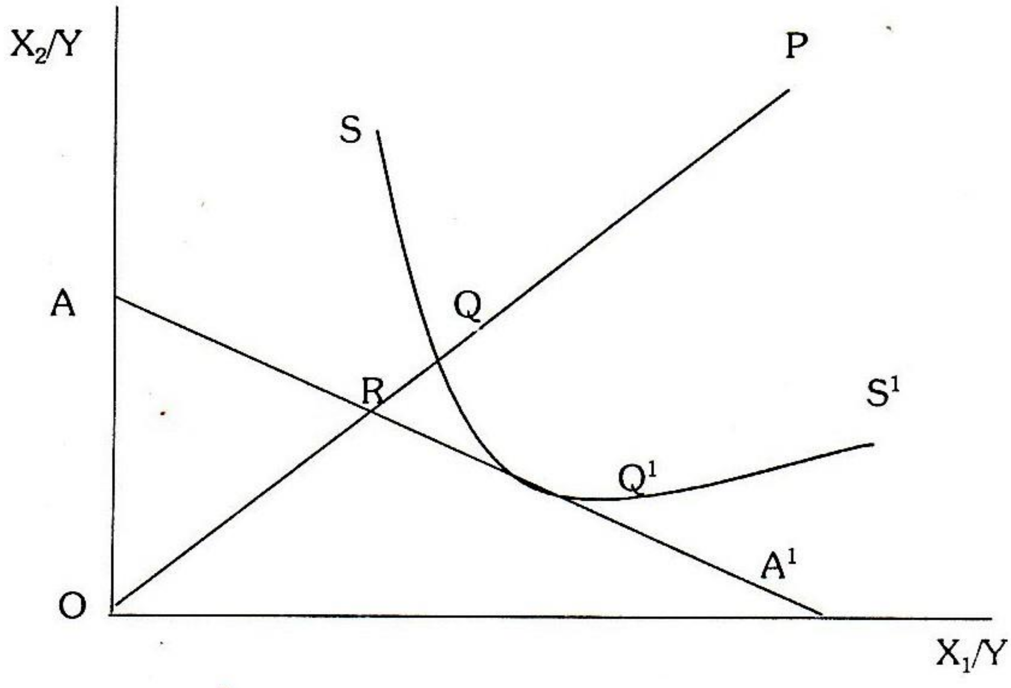

Figure 2.1: Farrell's efficiency measures

From figure 2.1, $\overline{SS^1}$ represents an isoquant line for two inputs (X_1 and X_2). If a firm uses quantities of inputs, defined by the point P, to produce a unit of output, the technical efficiency of that firm is defined to be the ratio OQ/OP, which is the proportional reduction in all inputs that could theoretically be achieved without any reduction in all outputs. Point Q is technically efficient because it lies on the efficiency isoquant. With the knowledge of $\overline{AA^1}$, the allocative (price) efficiency of the firm operating at P is defined to be the ratio OR/OQ, since the distance RQ represents the reduction in production cost that would occur if production were to occur at the allocatively (and technically) efficient point Q^1, instead of at the technically efficient but allocatively inefficient, point Q. The overall (economic) efficiency is defined to be the ratio OR/OP, being the product of technical and allocative efficiency, i.e. (OQ/OP)(OR/OQ) =(OR/OP).

Efficiency measurement is very important because it is a factor for productivity growth. It is evident that productivity growth may be achieved through either technological progress or efficient improvement, but the policies required to address these two issues are likely to be different (Coelli, 1995). However, productivity and efficiency are synonymous in the context that optimal productivity of resources implies efficient utilization of these resources in the production process (Olayide and Heady, 1982).

Measurement of efficiency has resulted into specification of various estimation methods that have been widely used by various researchers. In practice, measurement of efficiency is achieved through transformation function that has been empirically constructed from observations or data points. Measurement of this function and the potential deviation from such frontier involve numerous methods. According to Kalaitzandonakes, *et al* (1992), these methods can be categorized according to:

The specification of the frontier (i.e. parametric or nonparametric);

The way the frontier is computed (i.e. through programming or statistical procedures); and

The way deviation from the frontier are interpreted (i.e. as inefficiency or a mixture of inefficiency and statistical noise).

Studies on (a) and (b) dominate the economic literatures with each having specific characteristic and estimation procedure.

2.1.1.1 PARAMETRIC FRONTIER ESTIMATION

Parametric frontier estimation is based on a specific functional form hypothesized as a mathematical representation of the production frontier constructed with both programming and statistical procedures (Bravo-ureta and Rieger, 1990; Kalaitzandonakes *et al*, 1992). Parametric frontier estimation can be deterministic, stochastic and programming.

2.1.1.1a Deterministic Parametric Frontier

The term deterministic is generally used to describe that group of methods which assume a parametric form for the production frontier along with a strict one-sided error term. Pioneers in this area are the works of Aigner and Chu (1968), Afriat (1972), Schmidt (1976) and Seitz (1970).

The deterministic frontier model is defined by

$$y_i = \alpha + F(x_i ;\beta) + e \quad e \leq o, \; i = 1, 2....N \qquad (2.1)$$

where

y_i = the output of the ith firm; x_i is the corresponding (M x I) vector of inputs; (is a vector of unknown parameter to be estimated; F(.) denotes an appropriate functional form (in this instance, the Cobb-Douglas function) ; e is a non-negative variable representing inefficiency in production, i.e. the proportion between actual and potential output.

Afriat (1972) assumed a production model similar to Eq. (2.1) by assigning a Gamma distribution Gz (Z; n) to the random variable, e and introducing the statistical error $e = n - z_i$ and through maximum likelihood procedures he estimated the function. However, the maximum likelihood procedures are not independent of the distributional assumption of Ui (gamma, exponential, half normal, etc.) and as such different assumed distributions lead to different maximum likelihood parameter estimate. To eliminate this limitation, Richmond (1974) adopted an estimation approach based on ordinary least squares procedures referred to as corrected OLS or COLS. By this approach if μ is the mean of U, then Eq. (2.1) can be rewritten as:

$$Y_i = (\alpha + \mu) + F(x_i ; \beta) + (e + \mu) \text{ .... } (2.2)$$

such that $E(e - \mu) = o$. Under these conditions Eq. (2.2) can be estimated to give a BLUE of β through the OLS and by shifting the OLS constant parameter estimate upward until no residual is positive, and consistent α is estimated (Greene, 1980; Kalaitzandonakes *et al*, 1992).

Basically, the Afriat-Richmond production frontier comes about by a mere upward shift on the logarithmic scale of the corresponding "average" production function. Though, it is relatively easy to compute, it has been widely criticized. It takes no account of the possible influence of measurement errors and other noise upon the shape and positioning of the estimated frontiers, since all observed deviations from the estimated frontiers are assumed to be the result of technical inefficiency (Coelli, 1995). However, Timmer (1971) attempted to address the problem by arbitrary dropping a percentage of firms closest to the estimated frontier, and re-estimating the frontier using the reduced sample. This method has been widely criticized. Furthermore, because of the way technical inefficiency is defined, deterministic parametric frontiers are susceptible to outliers. The inherent problems of deterministic approach are better handle by stochastic approach.

2.1.1.1b **Stochastic Parametric Frontiers**

With the specification of Stochastic parametric frontier, deviation from the production frontier is accounted for not only by technical inefficiency but also by measurement error, statistical noise and other nonsystematic influences. Estimation of this was independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977) and has been extended by Jondrow *et al* (1982) to allow for estimation of the individual firm efficiency levels with cross-sectional data. The Stochastic frontier production function is defined by:

$$Y_i = F(x_i ; \beta) \ \exp.\ (v_i - u_i) \qquad i = 1, 2, \ldots N \qquad (2.3)$$

Where Y_i, $F(.)$, x_i and β are as previously defined in Eq.2.1. Vi is a symmetric error component that accounts for random effects and exogenous shock, while $u_i \leq 0$ is a one-sided error component that measures technical inefficiency. The model specified above is such that the possible production y_i, is bounded above by the stochastic quantity, $f(x_i;\beta)\ \exp\ (V_i)$; hence the term stochastic frontier.

Estimation of the model and separation of the technical inefficiency $-U_i$ from statistical noise , V_i requires specific assumptions about the distribution of U_i and V_i. Assume V_i to have normal distribution ($V_i \sim N\ (O,\delta^2{}_v)$) and U_i to have half-normal distribution ($U \sim |N(O,\ \delta^2{}_u|$), the parameters of the frontier and the density functions of V and U can be estimated by maximising the log-likelihood function defined by:

$$\ln Y = N \ln (2/\pi)^1/_2 + N\ln\delta^{-1} + \sum_{i=1}^{N}\ln\left[1 - F\left(e_i\lambda\delta^{-1}\right)\right] - \tfrac{1}{2}\,\delta^2\sum_{i=1}^{N}E_i^2 \qquad (2.4)$$

Where e = the sum of V and U; $\delta = (\delta_v^2 + \delta_u^2)$; $\lambda = \delta_u/\delta_v$; F = the standard normal distribution function; and N = the number of firms in the sample.

Note that U, instead of assuming a half-normal distribution can also assume exponential distribution (i.e. gamma distribution with parameters $r = 1$ and $\lambda > o$). The basic structure of the stochastic frontier model (2.3) is depicted in figure 2.2:

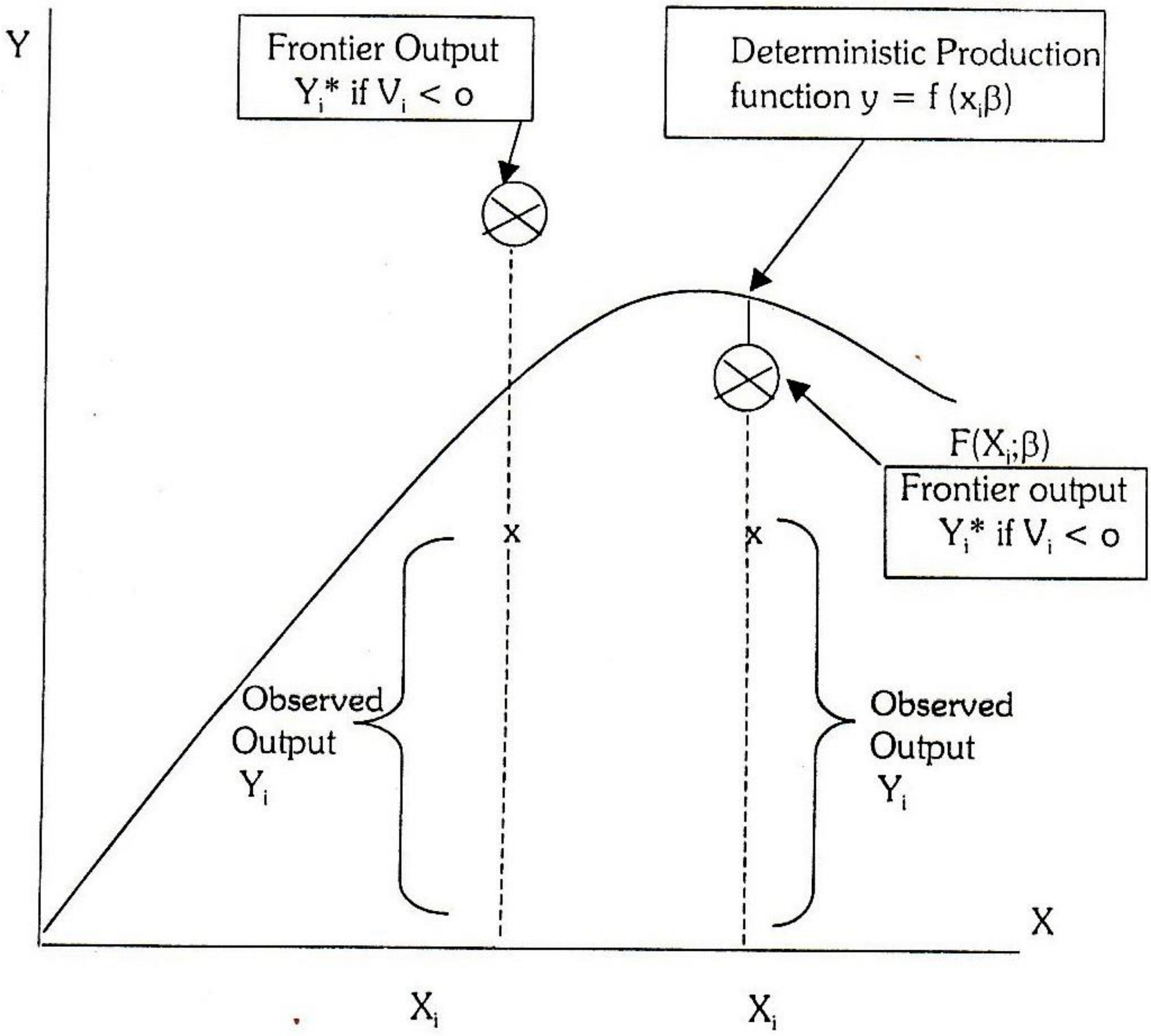

Figure 2.2: Stochastic Frontier Production Function

By estimating means of conditional distribution of U given v, firm level estimates of technical efficiency can be derived as given by Battesse and Coelli (1988):

$$E(U_i/e_i) = \mu_i + \sigma^* \{f(-\mu_i/\sigma^*)\ [1-F(-\mu_i/\sigma^*)]^{-1}\} \qquad (2.5)$$

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 2.5 at $e=N^{-1}\Sigma e_i$.

Besides ML method, Stochastic frontier production functions can be estimated using a variant of the COLS method suggested by Richmond (1974) and this method could be preferred because of ease of computation. But the ML estimator is asymptotically more efficient than the COLS estimators and given the availability of automated ML routines, ML estimation approach is mostly preferred and utilised. Therefore, this study utilises the MLE approach.

The Stochastic frontier is not however without problems. The main shortcoming is that there is no a priori justification for the selection of any particular distributional form of U_i (Coelli, 1995). However, the problem is partially solved by specifying a more general distributional forms, such as the truncated-normal and two parameter gamma, but the resulting efficiency measures may still be sensitive to distributional assumptions (See Stevenson, 1980 and Greene, 1990). Another major problem associated with Stochastic approach is that the firm estimates of technical efficiency is inconsistent as shown in Jondrow *et al*, (1982). Despite these criticisms, the approach permits the measurement of standard errors and test of hypotheses, which are not possible with the deterministic models because of the violation of certain maximum likelihood regularity conditions (refer to Schmidt, 1976; Coelli and Battesse, 1996).

2.1.1.2 NONPARAMETRIC FRONTIER ESTIMATION

The piecewise-linear convex hull approach to frontier estimation proposed by Farrell (1957) is considered to be origin of nonparametric frontier. This work was considered by only a handful of publications (e.g. Seitz, 1971) until Charnes *et al*, 1978 reformulated the approach into a mathematical programming and coined the term data envelopment analysis (DEA). Their exposition has been widely adopted for empirical studies.

Assume there is a sample of N firms where each firm utilises K inputs and M different outputs are produced. For the ith firm these are represented by the vectors x_i and y_i respectively. Within the nonparametric approach, multiple inputs and multiple outputs are reduced to a single virtual input and virtual output which are represented in ratio form. For each firm, a measure of the ratio of all outputs over all inputs, such as U_iY_i/V_iX_i, where U is an M x 1 vector of output weight and V is a K x 1 vector of input weight, is a measure of efficiency. Hence, for firm i the following mathematical programming model must be solved:

$Max_{u,v}(U_iY_i/V_iX_i)$,

Subject to

$U_iY_i/V_ix_i \leq 1, i = 1,2, \ldots N$

$U, V \geq 0$ (2.6)

Where, U and V = vectors of variable weights to be estimated and y_i and x_i = output and input vectors of the ith firm.

As the ratio is maximised, it would be constrained to be no greater than one, thus, all firms in the sample are forced to be on or below the frontier.

However, to avoid the problem of infinite number of solutions, [i.e. if (U^*, V^*) is a solution, then (αU^*, αV^*) is another solution, etc] a constraint $Vx_i = 1$ is imposed on the fractional programming model, Eq (2.6) and this is formulated as the following linear program:

$$\min_{\theta,\lambda} \quad \theta$$

subject to

$$-y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$\theta = \text{free}, \lambda \geq 0 \qquad (2.7)$$

Where θ is a scalar and λ is a N x 1 vector of constraints.

Computationally, nonparametric procedures have certain advantages over parametric approaches. The procedures remove the necessity of making arbitrary assumptions regarding the functional forms and the distributional form of the U_i. The procedures also allow estimation of frontier estimated with multiple outputs and multiple inputs without restoring to restrictive aggregation assumptions. On the contrary, some explicit drawbacks of the procedures are recognised. The approach suffers from the same criticism as the deterministic methods in that it takes no account of the possible influence of measurement error and other noise in the data (Coelli, 1995). Most importantly too, being nonparametric, the estimated production frontier have no statistical properties to be evaluated upon.

It should be noted that the above exposition is based on input orientation and assumed constant returns to scale (CRS). But Banker, Charnes and Cooper (1988) proposed a variable returns to scale (VRS) model to be used in a situation where the industries are not perfectly competitive. This was done by extending the CRS linear programming and adding the convexity constraint: $N1'\lambda = 1$ to Eq (2.7) to provide:

$\text{Min}_{\theta,\lambda}\, \theta,$

Subject to

$-y_i + Y\lambda \geq 0$

$\theta x_i - X\lambda \geq 0$

$N1'\lambda = 1$

$\lambda \geq 0,$ (2.8)

where N1 is an N x 1 vector of ones.

2.1.2 MAXIMUM LIKELIHOOD ESTIMATION

Maximum likelihood estimate, due to Fisher is a convenient measure of population parameter utilising a single or point estimation rather than confidence limits. It involves estimation of population parameters such that the probability density for obtaining the actual sample observations that have been obtained from the population is greater than the probability density obtainable with any other assumed values (estimators) of the population parameters (Draper and Smith, 1966 and Olayemi, 1998).

Consider a generalised linear regression model

$$y = x\beta + \mu \qquad (2.9)$$

Where y is a N x 1 vector of observations on the dependent variable, X is a N x K matrix of the values of the regressions, β is a K x 1 vector of the regression coefficient and μ is a N x 1 disturbance vector. We now define maximum likelihood estimators and prove that it exists by describing the geometry of the maximisation problem. This is done by making certain assumptions:

a) y_i values are normally distributed;

b) U is normally distributed to avoid problem of quasi-maximum likelihood estimates;

c) $E(u) = 0$ and

d) The population has a density function containing population parameters.

From Eq (2.9) we want certain estimators of the population parameters, β_o, β_i, δ^2. In order to find these maximum-likelihood estimators, we first specify the likelihood function for our sample observations (X_1Y_1), (X_2Y_2), ..., (X_nY_n) and maximise each for the unknown parameters much like we minimise our OLS regression function for the sum of squares of error. Therefore, the likelihood function to be maximised for β_o and β_i which appear only in the exponent is defined by Olayemi,(1998) as:

$$P(Y_1 \ldots, Y_n) = \left(\frac{1}{\sqrt{2\pi\sigma^2}} e^{-(1/2\sigma 2)} \right)^n \Sigma (Y_i - \beta_o - \beta_i X_i)^2 \qquad (2.10)$$

By taking the derivative of Eq. (2.10) with respect to the individual parameters and setting it equal to zero, the maximum likelihood estimators are obtained. However, it should be noted that the maximisation of the Eq. (2.10) is obtained by minimising the quadratic form or maximisation of negative exponent.

The process of obtaining the ML estimators is, however, rather difficult to obtain, at least in general. Therefore, in empirical studies, we resort to Zig-zag iterative procedure which Coelli, (1995) termed paramerization of the specified model.

2.1.2.1 PROPERTIES OF MAXIMUM LIKELIHOOD ESTIMATORS*

Generally, maximum likelihood estimators are identical to the ordinary least squares estimators with large-sample or asymptotic properties which hold under fairly general conditions.

1. **Consistency**: Though ML estimators are not necessarily unbiased, they are consistent (Parathasarathy, 1967; Lesser, 1974). Consistency of ML

* See Johnston and Dinardo, 1997, Pp 143 for more information.

estimator, θ, implies that the predicted probability P (x, θ) is a consistent estimator of the true probability P(x, θ) if θ is absolutely continuous. In a more general term, Ichimura and Thompson, 1998 stated that for any set $C \in \Re^k$, we may consistently estimate Pr $\{\beta_i \in C\}$ using the probability assigned to C provided βi lies on the boundary of C with probability zero. Therefore, for a ML estimator, θ, this property is concisely defined as

$$\text{Lim Pr } \{(\theta, \theta) > \varepsilon\} = 0, \text{ for any } \varepsilon > 0 \text{ or Plim } (\theta) = \theta$$

(2.11)

It then follows that a consistent ML estimator is the one with vanishing bias as sample size becomes large and the one of decreasing variance with large sample size.

2. **Asymptotic normality**: This property implies that the asymptotic distribution of θ is normal with mean θ and variance given by the inverse of information matrix, $\mathbf{I}(\theta)$. That is

$$\theta \sim N\,(\theta, \mathbf{I}^{-1}\,(\theta))$$

3. **Asymptotic efficiency**: The ML estimator has minimum variance in the class of consistent, asymptotically normal estimators (Johnston and Dinardo, 1997). Therefore, when θ is a vector of parameters and θ is the ML estimator, the

$\sqrt{n}\,(\theta\text{-}\theta) \xrightarrow{d} N\,(O,V)$ for some positive definite matrix V. If V denotes the variance matrix of any other consistent, asymptotically normal estimator, then V-V is a positive semi-definite matrix.

4. **Invariance**: This property stipulates that, assuming θ is the maximum likelihood estimator of θ and $f(\theta)$ is a continuous function of θ, then $f(\theta)$ is the ML estimator of $f(\theta)$.

5. **The Score has zero mean and variance I(θ)**: The zero mean is proven by integrating the joint density over all possible values of y to give a value of one. That is

$$\int \ldots \int f(y_1, y_2, \ldots, y_n; \theta) dy_i \ldots dy_n = \int \ldots \int L dy = 1$$

By taking partial derivative of both sides with respect to θ, we have.

$$\int \ldots \int \frac{\delta L}{\delta \theta} dy = 0$$

But

$$E(S) = \int \ldots \int \frac{\delta l}{\delta \theta} L \, dy = 0, \text{ or}$$

$$E(S) = \int \ldots \int \frac{\delta L}{\delta \theta} \, dy = 0$$

It then follows that the variance of S is

$$\text{Var (S)} = E(SS^1) = E\left[\left(\frac{\delta l}{\delta \theta}\right)\left(\frac{\delta l}{\delta \theta}\right)^1\right] = \mathbf{I}(\theta)$$

2.1.3 SUSTAINABILITY MEASUREMENT

The concept of sustainability was probably first advanced in 1980 by the International Union for the Conservation of Natural and National

Resources (Pearce *et al*, 1989; Le'le', 1991). It is a term that is multidimensional and all embracing. According to O'Riorden (1985), a sustainable agriculture combines the social, economic and environmental components of "sound husbandary" into a united package. Moreso, in the words of Brklacich *et al*, (1991), a sustainable agriculture should have a long-term horizon and can simultaneously maintain or enhance environmental quality, provide adequate economic and social rewards to all individuals in the production system and produce sufficient and accessible food supply. In the words of Plucknett and Wright, (1990), the Technical Advisory Committee of the Consultative Group on International Agriculture defined sustainability as "the successful management of resource for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources:"

Farshad and Zinck (1993) further noted that the concept of sustainability is a multifaceted one involving economic, agronomic, environmental, social and ethical consideration. Hence an average definition of sustainable agriculture would include such elements as soil fertility and productivity (rotations, integrated pest management, tillage method, crop sequences), management strategies (choice of hybrids and varieties, low cost inputs, etc), human needs (demand for basic food and fibres), economic viability, social acceptability, ecological soundness, time span (long term as opposed to short term profitability). Consequently, land use is sustainable when its productivity is economically adequate, socially just and culturally viable (NRC, 1993).

Economic perspective of sustainable agriculture focuses on the economic performance and viability of farming system which are sufficient to adequately reward producers and thereby maintain operation (NSE.SPRPC, 1981 and Ikerd, 1990). In commercial economies, farms which are unable to generate sufficient profit because of low farm product prices, reduced yield, higher cost of production, or whatever reason, are not self sustainable. In the opinion of Okigbo (1989) a sustainable agriculture is one which maintains an acceptable and increasing level of productivity that satisfies prevailing needs and is continuously adapted to meet the future needs for increasing the capacity of the resource base and other worthwhile human needs. He emphasised an integral approach to overall sustainable likelihood and development strategy which gives priority to better management of resources so that their uses in satisfying human needs minimize damage to the environment.

Smyth *et al*, (1993) re-echoed the idea of FESLM (Framework for the Evaluation of Sustainable Land Management) working party that "sustainable land use and management must combine technologies, policies and activities aimed at integrating socio-economic principles with environmental concerns so as to simultaneously ensure productivity, security, protection, viability and acceptability". On the basis of the aforementioned, Tisdell (1996) noted that conservative farming may not necessarily be a form of sustainable land management if the trade off between and among the various dimensions are not minimised. Further, Mario *et al*, (1992) maintained that, if management of agroecosystem results in environmental degradation, despite high economic return for human activity, then more natural resources are being harvested from the ecosystem than are being replaced.

By incorporating sustainability to land evaluation, Torquebiau (1992) pointed out that one means of evaluating the ecological sustainability of land use is via the use of indicators. These are the indicators of agroecosystem productivity and indicators of economic limits. These indicators allow one to reduce the quality of data required to represent complex relationship. If a farming system approach is to result in sustainable development, it must of necessity include the development of technologies and farming practices that enhance the productivity of land, labour and water resources, and/or improve plant and animal productivity through the introduction of biological technology or new management to meet the present needs without comprising the benefits of future generation (Bezunch *et al*, 1995).

2.2 LITERATURE REVIEW

The relevant literatures for the study are based on the followings:

Efficiency Measurement in Agriculture

Sustainable agricultural Production

Land use and soil fertility management

Economic-environmental modelling.

2.2.1 EFFICIENCY MEASUREMENT IN AGRICULTURE

Previous studies on efficiency of farm can be classified broadly into the following three categories, namely, deterministic parametric estimation, non-parametric mathematical programming and the stochastic parametric estimation. But according to the method chosen to estimate the frontier production function, two groups of literatures are identified, namely mathematical programming and econometric estimation.

The use of non-parametric techniques is limited in efficiency measurement in agriculture despite the fact that non-parametric methodologies can be used in situation where data is more limited and where production technologies are less well understood (Llewelyn and Williams, 1996). However, there are two non-parametric approaches to efficiency measurement. One is based on the works of Chavas and Aliber, (1993) and Chavas and Cox, (1988). This approach evaluates efficiency based on the neoclassical theories of consistency, restriction of production form, recoverability, and extrapolation, without maintaining any hypothesis of functional form. Alternatively, Farrell decomposed efficiency into technical and allocative. Fare *et al*, (1985) introduced a non parametric method of calculating efficiency across farms, which extended Farrell's approach by relating the restrictive assumption of constant returns to scale and of strong disposability of inputs which are the major criticisms of the method (Llewelyn and Williams, 1996).

The use of data aggregated across many farms has been the central aspect of most studies that adopt non-parametric approach in agricultural production analysis. Fawson and Shumway (1988) conducted a non-parametric analysis of the consistency of agricultural production behaviour for U.S. Sub regions, with joint hypotheses of profit maximisation; convex technology; and monotonic non-regressive technical change. They found that data from 1939 to 1982 were inconsistent with the hypothesis of profit maximisation. Chavas and Cox (1988) extended the non parametric approach by incorporating output augumenting (Hick-neutral) technical change to analyse U.S. agricultural technology. Profit maximisation without technical change was rejected for most periods, again using aggregate US data. They interpreted this as strong evidence of technical change.

Lim and Shumway (1992) applied the non-parametric approach to statewide production data for 1956 through 1982. Although results did not conform strictly to the profit-maximisation hypothesis, they were consistent with that hypothesis allowing for measurement error. Moreso, Ray and Bhadra (1993) adopted non-parametric approach to examine, at the farm level, the cost minimisation behaviour of Indian farmers involved in the production of a single crop. Their result did not confirm strong evidence for overall cost minimisation, although evidence did exist for variable cost minimisation. Featherstone et al (1995) investigated non parametrically, the optimizing behaviour of sample farms under profit-maximisation and cost minimisation hypotheses. Their result confirmed that some farms violate the profit maximisation hypothesis while some farms also violate the cost minimisation hypothesis. But the evidence against cost minimisation behaviour seems to be far less substantial than that against profit maximisation behaviour.

Estimation of efficiency via mathematical programming is also available in many literatures. Many previous studies in Africa employed static linear programming models (see Clayton, 1961; Ogunfowora, 1970; Abalu, 1975 and Crawford, 1982). Belete *et al*, (1993) in their study of efficiency of small-scale farmers in Ethiopia employed linear programming and its variant-MOTAD. Result of the study indicated a substantial potential for increasing net farm cash income by efficient allocation of available resources under current level of technology. An extension of utility-efficient programming to the non-linear discrete Stochastic programming method was developed and used in the analysis of economic efficiency of a sample of farmers in Iran by Torkamani and Hardaker (1996). The result indicated that it would be feasible to increase substantially farmers' total net revenue by increasing their economic efficiency in terms of technical and allocative efficiencies. The study further suggested that risk aversion plays an important role in farmers' behaviour.

Llewelyn and Williams (1996) conducted a nonparametric analysis of technical efficiency for irrigated farms using linear programming techniques. Their procedure allowed the relative technical efficiency for each farm to be determined and for inefficiency to be decomposed into pure technical inefficiency and scale inefficiency. The results showed that farmers operating inefficiently do so more often because of scale inefficiencies rather than pure technical inefficiencies as majority of the farms operate in the region of decreasing returns to scale rather than increasing return to scale.

Attempts to estimate firms efficiency using parametric approach are many and diverse. Studies based on primal approach where parameters were directly estimated mostly by using the ordinary least square (OLS) method are available. These parameter estimates were then used to check whether the first order conditions of profit maximisation are satisfied (See Hopper, 1965; Sahota, 1968; Saini, 1979). Moreso, according to Kumbhakar (1994) attempts were also made to model these deviations in terms of observable factors like education, experience, etc (See Ram, 1980).

Attempt to incorporate firm level prices and input use led to dual profit function formulation. Specifically, Ali and Flinn (1989) directly estimated farm-specific efficiency from a random coefficient profit frontier function using market prices. However, Wang *et al*, (1996) noted that the use of standard dual representations of the production structure requires the corresponding maintained hypotheses of cost minimisation and profit maximisation, subject to parametric market prices. And in the case of regulated industries or imperfect markets these hypotheses may be invalid. Furthermore, a generalised profit function (behavioural profit function) approach that incorporates market distortions resulting from imperfect market conditions has been developed in the literature. Kumbhakar and Bhattacharyya (1992) developed a behavioural profit function to test the appropriateness of a neoclassical profit function and the effect of education and farm size on allocative performance. Their model however, did not provide a numerical measure of profit efficiency of each farm. To take care of this shortcoming, Wang *et al* (1996) developed a shadow price profit frontier model to examine production efficiency of Chinese rural households in farming operations. Their model incorporates price distortions resulting from imperfect market conditions and socio-economic and institutional constraints, but retains the advantages of Stochastic frontier properties. The result rejected the neoclassical profit maximisation hypothesis based on market prices in favour of the general model, with price distortions. Therefore, reducing market intervention, allowing right to use of farmland to be transferred among households, encouraging migration of excess farm labour, and promoting farmers' education will improve rural households' efficiencies in agricultural production.

Econometric modeling of Stochastic frontier methodology of Aigner *et al* (1977) associated with the estimation of efficiency has been an important area of research in recent years. Basically, the studies are mostly based on Cobb-Douglas function and transcendental logarithmic (translog) functions that could be specified either as production function or cost function. Panel data, time variant data and cross-sectional data are mostly used. The first application of Stochastic frontier model to farm level agricultural data was by Battese and Corra (1977). But technical efficiency of farms was not directly addressed in the work. Kalirajan (1981) estimated a Stochastic frontier Cobb-Douglas production function using cross-sectional data and found the variance of farm effects to be a highly significant component in describing the variability of rice yield. Bagi (1984) used the Stochastic frontier Cobb-Douglas production function model to investigate whether there were any significant differences in the mean technical efficiencies of part-time and full-time farmers. The result showed no apparent significance, irrespective of whether the part-time and full-time farmers were engaged in mixed farming or crop-only farming.

Bagi andHunag (1993) estimated a translogarithmic Stochastic frontier production function and found technical efficiencies to vary from 0.35 to 0.92 for mixed farms and 0.52 to 0.91 for crop farms. Kalirajan and Flinn (1983) assumed a translog stochastic frontier production and by maximum likelihood estimation, the parameters were estimated and individual technical efficiencies ranged from 0.38 to 0.91 . They went further to regress the predicted technical efficiencies on several farm-level variables and farm specific characteristics. In most of the studies, it was found that the Cobb-Douglas Stochastic frontier does not provide an adequate representation for describing the data, given the specification of a translog model (see Bagi and Hunag, 1983; Bagi, 1982; Kalirajan and Flinn, 1983; Huang and Bagi, 1984 and Kalirajan and Shand, 1986).

Furthermore, Battese and Tessema (1993) estimated a stochastic frontier production function with time varying technical efficiencies using panel data. Given the specifications of a linearised version of Cobb-Douglas Stochastic frontier production function with coefficients which are a linear function of time, the hypothesis that the traditional response function is an adequate representation of the data is accepted for only one of the two villages considered. The technical efficiencies of individual farms exhibited considerable variation with either time-invariant or time-varying technical efficiencies. Hungson *et al* (1993) analysed the technical efficiency of natural rubber production farms using a time-varying stochastic frontier production function model for unbalanced data. Their results showed a bimodal distribution of technical efficiency indices with only few farms operating near the production frontier. Kumbhakar (1994) used a flexible (translog) production function to estimate allocative and technical efficiencies of cross-sectional farms. The maximum likelihood method of estimation was developed based on the production function and the first-order conditions of profit maximisation. The empirical results showed that the mean level of technical efficiency was 75.46 percent and as regards allocative efficiency, majority of the farms were found to be under-users of the endogenous inputs. Bravo-Ureta and Evenson (1994) used a stochastic efficiency decomposition methodology to derive technical, allocative and economic efficiency measures separately for cotton and cassava farms. An average economic efficiency of 40.1 percent for cotton and of 52.3 percent for cassava was found, which suggested considerable room for productivity gains for the farms through better use of available resources given the state of technology. Apezteguia and Garate (1997) estimated stochastic frontier production with cross-section data for Spanish agro-food industry. The result indicated that the Spanish agro food industry have a level of efficiency between 68 percent and 93 percent and the efficiency level was positively related to factor productivity and unitary labour costs.

Kalaitzandonakes *et al* (1992) studied the relationship between technical efficiency and farm size by measuring alternative frontier estimation. They found a positive relationship between farm size and efficiency. Coelli and Battese (1996) investigated agricultural production of Indian farmers using a stochastic frontier production function that incorporated a model for technical inefficiency effects. The parameters of the stochastic frontier production function where estimated simultaneously with those involved in the model for the inefficiency effects and the factors considered were found to have significant influence upon the inefficiency effects of the farmers. Tadesse and Krishnamoorthy (1997) examined the level of technical efficiency across ecological zones and farm size groups in paddy farms of the southern Indian State. The study showed that 90 percent of the variations in output among paddy farms, in the state is due to differences in technical efficiency. Based on the result of a two-way ANOVA, they rejected the null hypothesis that there is no difference in the average technical efficiency across small-, medium-, and large sized farms.

Yao and Liu (1998) utilised a stochastic frontier production function to investigate the determinants of grain production and technical efficiency in China. The results showed that the law of diminishing returns was in operation as more physical inputs were applied to shrinking land and that growth in grain output in the long term must rely on improvement in technical efficiency. Parikh *et al* (1995) measured economic efficiency in Pakistani agriculture by utilising behavioral and stochastic cost frontier function. The behavioral approach satisfied most of the assumptions of dual cost function and the likelihood ratio test rejects the market efficiency hypothesis implying less than optimum use of manure, labour, and fertilizer. A suboptimal use is explained by holding size, education, credit and subsistence needs. Their result further showed that small farms seen to be more efficient than large farms in the region; and a measure of inefficiency based on a stochastic cost frontier approach confirmed the results of the behavioral approach. Ali (1996) employed translog stochastic frontier production function to determine sustainable crop production by considering resource-use inefficiency and fertility of land. The results showed that it was possible to improve resource-use efficiency in wheat production to give 25 percent higher production at current levels, type, and quality of farm resources. Also, the fertility of the land was found to have deteriorated owing to long-term practices incompatible with soil and drainage conditions. Reinhard *et al* (1999) estimated the technical and environmental efficiencies of a panel of Dutch dairy farms. A stochastic translog production frontier was specified to estimate the output-oriented technical efficiency and input-oriented environmental efficiency of a single input-the nitrogen surplus of each farm. The result showed that the mean output oriented technical efficiency was rather high, 89 percent, but the mean input oriented environmental efficiency was only 44 percent. They concluded that intensive dairy farms were both technically and environmentally more efficient than extensive farms.

2.2.2 **SUSTAINABLE AGRICULTURAL PRODUCTION**

On a perspective term, previous studies on sustainable agricultural production are multidimensional. But specifically, these studies could be grouped into at least three dimensions: the biophysical, the social and economic. Therefore, any study that seeks to evaluate agricultural production on these three dimensions is actually a sustainability study. As a rule, Yunlong and Smit (1992) presented a framework within which the sustainability of agriculture can be assessed. Their model recognised biophysical, socio-political and techno-economic dimensions. The effect of modern agricultural practices on productive capacity of land resources is the basis of ecological (environmental) view of sustainability. It is however commonly held that contemporary agricultural practices characterised by intensive tillage and cropping exercise, and high rate of mechanisation and decimal input use have resulted in excessive amount of soil erosion and nutrient loss, improving the productive capacity of soil resources and placing greater emphasis on the use of purchased inputs (Dumanki *et al*, 1986 and Lal *et al* 1986). Scholes *et al* (1994) outlined the determinants of sustainable land use to include physical, biological and socio-economic factors. The socio-economic determinants include technical policies, population, infrastructure, inputs, institutions and cost-benefit relationships. Specifically, soil resources are logical indicators of economic limits because soil is widely viewed as the greatest limits to long-term productivity in low input agriculture such as slash-and-burn (FAO, 1984; Wolman, 1985; Kidd and Pimental, 1992). Correspondingly, crop yield represents an easily quantifiable measurement of agro-ecological productivity that is central to the need of subsistence farmers.

Analysing the concept of sustainable agriculture is better conducted using a farming system approach which corresponds best with measurement of social, economic and biophysical parameter (Manyong and Degand, 1995). Their study on sustainability of African small holder farming systems showed that the system as a whole is not sustainable and that improvements would be possible if the system were made more efficient, and that it is vital to introduce new technologies if complete sustainability is the ultimate aim. They concluded that multiple–objective mathematical (goal) programming models are appropriate techniques to address sustainability issues. Singh and Singh,(1995) studied land degradation and economic sustainability in attempts to measure the impact of soil salinity and water logging at farm level in terms of resource use, productivity and profitability of crop production and its consequent effect on employment of rural labours in the affected areas. They utilised Cobb-Douglas production function. The study observed a huge cut in non-land resource use on problem (Salt-affected) soils as compared to normal soils, which consequently resulted in low farm production and income and as a consequence, employment opportunities were also great on problem soils.

Lynam and Herdt (1989) suggested that total factor productivity (TFP) be estimated to measure sustainability of a production system. Their operational approach is based on trends in output as a single criterion of sustainability. They defined sustainability "as the capacity of a system to maintain output at a level approximately equal to or greater than its historical average, with the approximation determined by the historical level of variability". As such their relevant indicator to decide whether an agricultural system is sustainable or not is given by the ratio of value of output and value of input. Ehui and Spencer (1993) measured sustainability by estimating the interspatial and intertemporal total factor productivity of alternative farming systems, paying special attention to valuation of natural stock and flows. Harnington (1990) reviewed alternative approaches of measuring sustainability of an agricultural system to include yields trends, total factor productivity and the production function. Cassman and Pingali (1993) estimated total factor productivity for long term experimental and field monitoring data and concluded that resources under intensive rice production are deteriorating. Moreso, study by Ali and Velasco (1993) showed the deterioration in resources productivity under all intensive cropping system using yield trends, return per unit of input, total factor productivity, and the production function analysis.

Kangasniemi and Reardon (1997) studied the demographic pressure and the sustainability of land use in Rwanda by utilising regression analysis for crop cover index. Their interest was whether increasing land scarcity, reflected in miniaturization of farms, is associated with Rwanda farmers having unsustainable land uses. Their results showed that the estimated relationship between farm size and protective crop cover depends crucially on how the measure of vegetative cover is adjusted to account for high cropping densities. Without any adjustment, the association between land scarcity and erosive land use is strong; with the adjustment, it disappears, except for high altitude areas, where bananas, the only major - food crop that protects land well against erosion, do not grow well. Adger and Grohs (1997) attempted to reflect environmental indicators, such as soil erosion and deforestation as part of macroeconomic indicators in order to provide a sustainable national income measure. By employing a modified net product estimated for the agriculture and forestry sectors it was found out that the traditional measures overstate the value of agricultural sector's product by approximately 10 percent.

2.2.3 LAND USE, MANAGEMENT AND SOIL FERTILITY MAINTENANCE

Studies on agricultural land use and soil fertility management relevant to this study evaluate principle and practices of soil management that are essential for sustainable agricultural system. According to Greenland (1975) certain basic principles are quite imperative. These are the replenishment of chemical nutrients removed by crops; prevention of infestation of weeds, pests and diseases; maintenance of physical condition of the soil; reduction in the soil acidity or toxicity of elements; and reduction in the rate of soil erosion. Basically, Framework for the Evaluation of Sustainable Land Management (FESLM) has been evolved based on the above principles (IBSRAM, 1993). The framework is built on the levels that provide pathway which seek to connect the form of land use with the multitude of environmental, economic and social conditions which collectively determine whether a form of land management (or treatment) is sustainable or will lead to sustainability.

The properties and characteristics of land are the major determinants of choice for land use in a given location (Verheye, 1986). But this is seldom the case under small-scale peasant agriculture as land use and soil types are rarely closely associated (Ogunkunle and Eghaghara, 1992). Rai (1995) contended that low - external input farmers assess their land use options in terms of crop preferences, productivity, profitability, resource requirements (Land, labour and power), risk and soil quality. He went further to stress that choice and preference of optimal land-use options becomes quite difficult for marginal and smallholding farmers who are predominantly risk averse. Essentially, using land for agriculture results in the net removal of soil nutrients which must be replenished to provide a lasting cropping base since non-sustainable use of land has resulted into land degradation and soil infertility (Rai, 1995; Greenland, 1975).

Land use and management practices affect the fertility of soil to the extent that the clamour for conservation farming system and management has been a reawakening issue among researchers and policy makers. Kapinga *et al* (1995) carried out a land-use efficiency study to determine change in soil nutrients status and also to assess the competition, and mixture productivity of a cassava and sweet potato mix. They conclude that soil nutrients reduce more in intercropping pattern than in sole. Kleinman *et al* (1995) assessed the ecological sustainability of slash-and-burn agriculture and noted that the system is important to rural poor and given their resources endowments the peasant farmers can effectively use and manage their agricultural lands. Ekanade (1997) investigated the effect of continuous cultivation on hill-slopes for arable crops on the vegetation and soil components of the environment. The results of the study showed significant reduction in the structural and nutrient properties of the soils. The implication of the results showed effects of improper land use and management on the soil fertility. Furthermore, Prudencio (1993) investigated the ring management of soils and crops in the West African semi-arid tropics and concluded that: (1) the farming systems in the region inevitably mine the natural fertility base of the soil and become less productive when they evolve toward more permanent cultivation practices ; (2) only low management technologies are suitable for the farming systems in the region and do not have generality and can only apply to a portion of a typical farm land.

Sustainable land use requires planning for conservation, management and development of land. According to Mahalanobis and Adak (1994), land use planning should ensure that every piece of land is put under proper use to which it is best suited. That is, there should be continuous assessment of the status of land-use and its productivity vis-à-vis socio-economic condition of the people. Moreso, in a bit to evolve the most profitable crop combination and geometry that would be effective in checking soil erosion and loss of water via run-off, Mandal and Mitra (1989) confirmed intercropping as the best option. In the word of Lal (1990), effective land management systems and technologies are crucial to overcoming the misuse of soil that is at the least of many problems related to agricultural production. According to him, the solution lies in controlling land use and restoring its productivity, which can be achieved via innovative technology options. These could be in terms of land clearing and development, tillage methods and other agronomic practices. Research in tropical regions has indicated advantages of conventional (manual) over machine clearing (Lal *et al*, 1986). Maduakor *et al* (1984) noted that conservation tillage which involves seeding via a crop residue mulch or sod without flowing has definite advantages for soil and water conservation.

Eke *et al* (1990) undertook a research to evaluate the feasibility of utilising vegetable and small fruit crops as a means of controlling soil erosion on a limited resource farm and concluded that soil and organic matter losses were significantly affected by crop type, canopy cover, rainfall occurrence. Lal (1995) also examined the importance of crop residues management on soil productivity and quality via favourable effects on soil properties and life support processes.

Nitant and Tiwari (1990) noted that proper agro-techniques in land use are necessary in order to achieve higher yield and productivity in addition to sustainable soil and water conservation measures. Campbell *et al* (1998) examined soil fertility management in small-scale farming systems investigating, whether mixed farming systems are sustainable. It was discovered that farmers maintain crop production by using inorganic fertilizers and variety of locally-derived fertilizers ; manure, termitarium soils, crop residues, woodland litters, compost and house waste. Decisions concerning the land use, management and conservation are made by farmers in context of family concerns and priorities (Rai, 1995). Plucknett and Smith, (1986) noted that traditional agricultural production safeguards against outbreaks of pests and diseases and the vagaries of the weather by planting a variety of crops in the same field. In this manner, farmers could reduce the risk of total failure in the food supply. Kaoneka and Solberg (1994) ascribed major causes of land degradation to increased deforestation in the recent past coupled with inappropriate farming practices including overgrazing. Akintola (1975) revealed that land-use changes will apparently continue to follow the past trend of decreasing total farms and farmland, accompanished by increase in commercial land-use and as such rural land-use is progressive under temporal and spatial analysis.

2.2.4 ECONOMIC-ENVIRONMENTAL MODELLING

Basically, to operate on the continuum of environment and economic is the major concern of sustainable agriculture. A pure behavioural production function expresses output as a function of economically scarce inputs, assuming given technological and agroclimatic condition. However, a design of optimal management practices, government policy measures and commercial strategies for agriculture based on the traditional abstraction is hampered by difficulty of inaccurate measurement (Burrell,1991). Model simulation scenario which requires information about production responses to economic decision variables and state (environmental) variables, and the identification of simple indices and thresholds, are issues of necessity.

In an attempt to measure sustainability, interdisciplinary modelling have been developed and literature contains some useful attempts to grapple with the interaction between environmental functions and economic actions. At conceptual level Tschirhart and Crocker (1987); Costanza *et al* (1993) and Russell (1993) have much to explain. To draw extensively from the vernacular of Barbier (1990), the key question raised in environmental economic modelling is what useful economic functions does the environment provide and how are these functions affected by the process of economic – environmental interaction? He used two different formal approaches to answer these questions: the more conventional approach which is concerned with the optimal allocation of economically valuable exhaustible resources and an alternative analysis that considers the trade off between environmental quality and economic optimality.

Griffith and Zepeda (1994) constructed six linear programming models to examine trade-off between costs and production practices of intensification of milk production. The result of their study showed that significant economic and environmental trade off are found in response to low labour productivity or availability and low protein content of forages. Moreso, costs were identified as the focus on the economic side while on the environment side, intensification incentive to deforest, use of cut feed verus, more erosive pasture, and manure verus chemical fertilization were identified. Lutz and Munasinghe (1994) tried to integrate environmental concerns into economic analyses of projects. They concluded that efficient use of natural resources is a vital prerequisite for economic and social development. Therefore, one key role of ecological economics is to help value environmental and natural resources more precisely and internalise the cost and benefits of using such resources into the decision making process. In a way to analyse deforestation and economically sustainable farming system, Kaoneka and Solberg (1997), working on stated hypothesis: given present population growth trends, present farming systems are not economically sustainable, noted that for existing farming systems to become economically sustained, it is important to improve farming technology which could increase crop production via improvement of land productivity and to increase income from other sources. Such strategy will meet the increased food demand as a result of population growth as well as limiting the expansion of farmland via forest clearing.

Modelling cropping systems after the BARC sustainable agriculture demonstration farm, Kelly *et al* (1996) utilised EPIC (Erosion Productivity Impact Calculator) to simulate long-term impacts of different cropping system in terms of the trade off among net returns and different components of environmental quality. By a way of simulation via EPIC it was quite computationally convenient to obtain crop yield, soil erosion, and the environmental impact of Nitrogen, phosphorus and herbicides in response to weather and management practice over a simulated 30 years period. Further, Midmore *et al* (1996) executed an economic-environmental impact study to evaluate current production pattern and profitability of vegetable production, their result showed environmental impacts and externality cost of soil erosion and management practices to have adverse effect on vegetable production. Furthermore, Jones *et al* (1991) explained the versatile nature of EPIC in environmental-economic modeling. They noted that EPIC was designed to help decision-makers analyse alternative cropping systems and predict their socio-economic and environmental sustainability.

Putman and Dyke (1987) employed a large LP model by way of simulation to assess the impact of soil conservation practices and erosion on agriculture in U.S.A. Deybe and Flichman (1991) developed a regional agricultural model using EPIC to determine the possible effects of economic changes on regional supply and revenue as well as the level of farm structure and farm relationship. They concluded that the use of agronomic plant growth models and mathematical programming models is a possible methodology for obtaining results that combine political and economic effects with environmental aspect at a regional level. Schans (1991) employed an interactive multiple goal linear programming technique (IMGLP) for the optimization of arable farming systems that integrate economic and ecological goals. Production systems ranging from low-input to high-input are generated with a computer by a systematic variation of major crop management components. The farming systems selected with the models serve as a guideline for the introduction of sustainable arable farming systems. Manyong and Degand (1995) utilised multiple-objective mathematical (goal) programming in socio-economic and environmental modeling of small holder farming system. The result of their study showed that the system could be made to be more efficient if new technologies are introduced. Bockstael *et al* (1995) attempted an ecological and economic modeling in order to improve basic understanding of regional systems, assess potential future impacts of various land-use, development, and agricultural policy options, and to better assess the value of ecological systems. Starting with the existing spatially articulated ecosystem model of an area, they added modules to endogenise the agricultural components of the systems (especially the impact of agricultural practises and crop choice) and the process of land use decision making. According to Hewitt and Lohr (1995), researchers may ignore economic feasibility as a criterion for selecting among technologically feasible alternative when designing and implementing alternatives cropping sequences for on-farm testing. They developed a consistent approach for simulating economic returns and environmental characteristics of field level production system using ex-ante evaluation. Samarakoon and Abeygunawardena (1995) employed universal soil loss equation (USLE) to assess the rate of soil loss and the replacement cost approach was also used to assess on-site cost due to soil erosion. Their approach was based on the costs of repairing damage to productive assets caused by improper on-site land/soil management practices.

Ali (1996) utilised a production function in quantifying the socio-economic and environmental determinant of sustainable crop production. The results showed that soil fertility have deteriorated owing to long-term practices that are incompatible with soil and drainage conditions; the farmers are inefficient in resource use and that increasing population pressure on land, decreasing livestock number per cropped area, and diminishing fuel wood sources, have significantly reduced farm-based nutrient cycling, because farm yard manure had to be used for fuel. Byiringiro and Reardon (1996) also employed a production function in assessing the effect of farm size, soil erosion and soil conservation investments on land and labour productivity and allocative efficiency in Rwanda. The results showed that farms with greater investment in soil conservation have much better land productivity than average and that smaller farms are not more eroded than larger farms, but have twice the soil conservation investments. Also, land productivity benefits substantially from perennial cash crops and the gains to shifting to cash crops are highest for those with low erosion and high use of fertilizer and organic matter. Furthermore, Reinhard *et al* (1999) utilised econometric modelling to study both technical and environmental efficiency among Dutch dairy farms. Within their analytical framework they calculated environmental efficiency as a single-factor measure of input-oriented technical efficiency. The measure of environmental efficiency can identify farms with the smallest and the largest environmentally detrimental emissions to the environment; given their output and their use of conventional inputs.

Apparently, attempts at environmental-economic modelling are extremely complex and cumbersome, as only a few functional relationships have been quantified. Therefore, an interdisciplinary approach as this one requires system approach. This study takes a parallel modeling approach utilised by Ali (1996), Byiringiro and Reardon, (1996) and Reinhard *et al*, (1999). It shows how index of short run sustainability at farm level can be estimated within a stochastic transcendental logarithmic (translog) production frontier context.

CHAPTER THREE

3.0 METHODOLOGY

3.1 THE STUDY AREA

The study was conducted in Odukpani local government area and Itu Local government area of Cross River State and Akwa Ibom State respectively. The area situates along the "Calabar-Itu" Highway, a major road linking the two states with other states in the eastern part of the country. The area became accessible due to the major highway which was constructed in the early 1970s and since then there has been high land-use intensity for agricultural production by predominantly migrant farmers who moved from overpopulated hinterland and neighbouring states to settle for crop production.

The area falls within the rainforest ecological zone with pockets of mangrove swamps. The soils are rainforest soils and wetland soil that are predominantly deep to moderately deep and poorly drained. The texture of the soil is generally sandy loam, loamy sand or sandy clay loam to clay surfaces over sandy loam (FDALR, 1996). The terrain is nearly level to gently undulating plains with minor hills.

The climate is humid tropical with two distinct seasons-dry and wet season. Mean annual rainfall is at least 3200mm with maximum in July and September. Mean daily temperature ranges from 25 to 370C. The terrain of the area combine with a relatively heavy rainfall have made the land vulnerable to accelerating soil erosion and plant nutrient depletion.

The area is basically a farm settlement with little government presence. It has an evolving village structure with line settlement along the major highway. Farming activities continue through out a year in the area. Major crops produce are cassava, plantain, yam, melon, rice, cocoyam, maize, cucumber, fluted pumpkins, okra, etc. Progressively, the population of the area has been increasing as more farmers are migrating from their marginal hinterland to the area and land use intensity has being increasing.

3.2 DATA SOURCE AND COLLECTION PROCEDURE

Both primary and secondary data were used in the study. Farm level intensive cost itinerary surveys provided the basic primary quantitative and qualitative data. A cross-sectional data from 300 sample farmers were collected with the aid of pre-tested, structured questionnaires administered by six trained enumerators. The secondary data were obtained from the records of Cross River State and Akwa Ibom State Ministries of Agriculture and Agricultural Development Projects (ADPs). Data collected include socio-economic, agronomic and environmental data. The baseline survey covers information on family characteristics, land holding, land-use and crop production factors, input and output data as well as their prices, crop combination and diversification, land management systems etc. The survey lasted between June 1998 and February 1999.

3.3 SAMPLING PROCEDURE

Two-stage sampling technique was employed in selecting the sample needed for this study. First, six locations which are located along the major highway were selected across the two states based on the high intensity of farming operations. These comprise four villages from Odukpani local government areas of Cross River State and two villages from Itu local Government area of Akwa Ibom State. The second stage of sampling was selection of the farm households. This was done through a modified form of simple random sampling called the random walk method. This was because both Cross River State Agricultural Development Project (CRADP) and Akwa Ibom State Agricultural Development Project (AKADEP) lacked recent and comprehensive list of all the farm households in the area. This is so as the number of migrant farmers to the area increases over each year and to have a comprehensive list of all practising farmers in the area involves conducting yearly farm census. But both the two ADPs have not embarked on farm census in that area for some years now. Therefore, trained and resident enumerators, who are familiar with the area, were instructed to walk into a particular area and start sampling farms at a certain fixed interval and at every stage of data collection. Specifically, fifty farm households were sampled from each village. Field observations and complementary key informant interviews (KIIS) were held with some established farmers to validate information. Assistance of trained soil scientists was sought in the identification of certain land degradation parameters. Table 3.1 presents the sampling size .

Table 3.1 Distribution of Sampling Size Among the Sampled Villages

Villages	Sample Size
(A) Odukpani L.G.A.	
1. New Netim	50
2. Okoyong Usang Abasi	50
3. Okurikang	50
4. Usung Odot	50
(B) Itu L.G.A.	
1. Oku Iboku	50
2. Ayadehe	50
Total	300

Source: Field Survey 1998/99

3.4 ANALYTICAL FRAMEWORK AND TECHNIQUES

The analytical tools employed in this study are developed to analyse the data in order to fulfil the stated objectives of the study. Therefore, a combination of analytical tools including descriptive, budgeting, statistical and econometric procedures was utilised.

MODELS OF ANALYSIS

3.4.1 BUDGETARY ANALYSIS

This was used to assess the profitability of the various land use or crop combination by farmers. The net revenue derived from production is explicitly stated as:

$$NR = \sum_{i=1}^{n} P_i Y_i - C_i \quad (i = 1, 2, \ldots, n) \qquad \ldots\ldots\ldots\ldots (3.1)$$

Where

NR	=	Net revenue from farm farming activities
P_i	=	the market price of the ith crop (N/unit) in the enterprise (crop mix)
Y_i	=	the annual yield of the ith crop (unit/ha)
C_i	=	The imputed cost in producing the ith crop (N/ha)

3.4.2 PRODUCTION FUNCTION ANALYSIS

Multiple regression model based on stochastic parametric form was used to measure resource use efficiency, productivity of resource and the indices of sustainable land use and management of the farmers in the area.

Consider a Stochastic production frontier as:

$$Q = g\,(X, R, L, C; \beta)\ \exp\,(V_i\text{-}U_i)^1 \quad i = (1,2, \ldots,N) \qquad \ldots\ldots\ldots \ (3.2)$$

Where

Q = Output of crops measured in (ton/farm);

X= Vector of physical inputs and migrant status measured in (unit/farm) and as dummy respectively;

R = Land quality variable, measured as dummy variable;

[1] Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977) independently proposed the estimation of a Stochastic frontier production function, where white noise is accounted for by adding a symmetric error time (Vi) to the non-negative error in Eq. (3.2)

L = Vector of land use variables measured as indices;

C = Vector of land management practices assumed to have carry over impact on land quality measured by ranking, numbers and dummy.

β = Vector of parameters to be estimated;

V_i = random error due to mis-specification of the model

$-U_i$ = ratio of actual yield to maximum possible output (MPO), i.e inefficiency component of error terms.

g(.) = the suitable function (in this study, a translog function)[2]

The parameters (β_i) of Eq. (3.2) and the density functions of V_i and U_i are estimated by maximising the log-likelihood function given as:

$$\text{Ln}\ \phi = {}^{N}/_{2}\ \text{Ln}\ ({}^{2}/\pi) - N \ln \sigma + \sum_{i=1}^{N} \ln\ 1\text{-}F \left(\left(\frac{-\varepsilon i \lambda}{\sigma} \right) \right) - {}^{1}/_{2}\ \sigma^{2} \sum_{i=1}^{N} \varepsilon_i^{2} \quad \ldots\ldots \quad (3.3)$$

Where

N = the number of observations (300 farms)

σ = the standard deviation of the total error term

$\lambda = \sigma_u/\sigma_v$

F(.) = the standard distribution function

ε_i = component error term

π = 3.1415

---

2 Normal Cobb-Douglas Function is not ideal function for this study because it imposes unwarranted assumptions on technology, as it assumes that all inputs are substitutable, which is clearly not the case, especially in a study of this nature where different sets of inputs are considered.

Implicitly, an unrestricted translog production function which is general, flexible and allows analysis of interactions among variables was estimated. This was in line with works of Christensen *et al*, 1973; Antle and Capalbo, 1988; Driscoll *et al*, 1992 and Ali, 1996. However, it should be noted that the estimates of the translog may be invalid because of the violation of regularity conditions at extreme sample values to the inclusion of the second-order, terms, especially in small sample. But in this case, the problem is partially solved with the large sample size (N = 300) with better degree of freedom. The general form is:

$$LnQ_j = a_o + \sum_{i=1}^{n} a_i lnX_{ij} + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{g=1}^{n} b_{ig}(ln\,X_{ij}\,ln\,X_{ij}) + \sum_{k=1}^{o} c_K R_{kj} + \sum_{t=1}^{m} d_t lnC_{tj}$$
$$+ \sum_{i=1}^{n} b_{ii}(lnX_{ii})^2 + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{r=1}^{p} f_{ir}(ln\,X_{ij}\,ln\,l_{rj}) + \sum_{r=1}^{p} e_r\,ln\,l_{rj} + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{t=1}^{m} h_{it}(lnX_{ij}\,ln\,C_{tj}) +$$
$$\tfrac{1}{2}\sum_{r=1}^{p}\sum_{r=1}^{p} j_{rr}(ln\,l_{rj} \times ln\,l_{rj}) + \tfrac{1}{2}\sum_{k=1}^{q}\sum_{0\neq k}^{q} r_{ko}(R_{kj}\,R_{oj}) + \tfrac{1}{2}\sum_{t=1}^{m}\sum_{k=1}^{q} w_{tk}(lnC_{ij}\,R_{kj}) + \tfrac{1}{2}\sum_{t=1}^{m}\sum_{r=1}^{o} S_{tr}(lnC_{tj}ln\,l_{rj})$$
$$+U_j + V_i \qquad \text{............} \; (3.4)$$

Where j = 1, 2, ...,300 farms; i, g = 1, 2, ..., n are physical inputs; Q, X, R, L, C, V_j and U_j are as previously defined in Eq (3.2) and Eq. (3.3).

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.[3]

[3] The list of factors responsible for production may not be exhaustible and categorization of the factors may also not be generalisable. However, to quantify how sustainable land use and management practices are, this study therefore is built upon these four sets of variables.

3.4.2.1 MEASUREMENT OF EFFICIENCY INDEX

Measurement of farm level efficiency, e^{-u}, requires first the estimation of the non-negative error U, i.e., decomposition of E into its two individual components, U and V. The technique of decomposition as suggested by Jondrow *et al* (1982) involves the conditional distribution of U given ε expressed as:

$$E(U_i/\varepsilon_i) = \sigma^* \left(\left(\frac{f(\varepsilon_i\lambda/\sigma}{-F(\varepsilon_i\lambda/\sigma} \right) - \left(\frac{\varepsilon_i\lambda}{\sigma} \right) \right) \qquad \text{...........} \qquad (3.5)$$

Where

σ^* = $\sigma_u.\ \sigma_v/\sigma$ or g (.) – U ≡ Q – u

ε_i = U + V

σ = standard deviation of the total error term

λ = σ_u/σ_v

f(.) = the standard normal density function (PDF)

F(.) = the standard distribution function (CDF)

The population average technical efficiency is given as:

$$E(e^{-u}) = 2e^{\sigma 2u/2}\,[1\text{-}F(\sigma^u)] \qquad \text{...........} \ (3.6)$$

Where F is the standard normal distribution function. It should be noted that by taking the natural logarithm of –u, the farm specific resource use efficiency index is measured and $1\text{-}e^{-u}$ will give resource-use inefficiency.

3.4.2.2 PROJECTION OF EFFICIENCY INDEX DISTRIBUTION

In order to investigate and understand the structure and size distribution of estimated efficiency index, there is need for a projection to be made. This is to show future distribution of farms on the basis of the efficiency estimates. The assumption underlying this projection is that sometime in the near future, efficiency index would have changed to such a level that a certain average efficiency level will be attained.

The technique employed as suggested by Boxley (1971) involves a negative exponential functions expressed as:

$$Y = Ae^{-BX}E \qquad \text{............ (3.7)}$$

Where

Y = percentage of farms remaining above certain efficiency size limits

X = relative efficiency size (lower limit of efficiency class divided by average inefficiency index).

e = irrational number equal to 2.71828, and

E = the disturbance term.

The parameter A and B are derived by minimising the (E2 subject to the condition that

$A = 100/e^{BX}$

3.4.2.3 MEASUREMENT OF PRODUCTIVITY

The first-order partial derivative of Eq. (3.4) with respect to each physical inputs gives the production elasticities of the variables. Farm specific marginal productivities are then estimated as farm specific elasticities multiplied by farm specific average output, approximated as (Q_j/X_j).[4] Generally, for finite level of X_i input, MP_i can be positive for a range of values of X_j, but can be negative if $b_{ij} > 0$.

3.4.2.4 MEASUREMENT OF SHORT-RUN SUSTAINABILITY INDEX (SRSI)

This involves 2-step approach measurement. First, estimation of farm specific index of sustainable land use and management (ISM). Secondly, summing the index with farm specific inefficiency index (RUI).

Farm specific index of sustainable land use and management (ISM) is estimated at Eq. 3.4 with respect to all the agronomic practices (i.e. land use and management practices), evaluated at different level of input use and resource quality. This is given as:

$$ISM = \sum_{t=1} d_t + \sum_{r=1} e_r + \tfrac{1}{2} \sum_{t=1} \sum_{r=1} s_{tr} + \tfrac{1}{2} \sum_{i=1} \sum_{r=1} f_{ir} (\ln X_{ij}) + \tfrac{1}{2} \sum_{i=1} \sum_{t=1} h_{it} (\ln X_{ij}) + \tfrac{1}{2} \sum_{t=1} \sum_{k=1} W_{tk} (R_{kj}) \quad \ldots\ldots\ldots\ldots\ (3.8)$$

4. Translog function does not always generate elasticities or substitution of one, and the isoquants and marginal products derived from the translog depend on the coefficients on the interaction terms. Therefore, the marginal product of X_i in a two-input translog model at output 1, is, $MPP_{xi} = q[\beta_i/X_i + \gamma/2 \ln X_{ij} (X_i^{-1})]$, Debertin (1986), P. 209.

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:

$$SRSI = 1 - [(X_i \cdot p)(X_a \cdot p)^{-1}] + \sum_{t=1} d_t + \sum_{r=1} er + \tfrac{1}{2} \sum_{t=1} \sum_{r=1} S_{tr} + \tfrac{1}{2} \sum_{i=1} \sum_{r=1} f_{ir} (\ln X_{ij})$$

$$+ \tfrac{1}{2} \sum_{i=1} \sum_{t=1} h_{it} (\ln X_{ij}) + \tfrac{1}{2} \sum_{t=1} \sum_{k=1} W_{tk} (R_{kj})^5 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (3.9)$$

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.

3.4.2.5 BASIC ASSUMPTIONS OF THE ESTIMATION

Basically, the analysis does not extend to investigating how the agronomic practices adopted by farmers for crop production affect soil

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[5] $1-[(X_i \cdot p)(X_a.p)]$ is estimated after controlling for the sustainability effect of land use and management practices.

nutrient, organic matter, etc status of the state variable. But its validity is build on the following empirical assumptions:

1. a farmer basically practises the same type of land use and management practices each cropping season;
2. the farmers are faced with the same climatic factors and same soil type;
3. the farmers' practices can either improve the productivity of the soil as well as internal nutrient cycling or deteriorate nutrient status of the soil;
4. the environmental analysis of using and managing the agricultural land in the area is capture by farm specific land use and management index;
5. the agronomic practices have net carry-over effect on the soil and in retrospect, their effects are capture by the estimated frontier; and
6. the farm specific output level is jointly determined by input use and agronomic practices undertaken at farm level.

3.4.2.6 REGRESSION MODEL SPECIFICATION

The specification retained is as follows

$$\begin{aligned}\ln q = {} & \ln\beta_0 + \beta_1\ln X_1 + \beta_2\ln X_2 + \beta_3\ln X_3 + \beta_4\ln X_4 + \beta_5 D_1 \\ & + \beta_6\ln X_5 + \beta_7\ln X_6 + \beta_8 D_2 + \beta_9\ln X_7 + \beta_{10}D_3 + \beta_{11}D_4 \\ & + \beta_{12}D_5 + \beta_{13}\ln(X_1)^2 + \beta_{14}\ln(X_2)^2 + \beta_{15}\ln(X_3)^2 + \beta_{16}\ln(X_1 * X_2) \\ & + \beta_{17}\ln(X_1 * X_4) + \beta_{18}\ln(X_1 * D_1) + \beta_{19}\ln(X_1 * X_6) + \beta_{20}\ln(X_1 * X_5) \\ & + \beta_{21}\ln(X_2 * X_6) + \beta_{22}\ln(X_2 * X_5) + \beta_{23}\ln(X_6 * D_1) + \beta_{24}\ln(X_4 * X_5) \\ & + \beta_{25}\ln(X_1 * X_7) + \beta_{26}\ln(X_1 * D_3) + \beta_{27}\ln(X_1 * D_2) + \beta_{28}\ln(X_5 * D_3) \\ & + \beta_{29}\ln(X_6 * D_3) + \beta_{30}\ln(X_5 * X_7) + \beta_{31}D_4 * D_5 + \beta_{32}D_2 * D_5 \\ & + \beta_{33}\ln(X_7 * D_4) + \beta_{34}D_2 * D_4 + \beta_{35}\ln(X_7 * D_5) + \beta_{36}\ln(X_5 * X_6) \\ & + U + V \quad \ldots\ldots\ldots (3.10)\end{aligned}$$

The total number of possible interaction is $66(^{12}C_2)$, but this has been reduced to twenty-four in addition to twelve set of variables. This is necessary to ease computation burden and reduce the risk of multicollinearity and also to ensure that only economically meaningful and theoretically plausible interactions are retained.

To determine the presence of multicollinearity in the above equation, the Farrar - Glauber test that utilises Chi - square test was carried out. The test statistic is

$$x^2 = -[n - 1 - {}^1\!/_6(2k + 5)]\ln D \quad \ldots\ldots\ldots (3.11)$$

Where,

x^2 = Computed Chi - square statistic.

n = Sample Size.

k = number of explanatory variables.

InD= natural logarithm of the determinant of the matrix of pairwise correlation coefficients (r_{ij})

According to Olayemi, 1998, the chi-square distribution has $^1/_2k(k-1)$ degree of freedom and the null hypothesis to be tested is that r_{ij} = 0(for $I \neq j$) against the alternative hypothesis that $r_{ij} \neq 0$.

DESCRIPTION OF THE VARIABLES

Q = OUTPUT is the total quantity of crop mix in each farm standardised as grain equivalent (ton), weighted to control the variability inherent in yield. It is measured in either basin, bag or bundles which was converted to their equivalents in kilograms. (See appendix for grain equivalent conversion table).

EXOGENOUS VARIABLES

A. PHYSICAL INPUTS

X_1 = LAND is hectare of cultivated land. It is treated as exogenous input so as to determine the effect of different management practices on land. By conversion, between 6000-6500 heaps make an hectare in the area. By a priori expectation, $\beta_1 > 0$

X_2 =LABOUR is expressed as adult male-equivalent mandays, and is the summation of family labour and hired labour. It is treated as exogenous input because it is mainly family labour from family size and composition data.[6] The a priori expectation is $\beta_2 > 0$

X_3 = CAPITAL is expressed as the depreciation value of all the crude tools used in the season. Since the tools are assumed to have zero salvage values and their usage by farmers is unrestricted, a declining balance method of depreciation was used. It is treated as exogenous since different markets for their purchase are open to the farmers and the farmers have different composition of the farm tools. The priori expectation is $\beta_3 > 0$

X_4 =COST OF PLANTING is the value of variables items used per farm. It consists of planting materials (cuttings, seed/seedlings and tubers), rental value and agrochemicals (if any). It is treated as exogenous because about 90 percent of planting materials are owned not purchased. The a priori expectation is $\beta_4 > 0$

D_1 =MIGRANT STATUS is expressed as a slope dummy: D = 1 for migrant and D = 0 for non migrant. It is treated as exogenous since the area is evolving farm settlement where people migrant to settle for farming purposes.

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[6] Available labour is standardized into adult-equivalent mandays, which is about eight hours of work per day (Norman, 1972): 1 for adult male, $^2/_3$ for female and $^1/_3$ for children.

B LAND USE VARIABLE

X_5 = CROP DIVERSIFICATION INDEX is treated as exogenous to capture cropping pattern adopted by the farmers and calculated using Herfindel index as where Pi = proportion of the net farm income from ith crop in the combination. Spio (1996) revealed that mixed cropping has a higher total productivity per unit of land area and greater stability of yield and revenue than mono cropping, thus, the *a priori* expectation is $\beta_6 > 0$ under normal condition. CDI is given as:

$$CropDI = \sum_{i=1}^{n} Pi^2 \qquad \text{.......................} (3.11)$$

X_6 = NUTRIENT INTAKE INDEX 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 is based on nutrient depletion ability of crops in an environment where nutrient augmenting input like fertilizer 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 and Mitra, 1990) However, the nutrient intake index is given as

$$NII = \frac{1}{n} \sum_{i-1}^{n} WiTi \quad I = \ (1, 2,\ldots,n) \ \ldots\ldots\ldots\ldots\ldots\ldots \ (3.12)$$

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 intex 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, i.e. (7 < 0

C. **LAND MANAGEMENT VARIABLES.**

D_2 = Level of Tillage is measured as a slope dummy. D = 1 for tillage land and D = 0 for zero tillage. It is treated as exogenous variable because soil property is disturbed by level of tillage which can affect the level of crop productivity (Maduakor *et al*, 1984). Specifically, soil that have been tilled is likely to be degrades faster and loses nutrient easily (Spencer, 1989).

X7 = LENGTH OF FALLOW is expressed as the number of years a piece of land is allowed to stay fallow before cultivation is carried on it. It is treated as exogenous because in a low-external-input farming as the one practiced in the area, maintenance of soil fertility status depends on the restorative ability of the soil via vegetative regrowth (Spencer, 1990 and Lal, 1990) By apriori expectation, $\beta_9 > 0$

D_3 = FERTILIZATION is expressed as dummy: D = 1 for user of fertilizer and D = 0 for non-users. In the area, very little use of chemical fertilizer and manure is observed and soil fertility is maintained mainly by fallow. Therefore, for simplicity, it is assumed that farms are equally fertilized and the use of dummy to capture effect of fertilization of farm. By apriori expectation, $\beta_{10} > 0$ for users of fertilizers.

D. LAND RESOURCE QUALITY VARIABLES

D_4 = DRAINAGE is expressed as dummy: D = 1 for poor drainage and D = 0 for good drainage. It is treated as exogenous and use as a proxy variable to capture the condition of the farm as one expects a poor drained soil to be poor in nutrient status which requires more land augmenting practices for crop to be sustained. Bhalla and Roy (1988) incorporated farm land quality (Proxied by soil type, colour and depth) in their analysis of the relationship between farm size and productivity. $\beta_{11} > 0$ for well drained soil.

D_5 = TERRACES is expressed as dummy: D = 1 for flat topography and D = 0 for undulating and slope topography. It is treated as exogenous because farms with undulating terrace are marginal farmlands and farming on such lands requires special management practices to maintain or improve the soil fertility. By apriori expectation, $\beta_{12} > 0$ for better terrace.

3.4.3 LAND USE PATTERN ANALYSIS

This is investigated by measuring the index of crop diversification.

3.4.3.1 CROP DIVERSIFICATION INDEX

Entropy index formulated by Hackbart and Anderson (1975) and Herfindal index were used in this study.

Entropy index is given as:

$$CDI_e = \sum_{i=1}^{n} P_l \log P_i^{-1} \qquad \text{.................................} (3.13)$$

Where CDI_e is the crop diversification index;

P_i = Proportion of net income from ith crop.

The Diversification index is optimal when

$0 < 1/N.CDI_e \leq 1$

The Herfindal index is given as

$$CDI_h = \sum_{i=1}^{n} P_i^2 \qquad \text{...............................} (3.13)$$

Where CDI_h is the crop diversification index and

P_i = Proportion of net income from ith crop

CHAPTER FOUR

4.0 SOCIO-ECONOMIC CHARACTERISTICS OF THE FARMERS AND PATTERN OF LAND-USE AND MANAGEMENT

4.1 ANALYSIS OF THE SOCIO-DEMOGRAPHIC VARIABLE

4.1.1 GENDER OF THE FARMERS

Table 4.1: Gender Distribution of the Farmers.

Gender	Frequency	Percentage
Male	214	71.33
Female	86	28.67
Total	300	100

Source: Field Survey, 1998/99

The table 4.1 shows the gender distribution of the farmers which depicts more male than female owing farms. This result conforms with the cultural setting in the study area where male have more access to land than female.

4.1.2: AGE OF THE FARMERS

Table 4.2: Age Distribution of the Farmers.

Age Group (Years)	Frequency	Percentage
20-25	8	2.67
26-30	47	15.67
31-35	59	19.67
36-40	52	17.33
41-45	43	14.33
46-50	42	14.00
51-55	30	10.00
56-60	10	3.33
≥61	9	3.00
Total	300	100

Sources: Field Survey, 1998/1999

The table 4.2 shows the age structure of the farmers in the study area. The table shows that about 70 percent of the farmers are between 20 - 45 years of age, showing that they are in active age brackets. The mean age is 41.35 and this has implication on the available family labour and productivity of the labour. Kireta-Katewa (1985) noted that age has a direct bearing on the availability of farm labour and the ease with which improved agricultural practices are adopted.

4.1.3 EDUCATIONAL LEVELS OF THE FARMERS

Table 4.3: Distribution of the Educational Attainment of The farmers.

Educational level	Frequency	Percentage
No Schooling	99	33.00
Primary School	112	37.33
Secondary Level	71	23.67
Tertiary Level	18	6.00
Total	300	100

Source: Field Survey, 1998/1999

Basically, the levels of education of farmers have significant impact on productivities, income earning opportunities and ability of farmers to effectively adopt better management practices. From table 4.3 most of the farmers are literate (about 67 percent) with majority of them having primary education. Those who had tertiary education probably constitute the civil servant who engaged in part-time farming in the area.

4.1.4 OCCUPATION OF THE FARMERS

Table 4.4: Distribution of The Farmers to Their Main occupations

Occupation	Frequency	Percentage
Farming	196	65.33
Trading	37	12.33
Artisans/Crafts	27	9.00
Business	30	10.00
Civil Service	10	3.33
Total	300	100

Sources: Field Survey, 1998/1999

The table shows that most of the sampled farmers (65.33 percent) main occupation is farming and this implies that farming is undertaking in the area on a large scale and higher proportion of people depend on farming for daily existence. This result have effect on the level of cropping pattern and intensity in which the agricultural land is used.

4.1.5 MIGRANT STATUS OF THE FARMERS.

Table 4.5: Distribution of The Farmers on Migrant Status

Migrant Status	Frequency	Percentage
Migrants	136	45.33
Non-migrants	164	54.67
Total	300	100

Sources: Field Survey, 1998/1999.

The table reveals that approximately 2/5th of the farmers are migrants whose major occupation in the area is farming. Their primary goal may be profit maximisation with little or no interest in conservatory land management since they may not have property right on the land.

4.2 ANALYSIS OF PATTERN OF AGRICULTURAL PRODUCTION

This section deals with the description of pattern of ownership and utilisation of factors of production by the farmers in the study area.

4.2.1 LAND OWNERSHIP PATTERN

In a peasant agricultural setting, land availability is vital and depending on its ownership structure, the extent to which land is actually used can be explained. In the study area, different ownership pattern characterised the land as shown in the table below:

Table 4.6: Land Ownership Pattern in The Study Area

Mode of Ownership	Frequency	Percentage	Av. Land Size (ha)
Pledging/Mortgage	35	11.67	1.4
Rented/Leased Land	73	24.33	1.09
Family Land	101	33.67	4.04
Permanent Inheritance	41	13.67	3.75
Gift	8	2.67	0.78
Purchased	31	10.33	2.1
Group Land	11	3.67	9.15
Total	300	100	

Source: Field Survey, 1998/1999

Table 4.6 reveals that about 36 percent of the farmers do not actually own the land and the average land size available to them is about 1.245 hectares. Majority of the cultivated farmland (about 47.34 percent) are acquired via modes of ownership that provide property right to the farmers, that are family land and permanent inheritance. The table also reveals that about 3.67 percents of the respondents consolidate their fragmented farmlands and cultivate so as to take advantage of economies of size. Basically, the group lands belong to farmers of the same social club whose interests are to assist their members and to take advantage of extension services. From the table, it can be said that the distribution of land ownership pattern permit the agricultural lands to be used for both perennial and annual crop cultivation and smaller parcels are available to farmers whose tenancy on the land is temporal.

4.2.2 FARM PLOTS OF THE FARMERS

Table 4.7: Distribution of Number of Farm Plots Per Farmer in The Area

Number of Plots	Frequency	Percentage
1-2	156	52
3-4	81	27
5-6	56	18.67
>6	7	2.33
Total	300	100

Sources: Field survey, 1998/1999

Table 4.7 reveals that about 52 percent of the farmers cultivated between 1 - 2 plots and only 2.33 percent cultivated more than 6 plots. The result however may not be unconnected to the availability of farm labour, accessibility of farmland and other factors of production that the farmers can have access. It should be noted that the farmers depend solely on human effort and crude tools for their production and this can as well limit the number of plots the farmers can cultivate in a cropping season.

4.2.3 FARM INPUT CHARACTERISTICS

Table 4.8: Description of farm input characteristics

Descriptions	Sample Mean	Standard deviation	Minimum value	Maximum value	C.V (%)
Farm size (ha)	2.874	1.872	0.3	20	65.14
Family labour (Man days)	151.809	0.533	8	153.33	52.70
Hired labour (Man days)	33:803	0.533	4	153.33	1.56
Hired labour (₦.K)*	5070.48	3445.49	473.18	23,000	67.9
Total labour (₦.K)	27,841.83	15,445.94	1,200	89,300	55.5
Capital (₦.K)	917.44	724.99	128.7	25,000	79.0
Cost of planting (₦.K)	8247.36	7252.87	100	71500	87.9
Total cost (₦.K)	37,006.63	24423.79	5163.65	85125.85	66.00

* In the area of study one manday is equivalent to N150.00.

Source: Field survey, 1998 / 1999.

Table 4.8 revealed the farm characteristics in term of physical inputs used during the cropping season. On the average, farm size cultivated by each farmer is 2.874 hectares and much more family labour was used than hired labour. One of the probably reason for hiring little labour could be the fact that majority of the farmers are within the active age bracket as shown in table 4.2 and in addition to large family size could provide the needed assistance for farm operations. On the average, cost of labour constitutes about 75.23 percent of the total cost with capital cost and cost of planting having 2.479 percent and 22.86 percent respectively. It then follows that labour is the most important factor of production and that the farming activities in the area are mostly labour intensive.

4.2.4 MAJOR CROPS GROWN IN THE AREA AND THEIR YIELDS

Table 4.9: Distribution of crops grown and their yields per farm

Crops	Code	Number of Plot cultivated	Average Output	S.D.	Minimum Value	Maximum Value	C.V.(%)	Ranking
Maize (trons)	MEZ	173	5.51	3.12	0.4	50	56.62	2nd
Melon (Kg)	MEL	73	319.89	210.41	96	1230	66	4th
Cassava (ton)	CAS	271	45.48	44.96	4.5	276	99.0	1st
Okra (kg)	OKA	80	486.49	220.48	70	1000	45	3rd
Yam (ton)	YAM	56	28.38	22.72	7.3	124	80	6th
Cocyam (ton)	CYM	62	13.97	9.42	3	50	67	5th
Rice (ton)	RIC	10	13	9.03	1	20	69	9th
Pumpkin (kg)	PUM	16	124.44	79.83	10	357	64	7th
Pepper (ton	PER	12	4.5	2.3	0.5	10.07	51	8th
Total (ton)	TOT		53.785	48.01	0.16	276	89	-
Grain equivalent	GE	-	18.071	16.15	0.45	110	89	-

Source: Field survey, 1998 / 1999.

From table 4.9, it is apparent that cassava with average yield of 45.48 ton per farm (16.33 ton / ha) was the most preferred crop in the study area during the survey period and was cultivated by 271 farmers (90.33 percent). This was followed by maize with average yield of 5.51 ton per farm (1.92 ton/ha) and okra with average yield of 486.49 kg per farm (169.27 kg/ha) which were cultivated by 173 and 87 farmers respectively. The least cultivated crops were rice and pepper. The pattern of the distribution may not be unconnected to the perceive benefits of each of the crops to the food security, income earnings and risk aversion of the farmers as well as the ability of the crops to survive in the low external-input agriculture.

The coefficient of variation (c.v) on the yield of the crops grown reveals rather wide variability, This however may be explained by the variability observed in the farm size distribution(see table 4.6). The average output of all the crops grown per farm is 53.785 tons(18.71 tons/ha) with a coefficient of variation of 0.89.

4.2.5 REASONS OF CROP PREFERENCE

The choice of the crops grown by the farmers can be further explained by the farmers interest in the respective crops. The table 4.10 gives distribution of reasons of crop preference among the farmers.

Table 4.10: Distribution of Reasons of Crop Preference by The Farmers

Crops	Reasons for Cultivation					No. of plot cultivated
-	Income Generation	Food Security	Risk Mgt.	Land Mgt.	Ease of Cultivation/mgt	
Maize	81(46.82%)	40(23.12%)	30(17.34%)	10(5.78%)	12(6.94%)	173
Melon	37(51%)	10(13.69%)	15(20.55%)	5(6.85%)	6(7.91%)	73
Cassava	144(53.09%)	55(20.43%)	51(18.97%)	8(2.73%)	13(4.79%)	271
Okra	52(65%)	16(20.00%)	6(7.5%)	1(1.25%)	5(6.25)	80
Yam	18(32.14%)	23(41.07%)	8(14.3%)	5(8.93%)	2(3.57%)	56
Cocoyam	39(62.9%)	19(30.65%)	3(4.84%)	0(0%)	1(1.61%)	62
Rice	8(80%)	2(20%)	0	0(0%)	0(0%)	10
Pumpkin	4(25%)	12(75%)	0	0	0	16
Pepper	2(16.67%)	10(83.33%)	0	0	0	12
Average percentage	48.07%	36.36%	13.91%	5.11%	5.18%	
Preference weight*	385	137	113	29	39	703
Relative weight**	0.54	0.19	0.16	0.04	0.06	= 1

* Preference weight = $\sum_{i=1}^{n} Rij$, where Rij = Reason ith for cultivation jth crop

* Relative weight = $\sum_{i=1}^{n} Rij$/GT, where GT = grand total of preference weight.

Source: Field Survey,1998/1999.

Table 4.10 shows that income generation goal predominates the farmers choice of crops which is followed by food security goal with land management goal being the least reason. The results of preference weights and relative weights attached to each reason confirm the importance placed on income generation and food security by the sampled farmers. Specifically, relative to other conceivable reasons, about 54 percents of the farmers who grew the crops consistently ranked income generation as the major reason for growing the crops. But only about 4 percent of them primarily ranked land management the highest reason for choice of crops grown. It then follows that about 162 sampled farmers cultivated the crops primary for income generation, 57 of them considered food security of their households while only 12 sampled farmers were mindful of the type of crops cultivated and their relation with the soil properties and management. This result however confirmed the finding of Ogunkunle and Eghaghara,(1992) that, under small-scale peasant agriculture, land use, and crop choice are rarely closely associated with soil type.

4.3 ANALYSIS OF THE STATUS AND MANAGEMENT OF FARMLAND IN THE AREA

On-going land use and management practices can go along way to explain how susceptible farmland is to menace of degradation and subsequent nutrient depletion. This is possible through the assessment of certain indicators.

4.3.1 STATUS OF FARMLANDS BEFORE CULTIVATION

Basically, soil nutrient status of farms have much bearings on the status of farmland before it is put into use. In this study, the status of farmland is expressed in term of nature of vegetation as shown in table 4.11:

Table 4.11: Distribution of the Status of Farmland Before cultivation.

Description	Frequency	Percentage
Virgin Forest	32	10.67
Restorative growth	268	89.33
Total	300	100

Source : Field Survey, 1998/1999

The table shows that 89.33 percent of the cultivated farms have been previously cultivated and only 10.67 percent of the farms have been newly opened. In essence, more lands are converted into agricultural purposes. If the lands are not properly managed problems of land degradation may result especially in a situation where the length of time a piece of land is allowed to lie fallow is short. This is essentially so under restorative growth situation.

4.3.2 LENGTH OF FALLOW PERIOD FOR THE CULTIVATED LAND

Table 4.12: Distribution of Farms According to Length of Fallow Period

Length of fallow (Years)	Frequency	Percentage
1-3	62	23.13
4-6	142	53.00
7-9	45	16.67
≥ 10	19	7.00
Total	268*	100.00

* Total of these farms from restorative growth

Source : Field Survey, 1998/1999.

The table reveals that about 53 percent of the farms that were previously fallowed before planting had between 4-6 years of fallow period with only 7 percent of the farms having more than 10 years period of fallow. On the average, the length of fallow observed in the area of study amongst the sample farmers is about 5.15 years (c.v = 0.56), with minimum being one year (12.3 percent) and twenty years (1.12 percent) as maximum years. The most plausible reason for the wide gap in fallow period among the farmers is access to farmland in terms of tenurial arrangement. On the whole, the farming system in the area is evolving through shifting cultivation which can be considered to be a low-external input system with high efficiency from a peasant economic perspective.

Considering the fact that the average number of years a piece of farmland is cultivated per cropping season is 2.48 years (cv = 0.27) in the area, the Ruthenberg value is 0.325.[7] This shows the land use intensity in the area. The R value of 0.325 implies that the farming system practised by the sampled farmers is moving toward permanent cultivation. In essence, the length of fallow may not be enough for the soils to adequately restore its natural fertility. Depending on the agronomic practices adopted by the farmers, the land use may not be sustainable.

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[7] Ruthenberg value is
R-value = c/c+f, where c = number of cropping years (2.48) and f = number of fallow years (5.515)

4.3.3 DESCRIPTION OF LAND DEGRADATION PARAMETERS.

Factors like management, level of land utilisation and quality of land can actually cause signs of land degradation to be noticed. In this study, degrees of soil erosion and flooding were used to measure extent of land degradation and thus the level of soil nutrient depletion through soil lost.

4.3.3.1 LEVEL OF SOIL EROSION AMONG SAMPLED FARMS.

Table 4.13: Distribution Of Sampled Farms On The Bases of Erosion Indicators

Level of Severity	Frequency	Percentage
No sign	15	5.00
Slight	236	79.33
Moderate	41	13.67
Severe	6	2.00
Total	300	100

Source : Field Survey, 1998/1999

Table 4.13 shows that about 95 percent of the farms sampled had different levels of soil erosion symptoms indicating incidence of soil degradation and subsequent nutrient loss.

It should be noted that the measurement of level of severity of soil erosion was purely and the categorisation based on the type of soil erosion known. Slight erosion was noted by detachment of soil particles as well as deposition of soil at the base of plants in the farms. Therefore early stage of sheet erosion without any noticeable change in soil colour signified slight level of soil erosion. Moderate level of soil erosion have signs like early stage of rills and minor gullies in addition to large deposition of soil at the base of crops on the field. The severe sign of soil erosion had large and noticeable gullies with appreciable change in soil colour in relation to surrounding farms and bushes. With the level of soil erosion observed, it then follows that the lands were not adequately covered with crop canopies together with other necessary covering materials. The situation is further explained in the table below which shows the severity of flood on the sampled farms.

4.3.3.2 INTENSITY OF FLOODING ON THE SAMPLED FARMS

Table 4.14: Distribution of Sampled Farms on the Bases of Flood Indicator

Level of Severity	Frequency	Percentage
No sign	29	9.67
Slight	213	71
Moderate	50	16.67
Severe	8	2.67
Total	300	100

Source : Field Survey, 1998/1999

Table 4.14 shows that about 10 percent of the farms were not flooded. This may not be unconnected to the terrace and the drainage of the land and the rate at which the land are used and managed.

Both tables 4.13 and 4.14 point to the fact that insidiously, the lands in the area are degrading. On the long run, without adequate remedial and preventive measures, soil fertility may be affected which would jeopardise the food security of the area and the neighboring towns and villages.

4.4 ANALYSIS OF CROPPING PATTERN AND INDEX OF DIVERSITY

Decisions concerning the choice of cropping pattern and diversity are made by farmers based on their priorities and primary thrust of cultivation.
As shown in table 4.10 (Distribution of Reasons for crop preference), income generation and food security form the major thrusts of selecting crops in the area. As such, crops in the area are combined at different degrees per farm so as to meet the basic needs (reason) of farming. Table 4.15 however shows the distribution of sampled farmers on the bases of cropping patterns.

Table 4.15: Description of cropping pattern in the Area

Cropping Pattern	Frequency	Percentage
Sole Cropping	54	18
Inter Cropping	50	16.67
Mixed Cropping	196	65.33
Total	300	100

Source: Field survey, 1998 / 1999

The table reveals that majority of the farms have crops mixed together (82 percent). The random intermixed of crops in the area however ensured that the cultivated farmlands were adequately used. In essence, the combination of crops on this rather small parcel of farm (2.874 ha) in time and space maintains a high level of farm biodiversity, profitability and higher leverage for risk. But in situation of improper combination, the productivity of the crops would be adversely affected and land use would be unsustainable.

On the issue of crop diversity, about third-two (32) different types and levels of crop combination (geometry) were observed among the sample farms. However, on the criteria of level of occurrence, only cropping patterns with f $\geq$ 5% are presented in the table 4.16.

Table 4.16: Description of Major Crop Combination In The Area.

Combination	Frequency	%age of selected Farms	%age of Total Farm
MZE-CAS-CYM	25	8.77	8.33
CAS	41	14.39	13.67
CAS-CYM	25	8.77	8.33
MZE-CAS	48	16.84	16.00
MZE-CAS-YAM	21	7.37	7.00
MEL-MZE-CAS-OKA	38	13.33	12.67
CAS-OKA-YAM	24	8.42	8.00
MZE-MEL-LAS	20	7.02	6.67
MZE-CAS-OKA	23	8.07	7.67
MEL-CAS	20	7.02	6.67
Total	285*	100	95.01

* Less the other forms of crop combinations.

Source: Field survey, 1998/1999.

Basically, only ten crop combinations were popular among the sampled farmers. The table however shows that cassava-maize mix was the widely adopted by the farmers. Sole cassava and Melon-Maize-Cassava-Okra mix were the second and third widely adopted crop mixture. Descriptively, cassava and maize had the largest number of occurrence. This mode of mixture may not be unconnected to the easy adaptation of cassava and maize to the environment and the farmers interest on the crops for income generation and food security of their households. The table also reveals that the maximum number of crop in a combination is four. But from the list of those combinations not presented in the table 4.16, there are cases of five crop combinations, but in most cases, the fifth crop is mainly vegetables that are cultivated for domestic use.

4.4.1 INDEX OF CROP DIVERSIFICATION

The pattern of land use as regards planting of crops is measured with the indices of crop diversification. The indices used in this study are the Herfindal index and entropy index modelled in term of proportion of net income from the various crops in each combination. Table 4.17 and 4.18 show the indices of crop diversification based on Herfindel and entropy index.

Table 4.17: Herfindel Index Of Crop Diversification.

Description	Freqeuncy	Combination	S.D.	Min. Value	Max. Value	C.V.(%)
Sole	57	1	1	1	1	100
Two-crop combination	102	0.572	0.121	0.218	0.963	21.00
Three-crop combination	89	0.451	0.070	0.347	0.779	15.00
Four-crop combination	43	0.404	0.096	0.22	0.709	24.00
≥ Five-crop combination	9	0.348	0.131	0.179	0.602	37.00
Sample Mean	300	0.587	0.230	0.307	1	39.00

Source: Field survey, 1998/1999

Table 4.17 shows that about 34 percent of the farmers had two crop mixture on their field with combination mean of diversification index being 0.572. For the three crop combination and four crop combination, the average H-index is 0.451 (c.v = 0.15) and 0.404 (c.v=0.24) respectively. The result however, shows that as the number of crops in a combination decreases, the H-index increases and would become one for sole cropping implying specialization. But on the average, the H-index for all the sample farms is 0.589 (cv=0.39). The H-indices show that the sampled farmers undertook one form of cropping diversity or the other, but the majority of them practised two to three crop combinations.

To further explain the level of cropping pattern and diversity, entropy index is estimated and shown in table 4.18;

Table 4.18: Entropy Index of Crop Diversification

Description	Frequency	Combination	S.D.	Min. Value	Max. Value	C.V.(%)
Sole	57	0	0	0	0	0
Two-crop combination	102	0.267	0.078	0.04	0.584	29.00
Three-crop combination	89	0.339	0.057	0.159	0.504	17.00
Four-crop combination	43	0.467	0.072	0.265	0.560	15.00
≥ Five-crop combination	9	0.499	0.0714	0.324	0.563	14.00
Sample Mean	300	0.104	0.05	0	0.292	55.10

Source: Field survey, 1998/1999.

Table 4.18 reveals a 0.2679 (c.v. = 0.29) index for two-crop mixture and 0.499 (c.v=0.14) index for the Five or more crop mixture. The sample mean of the E-index is 0.288(c.v=0.58) showing that on the average, majority of the farmers are cultivating two to three crop combination. For the optimal level, the E-index of 0.104(c.v=0.55) shows that the cropping pattern of the sampled farmers fell within optimal levels.

Both tables 4.17 and 4.18 clearly show that the level of crop diversification among the sampled farmers is low. A high crop diversification pattern is normally reflected on a lower Herfindel index, and a higher entropy index. The mean results of both tables show that, on the average, majority of farmers favour two to three crop mixtures which could be regarded as environmentally and economically sound practices. This is true under low external input agriculture where the use of land augmenting materials like fertilizer is minimal and the cultivated crops have to depend solely on the available soil nutrient for their growth and development.

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 and 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 (Wen *et al*, 1992). However, the benefits depend on proper management of the land and the type of crops mixture. Where the rooting system of the combined crops are concentrated on a particular horizon, the combination might be bad for the combined crops.

Basically, from the analysis, farmers who practised four or more crop mixture are mostly migrant farmers. This is probably because, their accessibility to farmland may be restricted and they would want to combine as many crops as possible per plot just to maximise their set objectives. In this case, the farmer are more risk averse than those who cultivated between one to two crops.

4.4.2 INDEX OF SOIL NUTRIENTS 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 mostly of the same class of crops. 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 4.19 shows distribution of the sampled farmers on the based of how their crop diversity pattern can affect the rate of nutrient depletion.

Table 4.19: Distribution of Nutrient intake Index Among the Sampled Farmers.

Nutrient intake index	Frequency	Percentage
1-2	10	3.33
2.1-2.5	40	13.33
2.6-3.0	15	5.00
3.1-3.5	61	20.33
3.6-4.0	123	41.00
≥4.1	51	17.00
Total	300	100

Source: Field survey, 1998/1999.

Table 4.19 reveals that about 58 percent of the sampled farmers combined crops that have nutrient intake index of 3.6 and above and only negligible number of the farmers (3.33 percent) have nutrient intake index within the 1-2 class interval. Since the index measures the intensity of likely nutrient depletion by the combined crops, then it can be seen from the table that majority of the farmers combined crop that have greater tendency to deplete soil nutrient. This is not unconnected to the fact that all the ten major crop combinations observed in the area have or two root tuber crops (see table 4.16). 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 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.

4.5 FARM LEVEL INCOME ANALYSIS

Farm income is define as the monetary returns to the farm family's owned resources encompassing family and hired labour, owned and rental land, capital and other production inputs. Analysis of farm income involves budgetary technique which is considered as the sum of the gross values of crops produced during the cropping year less all the total costs on the same crops during the same year. This analysis is done by considering the major enterprises (combination).

4.5.1 FARM PRODUCTION COST

This comprises of depreciation values on the durable items, rental charges and all the variable cost items. Table 4.20 shows the distribution of total cost incurred by the farmers in production express on enterprises bases.

Table 4.20: Distribution of Farm Cost by Enterprise In The Study Area.

Enterprises	Av. Farm (ha)	Mean Cost	S.D.	Min. Value	Max. Value	Mean cost/ha	Ranking	C.V. (%)
MZE-CAS-CYM	3.066	36521.74	5657.23	30435.17	53340.47	11911.85	6th	15.0
CAS	2.457	33878.16	15385.16	5319.5	73915.5	13788.42	1st	45
CAS-CYM	2.736	27040.83	6934.88	12718.98	39603.84	9883.34	10th	25
MZE-CAS	3.419	42389.41	21642.23	12628.17	115800.5	12398.19	4th	51
MZE-CAS-YAM	2.476	327282.43	7876.42	17897.83	4456.17	13240.08	2nd	24
MZE-MEL-CAS-OKA	3.799	49862.61	19183.32	11154.67	85125.85	13125.19	3rd	38
CAS-OKA-YAM	3.738	35627.71	5921.11	24243.67	44897.50	9531.23	11th	16
MZE-MEL-CAS	2.915	33380.26	7707.41	15851.17	46829.47	11451.20	8th	23
MZE-CAS-OKA	2.195	25639.26	8765.72	16399.2	44621.1	11680.076	7th	34
MEL-CAS	1.766	21351.51	6137.76	11910.88	35327.000	12090.32	5th	28
Others	3.197	33261.71	12374.59	5163.65	55771.2	10404.04	9th	37
Whole Farm	2.874	37006.63	24423.79	5163.65	85125.85	12876.35	-	66

Source: Field Survey, 1998/1999.

Based on the average farm size cultivated for each of the enterprise, sole cassava have the highest cost per hectare (N13,788.42) followed by maize-cassava-yam mixture with average cost of N13,240.08 per hectare. But the average cost for the sampled farm is N12876.35/ha. The variability in cost across the enterprises does not follow a given sequence. This result may not be unconnected to the fact that what constitutes cost of production varies across the farmers and the cost not necessarily depend on the type of enterprise, labour cost constitutes over 75 percent of the total cost of production showing that low-external-input agriculture which is labour intensive is predominately practised in the area of study.

4.5.2 FARM REVENUE

This is the total farm gate value of the entire farm output of a farm during a given year. That is, it is obtained by multiplying the output of various crops by their farm gate prices. The farm revenue is shown in the table 4.21:

Table 4.21: Distribution of farm revenue by enterprises the Area.

Enterprises	Mean Value	S.D.	Minimum value	Maximum Value	A.V. Farm size (ha)	Mean Revenue/ha	Ranking	C.V. (%)
MZE-CAS-CYM	79420	28193.30	41920	140,000	3.066	25903.45	4th	35
CAS	63576.06	49098.04	7120	220800	2.457	25875.48	5th	77
CAS-CYM	55154.20	47653.58	18200	126000	2.736	20158.69	10th	86
MZE-CAS	141030.04	99183.19	26000	660000	3.419	41249.50	1st	70
MZE-CAS-YAM	74622.31	26262	20380	112850	2.476	30138.25	2nd	35
MZE-MEL-CAS-OKA	108282.04	70113.08	20845	259695	3.799	2850.77	3rd	65
CAS-OKA-YAM	62062.01	19326.76	30802.5	101800	3.738	16602.99	11th	31
MZE-MEL-CAS	74170.21	29088.81	35410	142000	2.915	25444.33	6th	39
MZE-CAS-OKA	51936.48	21679.46	35727.5	111395	2.195	23661.27	8th	42
MEL-CAS	44222.5	23521.84	28000	105900	1.766	25041.05	7th	53
OTHER	70258	28665.84	19500	114930	3.197	21976.33	9th	41
Total (AV)	81408.49	75496.44	7120	660000	2.874	28325.85	-	92

Source: Field survey, 1998 / 1999.

The table above reveals the distribution of farm revenue of the enterprises showing that maize - cassava mixture gave the highest return while the least came from cassava - okra - yam mixture. On the average, the gross revenue of the farm is N28325.85 / ha (C.V = 0.92) . As in the case of cost of production, the variability in gross revenue across the enterprises does not follow a definite sequence. However, the gross revenue estimated is largely influenced by such factors as crop output, type of crop grown, prices of the crops, cropping pattern, farm size, level of technology and general socio - economic environment of each farmer.

4.5.3 NET FARM INCOME

The net farm income is calculated each enterprise and is presented in table 4.22.

Table 4.2.2: Distribution of Net farm income by Enterprises and whole farm

Enterprises	Av. Revenue	Av. Cost	Net Income	Av. Farm Size (ha)	Net Income per ha	Output/Input	Ranking on Net income/ha	P * value
MZE-CAS-CYM	79420.00	36521.74	42,898.26	3.066	13991.60	2.17	5th	1.17
CAS	63576.06	33878.16	29,697.9	2.457	12087.05	1.88	7th	0.88
CAS-CYM	551854.20	27040.83	28,113.37	2.736	10275.35	2.04	10th	1.041
MZE-CAS	141032.04	42389.41	98,642.63	3.419	28551.31	3.33	1st	2.33
MZE-CAS-YAM	74622.31	32782.43	41,839.88	2.476	16898.17	2.28	2nd	1.28
MZE-MEL-CAS-OKA	109393 04	49862.61	58,419.43	3.799	15377.58	2.17	3rd	1.171
CAS-OKA-YAM	62062.81	35627.71	26,435.10	3.738	7071.99	1.741	11th	0.741
MZE-MEL-CAS	74170.21	33380.26	40,789.95	2.915	13993.12	2.22	4th	1.22
MZE-CAS-OKA	51936.48	25639.67	26,297.17	2.195	11980.49	2.03	8th	1.03
MEL-CAS	44222.50	213.51	22,870.99	1.766	12950.73	2.07	6th	1.07
Other	70258	33261.71	36,996029	3.197	11572.19	2.11	9th	1.11
All farm	81408.49	37006.63	44,401.36	2.874	15449.50	2.19	-	-

*P. Value = $\frac{\text{Net Income}}{\text{Value of Input.}}$

Source: Field Survey, 1998/1999.

Table 4.22 reveals that maize-cassava enterprise has the highest net farm income per hectare (N28851.31) and also the largest output-input ratio of 3.327 is observed for the enterprise. The least ranked enterprise in terms of net farm income per hectare and output-input ratio is the cassava-okra-yam enterprise with net farm income of N7071.99/ha and output-input ratio of 1.742.

However, on a more closer look at the table, it is seen that any enterprise where maize is planted in addition with cassava, such enterprise gives higher return to farmers factors of production and in those enterprises maize is conspicuously absent, the returns to factor of production are quite low. This is the case of the enterprises that are ranked 7th, 10th and 11th.

On the average, all the enterprises have impressive return to capital and are profitable. For the whole farms, a net farm income of N15,449.50/ha was obtained. Moreso, for every one naira spend in cultivating the crops, about N2.19 was derived as financial benefit. Also judging from P. value, which indicates profitability over one cycle, all the enterprises are financially sustainable. This is because the values are non-decreasing and satisfy the constraint or side condition of being greater than zero. This impressive result however confirmed the rationale behind the farmers' choice and preference of crops cultivated on the income generation criterion. Therefore, for the sampled farmers, the financial benefits are fulfilled.

It should be noted that the estimated net farm incomes are potential (not actual) income that are supposed to accrue to the farmers if all the outputs of each crop harvested are sold for cash. But this is rarely the case especially in a peasant setting where some farm outputs are kept as food reserves (meant to sustain the farm families during lean season), as stock of planting materials for next season and as gifts to friends, relatives and neighbours.

CHAPTER FIVE

5.1 ANALYSIS OF STOCHASTIC FRONTIER ESTIMATION

The frontier function was estimated using maximum likelihood estimation approach (MLE) through the FRONTIER 4.1 program developed and licensed by Coelli (1994). The results of MLE are given in the table 5.1:

Table 5.1: Maximum Likelihood Estimation Result

VARIABLES	PARAMETER	Es. Value	S.E.
Physical Inputs (a_i)			
Land (ha)	β_1	0.0382*	0.0211
Labour (Mandays)	β_2	0.6021***	0.2494
Capital (N.K)	β_3	0.00314	0.517
Material (N.K)	β_4	0.107***	0.0271
Migrant (Dummy)	β_5	-0.2951***	0.1030
Land Use Variables(e_r)			
Crop Diversification Index	β_6	-0.8176***	0.0958
Nutrient intake index	β_7	-0.7012***	0.0984
Land Management Variables (d_t)			
Level of Tillage (Dummy)	β_8	-0.2042	0.2548
Length of Fallow	β_9	0.7458**	0.3845
Fertilization	β_{10}	0.9184*	0.5728
Land Resource Quality Variable (C_k)			
Drainage (Dummy)	β_{11}	-0.059**	0.031
Terrace (Dummy)	β_{12}	0.1658	0.2474
Squared Terms (bii)			
Land x land	β_{13}	0.1094***	0.0435
Labour x labour	β_{14}	0.1028*	0.0622
Materials x material	β_{15}	0.0219***	0.0032
Interaction among Inputs (big)			
Land x labour	β_{16}	0.5060***	0.1259
Labour x material	β_{17}	0.3347***	0.0867
Land x migrant	β_{18}	0.0359	0.0710
Interaction of Physical Inputs and Land use variables (fir)			
Land x Geometry Index	β_{19}	-0.2146*	0.1162
Land x Crop DI	β_{20}	-0.0877	0.0690
Labour x Geometry Index	β_{21}	-0.386***	0.1144
Labour x Crop DI	β_{22}	0.1949	0.1545

Migrant x Geometry Index	β_{23}	0.5148**	0.2296
Material x Crop DI	β_{24}	0.2499***	0.0891
Interaction of Physical Inputs and Land Management variables (hit)			
Labour x level of Tillage	β_{25}	0.04117	0.2111
Land x Fertilization	β_{26}	-0.0554	0.0939
Land x level of Tillage	β_{27}	-0.024***	0.0891
Interaction of Land Use Variable and Land Management variables (str)			
Crop DI x Fertilization	β_{28}	-00581	0.1556
Geometry Index x Fertilization	β_{29}	0.3502**	0.1915
Crop DI x length of fallow	β_{30}	0.2139**	0.1188
Interaction among Land resource Quality variable (Vko)			
Drainage x Terrace	β_{31}	-0.3930	0.0412
Interaction of Land Management and Land Quality Variable (wtk)			
Level of Tillage x Terrace	β_{32}	0.1888*	0.1081
Length of Fallow x Drainage	β_{33}	0.3409	0.3478
Level of Tillage x Drainage	β_{34}	-0.1220***	0.026
Length of Fallow x Terrace	β_{35}	-0.1825	0.2982
Interaction among Land Use Variable (Jrr)			
Crop DI x Geometry Index	β_{36}	-1.453***	0.4632
Intercept	β_0	1.367*	0.7572

DIAGNOSIS STATISTICS

Quasi-function coefficient	0.8566
Ln(likelihood)	105.776
LR test	97.00
Sigma-square(δ^2)	0.8725*** (0.1757)
Gamma (γ)	0.9506***(0.3579)
Mu (μ)	-1.8214***(0.3275)

Asterisks indicate significance: *** 1%, **5%, *10%.

Source : Computer printout of Frontier 4.1.

Table 5.1 shows the likelihood parameter estimates of the Stochastic production Frontier (3.10) for all farms in the study area. It is evident from the table that the estimate of δs^2 (0.8725) is large and statistically significant and different from zero at (= 0.01. This indicates a good fit and the correctness of the specified distributional assumption of the composite error term. Moreso, the variance ratio, defined as $\gamma = \delta u^2 / (\delta u^2 + \delta v^2)$ is estimated to be as high as 95.06 percent, suggesting that systematic influences that are unexplained by the production function are the dominant sources of random errors. In other word, the presence of technical inefficiency among the sample farm explains about 95 percent variation in the output level of the crops grown. This confirms that in the specified model, there is present of one-sided error component. This actually implies that the effect of technical inefficiency, $E(e^{-u}) = 2e^{\sigma 2u/2} [1-F(\sigma_u)]$ is significant and that a classical regression model of production function based on ordinary least square estimation would be inadequate representation of the data. Therefore, the results of the diagnosis statistics confirms the relevance of stochastic parametric production frontier and maximum likelihood estimation.

The maximum likelihood estimates indicate the relative importance of the conventional and conditioning variables includes in the equation (3.10). Predominantly, the coefficients of the variables are of the right signs and magnitudes. Over 69 percent of the estimates are statistically significant at different critical values. These coefficients can be interpreted as the elasticities of output with respect to the inputs at the data point.[8] Based on this, production elasticities are shown in the table 5.2 :

[8] This is because the elasticity of output with respect to $\ln X_i$, E_i (the farm subscript is dropped) is $E_i = \alpha_I + \Sigma\beta_{ij} \ln X_j$. See Kumbhakar, 1994. pp. 148.

Table 5.2: Distribution of Production Elasticities Among The Variables

Set of variables	Estimated Value	Remark
Physical input and migrant	0.4553	SR-Decreasing Return to Scale
Land use and management	0.048	SR-Decreasing Return to Scale
Interaction terms	0.1192	SR-Decreasing Return to Scale
Overall	0.8566	SR-Decreasing Return to scale

Source: computed from ML estimates of table 5.1.

From the table, the sum of elasticities of output with respect to the conventional inputs together with the migrant status generates an estimated scale elasticity which indicates the presence of short run decreasing return to scale. This is the same for all the variables included in the model and therefore the totality of the parameter estimates gives a quasi function coefficient of 0.8566. This case of decreasing or diminishing returns portray a case in which each additional unit of input results in a smaller increase in product than the preceding unit. This is the case common in the production of farm crops. It is characteristic of the stages when optimum efficiency of production or resource use is being approached, as well as the situation where there exists a misallocation or over utilisation of input beyond the points of technical efficiency.

Specifically, the estimated elasticities of output with respect to the conditioning variables are of particular interest. They have a mean value of 6.86E-03 suggesting that, if other variables are held constant, a 10% change in the variable results in a little more than 0.0686 percent change in output level. Moreso, the value of elasticities of production for the interaction terms is of significant importance in explaining the variability in yield since they do not equal zero. Basically, in the translog function specified, there is absent of homotheticity and linear homogeneity and, the hypothesis of separability is rejected even at a high F - critical value. This is because the estimated generalised ratio test is statistically significant [$\chi_{.05}^2$ (36)=97 with a critical value of 12.59]. The positive production elasticities verified the assumption of monotonicity and concavity on all the data points, thus the production function is said to be well behaved.[9] Moreso, the problem of multicollinearity is not serious in the estimated model. This is because the computed chi-square statistic (36.237) is less than the theoretical critical value (82.40) at $\alpha = 0.10$

The estimate values of the conventional and conditioning variables are all statistically significant except capital, level of tillage and terrace. However, the nature of the variables and their interaction terms that are statistically significant would be discussed in the next section.

5.2 PRODUCTION ELASTICITY

5.2.1 PHYSICAL INPUTS AND MIGRANT STATUS

FARMLAND: The coefficient (0.0382) is statistically significant at $\alpha = 0.10$

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[9] See Carbo and Meller, 1979 and Kumbhakar, 1994 for further detail on a well behaved production function.

showing that land is an important factor explaining changes in output. But the magnitude of the coefficient shows high inelastic nature of output with respect to land. Increasing land size by 10 percent, output level would improve less than proportionate by a margin of 0.382 percent in a ceteris paribus case. This shows that there is still some scope for increasing output per plot by expanding farmland.

LABOUR: Labour appears to be the most important input in the area with an elasticity of 0.6021 being consistent with the general observation that peasant farming is labour intensive. Given the level of farmers' technology and tight cash situation the use of human effort which is readily available from the central nerve of farming activities. This is reflected on table 4.8 which shows that labour cost constitutes over 75 percent of the total cost of production. Accordingly, the result shows that if 10 mandays is provided for farming activity, output level would be increased by 6.021 unit. This is necessarily so since more man hours would be available at different stages of production starting from land clearing, planting to even harvesting.

MATERIAL: the production elasticity of output with respect to cost of planting is 0.107 showing an inelastic situation. By increasing the material cost by 10 percent, output level would improve by a margin of 1.07 percent in a ceteris paribus case. The estimated coefficient is highly significant even at a statistical level of $\alpha = 0.01$. This shows that there exist some scope for increasing output per plot by increasing material cost especially when land-augmenting materials like fertilizers, manure, etc are adequately applied.

MIGRANT STATUS: The migrant status coefficient is estimated to be negatively related to output level and is statistically significant at $\alpha = 0.01$. It therefore follows that for the migrant farmers, the autonomous output would decrease by 0.2951 unit relative to the non-migrant farmers. That is for migrant farmers the floating constant term would be 1.0719 while for the non-migrant farmers the autonomous output would be 1.367 unit. In other word, relative to non-migrants, the output levels of migrant farmers are smaller showing that land use and management practices adopted by the migrant farmers may not be as good as the practices of non-migrant.

Given the fact that the migrant farmers do not have long affinity to the cultivated lands, their management practices may be inimical to land productivity which would translate into poor output levels. Moreso, the objective functions of migrant farmers may be such that they combine crops indiscriminately without taking into consideration the level of competition among the crops for the available nutrient especially when land augmenting resource like fertilizer is not available. This is practically so as the migrant farmers whose accessibility to more farmland is constraint would cultivate more crops on a plot of farmland than non-migrant. This result is further confirmed by the fact that, on the average, majority of non-migrants combined between two to 3 crops per plot while migrant farmers combined between 4 to 5 crops in a mixture.

5.2.2 LAND USE VARIABLES (er)

CROP DIVERSIFICATION INDEX: Crop D.I is shown to have a significant relationship to the output level. The value of the estimated coefficient is -0.8176, indicating that higher level of crop diversification is associated with decreasing output. This result is so given the fact that the diversification practices may not be optimal in term of different classes of crops in a mixture and that the nutrient status of the land may not be adequate enough to support more crops per plot. This is especially true if only a small proportion of the farmers applied land augmenting resources. The exploratory result showed that only about 23.6 percent of the sampled farmers applied either chemical fertilizer or organic manure which may not have been enough for plant nutrition.

When more crops are grown on a piece of land without adequate management practices, the benefits associated with diversification would not be available to the farmers, especially when the nutrient status of the soil is poor and the land is not properly utilised. However, it is possible that the decline in output of crops grown as diversification increases may be transitory as farmers improve their ability to grow new and more crops (Llewelyn and Williams, 1996).

NUTRIENT INTAKE INDEX: The value of the estimated coefficient is negative (i.e. -0.7012) and is statistically significant at $\alpha = 0.01$ to the output level of crops grown. The result is consistent to the apriori expectation that crops which have heavy soil nutrient depleting abilities would have lower aggregate yield where soil is poor in nutrient status and land augmenting resources sparely added (if any) to the soil. The estimated value further shows that majority of the sampled farmers cultivated more root-tuber crops than other crops. This is shown in table 4.16 where root tuber crops appear in all the major combinations and over 110 farmers (36.67 percent) have up to two root-tuber crops in each combination. Furthermore, distribution of the nutrient-intake index among the sampled farmers confirmed that about 58 percent of the sampled farms grew crops that had greater tendency to deplete soil nutrient (see table 4.19). In essence, the nature and significance of the estimated coefficient implies that the cropping configuration practised by the farmers depleted the soil nutrients denoting inappropriate use of land the farmers.

5.2.3 LAND MANAGEMENT VARIABLES (dt)

LENGTH OF FALLOW: The estimated coefficient (0.7458) is statistically significant at $\alpha = 0.05$ and is positively related to output level. This shows that crop productivity can be improved if a piece of land is allowed to fallow for longer period, especially under a farming system where nutrient restoration depends on the re-growth of vegetation. In peasant agriculture, fallow regenerates the land and improves soil fertility. Therefore the coefficient of 0.7458 shows that crop output would increase over 7.5 times more if land is allowed to fallow for ten years. This implies that land productivity is improved under adequate and proper fallow management systems.

FERTILIZATION: The value of the estimated coefficient (0.9184) which is statistically significant at $\alpha = 0.10$ shows that application of land augmenting resources like fertilizer and manure have a positive effect on the crop output level. Therefore, on the plots of the farmers who applied any form of fertilizer, the autonomous output level increased 2.2854 relative to 1.367 for the none users of fertilizers and/or manure. This suggests that the use of external input like fertilizer and organic manure is quite necessary in areas where the nutrient status of the soil is low and land is shown to be over utilised.

5.2.4 LAND RESOURCE QUALITY (C_K)

DRAINAGE: The estimated coefficient is small in magnitude but statistically significant at $\alpha = 0.05$ showing that the drainage of farm have effect on the crop output level. That is a poorly drained soil is poor in nutrient status and as such productivity of the land is impeded if adequate management practices are not adopted. It therefore follows that poorly drained farms reduced crop output by the magnitude of the intercept dummy (i.e. 0.059). In a poorly drained soil, incidence of flooding is common and depending on the intensity, the fertility of the soil may be adversely affected.

5.2.5 SQUARED TERMS OF THE PHYSICAL INPUTS

Expectedly, all the squared terms estimated in the model are statistically significant at different levels of significance. Specifically, $(\text{Land})^2$ and $(\text{Material})^2$ show statistical significance at $\alpha = 0.01$ while $(\text{Labour})^2$ is statistically significant at $\alpha = 0.10$. The results however show statistically quadratic type of relationships with output. With respect to land, the squared term have positive relationship with output level.

For the labour, one interesting thing about the squared term is the magnitude of the estimated coefficient. Multiplying the labour available for farming operation under the same condition could only lead to less proportionate amount of output than initial available mandays. As a single variable, labour coefficient estimate was (0.6021) as against (0.1028) for squared term. One of the most plausible reason for this reduction in estimated magnitude may be that, considering the fixed nature of farm size, doubling labour would lead to overcrowding on the land and subsequent saturation of the resources.

This is the same situation for material cost. Therefore in the nutshell, when variable input have been doubled without allowing the fixed input to adjust in the short run, the resultant effect would be higher level of diminishing return to scale. This is reflected in the sum of the elasticities of output with respect to the squared terms of land, labour and material cost which is 0.2341 as against E_i = 0.7473 for land, labour and material cost.

5.2.6 INTERACTION AMONG PHYSICAL INPUTS (b_{ig})

LAND AND LABOUR: This interaction term has a positive affect on output level and is statistically significant at α = 0.01. It therefore implies that a unit increase in land with a corresponding unit increase in labour would lead to a less than proportionate increment in output level by 0.506 margin. It then follows that in the presence of adequate labour, land productivity could be improve leading to better output level, thus confirming the relative importance of labour as the most limiting factor in crop production. It should be noted that the joint effect of land and labour resulted in an estimate with positive relation with output level. By this result, it can be stated that if a large expands of land is to be cultivated, adequate labour must be available so that output level would have positive relation with farm size.

LAND AND MATERIAL: The estimated coefficient of the joint effect of land and cost of planting, (0.3344) is statistically significant at α= 0.01 and is positively related to output level. This result shows a less than proportionate increase in output level when farm size is increased by one unit given a corresponding unit increase in cost of planting. The result however, shows that if a farmer has enough planting materials to cultivate on a farmland available to him, the productivity of the land could be improved, leading to better crop yield.

5.2.7 INTERACTIONS OF PHYSICAL INPUTS AND LAND USE VARIABLE (fir)

LAND AND NUTRIENT INTAKE INDEX: The coefficient is statistically significant at α= 0.10 and is inversely related to the output level. This implies that given the status of farm size and the corresponding level of cropping configuration, the output level would be reduced. In essence, the scenario of cultivation where land is over utilised and the crops grown are heavy nutrient depletors would lead to a drastic reduction of output of the crops grown.

LABOUR AND NUTRIENT INTAKE INDEX: The estimate (- 0.3086) is statistically significant at α = 0.01 and is inversely related to output level. Therefore, the joint effect of labour available to a farmer and the level of crop configuration, in term of types (classes) of crops in a mixture could lead to depression in output level. This is apparently so as a farmer with much labour at his disposal would tend to involve in cultivation of root tuber crops that require mounds and perhaps ridge, but with more heavy nutrient depletors in a combination, the output level of crops grown would be adversely affected. In essence, no matter the level and intensity of other factors of production, any crop combination with high soil nutrition depletion affinity would result in poor output level especially under a low - external input agriculture. Therefore, if land is not optimally used, even under adequate labour supply, the output level would be adversely affected.

MIGRANT STATUS AND NUTRIENT INTAKE INDEX: The joint effect of migrant status and nutrient intake index is statistically significant at $\alpha = 0.05$ and is positively related to the output level. Therefore, taking migrant status as a slope dummy on nutrient-intake index, the result shows that the migrant farmers would combine crops that would deplete the soil nutrient, but would lead to negligible increase in crop production. In essence, migrant status influences the output level of crops to nutrient-intake index by 0.1139.

MATERIAL AND CROP DIVERSIFICATION: The estimated coefficient (0.2499) is statistically significant at $\alpha = 0.01$ showing that the joint action of cost of planting and crop diversification index have a positive effect on output level. It therefore follows that output of crop would increase when adequate provision is made in term of planting materials, agrochemicals, etc. and when the diversification practice is optimal. In essence, farmers would benefit from crop diversification if adequate planting materials and agrochemicals are used.

5.2.8 INTERACTION OF PHYSICAL INPUT AND LAND MANAGEMENT VARIABLE (hit)

LAND AND LEVEL OF TILLAGE: The coefficient of the joint action of land and level of tillage on output level (- 0.024) is statistically significant at $\alpha = =$ 0.01. It is rather small in magnitude and is inversely related to output level. This result is obvious given the respective importance of both farm size and level of tillage on output level of crops. In essence, land that is overutilised and is also heavily tilled would result in poor crop yield except adequate management measures adopted are to ameliorate the situation.

5.2.9 INTERACTIONS OF LAND USE VARIABLE AND MANAGEMENT VARIABLE

NUTRIENT INTAKE INDEX AND FERTILIZATION: The coefficient of joint action of nutrient-intake index and fertilization (0.3502) is statistically significant at $\alpha = 0.05$ and is positively related to output level. It then follows that when a farm is adequately fertilized, no matter the type of crops cultivated, the output level of the farm would be increased. Therefore taking fertilization as a slope dummy on nutrient-intake output level would improve. In essence, fertilization of farm influences the output levels of crops to nutrient-intake index by 0.1493 unit.

DIVERSIFICATION INDEX AND LENGTH OF FALLOW: The estimated coefficient (0.2139) is statistically significant at $\alpha = 0.05$ and has a positive relationship to output level. It therefore implies that more crops can be grown on a piece of land that has considerable fallow period and still output level be on increase. In essence, the benefit derivable from practice of crop diversification in terms of increased farm output could on be obtained under better fallow management system in a low-external input agriculture.

5.2.10 INTERACTION AMONG LAND RESOURCE QUALITY VARIABLE (r_{ko})

DRAINAGE AND TERRACE: The joint effect of drainage and terrace on output level is inversely related, but statistically significant at $\alpha = 0.01$. The result shows that when farmland is poorly drained and the topography (terrace) undulating, the output level of the crops grown would be depressed by the magnitude of the composite intercept dummy (i.e. 0.3930). This result however, confirms how prone poorly drained soil under undulating terrace is to incidence of flooding and erosion which are the two major problems of soil infertility.

5.2.11 INTERACTION OF LAND MANAGEMENT VARIABLE AND LAND QUALITY VARIABLE (w_{tk})

LEVEL OF TILLAGE AND TERRACE: The estimated coefficient (0.1888) is statistically significant at $\alpha = 0.01$ and is positively related to the output level. As a sloppy dummy, it therefore follows that under a stable and flat terrace the adverse effect of tillage on output level is reduced by the margin of 0.1888 unit. If the land is to be tilled for whatsoever purpose, the terrace of the land must be flat so that intensity and incidence of soil erosion could be avoided.

LEVEL OF TILLAGE AND DRAINAGE: The estimated coefficient (-0.1220) shows that the effect of level of tillage and drainage (slope dummy) is statistically significant at $\alpha = 0.01$ and is inversely related to output level. This implies that when the soil is poorly drained, the output level of the crops would be depressed considerably (i.e. about 0.53 times) under any form of land tillage. In essence, poorly drained soil whose physical structure has been destroyed as a result of tilling of the land would not hold enough nutrients

5.2.12 INTERACTION AMONG LAND USE VARIABLES (j_{rr})

DIVERSIFICATION INDEX AND NUTRIENT INTAKE INDEX: The estimated coefficient (-1.453) is statistically significant at $\alpha = 0.01$. It is rather quite large and has inverse relationship with output. This joint effect of crop diversification index and nutrient-intake index leads to more than a proportionate decrease in output level. This result therefore shows that under intensive crop diversification exercise, that is when more crops are grown together and if the grown crops have greater tendency to deplete soil nutrient, then the output of the crops grown would be adversely affected, leading to reduction in crop yield. This result particularly reveals that among the sampled farms heavy nutrient depleting crops of root tuber class are the predominant crops in combination. (See table 4.16).

5.3 RESOURCE PRODUCTIVITY

Having estimated the elasticities of output with respect to the physical inputs, it becomes necessary to evaluate the resource-use productivities. This is done by estimating the marginal and average physical productivities of the conventional inputs used by the farmers. On the average, the table 5.3 shows the level of resource use productivities and their respective values.

Table 5.3: Resource Productivity Estimates

Resources	Elasticity	Average Unit	MPP	APP
Land (ha)	0.0382	2.874	0.7148	18.7126
Labour (mandays)	0.6021	185.612	0.1745	0.2897
Capital (N.K)	0.00314	917.44	1.84E.04	0.0586
C. Planting (N.K)	0.107	8247.36	6.98E-03	6.52E-03
Average Total Output	-	53.78	-	-

Source: Computer from MLE Results

Table 5.3 shows the marginal and average physical productivities of the physical inputs. Specifically, the marginal physical productivities of land and labour have fulfilled the requirement of monotonicity as there are non-decreasing and greater than zero. The input productivities are discussed thus:

PRODUCTIVITIES OF LAND : The MPP and APP of land is estimated to be 0.7148 and 18.7126 respectively. Therefore, the MPP estimated shows that of land is increased by 10 hectares, crop output would increase by 7.148 tons, showing a less than proportionate increment. But on the average, an hectare of farmland contributes 18.7126 tons of crop output. By comparing MPP and APP of land shows that APP is higher than MPP. Therefore, the production process is at stage 2 with respect to land and thus land input is experiencing diminishing returns to scale.

PRODUCTIVITIES OF LABOUR : The MPP and APP are 0.1745 and 0.2897 respectively. The MPP estimated shows that the production process may be saturated with labour such that any marginal increment in labour input have negligible effect on the output level. By this, it implies that labour input may be experiencing diminishing returns to scale. The fact that APP is greater than MPP shows that, with respect to labour, the production process is at stage II.

PRODUCTIVITIES OF CAPITAL: The use of capital has a rather very negligible marginal effect on output given that the marginal physical product is almost approaching zero and the average physical product is also quite small in magnitude. This result however confirms the fact that in peasant agriculture, the use of modern farm tools is minimal and is mostly restricted to simple crude tools whose unit market cost is low. However, the production process is at stage II with respect to capital.

PRODUCTIVITIES OF PLANTING COST: Both MPP and APP are quite low but are still positive in value. The low MPP may be due to the fact that, planting materials can not on their own increase crop productivity if land and other input productivities are low. In a situation where land is overutilised, additional use of planting material would add little or nothing to crop output and in this case, lower crop productivity may result. Since there is decreasing diminishing returns to scale as MPP approach zero and APP is greater than MPP, the production process is at stage II with respect to cost to planting.

5.4 RESOURCE - USE EFFICIENCY

The farm specific resource - use efficiency indices were estimated using Eq (3.5). To give a better indication of the distribution of the individual efficiency, frequency distribution of farm specific efficiency is presented in table 5.4 :

Table 5.4: Distribution of Farm-Specific Resource-Use Efficiency Indices Among Farms

Class interval of efficiency indices	Frequency	Percentage
0.01-0.10	2	0.67
0.11-0.20	2	0.67
0.21-0.30	2	0.67
0.31-0.40	2	0.67
0.41-0.50	7	2.33
0.51-0.60	17	5.67
0.61-0.70	32	10.67
0.71-0.80	86	28.67
0.81-0.90	134	44.67
0.91-1.00	16	5.33
Total	300	100

Mean = 0.77

Mode = 0.84

Standard Deviation = 0.14

Minimum value = 0.01

Maximum value = 0.98

Skewdness = -0.50

Source: Computed from equation (3.5)

In addition to table 5.4, figure 5.1 gives a graphic presentation of the efficiency indices at farm specific level.

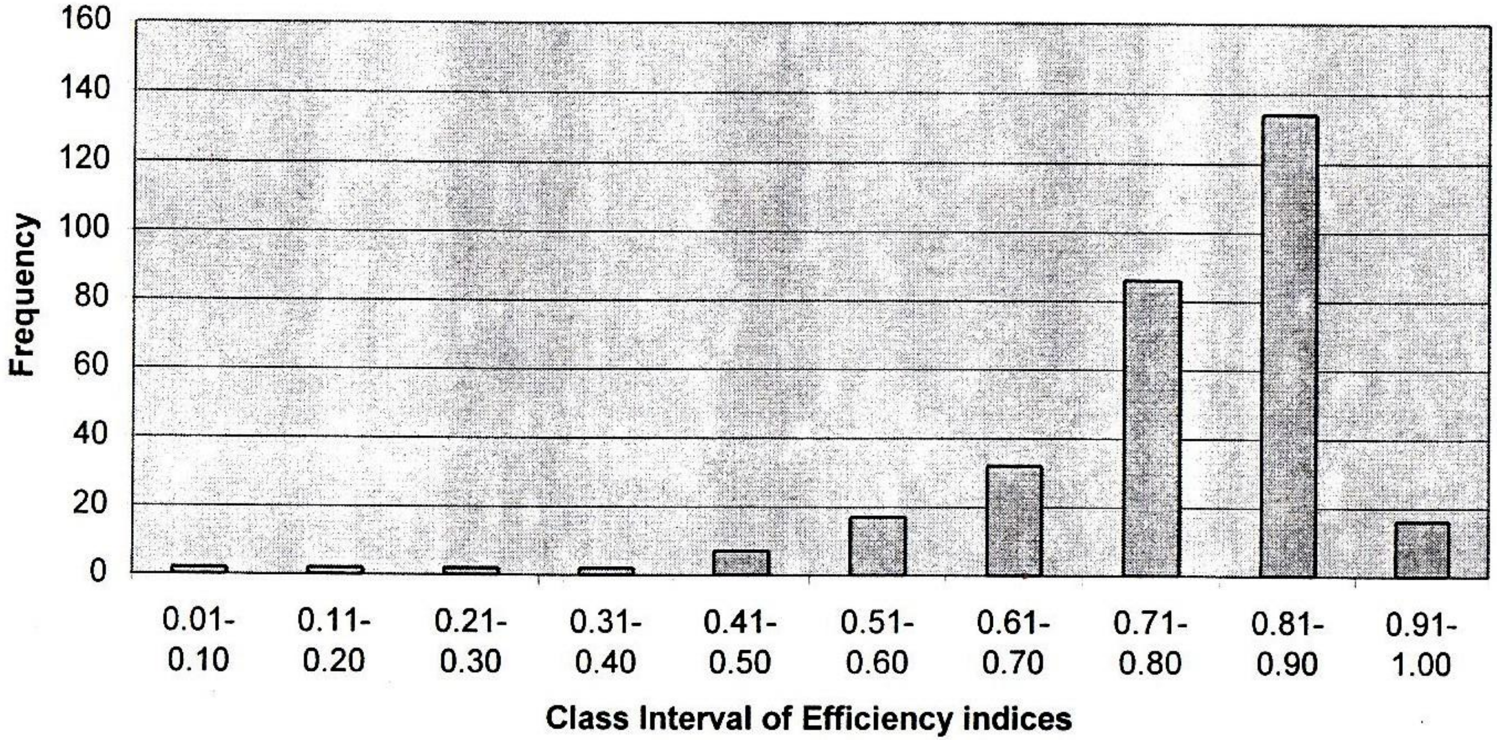

Figure 5.1: Farm Level Efficiency Index

From both table 5.4 and figure 5.1, the frequency distribution of efficiency shows a gradual rising from left to highest, and then a sharp fall to the right of the distribution. As the distribution spread from left to right at different intervals with modal class not falling into any of the extreme classes, therefore, the occurrence of the mode of distribution, 0.84 supports the use of more general distributions (than the often considered half-normal distribution or exponential distribution) for efficiency effects. The assumption of a general truncated-normal distribution for the efficiency term (Ui) is therefore justified. Furthermore, the assumption of a general truncated-normal distribution of Ui is supported by the statistical significant value of (-1.8214) for Mu(μ) from the regression result at $\alpha = 0.01$.

The average resource-use efficiency in the sample was 0.77 leaving an inefficiency gap of 0.23. This implies that about 23 percent higher production could be achieved without additional resources, or input use could be reduced to achieve the same output level. The minimum efficiency index observed among the farmers was 0.01 while the maximum value was 0.98. It therefore follows that the most efficient farmers in terms of resource use had index of 0.98 and the least efficient ones had resource use efficiency of 0.01. With the standard deviation of the efficiency being 0.14, then the coefficient of variation CV is 0.18. In terms of distribution, about 5.3 percent of the farmers had efficiency values of 0.9 - 1.00 interval. On the top of the efficiency table is the 0.80 - 0.89 interval class with about 44.67 percent of the farmers falling into this class. Only about 5 percent of the farmers have efficiency values of 0.01 - 0.49.

This rather high degree of technical efficiency suggests that very little marketable output is scarified to resource waste. The distribution of the efficiency estimates agree with previous works carried out in other peasant farming settings (see Ali and Byerlee, 1991; Coelli and Battese, 1996 and Parikh *et al*, 1995). It should be noted that the estimated efficiencies are purely output oriented technical efficiencies derived as the ratio of observed to maximum feasible output, conditional on technology and observed input usage.

The observed efficiency can be attributed to various factors ranging from technical production constraint, socio-economic factors and environmental factors. Specifically, in subsistence agriculture, scarce inputs may be allocated to various uses on the basis of their marginal shadow values thereby preventing the farmers from reaching the efficiency frontiers. According to Parikh *et al* (1995) marginal shadow values and marginal values productivities can differ for each of the inputs so that inefficiency may result. Furthermore, it has been contended that nonphysical inputs like experience, information asymmetry and other socio-economic factors might influence the ability of a farmer to use the available technology efficiently. When land use and management practices of the farmers result in degradation, attending frontier production level would be hindered. Basically, efficient use of resources is an important part of sustainability, which implies fewer inputs to produce the same level of output or higher output at the same level of input. This improves the productivity of fixed resources, and thus sustainability of production system. However, to actually measure the contribution of resource-use efficiency to the production process, an index of resource-use inefficiency ($1-e^{-u}$) is used together with the marginal effects of land-use and management practices on production.

5.5 FUTURE SIZE DISTRIBUTIONS OF EFFICIENCY INDEX

Table 5.5 shows the possible future distribution of farms when it is assumed that the actual and observed average efficiency index is reduced or increased by 25 percent respectively. The function used for the projection is presented thus:

$$LnY = \ln 101.22 - 0.942X$$

(10.87) (0.296) Se = 0.873; R = 0.93

Table 5.5: Present and Potential Distribution of Farms on Resource-Use Efficiency Index

		Potential Distribution	
Efficiency Class	Present	25% Reduction	25% increment
0.01-0.10	2	116	27
0.11-0.20	2	71	25
0.21-0.30	2	44	24
0.31-0.40	2	27	20
0.41-0.50	7	16	19
0.51-0.60	17	10	18
0.61-0.70	32	6	15
0.71-0.80	86	4	14
0.81-0.90	135	2	13
0.91-1.00	16	4	125
Mean	0.77	0.19	0.93

Source: computed from equation (3.7)

The potential distributions in table 5.5 show one way in which the assumed changes can be accommodated within the present distributional framework. The extrapolation, under ceteris paribus conditions, indicates that if the average efficiency index is reduced by 25 percent, the modal class would shift to the first class interval. This indicates that about 39.67 percent of the farmers would fall into the efficiency class interval of 0.01 - 0.10 as against 1.33 percent in the most efficient class (0.91 - 1.00). This is a situation where marginal shadow values and marginal value productivities differ for each of the inputs used. However, where mean efficiency index is assumed to be 25 percent higher than the present mean, the distribution of farms would change in such a way that only 9 percent of the farms would remain in the first class interval and about 41.67 percent of the farms would move to the last class interval. This is an indication that more farms would be distributed within the higher efficiency ranges. This could typify a scenario where most of the technical production constraint are removed and farmers are moving toward efficiency frontiers.

It remains a sound proposition to say that if the same kind of economic and land management practices are at work in the future as in the present, further development over the foreseeable future structure of farmers levels of resource-use efficiency assume a situation where more farms are likely to be less efficient. In other words there is overwhelming tendency for more farms to be less efficient in the future given the present structure. This is better shown by the degree of skewdness of the frequency distribution of the future efficiency index under the projected scenaria in figures 5.2 and 5.3

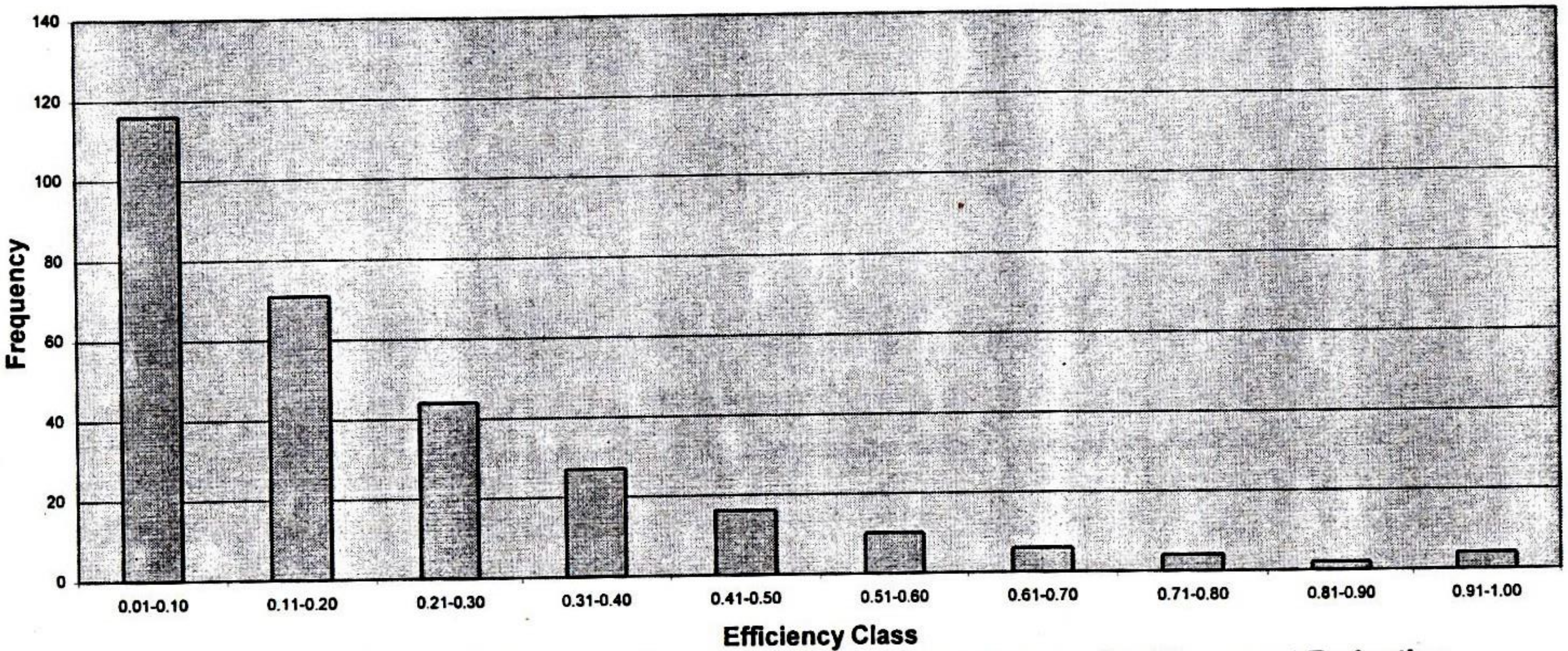

Figure 5.2: Future Distribution of Farm level Efficiency indices under 25 percent Reduction Scenerio

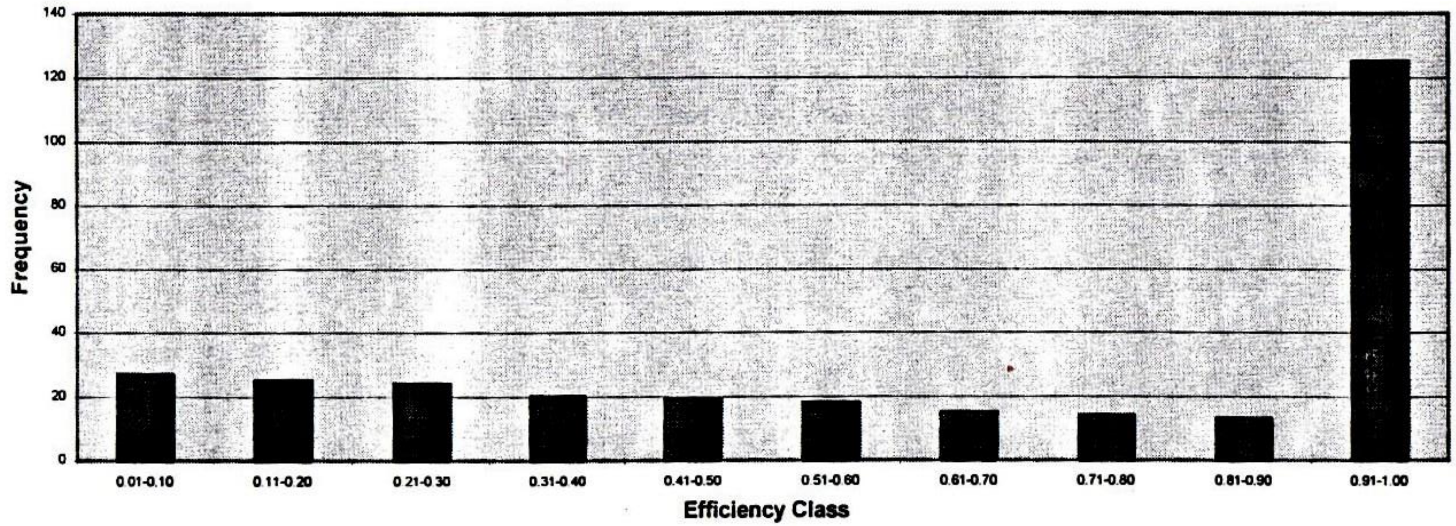

Figure 5.3: Future Distribution of Farm level Efficiency indices under 25 percent Increment Scenerio

5.6 SUSTAINABLE LAND USE AND MANAGEMENT INDEX

Farm specific index of sustainable land use and management was estimated using Eq (3.8). The distribution of the indices are presented in table 5.6

Table 5.6: Distribution of Farm Specific Sustainable Land Use and Management Index (ISM)

Class interval	Frequency	Percentage
(2.3-1.6)	1	0.33
(1.5-0.8)	6	2.00
(0.7-0.09)	36	12.00
(0.08-0.01)	155	51.67
0.01-0.04	11	3.67
0.05-0.08	4	1.33
0.09-0.3	44	14.67
0.4-0.7	30	10
0.8-1.1	4	1.33
1.2-1.5	5	1.67
1.6-1.9	2	0.66
2.0-2.4	2	0.66
Total	300	100

Values in parentheses are negative values

Source: Computed from Eq (3.8)

The distribution of the above table is presented in figure 5.4 below:

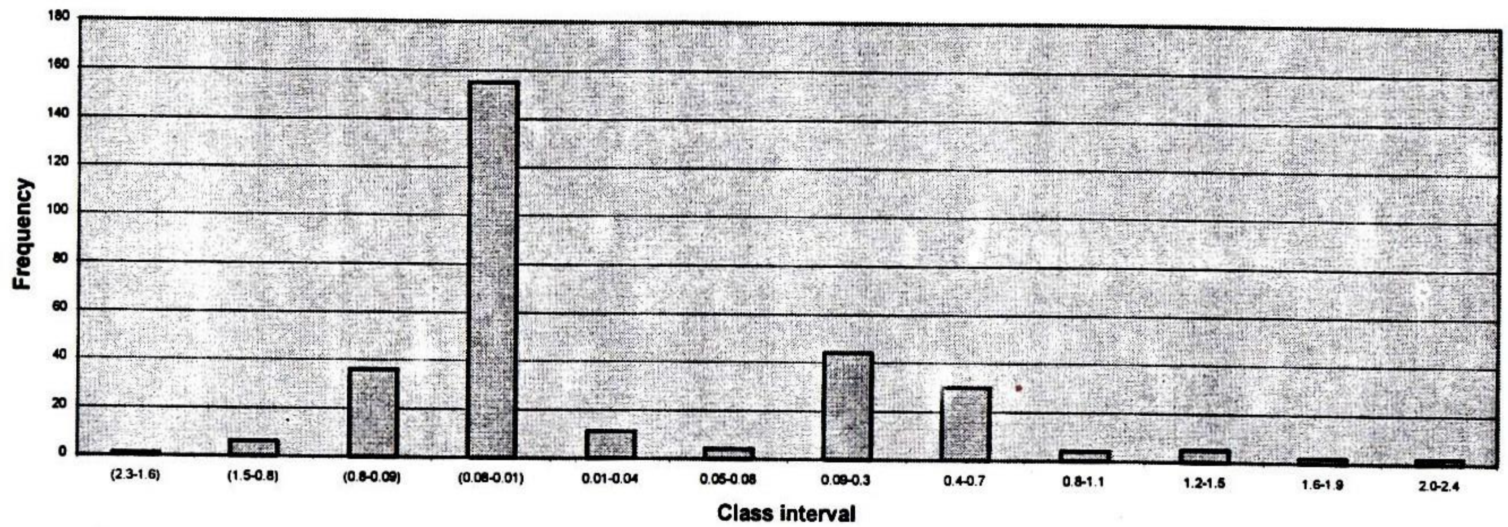

Figure 5.4: Distribution of index of sustainable land-use and management among farms

The indices of sustainable land use and management are farm specific that show the accumulated marginal effect of the land use and management practices on the land resource quality. The distribution of farms based on the ISM shows that about 66 percent of the farmers adopted land use and management practices that impaired land quality while only 34 percent of them adopted practices that improved the land quality, thus sustainable land use and management practices. It is specified that the farms with negative value of ISM paired land productivity and vice versa.

Specifically, on the top of the ISM table is the (0.08 - 0.01) interval class with about 51.67 percent of the farmers falling into this class. But on the whole, about 93.33 percent of the farmers fall into the classes of -0.7 to 0.7 with none of them specifically on zero value. By implication, the activities of the farmers do not actually leave the land undisturbed. It is either land status is impaired or improved. Correspondingly, though the land use and management practices of the farmers have both adverse and positive marginal effects on the land resource quality, the effects are not significantly high and different from zero for majority of the farmers. This is basically so as only one farmer fell into the -2.40 to –1.60 ISM class.

It therefore follows that about 51.67 percent of the farmers impaired land productivity by their management practices to the extent that crop output reduced by 8% and 1% percent. On the contrary, about 10 percent of the farmers improved land productivity via their agronomic practices to the extent that crop output increased by 4% and 8%.

The farm specific index of sustainable land use and management estimated in this study may be partial in the sense that all the relevant management practices that affect land quality have not been included in the analysis. But to large extent, the indices have measured the effect of land use and management practices normally adopted by the farmers on the land within the context of the assumptions in section 3.4.2.5.

5.7 SHORT RUN SUSTAINABILITY INDEX (SRSI)

Farm specific index of short run sustainability is a product of indices of farm specific resource use inefficiency (RUI) and farm specific indices of sustainable land use and management (ISM). It was estimated using Eq.(3.9). The distribution of indices are presented in table 5.7

Table 5.7: Distribution of Farm Specific Short Run Sustainability Index

Class Interval	Frequency	Percentage
(3.3-2.8)	1	0.33
(2.7-2.2)	3	1.00
(2.1-1.6)	5	1.67
(1.5-1.0)	25	8.33
(0.9-0.4)	42	14.00
(0.3-0.07)	68	22.67
(0.06-0.01)	75	25
0.01-0.06	44	14.67
0.07-0.3	24	8.00
0.4-0.9	5	1.67
1.0-1.5	6	2.00
1.6-2.2	2	0.67
Total	300	100

Values in the parenthesis are negative values.

Source: Computed from Eq (3.9)

The distribution of the indices are further presented in Figure 5.5.

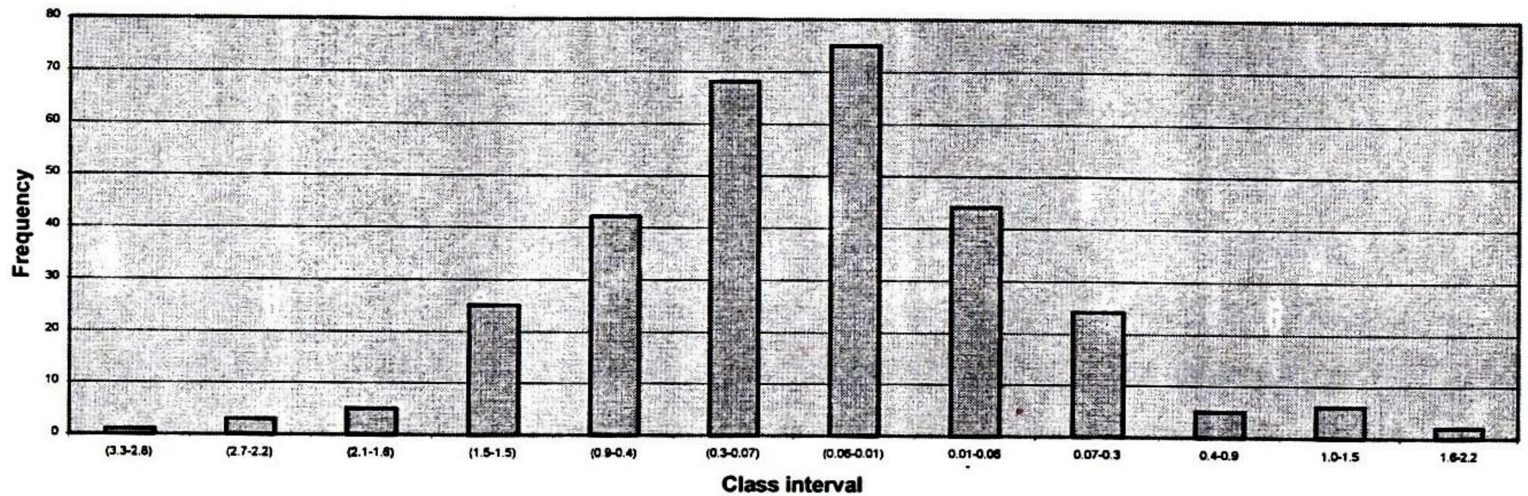

Figure 5.5: Distribution of Short-run Sustainability Index among Farms

Both table 5.7 and figure 5.5 show the distribution of the SRSI. The figure 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, 73 percent of the farmers fall within the class or the -0.01 to -3.3 while only 27 percent of the farmers fall within the 0.01 to 2.20 class interval. This result therefore shows that 73 percent of the farmers' land productivities declined owing to the net balance effect of the resource use inefficiency and effect of land use management practices. On the contrary, about 27 percent of the farmers improved their land productivity owing to the net balance of the resource use inefficiency and land use and management practices effect. In essence, considering the level of input combination and utilisation by the farmers within the context of their land use and management practices, only 27 percent of the farmers undertook sustainable production process.

Furthermore, it can be inferred from the SRSI distribution that about 14.67 percent of the farms (i.e. 44 farms) gained in productivity between 1% to 6% as a result of sustainable resource use efficiency and management while a productivity decline of 7% to 30% was observed on 22.67 percent of the farmers (i.e. 68 farms). However, the high concentration of the farmers within the SRSI range of -0.07 and 0.60 shows that in the short run, remedial and preventive measures can easily bring about improvement.

It is imperative to note that SRSI is estimated on the assumption that both resource use inefficiency index (RUI) and index of sustainable land use and management (ISM) are influenced by different factors. Based on this premise, a simple linear correlation coefficient expressing the degree of joint movement between the two indices was estimated and found to be $r = 0.128$. The null hypothesis of no correlation between the two indices in the farms was accepted at $\alpha = 0.05$ level. Therefore each of the indices affects sustainability index differently and at different magnitude. Their joint effects expressed as short run sustainability index compositely shows at farm level, the economic and environmental impact of crop production under a low external-input agriculture as the case under study.

5.8 RELATIONSHIP BETWEEN SHORT RUN SUSTAINABILITY INDEX AND YIELD LEVEL OF THE FARMS

Basically, increase in crop yield is a major integral aspect of sustainable farming. Better crop yield at farm level guarantee better economic returns to the farm and undoubtedly, where assumptions of perfect capital market or financial market, and a degree of certainty hold, there exist favourable economic characteristics in terms of profitability, liquidity and productivity.

At farm levels, the operational concern of subsistence farmers is how much crop yield they get from the production process. By no means but straight forward idea, lower productivity, expressed in poor crop yield should be reflected on the sustainability index estimated in this study. Therefore, to ascertain the relationship between short run sustainability index and crop yield at farm levels, a simple correlation analysis was estimated in addition to graphical representation of SRSI and yield levels.

Under the assumption of joint distribution of SRSI and yield level, that is bivariate distribution and normality, a correlation coefficient, r was estimated to be 0.359. With the assumption that the sampling distribution of the estimated r is symmetrical, rather than skewed, test of statistical significance at 0.01 critical level (2- tailed) showed that r=0.359 is statistically significant and difference from zero. Therefore, there exist a positive joint movement of SRSI and yield level. However, the magnitude of the correlation coefficient shows a rather weak relationship. Inferentially therefore, higher and positive SRSIs are accompany with higher crop yields. In a nutshell, the farms with higher resource use efficiency indices and positive indices of sustainable land use and management are likely to have high yield. This shows that the short run sustainability index is a good proxy to determine in site and post ante the farms that are within the path of sustainable farming system.

The extent of relationship between short run sustainability index (SRSI) and yield level is further shown in table 5.8 and figure 5.6.

Table 5.8: DISTRIBUTION OF SHORT RUN SUSTAINABILITY INDEX and YIELD LEVEL of FARMS

Class Interval of SRSI	Average yield (ton)
2.2-1.8	25.24
1.7-1.3	30.41
1.2-0.8	28.97
0.7-0.3	27.03
0.2-0.07	23.55
0.06-0.01	18.23
(0.04-0.01)	17.15
(0.08-0.05)	15.99
(0.3-0.09)	14.61
(0.7-0.4)	15.60
(1.1-0.8	13.21
(1.5-1.2)	13.31
(1.9-1.6)	14.90
(2.3-2.0)	13.09
(2.7-2.4)	13.52
(3.1-2.8)	13.69

Values in the parentheses are negative values.
Mean yield = 18.71 ton ha^{-1}

Source:FieldSurvey,1998/1999

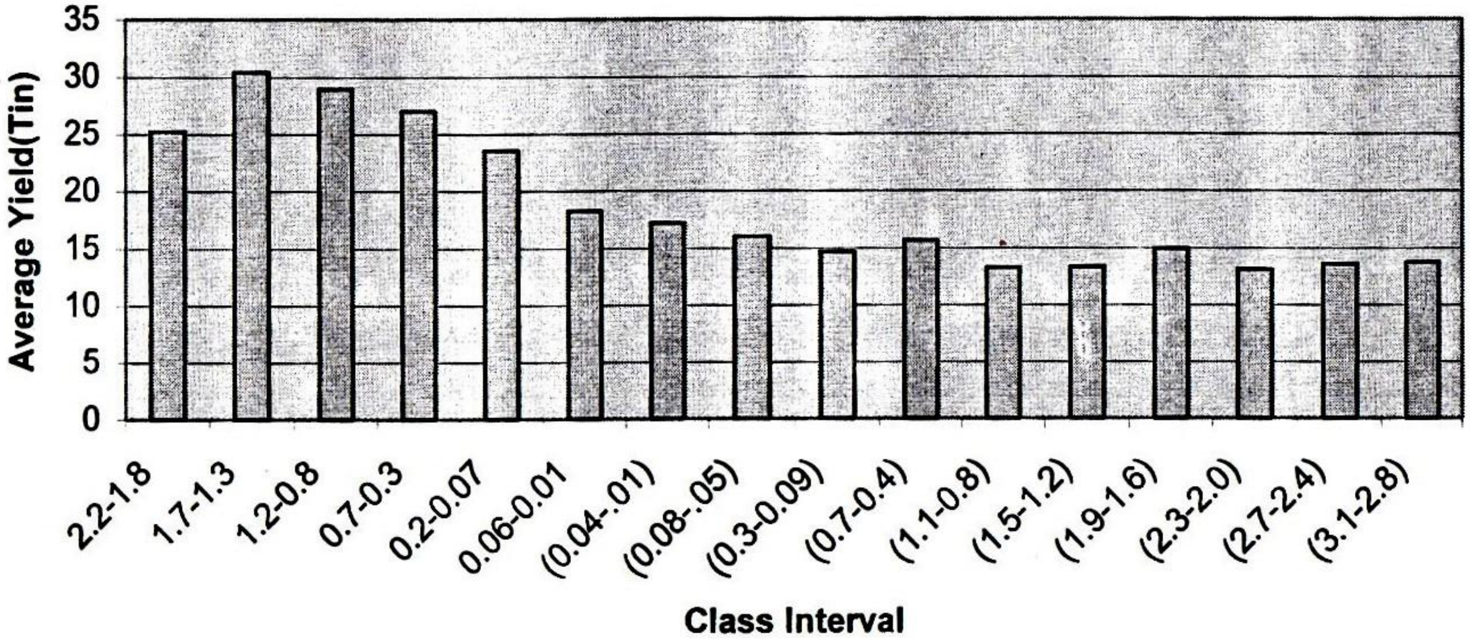

Figure 5.6: Relationship between Short-run Sustainability Index and Yield Level of Crops

Both table 5.8 and figure 5.6 further show the positive relationship between the short run sustainability index and the yield levels. Specifically, the yield reduction between the SRSI distribution range of 2.2 to 1.80 and -2.8 to -3.1 is about 45.78 percent. It is obvious from the scenario that gains in output from improvement in efficiency are possible when the land resource quality is maintained or improved through conscious and sustainable land use and management practices. Therefore, sustainability of low-external-input agriculture is threatened when there are problems of resource use inefficiency and poor land management. As rightly contented by Spencer and Swift (1992), the main sustainability concerns have been yield, yield stability and economic viability.

5.9 RELATIONSHIP BETWEEN SHORT RUN SUSTAINABILITY INDEX AND SOME LAND-USE AND MANAGEMENT PRACTICES

The extent to which some land use and management practices influence the farm specific short-run sustainability index is presented in table 5.9. Certain measurable parameters of land-use and management practices are related to the SRSI.

Table 5.9: Distribution of SRSI and Some Land-Use and Management Practices

SRSI Class	Frequency	Length of fallow (years)	$C.D.I_e$*	Nutrient intake index
(3.5-2.0)	28	3.18	0.437	3.9
(1.99-0.01)	193	6.21	0.339	2.8
0.01-1.99	73	7.03	0.346	2.3
2.00-2.50	6	10.47	0.204	1.5
Total	300	5.15	0.288	3.4

Source: Field Survey, 1998/1999

* $C D I_e$ => entropy index; values in the parentheses are negative values.

The table shows that the length of fallow, level of crop diversification and crop configuration have direct impact on the sustainability index. Where farmlands were not sufficiently fallowed and crops grown had higher nutrient intake index, the short-run sustainability indices estimated had higher negative values. On the contrarily, where farmlands were allowed to fallow for longer time and crops grown had lower nutrient intake index, the short run sustainability indices estimated had higher positive values. Also, where more crops were combined per cultivation cycle, the SRSI was adversely affected. Therefore improving land productivity has a direct link on how farmlands are used and managed, especially under a low-external-input agriculture where soil nutrient regeneration and recycling depend on bush fallow management.

5.10 PRODUCTION ELASTICITIES AND MARGINAL PRODUCTIVITIES OF THE PHYSICAL INPUTS UNDER DIFFERENT ENVIRONMENTS

The average sample elasticities and marginal productivities of the physical inputs were estimated from the OLS function under alternative environments. This was to empirically assess if elasticities and marginal productivities of input vary according to drainage, terrace and fertilization. The results of the estimation are reported only for those groups having more than twenty observations. Therefor six environments were considered and each environment is specified as:

ENVIRONMENT 1: This consists of farms with poor drainage, undulating terrace and without application of fertilizer or organic manure.

ENVIRONMENT 2; This consists of farms without good drainage and terrace, but have been fertilised.

ENVIRONMENT 3: This consists of farms with good drainage and terrace but without fertilization.

ENVIRONMENT 4: This scenario has farms with poor drainage, good terrace without fertilization.

ENVIRONMENT 5: This scenario has farms with poor drainage, but with good terrace and have been fertilised.

ENVIRONMENT 6: This scenario has farms with good drainage, terrace and have been fertilized.

The result of the estimation is presented in the table 5.10.

Table 5.10: Production Elasticities and Marginal Productivities of the Physical Inputs under Different Environments in the Area

Environ-ment	Environment			Frequency	Elasticities				Marginal Productivity				R^2	Output level (ton/ha^{-1}
	Drainage	Terrace	Fertiliza-tion		Land	Labour	Capital	C. Plant	Land	Labour	Capital	C. Plant		
1	0	0	0	23	-0.102	-0.505	0.781	-0.781***	-1.58	-0.132	$8.3x10^{-3}$	$3.68 x10^{-3}$	0.54	27.86
2	0	0	1	28	-0.138	0.728***	0.132	0.641***	-1.97	0.165	$3.6x10^{-3}$	$4.15 x 10^{-3}$	0.70	48.58
3	1	1	0	30	-0.101	-0.136	0.131*	0.774***	-2.05	-0.05	$1 x 10^{-2}$	$5.18 x 10^{-3}$	0.53	61.53
4	0	1	0	85	0.433	-0.236	$-1.19x10^{-2}$	0.639***	7.94	-0.07	$-9.1x10^{-4}$	$3.98 x 10^{-3}$	0.68	43.99
5.	0	1	1	34	0.113	-0.277	$-3.16x10^{-2}$	0.728***	-0.08	-0.08	$-1.67x10^{-3}$	$4.48 x 10^{-3}$	0.87	93.00
6	1	1	1	29	0.482***	-0.561**	$5.77x10^{-2}$	0.487**	0.18	0.18	$4.9x10^{-3}$	$3.01x10^{-3}$	0.78	64.75

Drainage: 1 for good drainage, 0 for poor drainage; Terrace: 1 for good terrace, 0 for undulating; Fertilization: 1 if a field have been fertilized, 0 if the field have not been fertilized; Frequency: Number of observation. Asterisks indicate level of significance: *** 1%, ** 5% and * 10%

Table 5.10 shows that the marginal productivities of the physical inputs varied according to alternative environments. But the variations do not follow definite sequence. However, the obvious thing about the scenario is that the quality of the land and application of fertilizer affect the productivities of the input used and the yield level. Specifically, under environment (6) where the drainage and terrace are good and the farms were fertilized, the MPPs of land and labour were 9.91 and 0.18 respectively and the output level was 64.75 ton/ha. On the contrarily, under environment (1) both the marginal productivities of land and labour were -1.58 and -0.132 respectively and the output level was 27.86 ton/ha. Furthermore, under environment 2 an additional land reduced production by 1.97 ton/ha and 2.05 ton/ha if the environment was classified as 3. However, the marginal productivities for capital and cost of planting materials are generally low under all the environments, but under scenario one, i.e. environment one, the marginal productivity of cost of planting material is negative.

Generally, there is a marked variation in the elasticities, marginal productivities and yield levels between environment one and six, though the variation has not reflected clearly in other environments. These two environments are extreme cases that classically show the extent to which the status of farmland and management practices can affect crop production. It therefore follows that there is substantial scope to improve productivity and yield at the existing level of inputs and resources if proper attention is given to practices of land use and management.

CHAPTER SIX

SUMMARY, IMPLICATIONS, CONCLUSION AND RECOMMENDATIONS

This study centered on the land management and resource-use efficiency of farm using farm specific data in intensively cultivated area of Cross River State and Akwa Ibom State, Nigeria. In doing this, the structure of farming was identified. The costs and returns associated with the crop cultivation were also determined. As the main thrust of the study, an analytical framework within which to evaluate sustainable use and management of agricultural land was developed. This was achieved via the use of a flexible (translog) production function to assess land productivity as affected by land use and management practices (i.e. agronomic practices), and resource use efficiency. Furthermore, the level at which different environments affect crop productivity was also investigated. The results of the analysis have been duely discussed. Therefore, in this concluding section, the major findings are summarized, implications stated with appropriate policy recommendations.

6.1 SUMMARY OF MAJOR FINDINGS

With the desire to quantify the determinants of sustainable use and management of farm lands within the context of the stated objectives of the study, the following understated points constitute more of the findings in the study:

- On the socio-economic characteristics of the farmers, majority of the farmers are male (71.33 percent); about 70 percent of the farmers are between 20 and 45 years of age with not less than 67 percent of them being literate and about 65 percent of them taking farming as their main occupation.
- In term of land ownership pattern, about 36 percent of the farmers do not actually owned the land they cultivated and the average farm size available to them is about 1.25 hectares as against average of 2.67 hectares for the farmers whose ownerships are permanent. Not more than 52 percent of the farmers cultivated between 1-2 plots and only 18.67 percent cultivated between 4-5 plots.
- Description of farm characteristics revealed that the average farm size cultivated by each farmer is 2.874 hectares. Labour is the most important factor as the average cost of labour constituted about 75.23 percent of the total cost of production with cost of planting and capital cost having 22.86 percent and 2.48 percent respectively. Family labour constitutes about 81.78 percent of the average farming labour.
- Findings on the farming systems revealed that mixed cropping is the dominant practice in the area. But cassava, maize, okra and melon are the mostly preferred and cultivated crops in the area.
- Income generation (48.07 percent) and food security (36.36%) are the major reasons for choice and preference of crops crown with only

about 5.11 percent of the farmers choosing crops for cultivation based on reason of land management.

- Not less than 89 percent of the cultivated farms have been previously cultivated and from this production, about 23.13 percent and 53 percent of the farm had length of fallow between 1 to 3 years and 4-6 years respectively with mean value being 5.15 years.
- In term of intensity of cultivation, the Rutherberg value of 0.325 showed that the farming system practiced in the area is moving toward permanent cultivation under natural fallow management system.
- Majority of the farmers (60.34 percent) practiced minimum tillage on their farms and about 79 percent and 71 percent of the sampled farms had slight signs of land degradation.
- Mixed cropping (65.33 percent) constituted the major cropping pattern in the area. But out of the thirty-two different crop combinations identified, only ten were popular and maize-cassava mixture and melon-maize-cassava-okra were widely cultivated.
- Two crops combination (34 percent) and three-crops combination (27.67 percent) were the major crops diversification patterns. But Herfindel and Entropy indices showed low level of diversification of crops among the sampled farmers.

- Based on the nutrient intake index, majority of the farmers (78.33 percent) combined crops that have greater tendency to deplete soil nutrients. That is, mixture where there are more root tuber crops.
- Analysis of cost involvement showed that sole cassava has the highest cost per hectare (N13,788.42) while cassava-okra-yam mixture has the least cost per hectare (N9531.23). But the farm revenue analysis revealed that maize-cassava mixture have the highest revenue, per hectare (N41,249.50) while the least revenue per hectare came from cassava-okra-yam mixture (N16,6602.99).
- Budgetary analysis showed that maize-cassava mixture have the highest net farm income per hectares (N28,851.00) while the least net farm income per hectares came from cassava-okra-yam mixture (N7,071.99). However, on the average, the net farm income per hectare in the area is N15,449.50.
- On the basis of output-input ratio, maize-cassava consecutively had the highest ratio (3.327) and the least ratio (1.742) expectedly came from cassava-okra-yam mixture. But the average output-input ratio for all the farms stood at 2.199, showing that on financial consideration, the farm operation was profitable.
- The sum of estimated scale elasticities revealed the presence of short-run decreasing return to scale with regards to all the variables

considered in the study (i.e. conventional inputs and the conditioning variables).

- The estimated production frontier fulfilled all the attributes of a well behaved production function and the diagnostic statistics suggested the presence of component error term, thus the use of stochastic parametric estimation.
- The estimates of all the physical inputs except capital showed statistical significance. But the sign and magnitude of estimate for land revealed that land has been overutilised as in term of mining of it.
- The estimated marginal and average productivities of the physical input showed that the farmers are operating at the stage II of the production process with respect to each of the conventional inputs.
- The distribution of the resource use efficiency revealed a rather general truncated-normal distribution showing a maximum value of 0.98 and a minimum value of 0.01 and the average resource-use efficiency in the sample of 0.77
- Majority of the farmers (about 66 percent) adopted practices that impaired land productivity while about 34 percent of the farmers improved land productivity through their land use and management practices.
- The net effect of resource use efficiency and land use and management practices represented as short run sustainability index showed that 73

percent of the farmer's land productivities declined while about 27 percent of the farmers improved their land productivity.

- The distribution of farms based on the short run sustainability index showed that short-run remedial and preventive measures can easily brought about improvement.
- Both resource use inefficiency and sustainable land use and management indices are influenced by different factors.
- Different land-use and management practices in terms of length of fallow, crop diversification and crop configuration have direct impact on sustainability of crop production.
- Although there is positive relationship between the estimate short-run sustainability index and yield level, the relationship is rather weak but is statistically significant.
- Production elasticities, marginal productivities and output levels are affected under different environment.
- The system of farming in the area have relatively meet the economic needs of the farmers but have undermined and not responsive to future use. This is reflected on the basis of technical efficiency of resource use and index of sustainable land use management.
- In terms of management of land, there is considerable overlap between different land and this is often affected by the way the farmers

perceived soil fertility status, types of crops grown on the land, and available resources.

6.2 ECONOMIC AND ENVIRONMENTAL IMPLICATIONS OF THE MAJOR FINDINGS

Within the context of sustainable agriculture, management of resources to satisfy human economic needs, while maintaining or enhancing land form the basic economic and environment ideas of production. A perspective analysis of how certain land use and management practices affect land resource use efficiency can determine how sustainable a production process sis. Based on this premise, the result of this study show the following economic and environmental implications:

- The labour intensive nature of farming in the area implies a continuous conflict in the demand for labour for farming and other operations.
- The presence of short-run diminishing return to scale in almost all the input suggests that more inputs can be used to expand production.
- The positive financial margins and better output-input ratios in all the enterprises also suggest that under proper management the farmers still stand a chance of increasing the profit levels of the enterprises.
- It is likely that swift changes in cropping system are not feasible owing to low risk taking capabilities of the farmers stemming from their small holdings and scarce non-farming employment opportunities.

- The level of average technical inefficiency among the farms suggest that certain proportion of marketable output is scarified to inefficient resource use.
- Cultivating on a marginal land with poor drainage and bad terrace would results in substantial output lost.
- The land use and management practices in the study area have impacts on soil erosion and plant nutrient depletion.
- Whatever the perceptions of the farmers with regards to crop mixtures, the amount of nutrient removed by the predominant crops grown were substantially higher than the amount replenished especially where the majority of the farmers did not apply any form of fertilizer.
- Although crop diversification and mixed cropping have attribute of soil fertility maintenance, to larger extent the farmers could not control land degradation.
- The amounts of organic matter and nutrient in the soil invariably decrease with increasing frequency and depth of tillage.
- The level of soil erosion and intensity of flooding in the farms can insidiously result in large-scale land degradation if adequate actions are not taken.
- The intensity of cultivation in the area would eventually lead to drastic reduction in the length of fallow period which would not be sustainable under the present level of external input use.

- On the basis of both biophysical environment of the area and the agricultural practices, it is plausible to assume that the agricultural lands in the area are undergoing degradation in terms of soil lost and nutrient lost.

6.3 CONCLUSION

The conceptual basis of this study centered on determining how certain sustainable land use and management practices are within the framework of resource-use efficiency and land resource quality maintenance. The empirical findings of the study showed the level and intensity of resource use and status of the agricultural land. The study clearly established that the peasant farmers have financial rewards in their farming operation, but there are substantial scope to improving productivity and output oriented technical efficiency at the existing level of input and resources.

The study also established that land use and management practices do affect the sustainability of crop production and that cultivating on a rather fragile environment (poor drainage and undulating terrace) resulted in less productivity of input used and lower output level.

In a nutshell, the farm level analysis of land use and management raised doubt as to how sustainable the system could be considering the signs and magnitudes of the estimated indices. On the basis of the analysis, the system of crop production practices in the study area show some remarkable signs of unsustainability in area of resource use efficiency and land resource quality.

6.4 RECOMMENDATIONS

The findings of this study and their implications to sustainable crop production have brought to fore a number of issues that needs to be addressed. Therefore the followings are some of the desirable actions required to ensure sustainable crop production in the area:

Soil Survey and Evaluation: Land suitability and capability study should be carried out before land is put into use. This is to ensure that choice of land use for a given location and purposes is based on the extent to which the land characteristics match land use requirements.

Provision of Land augmenting materials: There is urgent need for material like fertilizer, agro-chemicals and improved planting materials to be made available and affordable to the farmers so that majority of the farmers could apply these materials on the farms.

Adaptive Research and Extension Programmes: Government should encourage researches that would be farmer-oriented for awareness to be created on how to improve the quality of farm management practices currently in practiced. Extension agents should play active role in disseminating information on the usefulness of these practices and motivate the farmers to change if need be.

Need for better land use and Management: Basically, peasants do not change the present land use and management system easily and completely. On this premise, it is imperative to make the system environmentally and economically sustainable by minimizing tillage and other major forms of soil disturbance, and promoting practices that would ensure soil fertility restoration. These include promoting legume cultivation, mulching and conversion of all manure and crop residues into compost.

Needs for further research: This study is an attempt to determine how land use and management practices affect sustainability of crop production. It included different management options as explanatory variables in a production function. A similar analysis is needed which would identify and include more farm management practices and soil type. There is need therefore for a more comprehensive analysis in different ecological zones to be conducted.

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LAND MANAGEMENT AND RESOURCE-USE EFFICIENCY AMONG FARMERS IN SOUTHEASTERN, NIGERIA

This questionnaire is designed for the above named study. Please you are hereby requested to complete the questionnaire as required. The information supplied will be kept confidential and used purely for this academic purpose.

SECTION A: HOUSEHOLD CHARACTERISTICS

1. Age of farmer:...

2. Sex Male ( ) Female ( ) (tick one)

3. Marital status (tick one): (i) Single ( )(ii) Married ( ) Others (specify).....................

4. Provide information on the following: (i) number of children ( )
(ii) number of relations/others living in the house ( ) (iii) number of wives ( )

5. Education: (i) No schooling ( ) (ii) Primary school ( ) (ii) Secondary school ( )
(iii) Tertiary institution ( ) (v) Other (specify)..

6. What is Your main occupation?..............................

7. Which other(s) occupation do you engage in?................

8. What is the name of the area you are residing?.............

9. Are you an indigene of this area? Yes ( ) No ( )

10. If No in 9, when did you arrive in the area (or at what approximated age)?................

SECTION B:FARMING ACTIVITIES

11. Is all your farm units cultivated this section at one site? Yes ( ) No ( )

12. If not, how many plots have you cultivated this planting season?........................

13. Please provide information on your farm as follows:

i. Farm number	1	2	3	4	5	6	7	8
ii. Size of farm (Specify unit of measurement)								
iii. Distance of farm from house (in km or time)								
iv. How long have you been cultivating on the plot								
v. Was it a virgin forest before you start cultivating on it? Write "Y" for Yes and "N" for No.								
vi. How long will you cultivate on the land before allowing for fallow?								

14. Please provide information on the following:

	Last planting season		This year planting season	
Activities	Methods	Months	Method	Months
Land clearing. Soil preparation (tillage) Planting				

15. Please provide information on the following:

Plot cultivated	Crop grown	Variety(L/H)*	Seed rate kg/ha	Reasons for choice of crops/varieties	Proportion of land per crop	Sequence of planting

* L = Local variety; H = Hybrid variety

16. How each crop is planted:

Crops	Methods*

* Methods = Holed, dibbled, broadcast, ridged, mounded, etc.

17. What type of crop pattern do you practise in this planting season?

Plots	Cropping pattern*

* Cropping patterns = mixed cropping, intercropping, solecropping, e.t.c

18. Labour requirement for this planting season

Farm operation	Mo nth	Self time worked	Family and other non-paid labour			Hired Labour			Cost per unit of labour			Total labour input in man days	Tota l cost
			Days			Days			Days				
			M	F	C	M	F	C	M	F	C		
Land clearing													
Tillage													
Planting													
fertilizer													
Pesticides													
Herbicides													
Weeding													
Irrigation													
Weeding													
Harvesting													
Transport at-ing													
Marketing													
Others (Specify)													

19.Was the labour you had during last year adequate for your farm work? Yes ( ) No ( )
(Tick one)

20. If no, during what period (methods) of the year did you have difficulty in obtaining labour and for which farm tasks/job?

Time of year (Month)	Farm task/job*
i.	
ii.	
iii.	
iv.	
v.	
vi.	
vii.	
viii.	
ix.	
x.	

* Rank the task according to the severity of the problems.

21. Durable capital used (tools and equipment) for this planting season.

Type of tools	No. used	Time used ----------- No. of Hrs Days per day	Months of Engagement	Life span	Unit cost	Total cost
Axes						
Cutlass						
Hand forks						
Hoes						
Wheelbarrow						
Spade						
Others (Specify)						

22. Non-durable input for this planting season:

Item/Material	Quantity used	Source of supply	Unit cost	Type	Total cost
Seed (improved)					
Seed (Local)					
Stem cutting					
Tuber					
Fertilizer (Specify)					
Insecticides					
Herbicides					
Others (Specify)					

23. If you did not use any of the items or materials listed in question (21) and (22), Please state the items and indicate the reason why:

Item/Material	Reason for not using it
i.	
ii.	
iii.	
iv	
v.	
vi.	
vii.	

SECTION C: POST-PLANTING MANAGEMENT

24. Weeding situation: By which method do you weed your farm? Manual ( ) chemical ( ) manual and chemical ( )

25. If by chemical provide information for these:
i. type and rate ....
ii. amount of labour saved over manual ....
iii. any problem ....

26. How many times do you weed per cropping season ....

27. Practice of weeding (tick relevant ones) ....
(i) Clean weeding ( ) (ii) Weeding rounds per crop ( ) (iii) all crops weeded ( )
(iv) Other (specify)...

28. How did you dispose the weeded materials?......................

29. Chemical fertilizer used? Yes ( ) No ( )

30. If yes, provide information for the following:

Type	On Which crops	Rates	Frequency	How applied	Unit of measurement

31. Organic manure used? Yes ( ) No ( )

32. If yes, provide information for the following:

Type (FYM* green manure)	On Which crops	Rates	Frequency	How applied	Unit of measurement **

* FYM (Farm yard manure) -poultry, sheep/goat droppings, etc
** Unit of measurement, e.g. basket, headpan, bag and any local unit of measurement.

33. Is mulching done or crop residue left in the field and not trazed? Yes ( ) No ( )

34. If yes, (i) Is it spread out? ( ) (ii) left as it is? ( ) (iii) Mixed in the soil? ( )
(tick the relevant ones)

35. If not, what happens to crop residue? (i) removed ( ) (ii) Used as fodder ( ) (iii) Burnt ( ) (iv) Used for capacity ( ) (v) Used for other purposes (specify)......................

SECTION D: FARM DEVELOPMENT

36. Is the plot/Field cleared from forest/bush? Yes ( ) No ( )

37. If yes, when?..

38. When was the plot most recently cleared?................

39. Was fire used? Yes ( ) No ( )

40. Was crop grown on the same land before the present crop? Yes ( ) No ( )

41. If yes, try to establish the crop sequence

42. Has the land been fallow until now and how long and the fallow period?............

43. In your own opinion, what is the best time to rest a field after cropping?............

44. Did you cut down of any tree/palm when you open the land? Yes No

45. If yes, give reasons for cutting down the trees..

46. Presently how many tree and palm stands are in your farm.............................

47. Do you plant any tree or plant to protect the land? Yes ( ) No ( )

48. If yes list the plants and their ages..
....

SECTION E: OUTPUT

49. Please complete the following table*

Plot cultiv a-ted	Type and Quantity of crop harvested total yield	Amount given away and lose	Amount used as payment	Quantit y sold	Actual price per unit	Total Revenue
1						
2						
3						

4						
5						
6						
7						

* State the yield in units, e.g. killogrammes, tonnes, basket, basin, bags, e.t.c.

50. Has there been a change in crop yields over time? Yes ( ) No ( )

51. If yes,
(i) For what crop(s)?..
(ii) Over what time period...
(iii) Why did the change occurs...

52. Is there a wide fluctuation in yield from year to year? Yes ( ) No ( )

53. If yes,
(i) For what crop(s)?..
(ii) What are the means put in place to reduce the fluctuation in yield or minimise risks of crop failure.

....

....

SECTION F: LAND TENURE AND OWNERSHIP

54. By which of the following methods did you acquire your farm? (Indicate the order e.g. 1st, 2nd, 3rd, e.t.c).
(i) Direct purchase ( ) (ii) Inheritance ( ) (iii) Pledge ( )
(iv) Mortgage ( ) (v) Family/Clan right( ) (vi) Gift ( )
(vii) Lease ( ) (viii) Group farm land ( ) (ix) Communal right ( )
(x) Other (specify)..................

Plot	Method of acquisition	Cost (if any)

55. How do you measure the dimension of your farm locally?
....

56. Are there any restrictions on the purpose for which you may use your land?..

57. If you were to increase your farmland next year, could you easily acquire additional land?

58. If yes, by what method?......................................

59. Do you think the present land tenure arrangement encourages you to invest in land?

60. If no, how could it be improved....................

SECTION G: MARKETNIG

61. How is your produced bought? (Fill the appropriate columns and rows)

Quantity	At the farm gate	In the market	In the house
In bits			
In bulk			

62. If in the market or in the house, how did transport your farm produces? (tick appropriate boxes): by
(i) Vehicle ( ) (ii) Head poterage ( ) (iii) Bicycle ( ) (iv) Tractor ( )
(v) Motorcycle ( ) (iv) Other(specific)..................

SECTION H: LIVESTOCK MANAGEMENT

63. Do you keep livestock? Yes ( ) No ( )

64. If yes, list the livestock you keep...............................

65. Do you use the animal droppings on your farm?

66. If No, how do you dispose the dropping?................

SECTION I: FARM FEATURE AND PLAN

67. Form your view point describe the soil you cultivate on..............................

68. What is the drainage condition of your farm ....

69. In your view point, what is the productivity status of the soil?.....................

70. Is there evidence of: (1) Accumulation of soil particles behind trees in the farm ( ) (ii) Rills ( ) (iii) Gullies ( ) (tick the relevant ones)

71. Since you started cultivating on the farm, have you notice any change in the colour of the soil?

72. If yes, explain what could be the reason for the change...........................

73. Do you experience flooding in your farm? Yes ( ) No ( )

74. If yes, what do you do to protect the soil?...

75. Is your farm adjacent to another farm or bush?...

76. Have crops been damage or work delayed by bad
(i) Rain ( ) (ii) Drought ( ) (iii) Wind ( ) (iv) Flooding ( ) (v) Erosion ( ) (Tick relevant ones)

77. Is your plot on a slope? Yes ( ) No ( )

78. If yes, how do you arrange your crops on the farm?..................................

SECTION J: EXTENSION SERVICES

79. Have you been visited by any agricultural extension agent

80. If yes, how many time have you been taught the principle of land-use and management?........

81. What factors do you consider to have hindered your farm production work most? (Rank in order of importance)
(i) Limited land ( ) (ii) Poor fertility of land ( ) (iii) Labour shortage ( )
(iv) Lack of money ( ) (v) Distance from farm to markets ( )
(vi) Others (specify)..........

82. What are the ways you think could be adopted to improve land/soil quality?
(i)...
(ii)...
(iii)...
(iv)..
(v)..
(vi)..
(vii) ....