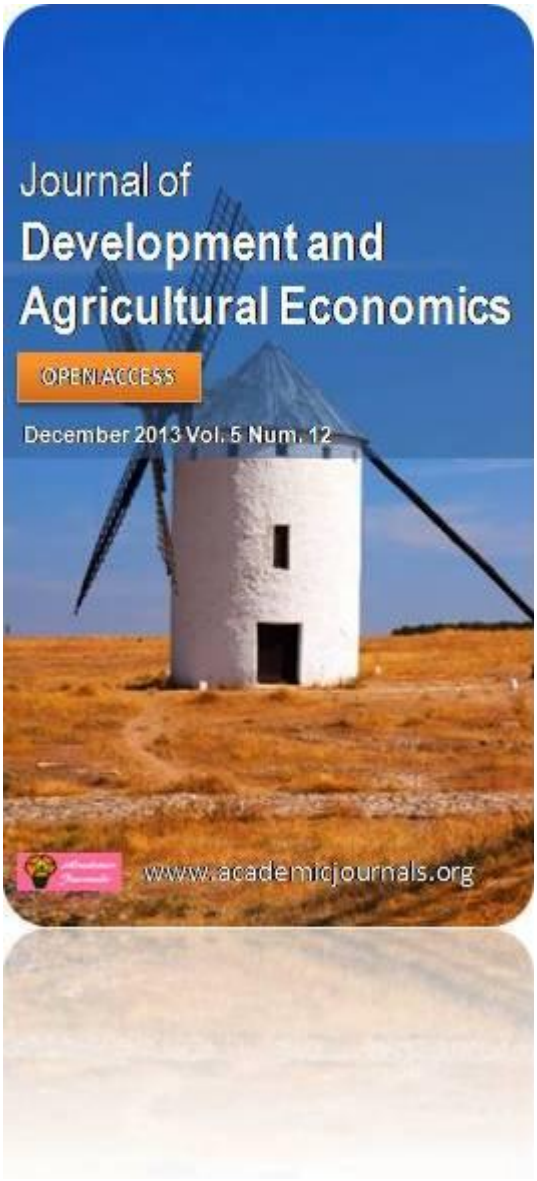

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Review

Optimal control theory and fishery model

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Adequate numbers of relations have been provided to find the three unknowns following three equations: the state equation, the adjoint equation and maximum principle equation. If rigor is sacrificed, then a partial solution is quickly obtained by using the concept of calculus of variation. Our appealing and intuitive harvesting policy would be that, refrain from harvesting along the singular path, because zero harvest is not optimal.

Key words: Harvesting, bang-bang-control, singular control, maximum principle hamiltonian, Euler equation and switching function.

INTRODUCTION

A large cross-section of contemporary problems in applied mathematics, related to Biology is concerned with the analysis and synthesis of dynamic processes. The structural stability of a dynamic system depends on the parameters or structural constants appearing in the system of differential equations describing the system. During the last three decades, the management of natural resources in general and that of renewable resources, in particular, has invited the attention of a large segment of researcher (Goundry, 1960; Crutchfield, 1967; Wat, 1968; Garrod, 1973; Gulland, 1974). Coyle studied the dynamics of management system (Coyle, 1977) and of capital expenditure (Coyle, 1979). If $h(t)$ represents the rate of removal or harvesting then the population growth with harvesting is described by the differential equation

$$\frac{dn}{dt} = f(n) - h(t) \qquad (1)$$

where $n(t)$ denote the size of a fish population at time t. Whenever the harvest rate $h(t)$, exceeds the natural growth rate $f(n)$, Equation (1) implies that the population level will decline as $\frac{dn}{dt}$ becomes negative. However, if $h(t) < f(n)$, then the population growth continue. If $h(t) = f(n)$, the population remains at a constant level. Thus, in this situation, the natural growth rate $f(n)$ becomes the 'sustainable yield' that can be harvested while maintaining the population at a fixed level. Symbolically, the sustainable yield Y will be given by:

$$Y = f(n) = En, \qquad (2)$$

where E is the effort per-unit catch. For density dependent growth models degree $f(n) \geq 2$, therefore, if h is constant and $h < \max\ f(n)$, then Equation (1) may possess two or more equilibriums. An explicit analysis of the model can be carried out only when $f(n)$ is given in explicit form. However, if $h(t) = h$, then Equation (1) implies that a maximum sustainable yield (MSY) is given

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by

$$Y_{\max} = h_{MSY} = \max_{n} f(n) \quad (3)$$

with the property that any larger harvest rate will result into the depletion, and hence eventual extinction of the population. In order to achieve the maximum revenue return from fish harvesting and also to determine an optimal policy for fish harvesting, Pontryagin's maximum principle have applied. In this direction, further, if we assume a constant price.

p, per-unit of harvested bio-mass, and a constant cost c, per-unit catching effort, then the total sustainable revenue TR and total fishing cost TC are given by

$$TR = pY(E) \quad (4a)$$

and

$$TC = cE \quad (4b)$$

The net revenue, which is the difference TR and TC is called the 'sustainable economic rent'. Thus

$$SR = TR - TC = p.Y(E) - cE. \quad (4c)$$

Gordon (1954) fundamental result state that, in the open-access fishery, effort tends to reach an equilibrium, the so-called bionomic equilibrium, at the level $E = E_{\infty}$, at which the sustainable economic rent is completely dissipated, that is

$$TR = TC \quad (5)$$

In Gordon's model of open-access-fishery, if $E > E_{\infty}$ then opportunity cost exceeds revenues, consequently fishermen leave the fishery. Conversely, if $E < E_{\infty}$, then revenues exceed opportunity costs and consequently efforts tend to increase, as now fishing is more profitable than other employment (Clark, 1990; Burghes and Graham, 1980). At this point a reasonable inquiry is: what is wrong with a situation in which fishermen earn their exact opportunity cost from fishing? A close scrutiny shows that, firstly, the fishery resource which is capable of producing positive economic rent, for an excessive level of effort is being utilized. Neither the fishermen, nor society at large, are enjoying the benefits that could accrue as when the fisheries were under management. This situation is called 'economic overfishing'. Secondly, the fishery may suffer from 'biological overfishing' in the sense that in this case sustained biomass yield is less than MSY.

MODELS

Shah and Sharma (2003) proposed a deterministic extension of Gordon-Schaefer (GS) model by setting

$$\frac{dn}{dt} = rn\left[1 - \left(\frac{n}{K}\right)^{\alpha - 1}\right] - En, \quad (6)$$

where $n(t)$ is the stock size, $r > 0$ is the intrinsic growth rate per unit, K is the carrying capacity of the system, E is the effort per unit catch, and α is a real positive number exceeding 1, that is $\alpha > 1$. The model encompasses the following three models, which have been extensively pursued in the management of fishery (Pella and Tomlinson, 1969; Holt, 1975).

(i) Gordon-Schaefer (GS) model with $\alpha = 2$,
(ii) Pella-Tomlinson model (PT) with $\alpha = 3$ and
(iii) Pella-Tomlinson model (PT) with $\alpha = 4$.

MAXIMUM PRINCIPLE AND OPTIMAL HARVESTING

Considering the concept of opportunity cost, the maximum sustainable yield may not be profitable economically. Now we shall re-examine the model from economic perspective. Usually the harvest rate is determined by the current stock size $n(t)$, and the rate of harvesting effort E. Therefore we can write

$$h(t) = Q(n, E). \quad (7)$$

The function $Q(n, E)$, which relates the factor of production n and E to the rate of production $h(t)$ is referred to as the production function. In our problem, we shall consider $Q(n, E)$ in the form:

$$Q(n, E) = G(n).E \quad (8)$$

The linearity in effort E, facilitates the application of the maximum principle to our model; therefore, the reasons for this choice are primarily mathematical. $G(n)$, in view of physical aspect, is any non-decreasing function of n. Next, suppose the price p per-unit bio-mass remains constant, and that the cost c of a unit of effort is also constant. The net economic revenue P produced by an input of effort E over unit time will be given by

$$P = p.h(t) - c.E \quad (9)$$

Combining Equations (7) to (9), we obtain

$$P = [p.G(n).E - c.E], \\ = [p - C(n)]h(t) \quad (10)$$

Where

$$C(n) = \frac{c}{G(n)}.$$

Now suppose that the sole owner's objective is to maximize the total discounted net revenue (the present value) $J(h)$, derived from harvesting of the fish population over finite horizon $[0,T]$, and given that

$$J(h) = \int_0^T e^{-\delta t}.P\,dt \;\; = \int_0^T e^{-\delta t}.[p - C(n)]h(t)\,dt \quad (11)$$

where $\delta > 0$ is a constant denoting the continuous discounting rate. In Equation (11) $h(t)$ may be viewed as a control variable, in conjunction with the constraint

$$h(t) = rn\left[1 - \left(\frac{n}{K}\right)^{\alpha-1}\right] - \frac{dn}{dt} \quad (12)$$

obtained from Equation (6). Combining Equation (11) and (12), our problem reduces to:

$$\max imize\left\{J(h) = \int_0^T e^{-\delta t}[p - C(n)]\left[rn\left(1 - \left(\frac{n}{K}\right)^{\alpha-1}\right) - \frac{dn}{dt}\right]dt\right\}. \quad (13)$$

It will be worth mentioning that if we sacrifice the rigor, then a partial solution can be quickly obtained by using the ideas of calculus of variation (Gelfand and Fomin, 1961; Elsgolts, 1970; Bolza, 1951; Weinstock, 1974). Functional $J(h)$ in Equation (13) is analogous to the functional

$$I(x) = \int_{x_0}^{x_T} g(t, x; \dot{x})dt$$

related to a variation problem seeking a path $x*$ from point x_0 to x_1 in a plane along which $I(x*)$ becomes maximum/minimum, depending on the nature of the problem (Maunder, 2002; Huo et al., 2012). Obviously, a necessary condition is that the path $x(t)$ must satisfy the classical Euler equation.

$$\frac{\partial g}{\partial x} = \frac{d}{dt}\left(\frac{\partial g}{\partial \dot{x}}\right) \quad (14)$$

In our problem an analog of the integrand is

$$g[t, n(t), \dot{n}(t)] = e^{-\delta t}[p - C(n)][f(n) - \dot{n}] \quad (15)$$

Therefore, n(t) must be a solution to

$$\frac{\partial g}{\partial n} = \frac{d}{dt}\left(\frac{\partial g}{\partial \dot{n}}\right)$$

or

$$e^{-\delta t}\left[-\frac{dC(n)}{dn}\{f(n) - \dot{n}\} + \{P - C(n)\}\frac{df}{dn}\right] = \frac{d}{dt}\left[-e^{-\delta t}\{P - C(n)\}\right] \quad (16)$$

On simplification Equation (16) reduces to

$$-\frac{dC(n)}{dn}f(n) + \{P - C(n)\}\frac{df}{dn} = \delta[P - C(n)]$$

or

$$\frac{df}{dn} - \left[\frac{f(n)}{P - C(n)}\right]\frac{dC}{dn} = \delta \quad (17)$$

Equation (17) is an implicit equation describing the growth curve of the population yielding maximum economic revenue. If $n*$ is the unique solution to Equation (17), then given an initial population $n(0) = n_0$, the optimal harvest policy may be stated as follows: Utilize the harvest rate $h*(t)$, that drives the population level $n = n(t)$ towards $n*$ as rapidly as possible. If $h_{\max}$ represents the maximum feasible harvest rate, then we have,

$$h*(t) = \begin{cases} h_{\max} & for \quad n > n* \\ f(n*) & for \quad n = n* \\ 0 & for \quad n < n* \end{cases} \quad (18)$$

In what follows, we shall apply Pontryagin's maximum principle (Pontryagin et al., 1962) for optimal control theory.

Pontryagin's MAXIMUM PRINCIPLE

Consider the differential equation

$$\frac{dn(t)}{dt} = f_0[t, n, h(t)], \quad (19)$$

with initial condition

$$n(0) = n_0 \tag{20}$$

where $f_0(t,n,h)$ is a continuously differentiable function of three variables t, n *and* h. The variable $n(t)$, which describes the state of system at time t, will be called the 'state variable', and the Equation (19) will be referred to as the 'state equation', and $h(t)$ as the 'control function'. Further the terminal time T will be called the 'time horizon', and may become infinite in a problem. Any piece-wise continuous real-valued functions $h(t)$ defined for $0 \le t \le T$ will be called an admissible control. For a given admissible control $h(t)$, the solution to Equation (19) will be called the 'response'. Finally, the condition

$$n(T) = n_T \tag{21}$$

will be termed as the 'terminal control', and a feasible control is one for which the response satisfies both the initial as well as the terminal condition. Now suppose that our objective functional is

$$J(h) = \int_0^T g[t, n(t), h(t)]dt \tag{22}$$

where $g(t,n,h)$ is a given continuously differentiable function and $n(t)$ denotes the response to the control function $h(t)$. The maximum principle is most conveniently described in terms of the so-called Hamiltonian H defined by setting

$$\begin{aligned} H &= H[t, n(t), h(t); \lambda(t)] \\ &= g[t, n(t), h(t)] + \lambda(t).f_0[t, n(t), h(t)] \end{aligned} \tag{23}$$

where $\lambda(t)$ is an additional unknown function, and is called the 'ad joint' variable in the optimal control theory. We now state the Pontryagin's maximum principle (without proof): If $h(t)$ is an optimal control and $n(t)$ is the corresponding response, then there exists an adjoint variable $\lambda(t)$ such that the following equations are satisfied, for all t, $0 \le t \le T$:

$$\frac{d\lambda}{dt} = -\frac{\partial H}{\partial n} = -\left[\frac{\partial g}{\partial n} + \lambda(t)\frac{\partial f_0}{\partial n}\right], \tag{24}$$

$$H[t, n(t), h(t); \lambda(t)] = \max_{h(t)} [H(t), n(t), h(t); \lambda(t)]. \tag{25}$$

The maximization is carried out over all admissible controls $h(t)$. It is pertinent to note that Equation (25), factually tells that

$$\frac{\partial H}{\partial h} = 0. \tag{26}$$

Now the question is how to apply this principle to a concrete problem? Here we have three unknowns $n(t)$, $h(t)$ and $\lambda(t)$. For these three functions, we have three equations, namely: the state Equation (6) for $n(t)$, the adjoint Equation (24), and the maximum principle Equation (25) equivalently Equation (26). Furthermore, we have initial condition Equation (20), and the terminal condition Equation (21). Thus, in principle, adequate number of relations have been provided to find the unknown functions $n(t)$, $h(t)$ and $\lambda(t)$. In case of our problem it is not possible to provide the terminal condition $n(T)$. But the function $J(h)$, given by Equation (22) can be written as

$$J[h(t)] = \int_0^T \left\{ e^{-\delta t}[p - C(n)]\left[rn\left(1 - \left(\frac{n}{K}\right)^{\alpha-1}\right)\right] - e^{-\delta t}[p - C(n)]\frac{dn}{dt}\right\} d(t). \tag{27}$$

or

$$J(h) = \int_0^T \left[A(n,t) + B(n,t)\frac{dn}{dt}\right].dt \tag{28}$$

Where

$$A(n,t) = e^{-\delta t}[p - C(n)]\left[rn\left(1 - \left(\frac{n}{K}\right)^{\alpha-1}\right)\right]$$

$$B(n,t) = -e^{-\delta t}[p - C(n)] \tag{29}$$

and $\frac{dn(t)}{dt}$ remains bounded for all times, that is,

$$A(n,t) \le \frac{dn}{dt} \le B(n,t). \tag{30}$$

Therefore, if we introduce

$$\frac{dn}{dt} = h(t). \tag{31}$$

Then the Hamiltonian of the problem becomes

$$H = (A + Bh) + \lambda(t)h = A + (B + \lambda)h \quad (32)$$

According to the maximum principle Equation (25), the optimal control $h(t)$ must maximize H in Equation (32). If we define

$$\psi(t) = B(n,t) + \lambda(t), \quad (33)$$

then $h(t)$ must satisfy

$$h(t) = \begin{cases} B(n,t) & if \quad \psi(t) > 0, \\ A(n,t) & if \quad \psi(t) < 0. \end{cases} \quad (34)$$

A control like $h(t)$, which assumes these extreme values (condition Equation 30) is called a 'bang-bang' control, and for obvious reason $\psi(t)$ is called the 'switching function'. Whenever $\psi(t)$ vanishes, then

$$H = A(n,t), \quad (35)$$

that is, Hamiltonian is independent of the control $h(t)$, and consequently the maximum principle does not specify the value of optimal control. The most remarkable case, the so called singular case, arise when $\psi(t)$ vanishes identically over some time interval of positive duration; thus, if

$$\psi(t) = B(n,t) + \lambda(t) \cong 0 \quad (36)$$

then the corresponding singular control $h(t)$ is determined as follows. Equation (36) yields

$$\begin{aligned} \frac{d\psi}{dt} &= \frac{\partial B}{\partial n}.\frac{dn}{dt} + \frac{\partial B}{\partial t} + \frac{d\lambda}{dt} \\ &= \frac{\partial B}{\partial n}h + \frac{\partial B}{\partial t} - \left(\frac{\partial H}{\partial n}\right) \\ &= \frac{\partial B}{\partial n}h + \frac{\partial B}{\partial t} - \frac{\partial}{\partial n}[A + (B + \lambda)h] \\ &= \frac{\partial B}{\partial n}h + \frac{\partial B}{\partial t} - \frac{\partial A}{\partial n} - \frac{\partial B}{\partial n}h \\ &= \frac{\partial B}{\partial t} - \frac{\partial A}{\partial n} = 0 \end{aligned} \quad (37)$$

But Equation (37) can be directly derived from the Lagrange's equation of the variational problem Equation (28). Hence Equation (37) is the equation of the singular path

$$n = n^*(t). \quad (38)$$

Therefore, $\psi(t) \cong 0$ corresponds to the singular solution given by Equation (38). Thus the maximum principle implies that the optimal control $h = \frac{dn}{dt}$ for a linear problem must be a combination of 'bang-bang' and a 'singular control'.

APPLICATION OF THE MAXIMUM PRINCIPLE TO FISHERY PROBLEM

For our problem the Hamiltonian H becomes:

$$H = e^{-\delta t}[p - C(n)]h(t) + \lambda(t)\left[rn\left(1 - \left(\frac{n}{K}\right)^{\alpha-1}\right) - h(t)\right]. \quad (39)$$

Therefore, the switching function is given by

$$\psi(t) = e^{-\delta t}[p - C(n)] - \lambda(t). \quad (40)$$

Consequently, the singular path $\psi(t) = 0$, gives

$$\lambda(t) = e^{-\delta t}[p - C(n)]. \quad (41)$$

But this is precisely what is obtained on setting $\frac{\partial H}{dh} = 0$. Thus,

$$\frac{\partial H}{dh} = e^{-\delta t}[p - C(n)] - \lambda(t).$$

or

$$\lambda(t) = e^{-\delta t}[p - C(n)]$$

which is precisely Eq.(41). When $n(T)$; is not specified, we invoke the 'free terminal-value condition', which reads

$$\lambda(T) = 0 \quad (42)$$

Now in our problem, since $p > C(n^*)$ the free-terminal-value condition Equation (42) implies that we must leave the singular path $n = n^*$ before $t = T$, while off the singular path we must use a 'bang-bang' control. Recalling that,

$$0 \le h(t) \le h_{\max}, \quad (43)$$

and comparing Equation (43) with Equation (30), we get the optimal policy for harvesting via Equation (34), that is, as $h = 0$ is not optimal, and $h = h_{\max}$ for $t \le T$, provides a positive contribution to present value. Therefore the policy should be:

(i) Singular path $h = 0$ for $t \le t_0$,

(ii) Maximum harvest $h = h_{\max}$ for $t_0 < t < T$.

CONCLUDING REMARKS

In this paper, we have examined the generalization of Gordon-Schaefer fishery model from the economic perspective. In view of physical aspect, the harvest rate has been determined by the current stock size and the rate of harvesting effort. The linearity in effort facilitates the application of the maximum principle and for optimal control we have applied the Pontryagin's maximum principle. In order to solve the proposed non-linear fishery model we have used the more powerful optimization techniques provided by the calculus of variation. We derived the conditions under which the system will exhibit optimality. The optimal control implies that, we should leave the singular path before the time horizon while harvesting is maximum near the final time because it provides a positive contribution to the present values. However, time near to time horizon provides a positive contribution to the present value.

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Full Length Research Paper

Livelihood diversification and welfare of rural households in Ondo State, Nigeria

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Agriculture, the main source of livelihood in Nigeria, especially in the rural areas, is plagued with various problems. As a result, most of the rural households are poor and are beginning to diversify their livelihoods into off and non-farm activities as a relevant source of income. This study examined the effect of livelihood diversification on the welfare of rural households in Ondo State. Primary data used in the study were obtained from 143 respondents selected employing a multistage sampling technique. Data were analyzed using descriptive statistics, multinomial logit and the logit regression models. The distribution of respondents by the type of livelihood strategy adopted revealed that almost three-quarters of the respondents adopted the combination of farm and nonfarm strategy. Econometric analysis showed that household size, total household income and primary education of the household head were the dominant factors influencing the choice of livelihood strategies adopted. Income from non-farm activities, as well as income from a combination of non-farm and farming activities, impacted welfare positively relative to income from farming activities. The study recommends the promotion of non-farm employment as a good strategy for supplementing the income of farmers as well as sustaining equitable rural growth.

Key words: Ondo State, livelihood diversification, welfare, rural households, Nigeria.

INTRODUCTION

In Africa, various studies have shown that while most rural households are involved in agricultural activities such as livestock, crop or fish production as their main source of livelihood, they also engage in other income generating activities to augment their main source of income. A majority of rural producers have historically diversified their productive activities to encompass a range of other productive areas. In other words, very few of them collect all their income from only one source, hold all their wealth in the form of any single asset, or use their resources in just one activity (Barrett et al., 2001). In Nigeria, the agricultural sector is plagued with problems which include soil infertility, infrastructural inadequacy, risk and uncertainty and seasonality among others. Thus, rural households are forced to develop strategies to cope with increasing vulnerability associated with agricultural production through diversification, intensification and migration or moving out of farming (Ellis, 2000). In other words, the situation in the rural areas has negative welfare implications and predisposes the rural populace to various risks which threaten their livelihoods and their existence. As a result of this struggle to survive and in order to improve their welfare, off-farm and non-farm activities have become an important component of livelihood strategies among rural households in Nigeria. Further, the growing interest in research on rural off-farm and non-farm income in rural economies is increasingly showing that rural peoples' livelihoods are derived from

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diverse sources and are not as overwhelmingly dependent on agriculture as previously assumed (Gordon and Craig, 2001). This could be owing to the fact that a diversified livelihood, which is an important feature of rural survival and closely allied to flexibility, resilience and stability is less vulnerable than an undiversified one, this is due to the likelihood of it being more sustainable over time and its ability to adapt to changing circumstances. In addition, several studies have reported a substantial and increasing share of off-farm income in total household income (Ruben and van den Berg, 2001; de Janvry and Sadoulet, 2001; Haggblade et al., 2007). Reasons for this observed income diversification include declining farm incomes and the desire to insure against agricultural production and market risks (Matsumoto et al., 2006). In other words, while some households are forced into off-farm and non-farm activities, owing to less gains and increased uncertainties associated with farming (crop and market failures), others would take up off-farm employment when returns to off-farm employment are higher or less risky than in agriculture. Mainly, households diversify into non-farm and off-farm activities in their struggle for survival and in order to improve their welfare in terms of health care, housing, sustenance, covering, etc. Thus, the importance and impact of non-agricultural activities on the welfare of rural farm households can no longer be ignored.

An understanding of the significance and nature of non-farm and off-farm activities (especially its contribution to rural household income or resilience) is of utmost importance for policy makers in the design of potent agricultural and rural development policies. Further, the rising incidence of low level of welfare of rural households in Nigeria, that remains unabated despite various policy reforms undertaken in the country, requires a deeper understanding of the problem and the need to proffer solutions to the problem through approaches that place priority on the poor and ways on which rural households through diversification can maintain their livelihood.

LITERATURE REVIEW

In Africa, the average share of rural non-farm incomes as proportion of total rural incomes, at 42%, is higher than in Latin America and higher still than in Asia (Reardon et al., 2000). Most evidence shows that rural non-farm activity in Africa is fairly evenly divided across commerce, manufacturing and services, linked directly or indirectly to local agriculture or small towns, and is largely informal rather than formal. Also, while households earn much more from rural nonfarm activity than farm wage labour, non-farm wage labour is still more important than self-employment in the non-farm sector (Reardon, 1999; Haggblade et al., 2007). Hussein and Nelson (1998) in their study on sustainable livelihood and livelihood diversification concluded that while livelihood diversification is normal for most people in rural areas of developing countries in Africa, non-agricultural activities are critical components of the diversification process. Further, livelihood diversification is pursued for a mixture of motivations and these vary according to context: from a desire to accumulate, invest and the need to spread risk or maintain incomes, to a requirement to adapt to survive in eroding circumstances or some combination of these. In addition, the character of livelihood diversification is dependent primarily upon the context within which it is occurring (the differential access to diversification activities and the distribution of the benefits of diversification). However, the poorest rural groups probably have the fewest opportunities to diversify in a way that will lead to accumulation for investment purposes.

According to Babatunde and Quaim (2009), the pattern of income diversification among rural households in Nigeria, showed that majority of the households have fairly diversified income sources. On the average, while only 50% of the total household income is generated from farming, the rest comes from different off-farm sources. However, there are notable differences across income strata. While farming remains the dominant income source for the poorest, off-farm occupation especially self-employed activities are the main sources of income for relatively richer households. Also, Ellis (2000) using regression models, showed that households have unequal abilities to diversify their income sources and that education, asset, endowment, access to credit, and good infrastructure conditions, increase the levels of household diversification. These factors improve the opportunity to start own business and find employment in the higher paying non-farm sector.

In other words, resource-poor households in remote areas are constrained in diversifying their income sources. Ibekwe et al. (2010) using double log regression, noted that a distress diversification hypothesis is supported by the negative relationship between nonfarm income and the farm output per hectare of land in South Eastern Nigeria. They accounted for household's involvement in nonfarm activities by reference to their demographic features and to other household specific characteristics such as occupation, education level, number of spouse(s), family size and land holding as well as farm output. It could be inferred from the result that land holding size, years of workers education, per hectare value of agricultural output, occupation and age of household head are the major determinants of nonfarm income at the household level in South Eastern Nigeria . The study suggested that economic and social factors should matter in nonfarm sector policy in Southeast Nigeria if diversification is to be encouraged.

MATERIALS AND METHODS

This study was carried out in Odigbo Local Government Area of Ondo State, Nigeria. Odigbo Local Government is headquartered in

the town of Ore town. It has an area of 1,818 km^2, a population of 230,351 persons and 11 wards (NPC, 2006). The major vegetation type in the area is rainforest with a slopy topography. The area is predominantly agrarian and notable food and cash crops grown in the area include: plantain, banana, cassava, maize, yam, cocoa, oil palm and kola. The region has averagely high temperature which ranges between 21 to 29°C and high relative humidity with two distinct seasons namely: the rainy season which lasts from March/April to October/November and the dry season which lasts from the rest of the year October/November till March/April. Primary data used in this study were obtained in a cross-sectional survey of rural households in the study area. The collection of data involved the use of structured questionnaires to obtain information on socio-economic and demographic characteristics such as household size, level of education, age of household heads, land holdings etc. as well as consumption expenditure, other indicators of well-being of the rural households and diversification activities of the respondents.

A multistage sampling technique was employed in selecting the representative households used for this study. The first stage was the purposive selection of Odigbo Local Government Area out of the eighteen Local Government Areas in Ondo State owing to the predominantly rural nature of the area. In the second stage, three wards out of the eleven wards in the Local Government were randomly selected while the third stage involved the selection of households based on probability proportionate to size of the households in the wards. Consequently, a random sample of 54 respondents were sampled in Oniparaga ward, 45 respondents from Ago-Alaye ward and 51 respondents from Araromi-Obu ward making a total of 150 households. However, due to incomplete questionnaire information by seven of the respondents, only information from 143 households was used for the study . These 143 households constituted the sample size used for the study. The analytical techniques employed in this study include: descriptive statistics, multinomial logistic regression and the logit regression models.

Multinomial logistic regression

When there is a dependent categorical variable, the multinomial logistic regression model is commonly used. The regressors are the same across all choices for each observation. The model is specified as:

$$p_{r(Y_{i=}\, j)} = \frac{\exp\left(X_i \beta_j\right)}{\sum_{j=0}^{J} \exp\left(X_i \beta_j\right)} \qquad j = 0\text{----}2$$

Where Yi = 3 unordered categories of livelihood strategies adopted by the respondents: Y1 = those who adopt non-farm strategy alone; Y2 = those who adopt a combination of farm and nonfarm strategies; Y0 = those who adopt farm strategy alone; Y0 is the reference case.

Welfare measurement

Following the adoption of Foster, Greer and Thorbecke- FGT (1984) class of poverty measures, households' total monthly expenditure was used to determine households' poverty status. The poverty line was constructed as two-thirds of the mean monthly per-capita expenditure of all households. This approach has been used by several researchers and institutions (NBS, 2005; Oni and Yusuf , 2008) as a measure of welfare. Households were then classified into their poverty status based on the poverty line:

$$FGT_{\alpha} = \frac{1}{N}\sum_{i=1}^{H}\left(\frac{z - y_i}{z}\right)^{\alpha}$$

Where Z is the poverty line; N is the total number of people; H is the number of poor who are below Z; yi is the expenditure of the ith individual; α is a "sensitivity" parameter which can take values between 0 and 2.

Hence, non-poor households were those whose monthly expenditure was above or was equal to two-thirds of the mean per capita expenditure of all households while those whose per capita expenditure was below two-thirds of the mean monthly per capita expenditure were classified as poor.

Logit regression model

Logit regression analysis examines the influence of various factors on a dichotomous outcome by estimating the probability of the event's occurrence. It does this by examining the relationship between one or more independent variables and the log odds of the dichotomous outcome by calculating changes in the log odds of the dependent as opposed to the dependent variable itself. The log odds ratio is the ratio of two odds and it is a summary measure of the relationship between two variables (Olayemi et al., 1995). The Logit model is presented as:

$$P = \frac{\exp(z)}{1+\exp(z)} \qquad (1)$$

Where P is the proportion of occurrence.

$$Z = \beta_0 + \beta_1 X_1 + \ldots\ldots\ldots + \beta_n X_n \qquad (2)$$

Where X_1 ..... X_n are the explanatory variables. The inverse relation of Equation 1 is:

$$Z = \ln\left(\frac{P}{1-P}\right) \qquad (3)$$

That is, the natural logarithm of the odds ratio, known as the logit. It transforms P which is restricted to the range [0, 1] to a range [–∞, ∞].

Y = Poverty status of households (Poor = 1, 0 otherwise).

The independent variables include:

X_1 = Age of the respondents (in years);
X_2 = Gender of household head (male = 1, 0 if otherwise);
X_3 = Primary education (yes = 1, 0 if otherwise);
X_4 = Secondary education (yes = 1, 0 if otherwise);
X_5 = Tertiary education (yes = 1, 0 if otherwise);
X_6 = Primary occupation of household head (farming = 1, 0 if otherwise);
X_7 = Own house (yes = 1, 0 if otherwise);
X_8 = Household size;
X_9 = Marital status (married = 1, 0 if otherwise);
X_{10} = Total household income (₦).

RESULTS AND DISCUSSION

Table 1 presents the socio-economic characteristics of

Table 1. Socio- economic characteristics of the respondents.

Variable	Frequency	Percentage
Age		
20-39	36	25.2
40-59	79	55.2
≥60	28	19.6
Sex		
Male	121	84.6
Female	22	15.4
Marital status		
Single	6	4.2
Married	117	81.8
Seperated/divorced	7	4.9
Widowed	13	9.1
Household size		
1-6	86	60.1
7-12	55	38.5
>13	2	1.4
Educational status		
No formal education (NFE)	23	16.1
Primary	55	38.5
Secondary	42	29.4
Tertiary	23	16.0
Primary occupation		
Farming	79	55.2
Artisan	16	11.2
Trading	31	21.7
Govt. salaried Job	17	11.9
Type of livelihood strategy		
Strategy adopted		
Farm only	10	7.0
Non farm only	28	19.6
Farm and non farm	105	73.4
Monthly income (₦)		
11,000 - 30,000	50	35.0
31,000 - 50,000	56	39.2
51,000 - 70,000	18	12.6
>70, 000	19	13.2
Total	**143**	**100.0**

Source: Field survey (2012).

the respondents. Results revealed that more than four-fifths (84.6%) of the households were headed by males while more than half (55.3%) of the respondents were in their economic active age. The average age of the respondents stood at 47.5 ± 11.9 years in the study area. While married household heads were in the majority (81.8%) in the study area, about three-fifths of the respondents had household sizes of between 1 and 6

Table 2. Reasons for diversification.

Reason for diversification	Frequency	Percentage
Limited agricultural income	7	4.9
Large family	2	1.4
Availability of nonfarm opportunities	3	2.1
Seasonal nature of agric produce	3	2.1
Favourable demand for goods and services	7	4.9
To live well	11	7.7
Limited agricultural income and large family	67	46.9
Limited agricultural income, large family and availability of non farm opportunities	20	14.0
Seasonal nature of agric produce and availability of non-farm opportunities	23	16.0

Source: Field survey (2012).

Table 3. Factors influencing the choice of livelihood strategy adopted.

Variable	Nonfarm		Combination of farm and nonfarm	
	dy/dx	Z	dy/dx	Z
Gender	14.10	0.01	12.63	0.01
Age	-0.057	-1.07	-0.001	-0.02
Household size	0.89	2.92*	0.65	2.53*
Total income	0.07	2.11**	0.001	1.86***
Own house	0.26	0.18	0.13	0.09
Married	-14.20	-0.01	-14.04	-0.01
Primary education	-2.55	-1.79***	-1.74	-1.70***
Secondary education	14.97	0.01	14.81	0.01
Tertiary education	-1.66	-0.84	-2.16	-1.26

Source: Field survey (2012). * significant at 1%, **significant at 5%, ***significant at 10%. Number of observation = 143. LR chi^2 (18) = 59.58. Prob> chi^2 = 0.0000. Log likelihood = -73.056464., Pseudo R^2 = 0.2896.

members. The average household size stood at 6.1 ± 2.6 in the study area. With respect to the educational status of the respondents, almost two-fifths of the respondents had primary education while only 16.1 had no formal education. This implies that most of the respondents have one form of formal education or the other. Highlights of the occupational analysis of the respondents revealed that more than half of the respondents were engaged in farming as their primary occupation, indicating that farming is the predominant occupation in the study area. This is expected as most households in the rural areas depend mainly on agriculture as their primary source of livelihood. However, literature has shown that diverse income portfolio, creates more income and distributes income more evenly. Thus, it is easier to adopt the combined livelihood strategies than switching full time between either of them (Ellis, 2000). In line with this, as shown in the table, very few of the respondents obtained income from only one source as almost three-quarters of the household heads engaged in a combination of farm and nonfarm activities. With respect to the monthly income distribution of the respondents, more than half of the respondents earn between ₦31,000 and ₦70,000 monthly while a little above one-tenth of the sampled respondents earn over ₦70,000 per month. The average monthly income of the respondents in the study area stood at ₦46,533 ± ₦24,315.

As presented in Table 2, most of the respondents had various reasons for diversifying into other activities. Some of these reasons include limited agricultural income, large family size, availability of non-farm opportunities, seasonal nature of agricultural produce, favourable demand for goods and services or a combination of these, among others. However, the main reason for diversification reported by almost half of the respondents in the study area was a combination of limited agricultural income and large family size.

The result of the multinomial regression analysis of the factors influencing the choice of livelihood strategies adopted by the respondents in Odigbo Local Government of Ondo state is presented in Table 3. The chi-square value of 59.58 which was significant at 1% level shows that the model has a good fit for the data. The marginal effects result of the regression is reported as follows.

Table 4. Poverty status of households.

Poverty status	Frequency	Percentage
Non-poor	82	57.3
Poor	61	42.7
Total	143	100.00

Source: Field survey (2012).

The coefficient of household size of 0.89 was significant at 1%, implying that an increase in the household size by one member increased the likelihood of adopting the only non-farm strategy by 0.89 relative to the adoption of the only farm strategy. That is, the larger the household size, the higher the likelihood of opting for the only non-farm livelihood strategy. This result is inconsonance with the findings of Harjes (2007), in which increase in household size increased the likelihood of adopting nonfarm activities. Similarly, the coefficient of total income of household of 0.07 was positive and significant, implying that a naira increase in total household income increased the likelihood of adopting the only non-farm strategy relative to the only farm strategy.

This may be owing to the fact that nonfarm activities give higher returns in terms of income. This finding corroborates the findings of Babatunde and Qaim (2009). On the other hand, the coefficient of primary education was negative (-2.55) and significant indicating that household heads with primary education are less likely to adopt the only non-farm strategy relative to the only farm strategy where they are likely to have better prospects. This result is supported by the findings of Norsida and Sadiya (2009) that individuals who have more years of schooling have a higher likelihood of participating in non-farm work. In other words, the higher the level of education, the higher the likelihood of participation in non-farm activities.

With respect to the choice of the combination of farm and non-farm strategy as a livelihood option, the coefficients of household size and total household income were positive and significant suggesting that a member increase in the household size and a naira increase in total household income increased the likelihood of adopting a combination of farm and nonfarm strategy. This could be owing to the fact that in large sized households, limited resources are spread thinly on maintaining a large number of people in terms of meeting their basic and other needs and the fact that increased household size is also synonymous with more dependants who do not contribute to household income. Thus, households in order to augment household income for meeting the basic needs of the family will engage in a combination of farm and non-farm strategy relative to the choice of the farm strategy only. This result corroborates the findings of Babatunde and Qaim (2009) and Ellis (2000).

On the other hand, the coefficient of primary education was negative and significant implying that household heads with primary education are less likely to adopt a combination of farm and nonfarm strategy. From these findings, it is evident that the major factors influencing the choice of livelihood strategy adopted in Odigbo Local Government area of Ondo State are household size, total household income and primary education of the household head. Per-capita expenditure was used as a proxy for welfare in this study. Based on this, the poverty line constructed as two-thirds of the mean per-capita expenditure of all the households stood at ₦2,752.03. This implies that households whose per capita expenditure fall below ₦2,752.03 were classified as poor while households whose per capita expenditure equaled or was above the poverty line were classified as non-poor.

Based on the poverty line, households were classified into their poverty status as either non-poor or poor as presented in Table 4. The table shows that 42.7% of households in Odigbo local government area of Ondo state are poor while 57.3% are non-poor. Table 5 presents the effect of livelihood diversification as well as other socio-economic factors that influence rural households' welfare in Odigbo Local Government area of Ondo State. The 'chi square' value of 107.35 which was significant at 1% indicates that the model has a good fit. The results of the marginal effects after Logit are reported as follows:

The coefficient of gender was negative and significant implying that households headed by males have a lower level of welfare than their female counterparts. Specifically, being a male headed household increased the likelihood of being poor by 0.313. Similarly, the coefficient of secondary education was negative implying that household heads with secondary education have a lower likelihood of being poor relative to those with no formal education. On the other hand, the coefficient of household size was positive indicating that a member increase in household size increased the likelihood of being poor by 0.132. This could be as a result of greater burden on the actively working members of the household.

While the coefficient of the use of firewood as a source of energy for cooking was positive, the coefficient of living in a flat/apartment was negative. This implies that households using firewood as a source of energy for cooking have a higher likelihood of being poor, while households living in a flat/apartment have a lower likelihood of being poor. These are reflections of the level of welfare of the households as these variables are usually determined by the level of income of such households. Income from non-farm activities as well as income from a combination of non-farm and farming activities, impacted welfare positively relative to income

Table 5. Effect of livelihood diversification on household welfare.

Variable	dy/dx	Coefficient	Z
Gender	-0.313	-3.546	-2.34**
Age	-0.086	-0.050	-1.54
Household size	0.132	0.772	3.56*
Married	-0.295	-1.424	-0.57
Primary education of HH	-0.209	-1.393	-1.30
Secondary education of HH	-0.287	-1.997	-1.74***
Tertiary education of HH	-0.149	-1.087	-0.86
Firewood	0.355	2.577	3.23*
Own house	0.127	0.836	1.24
Protective well	-0.100	-0.563	-0.86
Flat/apartment	-0.215	-1.351	-2.01**
Non farm income	-0.036	-3.299	- 4.52*
Farm + non-farm income	-0.411	-2.501	-3.09*

Source: Field survey (2012). *Significant at 1%, **significant at 5%, ***significant at 10%. Number of observation = 143. LR chi^2 (14) = 107.35. Prob> chi^2 = 0.0000. Log likelihood = -43.897308. Pseudo R^2 = 0.5501.

from farming activities only. This is expected as agriculture in the rural areas of Nigeria is largely characterized by low capital involvement, use of crude implements, poor infrastructural and storage facilities and human drudgery which ultimately leads to lower average earnings. Hence, nonfarm activities and a combination of farm and non-farm activities were pursued as strategies to increase household welfare in the study area.

CONCLUSION AND RECOMMENDATIONS

This study has shown that non-farm income plays a very important role in augmenting farm-income as almost three-quarters of the respondents adopted a combination of farm and nonfarm strategy. This is an indication that farming alone is not an adequate source of revenue for the rural households. Therefore, promoting non-farm employment may be a good strategy for supplementing the income of farmers as well as sustaining equitable rural growth. This could be achieved through training programmes directed towards training farmers in skills that can be used in non-farm jobs in their vicinity as well as improvements in infrastructure, education and financial markets.

Specifically, engagement in non-farm activities, apart from reducing income uncertainties and providing a source of liquidity in areas where credit is constrained, could increase agricultural productivity as it provides the resources necessary for investment in advanced agricultural technologies. The adoption of better technology is expected to be highly profitable and will encourage the transition from traditional to modern agriculture. Therefore, there is a need for the government to formulate policies to increase the availability of non-farm jobs in the rural areas. Further, the private sector should be encouraged to create income-generating activities in the rural areas to enhance their livelihood diversification activities and ultimately their living standard.

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The relative attractiveness of payment for the delivery of public extension visits

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The operational financial problems facing public extension services worldwide have led to calls for users of such services to contribute towards the recurrent cost of extension delivery to improve financial sustainability, accountability and service effectiveness. The paper, therefore, examined the impact of producer perception on the adoption of fee-for-public extension visits. A sample of medium and small-scale commercial crop farmers chosen by non-probability sampling techniques was interviewed using a semi-structured questionnaire, in September and October 2010 in three districts of the Free State Province of South Africa. A perceived low prominence of payment for the delivery of public extension visits was found to have a negative impact on acceptance to pay for the delivery of extension visit; awareness of the disadvantages as well as lack of awareness of the advantages of payment for the delivery of public extension visits also had negative impacts on acceptance to pay for the delivery of extension visits. This notwithstanding, survey findings showed that respondents do have a favourable perception of payment for the delivery of public extension visits. This bodes well for exploring this new idea further because it has the potential to generate extra operational funding to support the delivery of more public extension visits.

Key words: Relative attractiveness, operational finance, payment, delivery, extension visits.

INTRODUCTION

Persistent recurrent financial problems pose serious constraints to public extension worldwide, affecting both developed and developing countries (Fei and Hiroyuki, 2000; World Bank, 1994). This has led to calls for users of such services to contribute towards the operational costs of the service delivery to ensure the services' financial sustainability, accountability and effectiveness (Neuchâtel Group, 2002; Holloway and Ehui, 2001 cited in Anderson, 2008). The factors that contribute to financial problems in extension organizations have been documented. Among these are fluctuating budget trends due to shortfalls in national budget expenditures (FAO, 1990). The agricultural extension service in South Africa is not immune to these financial problems (Umhlaba Rural Services, 2007; National Treasury, 2009; Minister of Finance, 2011). Personnel expenditure is another factor that reduces the amount of money for extension field work (Sulaiman and Sadamate, 2000; National Treasury, 2003). High extension personnel expenditure in South African in the 1990s has been acknowledged (Ministry of Agriculture and Land Affairs, 1998). Ten years on, the problem still persists as Jacobs (2003) noted in the Western Cape extension service. Salaries and wages consumed 82% of the extension budget for the 2003/2004 financial year leaving only about R2 million (18%) as operating capital. Transport and communication constitute the bulk of the operating capital budget (Jacobs, 2003).

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According to Swanson and Rajalahti (2010), an effective extension system should allocate about 30% of the total extension budget to extension programmes and operation expenses, and no more than 65% for salaries and personal benefits. The prevailing situation in most extension organizations, however, is that up to 80% of the budget is used for salaries and benefits in most extension systems worldwide (Swanson and Rajalahti, 2010). Another issue causing operating financial problems in public extension organizations is the cost of extension visits. The latter takes up by far the largest proportion (47.15%) of extension funds (Wilson and Gallup, 1955). Dinar (1996) quoting Elkana and Epstein (1972) indicate that extension visits take up 39% of the total time of the extension advisor. This indicates that extension visits to farmers take up a lot of financial resources to accomplish. The effects of financial constraints on the effectiveness of extension work are well known. Fiscal constraints lead to limited resources for extension work (Feder et al., 1999) including lack of capacity (Working Group on Agricultural Extension, 2007). Farm visits are reduced to, perhaps as little as one per month or less (Oladele, 2008; Ajayi, 2006) or become irregular (Ulimwengu and Sanyal, 2011). Fiscal problems also lead to late release of budgeted funds, which negatively affects field extension work (Bagchee, 1994). In the South African context, some of these financial problems facing the free public extension service in the Provinces and their manifestations include the absence of extension advice and training to respond to participant needs among land redistribution for agricultural development (LRAD) beneficiaries (May et al., 2001; Umhlaba Rural Services, 2007).

Nationally in South Africa, extension agents mentioned the following in order of importance as what they saw as insufficient regarding different resources for extension work: transport, followed by available kilometres, then equipment and office accommodation and lastly, extension teaching aids (Düvel, 2002). The range of farmers served by the public extension is wide. Medium and small-scale farmers including LRAD programme beneficiaries targeted for this study comprises about 50% of the clientele of the public extension service. The vast majority of these farmers receive agricultural extension information/services through farm visits and this presents enormous financial challenges for the public extension service. There is potential for user co-financing of public extension services among other measures as has been discussed at policy level in South Africa, to solve some of the problems of financial sustainability (Ministry of Agriculture and Land Affairs, 1998; Department of Agriculture, 2005). There are indications that extension cost recovery initiatives are spreading around the world (World Bank, 2006 cited in Anderson, 2008). Among the extension activities that have been commercialized in some developed and developing countries are dissemination of information and direct contact with growers in the field (Dinar, 1996 citing Le Gouis, 1991). However, in South Africa, there is no empirical evidence that producers would accept to pay for the delivery of public extension visits. Some examples of payment for extension service including farm visits exist in the literature.

Most of these studies focus on payment for general extension services and the analyses center mainly on the independent factors of adoption or demand factors for example, Ajayi (2006) in Nigeria; Yapa and Ariyawardanain (2005) in Sri Lanka and Foti et al. (2007) in Zimbabwe. A few studies on payment for extension visits have also been documented. Similarly, the analyses are limited to demand and supply factors, while farmers needs and perceptions do not feature at all. These studies include Shekara (2001) in India; Holloway and Ehui (2001) in Ethiopia and Dinar (1996) in Israel. The mediating variables that is, needs of the farmer in relation to the extension innovation as well as the perception of the farmer regarding the adoption of an innovation or otherwise, that have been found to be key factors explaining the adoption of innovations more than the independent variables in many studies do not feature in these other studies mentioned hitherto (Duvel, 1975; Koch, 1987; Sartorius Von Bach and Gronewald, 1991; Louw and Duvel, 1993). A situation determination has to be based on a scientifically sound theory. Understanding the relevant determinants of adoption behavior and applying them in extension situation surveys to solve human-related problems in development work will make questionnaire design no more a hit –and- miss exercise but one that is based on the most important causes of human adoption behavior as proven by research. This is the expected contribution of this paper to current studies on farmer payment for extension farm visits.

Farmers in South Africa, including commercial farmers, do not pay for extension advice (Botha and Treunicht, 1997:44) and there is no indication to date that they are paying for the cost of farm visits. Policy proposals suggest the possibility of requesting farmers to make token payments for public extension services (Ministry of Agriculture and Land Affairs, 1998:47). To date, the researcher is not aware of any studies on user payment for public extension visits in this country. Without the knowledge of farmers' willingness to contribute towards the cost of farm visits, the operational budget for the public extension service, funded from treasury allocations alone, will continue to experience constraints in view of the fact that farm visits take up a large chunk of the recurrent costs of extension budgets for the majority of farmers services by public extension. Knowledge of this vital information will help policy makers to determine the most appropriate cost structure to put in place for farm visits that will ensure financial sustainability, so that this group of farmers in the study will continue to receive regular visits and, therefore, the agricultural information/services they require to run profitable farming

businesses. So far this knowledge about the potential contribution of medium and small-scale commercial farmers towards the financial sustainability of the public extension service is lacking within the public extension service. This study is expected to fill this knowledge gap through analyzing how attractive payment for public extension visits is to the producers. The study will also add value to the current literature by analyzing the key determinants of adoption in terms of payment for public extension farm visits. This attempt could increase our knowledge in terms of the relevant variables for farmers' acceptance to contribute towards public extension farm visits.

The purpose of this paper, therefore, was to determine impacts of farmers' perceptions on the adoption of payment for the delivery of public extension visits. Hypotheses to test this objective were:

$H0_1$: The perceived low prominence of payment for the delivery of public extension visits negatively influences the adoption of payment for the delivery of public extension visits.
$H0_2$: An awareness of the disadvantages of payment for the delivery of public extension visits negatively influences the acceptance to pay for the delivery of public extension visits.
$H0_3$: An unawareness of the advantages of payment for the delivery of public extension visits negatively influences the acceptance to pay for the delivery of public extension visits.

The paper begins with an introduction which sets the study problem in context and highlights the relevant literature on payment for extension visits with emphasis on gaps in the literature and contributions of the study to current literature and policy.

This section ends with a statement of purpose and research hypotheses. This is followed by the methodology that details the methods used to collect data, description of study sample, questionnaire variables and a specification of a statistical model to analyze the data collected. A theoretical framework within which the relevant variables for study are embedded is discussed. This leads to the adoption of the work of Duvel (1991) as the framework for analyzing the perception of respondents for a systematic and purposeful analysis of the relative attractiveness to the farmer respondents of payment for the delivery of public extension visits. The results of the study are presented next to report on whether or not the research hypotheses were supported as well as a discussion revealing the findings in relation to previous studies. The paper ends with summary and concluding remarks to highlight the major findings and implications for policy.

METHODOLOGY

A semi-structured, self-administered questionnaire was used to collect information from 97 medium and small -scale commercial crop farmers in three of five districts of the Free State Province of South Africa, from 1 September to 7 October 2010. Convenience and purposive approaches were the two non-probability sampling techniques employed because there was no list of farmers from which to select farmers. In one sense, the selection of respondents to be included in the survey was purposive sampling because those respondents were typical of the small and medium-scale farmers the researcher had in mind; in another, the selection was convenience sampling because those judged as typical were available and willing to participate in the survey. In addition to other information, the farmer questionnaire asked respondents to nominate any number of attributes of payment for the delivery of public extension visits that they saw as disadvantageous and advantageous. They were instructed to rank these nominations and also to indicate their willingness to pay for the delivery of more visits by the public extension agent. The number of the nominations represented the strength of a force/attribute. The prominence of payment for the delivery of public extension visits compared with the free public extension visits was assessed by asking farmers to state whether they thought payment for the delivery of more public extension visits could contribute a big difference (increase) or no difference/loss to the yield, gross farm income and level practice management they aspired to have.

Following Stockburger (1998), in which categorical variables with two levels may be directly entered as predictors or predicted variables in a multiple regression model, a multiple regression model was specified to study the relationship between the study variables and payment for the delivery of public extension visits. The prediction of Y is accomplished by the following equation:

$$\dot{Y}_I = b_0 + b_1 X_I + \varepsilon_1 \qquad (1 = 1, 2, 3,.....n) \qquad (1)$$

Where $\dot{Y}$ is the predicted value on the dependent variable, payment for the delivery of public extension visits, the b values are the regression weights or the coefficients of the predictor variables, the X's represent the various predictor variables (mediating variables), ε_1 is the error term and n is the number of observations.

The data were analysed using SPSS. The data analyses comprised descriptive statistics; Chi square (X^2) tests of independence, and multiple regression analysis.

Theoretical framework

All normal human behaviour could be said to be motivated. The means chosen, therefore, by the farmer to satisfy a primary goal are not necessarily the most appropriate ones, but the ones that are subjectively perceived by the farmer as being the most appropriate. For this reason, the farmer's views/perceptions are particularly important in understanding an individual's adoption behaviour or lack thereof. In this regard, Düvel (1974) postulated that in an effort to move towards a goal object to satisfy a need, the tendency (T) to move to a goal object to satisfy a need or act becomes important. This tendency to move depends on the perceived attractiveness or valency (V) of the goal object and the probability (P) that the goal object will satisfy the need. This can be represented by the equation:

$$T = f(P, V) \qquad (2)$$

There are problems associated with the accurate measurement of P; and because it is also reflected in V, particularly when the prominence of an innovation is determined, led to the proposition that it could be ignored (Düvel, 1974). The attractiveness relates to the advantages and disadvantages of the innovation. The adoption of an innovation also involves risk that adopters need to consider. Risks, however, are difficult to assess and predict, therefore, risk

Table 1. Advantages and disadvantages of payment for the delivery of extension visits (N = 97).

Perception	Nomination frequency per rank order								
Advantages	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**Total nominations**	**Total[1] weighting**
Respect	58	5	5	1	8	11	9	97	114
Demand	22	22	20	9	11	8	2	97	319
Accountability	36	7	8	9	21	13	3	97	212
Relationship	38	12	5	14	11	12	5	97	215
Efficient	27	21	18	7	8	9	7	97	293
More visits	27	18	22	22	6	2	0	97	328
Perception	**Nomination frequency per rank order**								
disadvantages	0	1	2	3	4	-	-	**Total nominations**	**Total[2] weighting**
Overtaxed	56	15	23	3	0	-	-	97	135
Can not afford	29	24	21	18	5	-	-	97	200
Neglect	53	5	8	25	6	-	-	97	94
Bribery	95	0	1	1	0	-	-	-	5

[1]Based on a weighting of 6 for 1st rank order etc, 1 for a 6th rank order and 0 for no advantage. [2]Based on a weighting of 4 for 1st rank order etc, 1 for a 4th rank order and 0 for no advantage.

perception could be distorted in various ways (Leeuwis and van den Ban, 2004). In view of these difficulties, one has to rely on an approach that is able to reduce the numerous factors of perception to a few that are able to adequately explain the variance in the adoption of an innovation for practical purposes. To achieve this, there was need to reduce the large number of intervening factors associated with behaviour analysis in the Tolman (1967) model to a manageable and practically, workable number, which is comprehensive enough to account for all causes of behaviour. Düvel (1991) in this wise, built on the earlier theoretical models (Lewin, 1951; Rogers, 1983) and proposed the mediating variables concept. The latter comprises needs, perception and knowledge.

To allow for a wider spectrum of specific forces, Düvel (1987) put forward a more refined list of Rogers (1983) attributes of an innovation and therefore, of perception. In this way, "relative advantage" was refined as relative advantages (Düvel, 1987) and the concept 'prominence' was introduced as an equivalent of Roger's innovation attribute, 'relative advantage' (Düvel, 1987). The relative attractiveness of an innovation is thus redefined to include its relative advantages and prominence (Düvel, 1987). The relative advantages concept (advantages and disadvantages) concurs with Leeuwis and van den Ban (2004) comment on the relationship between farmer evaluation of advantages and disadvantage of an innovation and adoption. The other dimension of perception in this redefinition is incompatibility of the innovation with the situation of the adopter (Düvel, 1987). The latter corresponds to the socio-economic, communication etc. circumstances of the adopter. They are subjectively perceived and make up what is commonly referred to as the independent variables of adoption and are, therefore, normally analyzed as independent variables. The perception of the attributes of an innovation, whether they are attractive (positive valency/forces that enhance adoption and correspond to 'advantages') or unattractive (negative valency/forces that restrain adoption and correspond to 'disadvantages'), therefore, is particularly important regarding the adoption of innovations (Düvel, 1987). These valencies relate to the field forces identified by Lewin (1951) as the direct causes of behaviour. The researcher, therefore, expects that an analysis of perception as immediate forerunner of behaviour will provide essential information for a systematic and purposeful analysis of farmer producers' contribution towards or payment for the delivery of public extension visits.

The relative attractiveness of the payment for the delivery of public extension, comprising the relative advantages and prominence, was, therefore, investigated in this study.

RESULTS AND DISCUSSION

The advantages and disadvantages of payment for the delivery of public extension visits

Table 1 provides a summary of respondents' opinions concerning the advantages and disadvantages of the payment for the delivery of public extension visits. In this case, 0 represents no advantage or not a disadvantage and 1 represents most important advantage or most important disadvantage, 2 is next most important advantage or next most important disadvantage, as the case may be etc. Findings (Table 1) suggest that only 27.8% respondents did not see more visits as an advantage of the payment for the delivery of public extension. All others saw an advantage; although ranked differently in paying for the delivery of more public extension visits; hence, more visits received the highest weighting (328). The possibility of demanding the type of service needed in a paid public extension system was an important perceived advantage and received the second highest weighting (325). Affordability was indicated as an important disadvantage, receiving the highest weighting of 200. Most respondents (70%) associated payment for the delivery of more public extension visits with high cost which they could not afford to pay and, therefore, saw it as a disadvantage. The issue of affordability again received a slightly higher nomination (38.1%) on a related question that asked respondents to indicate the most important hindrance/obstacle preventing them from accepting to pay for the delivery of public extension visits (Table 2). Most respondents (61.9%), however, had no

Table 2. The most important hindrance to respondents' acceptance to pay for the delivery of public extension visits as mentioned by respondents (N = 97).

Reason for not accepting to pay	Nominations by respondents	
	N	%
Financial	37	38.1
No problem with the idea	34	35.1
Non-financial	26	26.8

Table 3. Distribution of respondents perceived disadvantages of payment for the delivery of public extension visits according to their decision to pay for the delivery of public extension visits (N = 97).

Decision to pay	Respondents' per awareness category[1]							
	Low		Medium		High		Total	
	n	%	n	%	n	%	N	%
No	5	7.6	6	85.7	19	79.2	30	30.9
Yes	61	92.4	1	14.3	5	20.6	67	69.1
Total	66	100.0	7	100.0	24	100.0	97	100.0

X^2 = 52.826, df = 2, p = 0.000. [1]Based on total number of perceived disadvantages.

Table 4. Distribution of respondents perceived advantages of payment for the delivery of public extension services according to their decision to pay for the delivery of public extension services (N = 97).

Decision to pay	Respondents' per unawareness category[1]							
	Low advantage		Medium advantage		High advantage		Total	
	n	%	n	%	n	%	N	%
No	20	87.0	4	30.8	6	9.8	30	30.9
Yes	3	13.0	9	69.2	55	90.2	67	69.1
Total	23	100.0	13	100.0	61	100.0	97	100.0

X^2 = 46.501, df = 2, p = 0.000, significant at 0.01. [1]Based on total number of perceived advantages.

problem with the idea of payment or had reasons that were not financially related.

The awareness of the disadvantages and unawareness of the advantages of payment for the delivery of public extension visits were hypothesized ($H0_2$ and $H0_3$, respectively) to impact negatively farmers' decision to accept to pay for the delivery of public extension visits. The findings of the investigation of the influence relationships between awareness of the disadvantages and unawareness of the advantages of payment for the delivery of public extension visits and producers acceptance to contribute towards the delivery of public extension visits are presented in Tables 3 and 4, respectively.

The awareness of the disadvantages of payment for the delivery of public extension visits

There is evidence in the findings to suggest that study hypothesis ($H0_2$) was supported in view of the significant differences in opinions (p = 0.003). This was indicated by the fact that of the 30 respondents who would not pay, most of them (79.2 to 85.7%) saw two to three or more disadvantages in the payment for the delivery of public extension visits. This shows that survey respondents' awareness of the disadvantages of payment for the delivery of public extension visits negatively impacted their decision to adopt this idea. This finding concurs with past studies. Msuya (2007) found that non-adopters of recommended fertilizer application saw no advantages with the recommendation. Similarly, Hudson and Hite (2002) found that producers who perceive that the costs of the innovation under study outweigh the benefits had a much lower willingness to pay than producers who believed the benefits outweigh the costs.

Unawareness of the advantages of payment for the delivery of public extension visits

Analysis of data (Table 4) indicates that there was a

Table 5. Distribution of respondents' perceptions of the effect of payment for the delivery of public extension visits on yield according to decision to pay for public extension delivery visits (N = 97).

Decision to pay	Respondents' per prominence category					
	Not sure, no difference or loss		Big difference (increase)		Total	
	n	%	n	%	N	%
No	29	93.5	1	1.5	30	31.2
Yes	2	6.5	64	98.5	66	68.8
Total	31	100.0	65	100.0	96	100.0

Missing = 1, X^2 = 82.709, df = 1, p = 0.000, significant at 0.01.

Table 6. Distribution of respondents' perceptions of the effect of payment for the delivery of public extension visits on gross farm income according to the decision to pay for the delivery of public extension (N = 97).

Decision to pay	Respondents' per prominence category					
	Not sure, no difference or loss		Big difference (increase)		Total	
	n	%	n	%	N	%
No	26	96.3	4	5.8	30	31.2
Yes	1	3.7	65	94.2	66	68.8
Total	27	100.0	69	100.0	97	100.0

Missing = 1, X^2 = 73.979, df = 1, p = 0.000, significant at 0.01.

significant relationship between unawareness of the advantages of the payment for the delivery of public extension visits and the decision to pay for the delivery of public extension visits (p.001). The finding in this paper concurs with Duvel and Scholtz (1986) who found that the non-acceptability of recommended veld grazing management practices was due to unfavourable psychological field forces regarding the economic incentives of controlled selective grazing. Most respondents that would not pay (87%) saw no advantage or only one advantage in the payment idea. This finding, therefore, supported the research hypothesis ($H0_3$). In other words, survey respondents' unawareness of the advantages of payment for the delivery of public extension visits also had a negative impact on their decision to adopt this innovation.

Prominence of payment for the delivery of public extension visits

Although, the perceived advantages of payment provide a favourable picture for producers' acceptance to contribute towards the delivery of public extension visits as indicated for example by 69.2 to 90.2% of respondents (Table 4); it is possible that other alternatives, in this case, free public extension visits, are perceived to be more attractive and, therefore, more prominent. This would negatively affect the adoption of payment for the delivery of public extension visits. This assumption was tested by asking respondents to compare the free and the paid public extension visits, and to indicate what effect they thought payment for the delivery of public extension visits would have on their aspirations concerning yield, gross farm income and farm management practice. Table 5 summarizes respondent's perceptions on yield in this regard. The results indicate that the innovation, payment for the delivery of public extension visits, compared with free public extension visits, was not seen as being able to improve a respondent's increase in yields. The differences in opinions among respondents on this matter were highly significant (p = 0.003). Of the respondents who had a comparatively low view of the payment idea (31), most of them (93.5%) said they would not pay. In other words, they believed it would not help improve their crop yields. This low perception, therefore, would have a negative impact on the adoption of the payment idea.

Msuya and Düvel (2007) made a similar finding regarding the prominence of recommended seed spacing and its adoption. The research hypothesis ($H0_1$) was thus supported by this finding. The results in Table 6 suggest that there were differences in opinions of respondents concerning the effect of payment for the delivery of public extension visits on their aspired gross farm income compared with free public extension visits (p = 0.002). Similar to the findings in Table 5, of the respondents 27 respondents who had a low perception of the payment idea; most of them (96.3%) indicated they would not support the payment idea because they thought their gross farm income would be negatively affected. This finding again supported the research hypothesis ($H0_1$). The influence of perceived low prominence of payment for public extension visit on improvement of farmers'

Table 7. Distribution of respondents' perceptions of the effect of payment for the delivery of public extension visits on improvement in farm management practices according to decision to pay for the delivery of public extension (N = 97).

Decision to pay	Respondents' per prominence category					
	Not sure, no difference or loss		Big difference (increase)		Total	
	n	%	n	%	N	%
No	28	93.3	2	3.0	30	31.2
Yes	2	6.7	64	97.0	66	68.8
Total	30	100.0	66	100.0	96	100.0

Missing = 1, X^2 = 78.285, df = 1, p = 0.000, significant at 0.01.

management practices was investigated and the findings are presented in Table 7. The research hypothesis ($H0_1$) was again confirmed by the findings of this investigation (Table 7), because of the highly significant differences of opinion on this matter (p = 0.002). The findings here were similar to those presented earlier in Tables 4 and 5. Of the 30 respondents who would not pay, the majority (93.3%) also thought their farm management practices would not be any better by paying.

The finding in this study concurs with Habtemariam (2004) who similarly found that the majority of respondents who perceived the recommended phosphate fertilization to have a low prominence compared with the current practice did not adopt it. The study was based on non-probability sampling. This constrains the generalization of the findings to the wider population of medium and small-scale commercial crop farmers in South Africa. It might, therefore, require replication of the study using a probability sampling approach to further validate the conclusions in this study regarding the broader medium and small-scale cropping farmers. This limitation notwithstanding, does not invalidate the findings in terms of their ability to answer the research question and the contribution to the body of knowledge in the field of extension.

Conclusion

Respondents' perceptions were found to influence the acceptance to pay for the delivery of public extension visits. In all the three perception areas investigated namely, yield, aspired gross farm income and farm management practices in which the prominence of payment for the delivery of public extension visits was compared with free visits, the results were similar: a perceived low prominence of payment for the delivery of public extension services compared with the free services had a negative impact on the payment. Awareness of the disadvantages of the payment for the delivery of public extension visits had a negative influence on the acceptance to pay for the delivery of public extension visits. The single most outstanding disadvantage of the payment for the delivery of public extension visits was the perceived high cost. The respondents indicated they could afford it. Affordability again received the highest nomination as the most important hindrance to the acceptance to pay for the delivery of public extension visits. Affordability notwithstanding, most respondents mentioned reasons that were not financially related or had no problems with the idea of payment. This suggested that farmers were willing to contribute towards the delivery of public extension visits.

Unawareness of the advantages of payment for the delivery of public extension visits was also found to have negative influence on the acceptance to pay for the delivery of public extension visits.

This study has shown a number of negative forces (disadvantages of payment for public extension visits) that could hinder the adoption of payment for the delivery of public extension visits. To get producers to support the payment idea, there was a need, therefore, through extension programmes to systematically eliminate or weaken those negative forces (for example, public extension not worth paying for, public extension services need to be improved, paying too much tax already, reject the idea of paying for public extension services could lead to bribery in the department etc.) that could meaningfully be changed. A number of these negative forces relate to protests by respondents and once these are dealt with, adoption of payment for the delivery of public extension visits would not be hindered. The forces identified in this study with respect to payment for the delivery of public extension visits could become objectives in extension programmes to promote the adoption of this innovation as has been previously indicated. One way to overcoming resistance caused by affordability and improving the prominence of the payment idea so that all farmers buy into the idea, is to show more tangible evidence of increased financial benefits associated with payment by piloting the idea, as was done in Nicaragua (Keynan et al., 1997).

Another approach is to spread the cost of delivery that producers are to pay over a number of years so that as farmers' incomes from agricultural production increase, they are finally able to shoulder more of the cost. If government, for example, agreed with stakeholders that farmers would shoulder up to 25% of the total cost of delivering public extension visits, this could be staggered over say five years; in the first year of implementation,

farmers pay 5%, then 10% in the second year and so on as was done in Chile (Cox and Ortega, 2004). Group payment for an extension visit was another way to make it more affordable for individual producers, especially, where producers operate in groups as was the case with most of the farmers in this study. Evidence from the study, however, indicates that most respondents, who found the payment idea more prominent for example, would make a big, positive difference in their yields, would improve their aspired gross farm income or farm management practices than the free service had intentions to pay. Similarly, most respondents who saw one or no disadvantage or who saw more than three advantages said they would pay for the delivery of public extension visits. These findings bode well for the payment idea; policy makers need to explore this subject further and finally put plans in place to implement it because it has the potential to generate extra operational funding to support the delivery of more public extension visits.

The increased number of visits will expose producers to more farm management information and eventually improve their production, and profits, all things being equal.

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Review

Measuring the effect of climate change on agriculture: A literature review of analytical models

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This article provides a short overview of the principal models that can be used to estimate the effects of climate change on agriculture. The models are classified in relation to the following criteria: the specific impacts they aim to assess, their ability to measure production and/or economic losses, and the adoption of social indicators of the effects and responses. The weaknesses and strengths of the models are also identified and discussed. The most relevant factors for the choice of the most appropriate model are analysed. Through a comparative analysis of the literature, an easily adoptable scheme for selecting the most appropriate method to estimate the effects of climate change according to the characteristics of the case study is identified. The adopted classification scheme demonstrates that one model is capable of simultaneously considering many aspects related to climate change and classifying these in different class.

Key words: Climate change, impacts, agriculture, models.

JEL Classification: C50, Q15, Q51.

INTRODUCTION

Agriculture is one of the sectors most affected by ongoing climate change. The wide range of literature on this subject demonstrates that damages caused by climate change can be relevant to both cropping and livestock activities (IPCC, 1990; Adams et al., 1998). Climate change will have a significant effect on the rural landscape and the equilibrium of agrarian and forest ecosystems (Walker and Steffen, 1997; Bruijnzeel, 2004). In fact, climate change can affect different agricultural dimensions, causing losses in productivity, profitability and employment. Food security is clearly threatened by climate change (Sanchez, 2000; Siwar et al., 2013), due to the instability of crop production, and induced changes in markets, food prices and supply chain infrastructure.

Moreover, because of the multiple socio-economic and bio-physical factors affecting food systems and, consequently food security, the capacity to adapt food systems to reduce their vulnerability to climate change is not uniform from a spatial point of view (Gregory et al., 2005).

However, besides its primary role in producing food and fibres, agriculture performs also other functions, such as the management of renewable natural resources, the construction and protection of landscape, the conservation of biodiversity, and the contribution to maintain socio-economic activities in marginal and rural areas. Climate change could affects also this multifunctional role of agriculture (Klein et al., 2013).

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The ongoing effects of climate change require the individuation of mitigation policies to reduce greenhouse gas emissions and identify appropriated adaptation strategies that aim to contain agricultural losses both in market goods and environmental services (such as protection of biodiversity, water management, landscape preservation and so on). These strategies can easily be identified and applied if the economic effects of climate change on agriculture are assessed. However, creating models that are able to assess these effects accurately can present difficulties for several reasons. The first is data availability: while data are frequently available, they are often not disaggregated on the necessary temporal and/or spatial scales. Another reason is that research about the effects of climate change involves multidisciplinary skills and competencies because analyses of the effects of climate change involve many factors such as the consideration of (Bosello and Zang, 2005):

1. Climate and other induced climate-change environmental aspects,
2. Biological and plant physiology aspects,
3. Technical and socioeconomic factors,
4. Strategies to coping with the effects of climate change,
5. Impacts on/of the main economic adjustment mechanisms at the national and international level,
6. Feedback of the changed conditions on climate.

Economic and agricultural policies play an important role in such analyses, as does the geographical scale (e.g. local, regional or international) considered for the analysis. In addition to these aspects, it is also important to consider the temporal and spatial variability of the events which in turn causes a difficult predictability of future scenarios.

Considering all these aspects simultaneously is problematic. For this reason the literature proposes several models that are suitable for estimating the effects of climate change on agriculture addressing specific research issues. In light of this the present article offers an overview of the models most used to estimate the effects of climate change on agriculture (section 2) aimed to classify these models and to propose a logical scheme to help researchers in the selection of the model that best suits their research goals (section 3). The fourth section presents the conclusions.

LITERATURE REVIEW

The literature suggests that various models can be employed to assess the effects of climate change on agriculture. Each model has advantages and shortcomings, and presents different levels of complexity and completeness in relation to the specific aspects considered in its analysis. These peculiarities are discussed below for each models category.

The effects of climate change were evaluated by several scholars with consideration given only to the changes in the production of specific crops (principally maize, rice, cotton and soybean), using the so-called 'crop simulation models'. These models restrict the analysis to crop physiology, and simulate and compare crop productivity for different climatic conditions (Eitzinger et al., 2003; Torriani et al., 2007a). Crop models are considered 'agriculture oriented' because the analysis of these models is focused on the biological and ecological consequences of climate change on crops and soil. In these models, farmers' behaviour is not captured and the management practice is considered fixed. Moreover, they are crop and site specific, and they were calibrated only for the major grains and for a limited number of places (Mendelsohn and Dinar, 2009).

Others scholars estimated the sensitivity of yields to climate using empirical yield models that apply the production–function approach (Terjung et al., 1984; Eitzinger et al., 2001; Isik and Devadoss, 2006; Lhomme et al., 2009; Poudel and Kotani, 2013). The basic idea of this approach is that the growth of agricultural production depends on soil-related and climatic variables that are implemented as explanatory variables in the model for estimating the production function. Changes in climate scenarios are usually simulated using the general circulation model (GCM) (Chang, 1977; Randall, 2000).

In the production function approach, the economic dimension is of secondary importance and is considered in a partial and simplified manner (Bosello and Zang, 2005), even if these models produce important information for larger model frameworks that consider economy, later discussed. Some studies explicitly assess the economic impact of climate change through the estimation of the economic production function (Adams, 1989; Rosenzweig and Parry, 1994). However, other research evaluates the economic effects of climate change by implementing the results of agronomic analyses or of empirical yields models in mathematical-programming models (Kaiser et al., 1993; Finger and Schmid, 2007).

The main weakness of the production–function model is that it is crop and site specific. It endorses the so-called 'dumb-farmer' hypothesis, which excludes from analysis the plausible adoption by farmers of strategies for coping with the effects of climate change, for example, strategies that replace crops that are most sensitive with others that are less so (Rosenzweig et al., 1993; Reilly et al., 1994).

To overcome this limitation, Mendelsohn et al. (1994) proposed the Ricardian model. The principal characteristic of the Ricardian model is that it treats adaptation to climate change as a 'black box'. In fact it estimates the relationship between the outcomes of farms and climate normals using cross-sectional data and including, among regressors, appropriate control variables. As such, it implicitly considers farmer adaptation

strategies without the need to implement such strategies as explicit exploratory variables (Mendelsohn and Dinar, 2009).

However, this aspect could also represent a weakness in the model if the aim of the analysis were to estimate the effect of farmer adaptation strategies on climate change. Due to this weakness in analysis, models have been proposed that use mathematical programming to consider specifically farmer adaptation strategies (Adams et al., 1990; Kaiser et al., 1993; Mount and Li, 1994), especially concerning irrigation (Medellín-Azuara et al., 2010). However, these applications often suffer the limitation of considering hypothesised and simulated strategies that can be derived by incorrect simulation of the farmers' goal function.

The latest applications of the mathematical-programming model use positive mathematical programming (PMP) (Qureshi et al., 2010, 2013; Howitt et al., 2012). These surpass the traditional limitations of linear-programming methods, for example, the unavailability of detailed information about the relationship between inputs and yields through the function cost. In the field of the assessment of climate change impacts on agriculture this model is particularly suitable for analysis of the effects of drought on agriculture because it allows different aspects related to the use and availability of water to be explicitly treated. However, given that this model needs to consider data that can be difficult to collect (e.g. water cost by considering the source of water, the water requirements of crops, and the availability of water resources), its applicability is also limited.

More recently, other research has attempted to overcome the limitations of the Ricardian model in considering farmer adaptation strategies[1] by using econometric models estimated on farm survey data. These applications explicitly treat farmer adaptation strategies by using their proxies as explanatory variables (Di Falco and Veronesi, 2013a, b; Oluwasusi, 2013) or by modelling adaptation as the dependent variable (Gebrehiwot and Van Der Veen, 2013). These applications have the advantage of being able to estimate using the available data.

Moreover, they are suitable to be specified through sophisticated models that can consider specific characteristics of the database such as endogeneity, stratified samples, spatial correlation, and panel and time-series data. With such applications, it is also possible to hypothesise different equation functional forms (e.g. linear, log-linear, quadratic, Box Cox) as well as different distributions for the error term (e.g. normal, Weibull, probit, logit) while at the same time, using the most suitable estimator (e.g. ordinary least squares, maximum likelihood estimator) according to the specific model. However, the predictive ability is strongly connected with the accuracy of the model specification and the data quality. On this last aspect impacts the impossibility to consider strategies that are new. In fact in the past we did not have climate change so in the future new approaches need to be developed.

All the models that have been discussed focus on the agricultural sector, its specific branches, or crops without considering the relationships with other economic sectors. For this reason, further research developed general equilibrium economic models (GEMs) (Darwin et al., 1995; Borsello and Zang, 2005; Calzadilla et al., 2010a, b). GEMs examine the economy as a complex system composed of interdependent components (e.g. industry, factors of production, institutions and international economic conditions). GEMs have the advantages: to capture economy-wide and global changes, and to measure the effects of climate change on other economic sectors. Conversely, they are limited in that they aggregate in a single entity different sector characterised by specific economic and spatial dimensions. For example, agriculture is generally considered as an aggregate sector at the national level without considering its local specificities. Similarly, production factors (including irrigation water) are implemented in the model as undifferentiated commodities. Further, GEMs do not consider farmer adaptation to climate change or all dimensions, skills, and competencies that should be involved in the analysis of the effects of climate change (Mendelsohn and Dinar, 2009).

Consequently, researchers developed integrated assessment models (IAMs)[2] that combine the use of GCM with data on crop growing, soil usage, and economic models (Prinn et al., 1999; Kainuma et al., 2003). IAMs describe the causes and effects of climate change, integrating knowledge from different academic disciplines into a single framework to generate useful information for policymakers (Dinar and Mendelsohn, 2011).

The integration of such varied skills and disciplines means IAMs are often particularly complex. Moreover, interactions between agriculture and land usage with climate are only partially treatable in such models and the accuracy of this model is subject to the treatment of complex interactions (e.g. the availability and the competitive use of water between economic sectors). Another limitation is that productivity is treated as an exogenous variable, even if it is strongly correlated with the climate (Dinar and Mendelsohn, 2011). Tables 1 and 2 summarises the advantages and limitations for each of the models that have been discussed in the literature review.

[1] Seo and Mendelsohn (2008) propone a multiple-stage model called the structural Ricardian model that first estimates an adaptation model on farmer choice, and then estimates the conditional income for each choice using a traditional Ricardian formulation.

[2] For more information on IAMs, see: IMAGE (http://www.mnp.nl/en/themasites/image/index.html) or IGSM-MIT (http://globalchange.mit.edu/igsm/).

Table 1. Principal models used to estimate the effects of climate change on agriculture.

Model	Brief description	Advantages	Limitations
Crop simulation	This model restricts the analysis to crop physiology, and simulate and compare crop productivity for different climatic conditions	It is based on a deep understanding of agronomic science It is suitable to integrate effects of carbon dioxide fertilization It is calibrated to local condition	Analysis is focused on the biological and ecological consequences of climate change on crops and soil Economic dimensions are not considered. This model can be coupled with other models to better treat economic dimension. In the traditional formulation adaptation is not considered and the farmer's management practice is considered fixed. Some researchers consider adaptation exogenously. It do not consider crop's switching. It is crop and site specific It was calibrated for the main grains and for a limited number of places
Production Function	Yields sensitivity to climate is estimated assessing a empirical production function that links water, soil, climate and economic input to yields for specific crops.The effect of climate change is assessed by considering yield variations comparing two alternative scenarios. Future climate scenarios are usually simulated using a GCM.	Easy to estimate It is possible to measure the effect of weather on yields over time	Crop specific Social and economic dimensions of agriculture are considered of secondary importance. This model can be coupled with other models to better treat economic dimension. Assumption of the 'dumb-farmer' hypothesis (farmer adaptation strategies are not considered) Calibrated for a specific context; if the location is not representative, can provide biased predictions.
Ricardian	This model treats the full range of farmer adaptation strategies as a black box by performing a cross-sectional regression of land values or net revenues on climate normals and other control variables. Climate normals are calculated as averages in a long-term scenario (usually 30 years). The effects of climate change are assessed in terms of farm outcome variations, comparing the current situation to simulated scenarios.	Does not assume the 'dumb-farmer' hypothesis Easy to estimate Possible to consider spatial correlations and to analyse panel data Possible to elicit farmer adaptation in estimation if a multinomial logit model (e.g. a structural Ricardian model) is used.	Omitted variables, such as unobservable farm and farmer characteristics could lead to bias of unknown sign and magnitude In the traditional formulation, farmer adaptation strategies are considered but not explicitly treated In the traditional formulation, the role of irrigation is not considered. More recently, this variable was included among the regressors. However, it is not treated endogenously and multicollinearity problems are not adequately considered Analysis is focused on the economic dimension of agriculture and only indirectly on other dimensions (e.g. biological and social) Assumes a partial equilibrium model and does not consider relationships with other sectors Assumesthe output and input prices constancy and does not measure adjustment costs.

Table 1. Contd.

PMP	This is an economic management model estimated by solving a mathematical-optimisation problem using farm data. The pay-off function can be formulated considering the profit (to be maximised) or the cost (to be minimised). The latter, known as the Positive Mathematical Programming, surpasses the traditional limitations of linear-programming methods such as the unavailability of detailed information on the relationships between inputs and yields through the dual function cost.	Useful for assessing the economic effects of climate change, especially in the simulation of irrigation-farmer adaptation options and/or water policies, including water markets and irrigation efficiency improvement.	Difficult to estimate Often difficult to find data on technical coefficients and limiting production factors Assumes simulated farmer strategies not obtained from observed choices in specific climatic scenarios.
GEM	These look at the economy as a complex of interdependent components (e.g. industry, production factors, institutions).	Assumes a general economic equilibrium, considering all economic sectors Captures economy-wide and global changes such as those linked to input and output prices Provides information on the effect of climate change in different regions Measures the effect of climate change on other economic sectors.	Difficult to estimate Aggregates into one single entity sectors that are different in economic and spatial characteristics Production factors, including irrigation water, are considered in the model as undifferentiated inputs Difficult to analyse farmeradaptation strategies Doesnot allow consideration of details of the studied phenomena.
IAM	These are based on the joint use of General Circulation Model, crop growing, soil usage, and economic models. These models integrate different skills and competencies.	Analysis simultaneously considers all agricultural dimensions Generates useful information for policymakers.	Difficult to estimate These models can be very complex In some cases the required data are not available Interaction between agriculture and land use with the climate are only partially treatable Accuracy of model is subject to the treatment of the complex interaction between different factors, especially concerning water usage and availability Productivity is treated as an exogenous variable.

CLASSIFICATION OF MODELS, RESEARCH QUESTIONS TO BE ANSWERED, AND CRITERIA FOR CHOOSING THE MOST SUITABLE MODEL

To assess the effect of climate change on agriculture, the choice of the most appropriate model depends on the following factors:

1. The level at which the analysis needs to be conducted—this could be the agricultural sector; whole, or one crop, or a particular agricultural branch[3]

2. The (temporal or spatial) scale of analysis; as a

[3] The literature discusses numerous applications that estimate the effect of climate change on permanent cultivations (Lobell et al., 2006), viticulture (Tate,

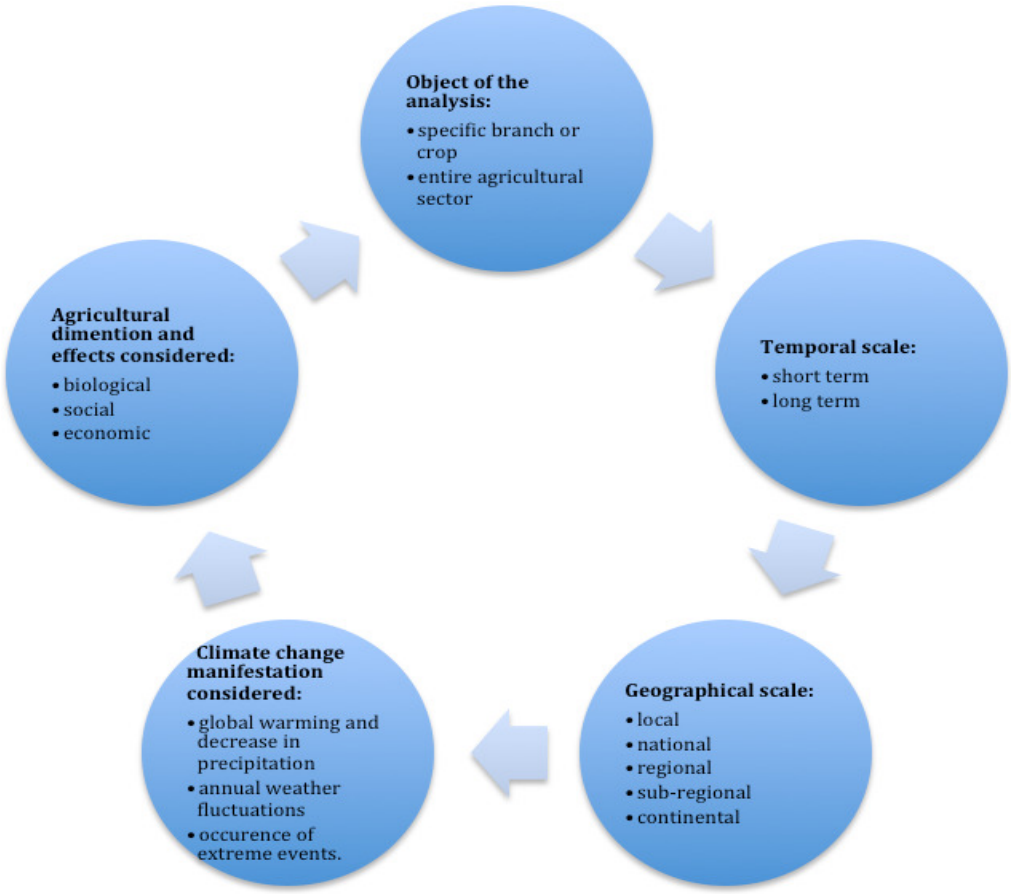

Figure 1. Aspects that influence the choice of model to be used; Source: Authors' elaborations.

whole, or one crop, or a particular agricultural branch[4];
3. The climatic phenomenon used to measure the analysed climate change (Tate, 2001; Bernetti et al., 2012), and livestock (Seo, 2008; Reynolds et al., 2010; Kimaro and Chibinga, 2013);
4. The agricultural dimension (biological, social or economic) with respect to which climate change impacts are assessed.

Figure 1 summarises the hierarchical links between these elements. The first aspect (the level of the analysis) and the fourth aspect (the agricultural dimension to be considered for estimating the effects of climate change) are connected. In fact, the models devoted to the analysis of the biological dimension of agriculture are crop specific; consequently, they concern only a single crop or branch. Conversely, the models devoted to assessing the effect of climate change on the social or economic dimensions of agriculture can consider the agricultural sector as a whole or one of its branches.

In reference to the scale of analysis it can concern cross-sectional, panel, or time-series data. In the latter case the length of the time period to be considered depends on the analysed scenario. The spatial scale can be very significant when the empirical evidence demonstrates that the magnitude of the effect of climate change varies significantly according to the location and the size of the areas studied. Previous research has highlighted that agriculture in warmer areas is more affected by climate change than agriculture in colder areas (Mendelsohn et al., 1994; Schlenker et al., 2005). However, the effects can vary dramatically on international, national and local scale (Bindi and Olesen, 2011). This variation in the effects is due to differences in adaptation strategies, which correlate highly with the local cultural, institutional and environmental conditions.

Another important issue to be considered is the specific manifestation of climate change that the model considers in calculating its effect on agriculture. This issue may concern:

1. A general increase in temperatures, accompanied by a decrease in precipitations characterising a long-term scenario (climate warming and precipitations change);

[4] The literature discusses numerous applications that estimate the effect of climate change on permanent cultivations (Lobell et al., 2006), viticulture (Tate,

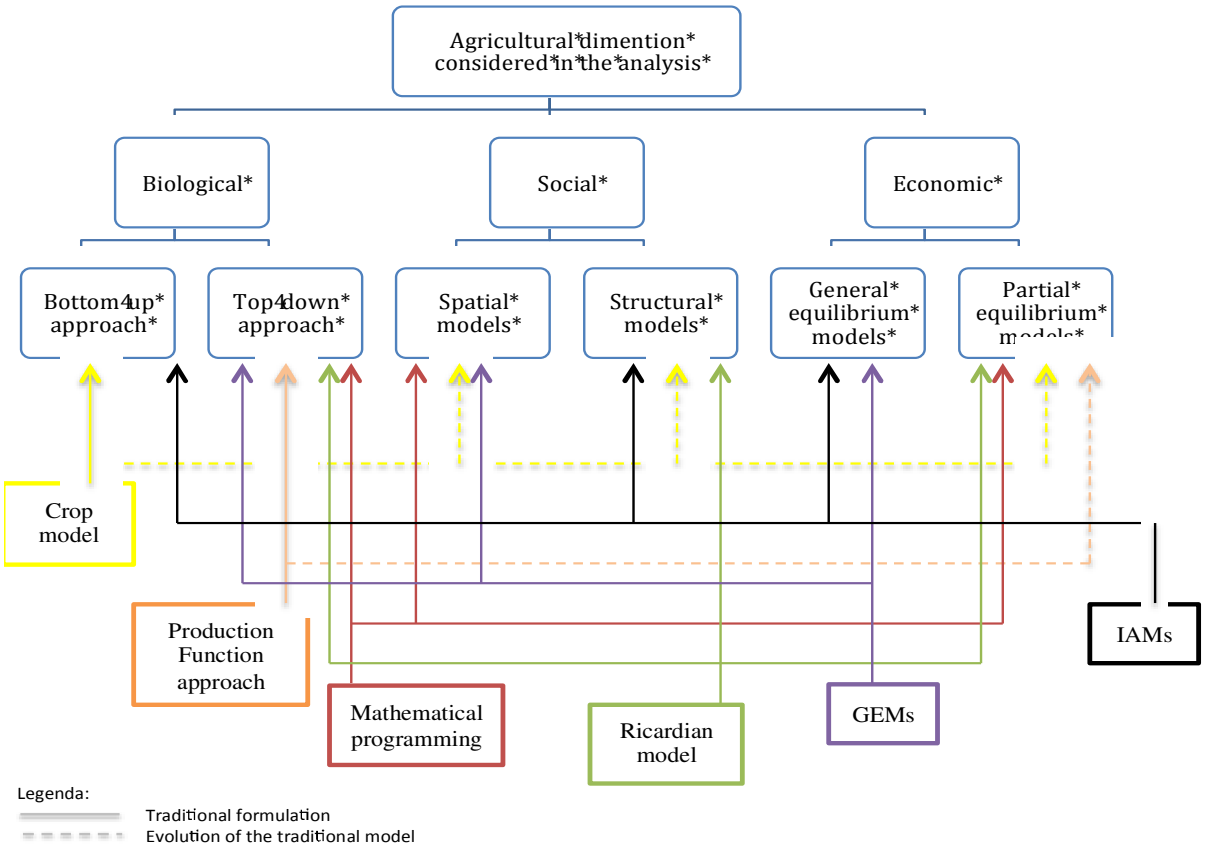

Figure 2. Classification of models by agricultural dimension, Legend: Traditional formulation; Evolution of the traditional model; Source: Authors' elaborations.

2. Annual fluctuations in the weather in terms of temperature and precipitations;
3. The frequency of extreme weather events such as droughts or floods.

Each of these aspects plays a different role and causes different effects on agriculture. The issue that has been the subject of most research is the effect of climate change in a long-term scenario. This has been widely analysed using the Ricardian model. The other two forms of the effects of climate change have been less investigated. Annual fluctuations in the weather were examined by Kelly et al. (2005) and Deschenes and Kolstad (2011). The effects of drought were analysed by Trnka et al. (2010, 2011) and of cyclones by Dasgupta et al. (2011). Figure 2 presents a classification of models that consider the biological, social, and economic dimensions of agriculture.

As demonstrated in Figure 2, if the focus is on the effects in terms of production change, by considering the biological aspects and their dynamics, it is possible to implement plant-physiology models that correlate the production output to climate variables or vegetation distribution behaviours. As such, it is possible to explain the spatial distribution of crops in relation to the climate scenario. In this case the model adopted is a bottom-up model (Bosello and Zang, 2005). Alternatively, it is possible to use a top-down model (or spatial analogue), which analyses crop reaction to climate change based on the productivity values in different temporal and spatial scenarios.

Further, in the assessment of the social effects, it is possible to distinguish spatial versus structural models (Bosello and Zang, 2005). Through the analysis of choices, strategies, and technologies used in different climatic and geographic scenarios, both of these models provide the possibility of forecasting behaviours will be adopted by farmers to face climate change.

Spatial models analyse variations in a farm's performance when dealing with climate change without considering farmer adaptation. This type of model hypothesises that such variations do not affect the prices of agricultural commodities and inputs. Consequently, this model does not consider the effects of climate change on agricultural demand and supply. Moreover, spatial models implicitly assume the absence of progressive farmer adaptation processes through changes in production cost in the short-term and medium-term scenarios. It follows that it is not possible to differentiate climate-change adaptations endorsed by the

Table 2. Characteristics demonstrated by the most commonly used models to assess the effects of climate change on agriculture.

Model	Object of the analysis	Temporal scale	Geographical scale	Climate change manifestation	Agricultural dimension			References
					Biological	Social	Economic	
Crop simulation	A specific crop	Short time	Local	Weather annual fluctuation	Treated	Not treated in the traditional formulation. It is possible to treat it exogenously.	Not treated in the traditional formulation. However it is possible to couple this model with larger model frameworks that consider economy.	Eitzinger et al. (2003), Torriani et al. (2007)
Production function	A specific crop, a group of crops or a particular ecosystem	Both short term and long term	All possibilities	All possibilities	Not explicitly treated	Treated in a secondary manner.	In the traditional formulationtreated in a secondary manner. Some studies estimate and economic production function. Others couple this model with larger model frameworks that consider economy.	Terjung et al. (1984), Isik and Devadoss (2006), Poudel and Kotani (2013)
Ricardian	The whole agricultural sector or a particular branch or crop	Long term	All levels, providing enough climatic variability is assured	Global warming and precipitations decreasing	Not explicitly treated	Not explicitly treated in the traditional formulation but explicitly treated in the structural Ricardian model	Treated	Mendelsohn et al. (1994), Schlenker et al. (2005), Seo and Mendelsohn (2008), De Salvo et al. (2013), Massetti and Mendelsohn (2011)
Econometric model	The whole agricultural sector or a particular branch or crop	Both short term and long term	All levels, especially local, national or regional	All possibilities	This depends on the model formulation	This depends on the model formulation	This depends on the model formulation	Schlenker and Roberts (2006), Deschênes and Greenstone (2007), Di Falco and Veronesi (2013a, b).
PMP	The whole agricultural sector or a particular branch	Both short term and long term	All levels, especially local, national or regional	All possibilities	Not explicitly treated in the traditional formulation. Some researchers treat it explicitly coupling this model with a crop simulation model	Treated	Treated	Quresh et al. (2010), Howitt et al. (2012), Qureshi et al. (2013)

Table 2. Contd.

GEMs	The whole agricultural sector or a particular branch if appropriately formulated	Long term	All levels, especially national or higher	All possibilities	Not explicitly treated	Not explicitly treated	Treated	Darwin et al. (1995), Calzadilla et al. (2010a, b), Trnka et al. (2010, 2011)
IAMs	The whole agricultural sector or a particular branch if appropriately formulated	Long term	All levels, especially national or higher	Global warming and precipitations decreasing	Treated	Treated	Treated	Prinn et al. (1999), Kainuma et al. (2003)

agricultural sector from those deployed by the economy as a whole, and neither is it possible to separate these adaptations from those put in place to deal with factors other than climate change (Molua and Lambi, 2007).

The structural models through which the physical, social, and economic responses of agriculture to climate change are analysed overcome these limits. However, the application of these models is sometimes hampered by a need for detailed information on business-management practices.

By focusing only on the economic dimension, applicable models can consider a partial equilibrium or a general equilibrium in sectorial and/or geographical terms. GEMs, or economy-wide models, were used to estimate the economic effect of climate change on agriculture (e.g. Darwin et al., 1995; Borsello and Zang, 2005; Calzadilla et al., 2010a, b). These applications look at the whole economy and consider the relationships between sectors. However, they present some limitations (Table 1) that are overcome by the partial equilibrium models, which focus on a part of the economic system, consisting of a single market or a set of markets or sectors (Deressa, 2007).

The microeconomic partial equilibrium models can omit important aspects of the issue being considered, for example:

1. The re-allocation of production factors,
2. Changes in demand for agricultural products,
3. The interrelation of the economic sectors,
4. The dynamics of international markets,
5. The endogenous nature of market prices for agricultural products and inputs.

Moreover, the partial microeconomic equilibrium models can be divided into two broad categories: models based on the simulation of the crop-growth processes (crop-growth simulation models) and econometric methods (Kurukulasuriya and Rosenthal, 2003; Deressa, 2007) that also include the widely used Ricardian models. The choice of the best model to assess economic effects depends heavily on the specific aspects that the analysis has to consider and on the level of detail (Table 2).

Conclusion

The assessment of the effects of climate change on agriculture and the choice of the model that better suite the research aims remains a complex area for several reasons. First, data are not always available and/or disaggregated on the necessary temporal or spatial scales. Second, such research involves different skills and professional competencies, which means that analyses have to consider biological and physiological aspects; technical and socioeconomic features; and adaptation strategies adopted by farmers and breeders to face climate change. Third, a relevant role is played by aspects related to economic and agricultural policies and to the geographical (local, regional or international) scale of the analysis. Finally, a valid model should consider the temporal and spatial variability of climate; the uncertainty of future climate scenarios;

and the feedback of agricultural changes due to climate change.

Consequently, the selection of the most appropriate model should consider different aspects of the research problem, for example:

1. The specific object of the analysis,
2. The temporal and geographical scales,
3. The specific forms of climate change that are being considered (e.g. climate warming, weather fluctuations or extreme climatic events),
4. The magnitude of the effects expressed according to the agricultural dimensions (biological, social and/or economic) that the analysis aims to consider.

The choice of the model to be implemented is one of the most important steps in a assessment project. In the analysis of the effects of climate change on agriculture, the literature offers a multitude of applicable methods and tools, each of them with specific advantages and disadvantages. Consequently, the choice of the best model can be difficult due to a lack of perfect knowledge of all the possible alternatives. The choice of the model to apply for analysis often follows the trend of the moment, and is applied without detailed analysis of all the assumptions and hypotheses underlying the model. Choosing incorrect models causes a bias of results and an increase in unexplained variability that worsens the analytical framework of an already very complex area issue.

This article attempts to address this lack of information by offering to researchers a useful tool with which to identify all the possible alternatives of models analysing the effects of climate change on agriculture. This article has reviewed the literature and discussed the most popular analytical methods that are presented in the literature, and that are: the Crop Simulation Models, the Production-Function Model, the Ricardian Model, the Mathematical Programming, the General Equilibrium Model (GEMs) and the Integrated Assessment Models (IAMs). It has classified methods of analysis according to the principal aspects that have to be considered in when selecting a model, with particular emphasis on the dimensions under which the effects of climate change should be expressed. The adopted classification scheme demonstrates that one model is capable of simultaneously considering many aspects related to climate change and classifying these in different classes.

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Financial constraints and entrepreneurial activity choice among clients of micro finance institutions in Jimma area

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The research is intended to assess the small holder entrepreneurs' enterprise choices under financial constraint. Adapting economic model of household-production interactions, results from a survey of 140 smallholders was used on multinomial logit regression techniques. The paper makes the case that the access to finance has limited effect on the choice of entrepreneurial activity than individual differences did. It was also found that majority of the problems the entrepreneurs faced have no significant association with access to credit rather with macroeconomic and institutional factors. There has also been strong association of human capital, physical and social capital with entrepreneurial activity choice, implying enhancement of smallholder's entrepreneurship need to take into account other socio-economic factors besides the access to credit. The activity analysis has also showed that there is an out-flock of entrepreneurs from agriculture to non agricultural sector which would have a critical implication on the country's endeavor to food security. Generally, the study reveals sets of key variables relevant to the smallholders' entrepreneurial activity choice, and provides an evaluation of intensity of the effects of the variables. The paper concludes by bringing these critical insights to bear on possibilities for designing microfinance programs that would help flourish smallholder entrepreneurship which would gear towards realization of the country's long run development plan.

Key words: Entrepreneurship, activity choice, micro finance.

INTRODUCTION

Background and justification

Sub-Saharan Africa as a whole remains the world's most technologically backward, food-insecure and politically instable region with a considerable part of the population remain undernourished. However, recently, countries like Ethiopia have been growing at a relatively fast rate, which in turn has led to improvements in several areas such as trade, mobilization of government revenue, infrastructure development, and the provision of social services (UNCTAD, 2012). Nonetheless, sustainability of the economic progress and diversification of potential sectors requires technical progress tailored to the country's varied agro-ecologies, development of supporting

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institutions and moreover boosting entrepreneurial skill of the smallholders[1]. It has been suggested as way to break the poverty trap is to encourage petty entrepreneurship among the poor, in order to foster production surpluses and hence economic progress in the region (Khalid, 2003; Naude, 2010).

Currently, global development is entering a phase where entrepreneurship will increasingly contribute to economic development by facilitating self employment, income distribution and competition. Entrepreneurship in this context pertains to the actions of a risk taker, a creative venture in to a new business or the one who revives on existing business. The rapid ascent of emerging markets has sparked a renewed interest in understanding the role entrepreneurs play in shaping the transformation of developing countries, and what determines smallholders' entrepreneurship (Andre´ van et al., 2005; Antoinette, 2009). There is ample evidence that entrepreneurship is a key factor for economic development by carrying out innovation specifically in the flourishing of small businesses (Levine 1997; Naude, 2010).

In contrast to the old 'top down' development, the current approach which emerged over the past decade is the development 'from below'. This approach assumes that development is based on stimulating local entrepreneurial talent and subsequent growth of indigenous companies. Despite several interventions by the government and various development practitioners to improve the livelihoods of smallholders, in Ethiopia, the issue of small scale entrepreneurship development remains a key challenge (Khalid, 2003). This partly related with the fact that most policy makers as well as researchers treat entrepreneurs as a homogeneous group of actors that are uniformly affected by economic conditions or policy interventions. This view misses very fundamental differences among the types of entrepreneurs (particularly smallholders) who choose to be engaged-in varieties of activities (businesses), which affect the economy in various ways.

Virtually all of the literatures on factors facilitating entrepreneurship development noted that financial constraints are one of the biggest concerns impacting potential entrepreneurs around the world (Khalid, 2003; Beck et al., 2009; Popescu and Crenicean, 2012). Studies have shown that the relevance of credit to entrepreneurial activity choice depends on the individual level differences than macroeconomic conditions or access to finance, that is, the attitudes, skills and actions of smallholder producers (Sanyang and Huang, 2010; Popescu and Crenicean, 2012). Impact studies of microfinance institutions on development have concentrated on assessing the effects of credit programs on borrowers' as individuals, and as members of their household and enterprises wellbeing, largely overlooking the effects of financial access on choice of entrepreneurial activities. Though, there is solid empirical evidence that improved access to credit spurs enterprise growth; little is known about what type of enterprises are preferred by smallholders and what factors influence entrepreneurial activity choices of borrowers.

Reviews of literatures on microfinance and economic growth display several dimensions of financial constraints but few were concerned with the association of access to finance and entrepreneurial activity choice. Moreover, there is hardly any work on the relationship between entrepreneurial activity choice and loan utilization among smallholders. Therefore, this paper characterizes the entrepreneurial behavior of smallholders based on their access to microfinance among the clients of Eshet, Harbu and OCSCO (Oromia Credit and Saving Share Company) in South western Ethiopia.

RESEARCH METHODOLOGY

Description of the study areas

The study was conducted in Jimma zone, which is one of the 13 administrative zones in Oromia Regional State. Jimma zone is one of the major coffee growing zones in the country; currently the total area of land covered by coffee in the zone is about 105,140 ha, which includes small-scale farmers' holdings as well as state and private owned plantations. The Zone accounts for a total of 21% of the export share of the country and 43% of the export share of the Oromia Region (Anwar, 2010). The survey considered smallholder households that are the clients of Eshet, Harbu, OCSCO (Oromia Credit and Saving Share Company) microfinance institutions in *Seka, Yebu* and *Agaro* districts.

Data and data sources

A community based cross-sectional study design was employed based on the framework of household production model. The data for the study were collected from secondary and primary sources. The secondary data were collected from documentations of the financial institutions surveyed, and District and Zone Finance and Economic development office. In the survey both formal and informal methods were employed to collect the required information from clients of the microfinance, and key informants. Self administered semi structured questionnaire and individual interviews using the pre-tested questionnaire were made to generate the household level data.

Sample size and method of sampling

A multi-stage mixed sampling procedure was adapted for selecting the sample of borrower, in which a two stage purposive sampling (to select the districts and the FA[2]s) followed by random sampling techniques (to select the households) was used. The sample districts were selected based on secondary information with the help of knowledgeable people about the area and information from the microfinance institutions. Three major FAs from each district were then identified based on distribution of the microfinance institutions, and accessibility. From total of these nine FAs,

[1] the dominant social/economic group in Ethiopia

[2] Farmers' Association

proportional to the population (clients of the microfinance institutions), 140 households were selected for the study.

Methods of data analysis

Descriptive analysis and econometric analysis were used for analyzing the data.

Descriptive statistics analysis

Descriptive and inferential statistics were applied in documentation of the basic characteristics of the sampled clients along with the portrayal of entrepreneurial activity in the area. This employed use of descriptive statistics. The study also tested variables individually whether they had an effect on entrepreneurial utilization of credit using the Chi-square, F- test and t-tests.

Econometric analysis

In household production, model households are basic economic units making a number of decisions in their day to day life. To analyze factors that determine household's choice of entrepreneurial activity, the multinomial logit model was used. Multinomial logistic regression is used to analyze relationships between a non-metric dependent variable and metric or dichotomous independent variables. Based on Liao (1994), when a single dependent variable takes on three or more discrete and/or when their natural ordering is not clear then the responses are usually called multinomial responses.

The multinomial version of these models has logit and probit specifications. But the multinomial logit model is preferred, not only because of its computational ease but also it is based on basic economic theory of utility maximization (Liao, 1994). The model is derived from random utility function (McFadden, 1973). In random utility model it is assumed that individuals maximize their utility by choosing one of the alternatives available to them. In this case, it is assumed that the borrower maximizes his/her utility by choosing one among the available mutual exclusive alternative to invest their return from microfinance institutions.

Specification of multinomial logit model

The specification of multinomial logit probability model is given below: First, let j denotes a given discrete business alternative for the borrower, which takes the value from 0 to 2 whereby; j = 0) represent household's choice to support [3]their job before the loan; j = 1 represents households who diversified their businesses; j = 2 represents household who begin new business. Then, choosing the j = 0 as standard regime and assuming that the sum total of probabilities of all the three entrepreneurial alternatives must be unity. Using the unordered random utility model specification used in Wooldridge (2002), the model for the i^{th} respondent faced with j choice presented as follows: Suppose that the utility of choice j is:

$$U_{ij} = X_{ij} + \varepsilon_{ij} \quad (1)$$

In general, for an outcome variable with J categories let the j^{th} business strategy that the i^{th} household chooses to maximize its utility could take the value 1 if the i^{th} household chooses j^{th} entrepreneurial alternative and 0, otherwise. The probability that a household with characteristics X chooses business option (entrepreneurial alternative) j, P_{ij} is modeled as:

$$p_{ij} = \frac{\exp(\beta j' Xi)}{\sum_{j=0}^{J} \exp(\beta j' Xi)}, \quad J = 1, 2, 3 \quad i = 1, 2...n \quad (2)$$

Where: P_{ij} = probability representing the i^{th} respondent's chance of choosing entrepreneurial option j, X_i = Predictors of response probabilities, β_j = Covariate effects specific to j^{th} response category with the first category as the reference.

$\beta_1 \ldots \beta_J$ are m vectors of unknown regression parameters (each of which is different, even though X_j is constant across alternatives). By setting the last set of coefficients to null (that is, $\beta_J = 0$), the coefficients β_i represent the effects of the X variables on the probability of choosing the J^{th} alternative over the reference category. In fitting such a model, J –1 sets of regression coefficients are estimated.

RESULTS AND DISCUSSION

Demographic and socio-economic characteristics

Age and gender of the respondents

Tables 1 to 5 present the summary statistics of several key household variables. The results of the household survey show that the mean age of the respondents was 39 years with average 9 years of working experience in the main occupational activities. The mean age for male respondents was 39 (n = 97) and female's was 41 (n = 43). With regard to nature of the business (whether respondents have changed their main occupational activity because of the credit) and its relation to age, respondents were grouped into two categories, where households opted to expand their main occupation (59%) are found to be greater than those undertook new activity (41%). As displayed in Table 1, the mean age 42 years for the former category is significantly greater than the later (35 years), which may imply that older people are either reluctant to take on new businesses.

As shown in Table 2, from a total of 140 respondents, 69% were male and 31% were female. Majority of male respondents (76%) have changed their main occupation as a result of the loan, while 59% of female were found to change their occupation, though no significant association was observed between gender and change of entrepreneurial activity. Female's lower propensity to change business (as compared to the male counterpart) is more likely due to their lack of access to information, or lack of appropriate incentives to act on the information as well as restricted decision power on some basic resources.

Educational status of respondents

Entrepreneurship is a high risk investment, and as such only non-risk-averse individuals are likely to begin new

[3] This may include loan use to expand the enterprise or to compensate the loss in the previous period and continue on the same business

Table 1. Demographic and economic characteristics of the households by nature of business.

Parameter	Nature of the business		Average	t-value
	New venture mean (SD)	Expansion mean (SD)	Mean (SD)	
Age	35(9)	42(10)	38(11)	3.6***
Family size (Adult equivalent)	3.4(2.1)	4.2(2.3)	3.8(2.2)	1.98**
Formal education level/grade	7.28(3.4)	7(3.8)	7(3.6)	0.55
Land size (Hectares)	1.3(1.4)	1.6(1.8)	1.5(1.6)	1.06

***, ** statistically significant at 1%, 5% significance levels, SD = standard deviation.

Table 2. Gender and pre-loan economic activity of respondents by the nature of business.

Description		Nature of the business		Chi-square value
		New venture (N %)	Expansion (N %)	
Main occupation	Crop dominated livestock (I)	9	26	13.3***
	Pity trade dominated livestock (II)	15	12	
	Pity trade dominated crop (III)	10	14	
	Crop dominated pity trade (IV)	7	5	0.46
Gender	Female	11	20	
	Male	30	39	

***, statistically significant at 1% significance levels.

Table 3. Respondent's characteristics and post loan entrepreneurial activity.

Parameter	Entrepreneurial activity			Average	F - value
	Agriculture mean (SD)	Pity trade mean (SD)	Off-farm mean (SD)	Mean (SD)	
Age	43(10)	37(10.2)	35.6(9)	38(11)	7.3***
Family size (Adult equivalent)	4.5(2.5)	3.5(1.9)	3.4(1.2)	3.8(2.2)	3.6**
Formal education level/grade	7.4(3.9)	7.5(3.8)	6.2(3.5)	7(3.6)	1.5
Land size (Hectares)	2.3(2.3)	0.85(0.45)	0.88(0.46)	1.5(1.6)	8.1***

***, **, statistically significant at 1%, 5% significance levels respectively, Adult equivalent = AE, Hectares = ha.

Table 4. Relationship between nature of the business and the major problems faced.

Major problems	Nature of the business		Total %	Chi-square value
	New venture N (N %)	Expansion N (N %)		
Inadequate training/inception	11(8)	26(19)	27	13.254***
Poor follow up/support	6(4)	22(16)***[a]	20	
Limited marketing support	30(21)***[b]	21(15)	36	
Liquidity constraint	11(8)	13(9)	17	

*, **,* statistically significant at 1%, 5%, 10% significance levels.

venture (Miner and Raju, 2004). Education influences the selection to become an entrepreneur through various mechanisms. Primarily, human capital influences occupational choice and performance patterns within occupations. Mean educational attainment of household heads was 7 years of schooling, and 77% of respondents were found literate (Table 1). The survey found that women without formal education out-number men in the

Table 5. Relationship between nature of the business and Loan cycle.

Loan cycle	Nature of the business		Total N%	Chi-square value
	New venture (N%)	Expansion (N%)		
1st	17	14	31	18.31***
2nd	4	14***a	18	
3rd	6	20***a	26	
4th	15***b	10	25	

***, statistically significant at 1%, significance level, ***a there are significantly higher numbers of respondents expanded their business within 2 to 4 cycle than the other category, **b those who have embarked on new business in their 1st and last season are significantly higher than the ones did not.

same category. However, women's average formal education (7.41 years) is greater than that of male (6.21 years). This possibly is because of the fact that micro finances target on improvement of disadvantaged social classes; however males with higher education level mostly have further prospects elsewhere. In the independent sample t-test analysis, the average year of formal schooling for the ones changed their main occupation (7.3 years) was greater than (6.9 years) the respondents did not change their occupation.

Farm size and land tenurial status

The farm size was expressed in terms of amount of land actually cultivated in any farming season. the result showed that 16% (n = 23) respondents did not have title to land, among the respondents having land use right (83%) worked on pieces of land less than two hectares, only twelve (one percent) worked on more than two hectares of land. As illustrated in Table 1, the average farm size in the sampled households is 1.7 ha.

The evidence on the relationship between land size and change of business activity because of the loan demonstrates (Table 1), the respondents that changed their main occupation have less average land holding (1.3 ha) than the respondents opt to expand their existing business (1.6 ha). However, no or weak statistically significant correlation has been observed between land holding and the nature of the entrepreneurial activity undertaken.

Main occupational activities

The result of the survey on main occupational activities prior to the loan recognized four main activities. These are crop dominated livestock production, petty trade dominated crop production, petty trade dominated livestock production and crop production dominated petty trade. However, the activities are not mutually exclusive, for some of respondents simultaneously engaged in two or more occupations in varying degrees. As shown on Table 2, out of 140 household heads, 41% reported crop dominated livestock as their main occupational activity and 26% exercised petty trade dominated livestock, 24% engaged in petty trade-dominated crop farming and while 9% crop farming-dominated petty trade as their main source of income. As evident from Table 2, due to the loan, 40% of crop dominated livestock, 53% of petty trade dominated livestock production, 36% of petty trade dominated crop farming, and 31% of the crop dominated petty trade have changed their main businesses. The analysis of response on change of business entails that only less than a third of the respondents preferred to be engaged on agricultural production, while the remainders resorted to pity trade with varying degree of intensity. The out flock of entrepreneurs from agriculture to pity trade has a remarkable implication on the country's endeavor to food security and curbing food price hicks even though it widens the economic pillars. The activity shift from agriculture to non agriculture sector increases the general consumers while decreasing the number of food producers at least in the short run which may end up hiking up food prices.

The main occupations the respondents engaged-in after the loan are displayed in Table 2, where a significant association has been observed on age, family size and landholding of the respondents with the entrepreneurial activity engaged-in because of the loan. As it is noticeable in Table 3, household heads in the agriculture businesses (average of 43 years) are significantly older than that of petty trade (37 years) and off-farm activities (35 years) implying the scarcity of productive labor and product in agriculture sector. Similar to age of the respondents, the family size (4.5 AE) and agricultural land size (2.3 ha) in agricultural activity of the respondents was significantly higher than the ones in petty trade with 3.5 AE and 0.85 ha, and that of off-farm activity was 3.4 AE and 0.88 ha, respectively.

The main product the micro finances offer in the survey areas is a group-liability loan, followed by saving. Groups are formed by average of 6 to 10 members who agree to mutually guarantee the reimbursement of their loans. The loan size increases by 50% as the client progresses from one loan cycle to the next. The loan amount ranges from

1,000 Br to 5,000 Br per member depending on loan purpose and length of client ship. The entrepreneurs take on the following three major activities after the loan:

i. Petty trade (local food and drinks processors, cart transport, small hotels and tearooms and other retail activities) accounted 44%;
ii. Off-farm loan (handicraft, cattle fattening, cereal vending) 32%;
iii. Agricultural (purchase oxen, dairy) 24%.

As displayed in Table 4, respondents' rank the major problems encountered in the business decision process, where limited marketing support (36%) was the dominant problem followed by inadequate training during inception of the business (27%). There was a significant association between the problem faced and the entrepreneurial activity adapted. The number of respondents that reported limited 'market support' as a dominant problems are significantly larger under new business option than the ones expanded their older job, whereas respondents who ranked 'poor follow up' as a major problem are significantly greater in the group expanded their older business than the ones embarked on new ventures. This implies that majority of the problems faced by the entrepreneurs are not directly related to finance, but rather arise as a result of weak institutional support and linkages. This may mean for financial institutions to integrate their training and monitoring with extension and marketing services of concerned stakeholders.

Significant association was observed between lengths of participation in the lending program (loan cycles) and the nature of entrepreneurial activity tailored. Table 5 reveals that new clients have changed their business more proportionally than the relatively established clients. The evidence from Table 5 shows that majority of respondents (17%) that get on new ventures managed to change their activity on the first loan cycle. Possibly it is related with lack of entrepreneurial skill (poor training during inception and follow up). Focus group participants indicated that most of the clients are doubtful whether their business would be able to pay the debt, mainly in the first season. However, according to key informant's discussion, based on the performance form the first season, in the second and third years of their client ship, borrowers look for entrepreneurial solutions for their businesses.

Determinants of clients' choice of entrepreneurial activities

Prior to conducting the analysis multicolliniarity among the explanatory variables was checked so that the parameter estimates will not be seriously affected by the existence of multicolliniarity among variables. The variables were tested for hetroskedastisity and the test rejected for all variables, the null that there is a significant difference among the variables in the same group variances. Besides, practicality of the multinomial logit model depends on the independence of the alternatives (Liao, 1994).

In order to check the independence of the alternatives Haussmann's specification test of independence was undertaken. The test did not reject the null hypothesis of independence of the included business options suggesting there is no evidence against the specification. Also, because of the Haussmann's endogeneity test 'income of the household head' is left out of the model for it is endogenous with occupational choice. Finally, as shown in Table 6, the estimated model fitted the data reasonably well; the likelihood ratio tests indicated that the slope coefficients were significantly different from zero at less than 1% significance level.

DISCUSSION OF RESULTS

Age

The age of the household head measured in years is a continuous variable implying experience in his/her main activity. It was found to be significantly and positively related to diversification option but negatively related to business expansion option. This positive sign entails that, keeping all other variables constant, the likelihood of diversifying the business at hand increases as the age of household head increases, as compared to expanding/sustaining the business. Whereas the negative sign in the expansion column imply that an increase in age is negatively related with the probability of expanding businesses as compared to staying in the same business (Table 6).

This is principally, at older ages the physical ability of the household head decreases to manage the available business let alone to expand it; however households diversify their enterprises to sustain that level of income which may support livelihood of the family. Furthermore, in relation to an increase in age, social responsibility shares the time otherwise would have been used for the main occupation. Additionally, individuals who have stayed for long in a business may establish a goodwill or social capital (regular client) in the business which they are less willing to change because of loss of their regular clients and fear of institutional arrangement in the new business.

An increase in the age of the household head by a year increases the odds of choosing the diversification option increases by 16% and the likelihood of expanding the business at hand decreases by 1.2%. Corresponding to this, Sinha (1992) also elucidated that older people are risk averse and choose to widen their means of guaranty. This result is also consistent with standard job-shopping

Table 6. Multinomial logit estimates of determinants of clients' entrepreneurial options (Marginal effects).

Explanatory variables	Expansion $\frac{\partial y}{\partial x}$ (Z value)	Diversify $\frac{\partial y}{\partial x}$ (Z value)	NewBizz $\frac{\partial y}{\partial x}$ (Z value)
AGE (age number of years)	-0.010(-1.19)	0.016(2.03)**	-0.005(-0.51)*
EDULEV (education in years of formal schooling)	-0.048(1.24)	0.01(2.19)**	-0.05(1.2)*
FAMSZ (family size in Adult equivalence)	0.121(0.78) ***	.000(2.76)***	-0.121(-2.69)
TLU (livestock In TLU)	-0.001(-0.27)	-0.002(-0.41)	0.003(0.64)
Land (farmland in hectare)	-0.000(-0.91)	0.000(2.8)	-0.000(-1.19)
CRIS (expected risk in probability)	-0.049(-1.34)	0.03(0.79)	0.019(-0.80)
Social expenditures in Birr	0.094(-1.69)	-0.149(-2.95)**	0.055(0.52)
Marketing information (Yes/no)	-0.105(-2.54)	0.100(2.34) **	0.005(0.67)
Market price (in Birr)	0.012(0.78)	-0.000(-2.12)	-0.011(-2.21)
Multiple sourcing (Yes/no)	0.09(0. 90)	-0.171(-2.01)	0.08(0.80)**

***, **,*significant at 1%, 5%, 10% respectively, $\partial y/\partial x$ = marginal effects. Number of observations = 140, Wald chi^2 (24) = 60.05, Prob > chi^2 = 0.0001, Log pseudo likelihood = -119.790, Pseudo R^2 = 0.1971.

models such as Johnson (1978) and Miller (1984) which predict that younger workers will try riskier occupations first, and their argument that the probability of switching into new ventures is roughly independent of age and total market experience.

Education

Formal years of schooling of household head (a discrete variable) was found to be negatively and significantly correlated with the new venture option, and positively with the diversification option. The negative sign points out that as education level of the household head increases the possibility that the household chooses to engage in new business contracts as compared to expanding the old business. This is possibly because as level of education increases, households analyze the risks associated and interpret the available information in a more productive way than lower education level.

Hence, smallholder households with a better knowledge did seen to engage in new businesses (lose their guaranty) unless the information they get persuades them to do (opportunity cost of adapting the strategy is lower). More importantly, poor households are known to distribute risks over portfolios of asset (Siegel and Alwang, 1999). Thus, as the level of education increases by a year of schooling, the probability that the household will choose to engage in new business falls by 5% while, the probability to diversify the business increases by 1% as compared to the reference category. Similarly, Van der Sluis and Van Praag (2008) studied the relationship between education on entry into and performance in entrepreneurship in developing countries; the relationship between schooling and performance is unambiguously positive.

More education increases the outside opportunities and drive potentially successful entrepreneurs to other occupations where the marginal value of additional education is higher than for entrepreneurship. This result is consistent with the view that men with better education level are more likely to switch into new ventures if they have better assets. However, micro finances are meant to serve the disadvantaged social groups that lack basic resources. Therefore, besides the education level, the wealth status of the household determines entrepreneurial activity choice.

Family size

Family size measured by adult equivalence was found to have a positive and significant relation with the new business and diversification options. The positive relationship between economically active labor force and choosing the new business position entails that keeping all other variables constant, the probability of being engaged in new ventures increases as the economically active family size increases.

The marginal effect of an increase in amount of labor by one adult equivalent increases the likelihood of opting for new venture by 7.2%. It is possibly because changes in family composition and in the roles as well as relations of family members have implications for the emergence of new business opportunities (entrepreneurial skill), opportunity recognition, business start-up decisions, and the resource mobilization process (Aldrich and Jennifer, 2003).

In other way, in view of the fact that the household head need to support all the members, he/she looks for opportunities to diversify and secure livelihood. Therefore, an increase in family size by an adult equivalence increases the probability to diversify by infinitesimally smaller percentage. The percentage is so

smaller because the unit of measurement, adult equivalence, gives higher weight to the more economically active labour (and so less for the non productive family member).

Land size

The variable measures the size of productive land holding in hectares. It represents household's physical asset holding and influences the nature of the activity the household may undertake. The analysis exposed that, as the size of land holding increase, the households' likelihood to expand the available business increases. In other way, land shortage is positively associated with the likelihood of new business option. Families without land usually rely on their livelihood income from working as hired labor or non-farm activities. This enhances the opportunity to come across and learn the nature of different businesses, which may boost the likelihood of engaging on new ventures whenever limitations are alleviated. The marginal effect of an increase in a hectare of land increases the probability of expanding the existing business by less than one percent. As Vollrath (2007) discussed, land inequality can be an important factor influencing the propensity to become an entrepreneur through different channels mainly for land can be used as collateral for bank loans, especially in cases of loans needed to start a new firm or to enlarge an existing one.

Multiple sourcing

It is a dummy variable having value of 1, if the household has multiple sources of credit and 0 otherwise. The variable, whether the household has borrowed from multiple sources or not, correlates positively and significantly with new business option if the household had more than one source. The positive relationship shows that, other variables fixed the odds in favour of choosing to set up new business increases, if the borrower had multiple sources as compared to expanding the existing business. Roughly, it means that if the household has single source of credit, the possibility of expanding his business increases. This may seems to correspond with Crépon et al. (2011), argument that money is fungible and credit is only loosely monitored, and one might have expected that the loans would help those who desired to start something new. However, particularly in this case, it is the inadequacy of amount of loan sighted as the reason for the positive relation between multiple sourcing and the new business option. As the household has multiple sources in reference to single source, the probability that the household would opt to start a new business increases by 8% as compared to the expansion option.

Besides, in rural areas, micro finances are encouraged to finance existing activities, which had a track of records. This was to make sure that repayment rates would be high. The close attention paid to repayment rates, which may lead to certain conservatism by credit officers, and may reduce the extent to which microcredit indeed leads to starting new, profitable activities (Beck et al., 2009; Field et al., 2011).

Collect and utilize market information

The variable was used as a dummy variable taking value 1 for collecting and using market information and 0, otherwise. Having access to market information is positively and significantly related to diversifying options. Household heads that collect and make use of market information are encouraged to diversify their business as compared to expanding the existing business. The positive relationship indicates that keeping all other variables constant, the likelihood of choosing to diversify the existing business increases as the household collect and utilize market information than not by 10%, as in reference to the expansion option.

Recent research indicated that frequent interaction with customers (the use of formal procedures for collecting and utilizing market information) has a positive impact on new product performance, which in turn should impact new venture performance (Parry and Song, 2010). It implies that having access to market information enlightens the household about the market prices, and demand, if they found the market to be disgusting, they refrain from diversifying the business.

Expenditure on social purposes

This variable is a continuous variable measured in terms of amount of money expend on social rationale. The variable is used in the model to include expenditures like marriage and circumcision expenditures, funeral and other religious or traditional ceremonies. The model result shows these expenditures correlate positively and significantly with continuing on the established business option. The positive signs entail that the increase in the likelihood of continuing in the established business increases as households engaged more on social commitments (Table 6). On the other hand, the variable was found to have negative and significant relation with the new business option, indicating that expenditures on social issues curtain the possible amount of money that would otherwise be used for new venture establishment.

Participation in social commitments increase the social capital of the household head may be to the extent that it serves as a trade mark for his business. Therefore, it was evident that the increase in the amount of social purposes increases the likelihood of staying on the same business, increases by 93%. Pertaining to the new

business option, since the social purpose and its return decreases the amount of time, money and marketable surplus, the likelihood of choosing new business option decreases by 15% in contrast to the reference category.

CONCLUSION AND RECOMMENDATION

The results indicate the presence of a fundamental set of reasons for business start-up, expansion and or diversification in addition to a mere access to finance. It appears that, like the economic theories, rather than the access to credit, the amount of loan is important in determining entrepreneurial activity decision. Variables employed have been found to have different effects on the choice of entrepreneurial activity options both in the trend and magnitude. However it has been difficult to single out the effects of other source of income besides loan (remittances, windfall gains *etc.*). This study also found that access to credit increased a move to non-farm activities and this have an ambiguous consequence in the long run development of agriculture and hence food security. Microfinance institutions give trainings and monitor the activities of their clients; however, there is lack of distinction of problems faced by different entrepreneurs, some being beginners fail in marketing their products, others lack basic skill of operation. The significant relationship between problems faced and entrepreneurial activity choice supports this conclusion. In addition to the external factors like credit, entrepreneur's own characteristics and interaction of the factors affect the choice of the entrepreneurial activity.

Therefore, if micro finance is to boost entrepreneurship, it should be on the enterprises having long last impact on the country's development and social welfare. Further, micro finance programs should be aligned with the country's strategic plan in such a way that it can expand and strengthen sectors that have higher multiplier effect. Also, it is advisable for microfinance institution's endeavor to enhance the quality of their advisory services by focusing on specific problems the entrepreneur faced rather than giving general training perceiving entrepreneurs as homogenous.

Financial institutions and entrepreneurship development organizations need to establish specialized units to provide the framework and strategy necessary in designing and delivering effective credit policies as well as programs for attracting and enlightening members of the small business sector. Finally, the results of this paper have important implications for microfinance institutions and other stakeholders making general efforts to support entrepreneurial activities of smallholders. Future studies should investigate the relationship between enterprise choice and credit service, employing larger sample sizes, wider variables, encompassing wider and different geographical, cultural and economic aspects.

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Oil pollution and technical efficiency of food crop farmers in the Niger Delta region of Nigeria

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A study was carried out to investigate into factors responsible for technical inefficiency of food crop farmers in the oil polluted and non-polluted areas of Niger Delta. Data were collected from 270 (140 for oil polluted and 130 in unpolluted area) farmers selected through a multistage random sampling technique. A stochastic frontier function that incorporated inefficiency effect was estimated using the Maximum Likelihood Estimation (MLE) technique. The MLE of the stochastic production function revealed mean technical, efficiency of 78% in polluted area while the corresponding values in unpolluted area were 88%. The most efficient farmer had the technical efficiency (TE) of 0.93 and least efficient farmer of 4.48. Farmers with efficiency index between 4.48 and 0.65 constituted 31% while 68.2% of the farmers had efficiency index between 0.70 and 0.95. The predicted technical efficiency varied widely across farms between 28 and 86% for farmers in polluted area while between 38 and 96% for the farmers in unpolluted area. The results show that farmers generally in the study area are not technically efficient, although the farmers in the unpolluted area are relatively more efficient than farmers in the polluted area. The implications are that the policies that would reduce oil pollution and encourage farmers to utilize their resources optimally should be put in place. Hence, in order to halt the continual degradation of the Niger Delta environment there is need for the enactment and enforcement of stringent environmental laws to protect the area.

Key words: Nigeria, Niger Delta, stochastic function, oil pollution, technical efficiency, food crops farmers.

INTRODUCTION

Food remains a major requirement for man's survival and the need to produce enough food to feed the teeming population continues to be a major focus in the developing countries. Efforts to produce enough food in countries like Nigeria are however being frustrated by a number of natural, human and economic factors. Food production in the Niger Delta zone which incidentally is the oil producing area of the country is hampered by a number of environmental problems and prominent among them is oil pollution occasioned by the oil exploration involving several million barrels of crude oil have been going on in that area. Hundreds of cases of oil spills reported (Eronmosele, 1998; Egwaikhide and Aregbeyan, 1999). It is also reported that an on average about 86% of the total gas production from 1970 to 1996 was flared. The effects of oil spillage and gas flaring have been a source of major concern. Indeed, gas flaring has been identified as the major cause of respiratory infection among the Niger Delta people including the farmers as well as the cause of reduced growth potentials of farm crops. Oil pollution has been identified among the factors causing land degradation which results in the

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reduction of the soil's ability to contribute to crop production and a change to the land that makes it less useful for human beings.

Chindah and Braide (2000) in a study on the effects of oil spill on crop production in the Niger Delta reported that oil spill caused great damage to the plant community due to high retention time of oil occasioned by limited flow. They observed that oil pollution affects the physiochemical properties of the soil such as temperature, structure, nutrient status and pH which results to wilting and die back of some plants. Benson and Odinwa (2010) found that cassava planted in oil polluted soil recorded low yield. Land degradation also reduces productivity thereby contributing to the low efficiency of the farmers. Inoni et al. (2006) observed that oil spill reduced crop yield, land productivity and greatly depressed farm income. They found out that a 10% increase in oil spill reduced crop yield by 1.3% while farm income declined by 5%. Orubu et al. (2004) discovered that oil pollution contributes to the depletion of the active labour force as well as the farm size which affect the efficiency and productivity of the farmers. Efficiency is a very important factor of productivity growth, especially in developing agricultural economies where resources are meager and opportunities for developing and adopting better technologies are dwindling (Ali and Chaudhry, 1990). In such economies inefficiency studies help to indicate the potential possibility to raise productivity by improving efficiency without necessarily developing new technologies or increasing the resource base (Bifarin et al., 2010). The concept of efficiency is concerned with the relative performance of the processes used in transforming given inputs into outputs. Economic theory identifies at least three types of efficiency. These are technical, allocative and economic efficiencies.

Allocative efficiency refers to the choice of an optimum combination of inputs consistent with the relative factor prices. Technical efficiency shows the ability of firms to employ the 'best practice' in an industry, so that no more than the necessary amount of a given sets of inputs is used in producing the best level of output. Economic efficiency is the product of technical and allocative efficiencies. Efficiency is a very important factor of productivity growth, especially in developing agricultural economies where resources are meager and opportunities for developing and adopting better technologies are dwindling (Ali and Chaudhry, 1990). It is often assumed that factors affecting farm households' technical efficiency (TE henceforth) are due to demographic and socio-economic characteristics. However, Pascual (2001) noted that input quality (and not just quantity) is important when deriving TE measures. Coelli (1995) recognized that environmental factors such as soil quality may also influence technical efficiency measures. This study is concerned with the assessment of the effect of oil pollution on farmers' efficiency. The outcome of the analysis is relevant for policy making in the Niger Delta. It will help to assess the role of environmental (soil) quality and relevant demographic and socio-economic factors affecting the agricultural performance of food crops farmers in the region.

METHODOLOGY

Data

Data used for this study were collected from 270 food crops farmers (140 from oil polluted area and 130 farmers from non- oil polluted area) in 31 villages in Rivers and Delta States of the Niger Delta Region of Nigeria through multi-stage sampling procedures. The data covered socio-demographic characteristics of the farmers, types of crop grown, labour used, membership of association, sources of fund for farming, land ownership status, incidence of oil pollution, prices of output and wages.

Theoretical framework

Several techniques have been developed for the measurement of efficiency of production. These techniques can be broadly categorized into two approaches: parametric and non parametric. Under the parametric technique we have deterministic parametric frontier (Afriat, 1972) and stochastic parametric frontier (Aigner et al., 1977). The parametric stochastic frontier production approach (Aigner et al., 1977); Meeusen and van den Broeck (1977) deals with stochastic noise and permits statistical test of hypotheses pertaining to production structure and the degree of inefficiency. As in Bravo-Ureta and Evenson (1994) and Bravo–Ureta and Rieger (1991), the parametric technique cost decomposition procedure is used to estimate technical, allocative and economic efficiencies. Following Sharma et al. (1999), the firm's technology is represented by a stochastic production frontier as follows:

$$Yi = f(Xi; \beta) + \varepsilon i \quad (1)$$

Where Yi denotes output of the ith firm, Xi is a vector of functions of actual input quantities used by the ith firm; β is in vector of parameters to be estimated and εi is the composite error term (Aigner et al., 1977; Meeusen and Van den Broeck, 1977) defined as:

$$ei = vi - ui \quad (2)$$

Where vis are assumed to be independently and identically distributed N (0.02) random errors, independent of the uis; and the uis are non-negative random variables, associated with technical inefficiency in production which are assumed to be independently and identically distributed and truncation (at zero) of the normal distribution with mean μ and variance σ_u^2 $|N(\mu u;\sigma_v^2)|$

The maximum likelihood estimation (MLE) of Equation 2 provides estimation for β and variance parameter $\sigma^2 = \sigma_u^2 + \sigma_v^2$, and $v = \sigma_u^2 / \sigma_v^2$. Subtracting vi from both sides of Equation 1 yield:

$$\Psi i = \Upsilon i - vi = f(\mathrm{X}i\beta) - ui \quad (3)$$

Where Ŷi is the observed output of the ith firm adjusted for the stochastic noise captured by vi.

Empirical model specification

Theoretically, a production frontier defines the maximum output

attainable for a given level of inputs. Therefore, in order to estimate an efficient frontier, farm level data on input and output quantities are required. However, it is often the case that input quantity data are not available. Data are often available, however on farm output revenue and input expenditures. Therefore, a common approach is to use revenue and expenditure data as proxies for input and output quantities for example, Aly et al. (1987), Grabrowski et al. (1990) and Neff et al. (1991). In traditional agriculture, multiple outputs and inputs are common features and for the purpose of efficiency, analysis output is aggregated into one category and inputs are aggregated into seven categories namely: farm size, fertilizer, labour, capital, land that is, rental value of land, other variable inputs. The stochastic frontier production function used in this study is a linearized version of Cobb-Douglas production function. The stochastic frontier production function in Equation 4 and the inefficiency model in Equation 5 were simultaneously estimated as proposed by Battese et al. (1996).

Specification of technical efficiency model

$$\ln Y = \beta o + \beta_1 \ln X_{1}j + \beta_2 \ln X_{2}j + \beta_3 \ln X_{3}ij + \beta_4 \ln X_{4}ij + \beta_5 \ln X_{5}ij + \varepsilon i \quad (4)$$

Where subscripts ij refer to the ith observation on the j^{th} farmer; In = denotes logarithm to base e; Y = represents the farm output in grain equivalent (Kg); X_1 = total farm size under cultivation (in hectares); X_2 = family labour used in production (mandays); X_3 = is hired labour used in production (in man-days); X_4 = is material inputs of seeds and other planting stocks (in kgs and cuttings); X_5 = quantity of fertilizer used (in kgs); εi = error term (vi - ui).

It is assumed that the technical efficiency effects are independently distributed and varies and uij arises by truncation (at zero) of the normal distribution with mean μ and variance σ^2; where uij is defined by equation.

Inefficiency model

$$Uij = \alpha o + \alpha_1 \ln Z_1 ij + \alpha_2 \ln Z_2 ij + \alpha_3 \ln Z_3 ij + \alpha_4 \ln Z_4 ij + \alpha_1 \ln D_1 1ij + \alpha_2 \ln D_2 1ij + \alpha_3 \ln D_3 1ij + \alpha_4 \ln D_4 1ij \quad (5)$$

Where uij represents the technical inefficiency of the ith farmer; Z1 denotes age; Z2 represents sex;
Z3 represents family size; Z5 represents years of schooling; D1 denotes dummy variable for membership of association; where one denotes membership of association and zero is otherwise. D3 denotes dummy variable for ownership of farmland; where one denotes who own their farmland zero is otherwise. D4 denotes dummy variable for source of fund for farming; where one represents those who depend on personal saving for their farming activities and zero is otherwise. D5 denotes dummy variable for pollution; where one denotes farmland where there is oil pollution and zero is otherwise.

The β and α coefficient are unknown parameters to be estimated together with the variance parameters. The parameters of the stochastic production function are estimated by the method of maximum likelihood, using FRONTIER 4.1* program (Coelli, 1994). The maximum likelihood estimation (MLE) procedure is used because it is asymptotically efficient; consistent and asymptotically normally distributed.

Description of variables

Farm output

Output is the total quantity of crop mix in each farm converted to their grain equivalent in kilograms.

Farm size (XI)

This is expressed in hectares. On the expected sign of the coefficient, there seems to be no consensus of opinion (Oredipe, 1998). Hence, the sign of the coefficient of the variable cannot be predicted a-priori.

Farmily labour (X2)

Because family labour is not paid for in the study area, large family labour may not reflect considerable increasing output nor be matched with increase in resource pool. Inefficiency may set in if there is excess labour on the farm. The coefficient of this variable is therefore expected to be negative.

Hired labour (X3)

Labour intensive technologies will require additional or specialized skill, which can be secured through hired labour. Hired labour constitutes a major constraint to attainment of optimal productivity level and is expected to be positively related to technical efficiency level.

Planting stock (X4)

The quantity and quality of planting stocks use in farming have considerable influence on the ultimate yield from the farm. Thus, it is expected that good quality planting stock will positively affect farm output.

Fertilizer (X5)

It is generally believed that fertilizer application improves the fertility of the soil and secures greater yield from the farm. This however depends on several factor like the quantity applied and the timing of application. The coefficient of the variable is expected to be positive to output.

RESULTS AND DISCUSSION

The socio-economic characteristics of the respondents are presented in Tables 1 and 2. They seem to exhibit similar pattern. This is quite understandable as they are people with the same cultural, historic and geographical background. The average age of the farmers is 43.3 years. The highest percentage of farmers (71.9%) is within the age bracket of 31 and 50 years. This shows that most farmers from the study areas are still young. On the gender aspect, male farmers are more than female farmers. The percentage of female farmers is 30.7%. This indicates that women involvement in farming in the study area is low. The average family size is 5.18. This large family size implies availability of family labour to the farmers. The literacy level of most farmers is relatively moderate with about 23% having no formal education while 18.1% had primary education. Over 53% of the

Table 1. Socio-economic characteristics of respondents in the study areas.

Demographic variables	Characteristics	Polluted		Unpolluted	
		Frequency	Percentage	Frequency	Percentage
Gender	Male	84	61.8	65	48.5
	Female	52	38.2	69	51.5
Age	21-30	19	14.0	12	9.0
	31-40	34	25.0	36	26.8
	41-50	41	30.1	45	33.6
	51-60	25	18.4	29	21.6
	61 and above	17	12.5	12	9.0
Marital status	Single	19	14	14	10.4
	Married	99	72.8	103	76.9
	Divorced	01	0.7	02	1.5
	Widow/widower	17	12.5	15	11.2
Household size	1-5	74	54.4	83	61.9
	6-10	62	45.6	51	38.1
Educational qualification	No formal education	26	19.1	31	23.1
	Primary education	18	13.2	25	18.7
	Secondary	29	21.3	30	22.4
	Tertiary	57	41.9	34	25.4
	Vocational	6	4.4	14	10.4
Years of farming	0-5	13	9.6	17	12.7
	6-10	30	22.1	23	17.2
	11-15	31	22.7	27	20.1
	16-20	15	11.0	19	14.2
	21-25	13	9.6	15	11.2
	26 and above	34	25	33	24.6
Land tenure	Family land	44	32.4	61	45.5
	Communal land	15	11.0	12	9.0
	Rented land	53	39.0	45	33.6
	Purchased land	24	17.6	16	11.9
Farming system	Mixed cropping	107	78.7	103	76.9
	Agroforestry	29	21.3	31	23.1
Farm size	0-2.0	102	75.0	103	76.9
	2.1-3.0	23	16.9	24	17.9
	3.1-4.0	2	1.5	2	1.5
	4.1 and above	9	6.6	5	3.7

Source: 2002.

farmers have post- primary education. The marital status of farmers shows that 13.7% of the farmers are singles while over 80% are married. Membership of co-operative societies is not very common among the farmers. Among the respondents only 22.6% belong to co-operative societies. This shows that majority of the farmers are not exploring the benefits accruable from co-operatives societies. The farming experience of farmers shows that most of the farmers have been in the farming business for an average of 16 years. Resulting from the vagaries of farming operation due to unfavourable environmental condition in the study area, 57% of the farmers engage in other jobs like fishing, trading etc, to supplement income from farming activities. The farmland ownership structure shows that most respondents (64.1%) farm on communal and leased lands.

Table 2. Summary statistics of socio- economic characteristics of respondents.

Variables	Oil polluted soil environment				Un- polluted soil environment			
	Sample mean	Minimum value	Maximum value	Standard deviation	Sample mean	Minimum value	Maximum value	Standard deviation
Age	42.4	20	59	10.7	42.95	20	45	11.3
Family size	5.06	1	9	2.13	5.34	1	9	1.9
Years in schooling	9.9	0	19	7.07	11.66	0	19	6.6
Years in farming	16.6	2	32	8.5	15.99	5	27	8.5
Farm size	1.5	0.2	6.07	0.87	1.59	.2	5.89	1.03
Family labour (man days)	82.8	10	215	44.5	83.82	11	200	42.3
Hired labour (man days)	2.95	0	15	2.7	3.55	0	15	3.37
Quantity of fertiliser used (kg)/ha	66.5	0	600	111.57	53.5	0	666.7	113.86
Total output (kg)/farmer	836.5				1546.7			
Average gross revenue (n)	28,834	5,000	300000	33,066	33361.51	5,000	200000	30290.0
Total cost (n)	7516	1200	28200	5064.4	8022.38	1600	24600	6511

Source: Field data (2002).

All the farmers in the area practice mixed cropping with over 50% planting between 4 to 7 different crops on the same plot. About 51.8% of the farmers attested to the pollution of their farm with petro-chemical products while 48.2% reported that there was presence of oil pollution in their farmlands. In summary, the socioeconomic characteristics of the farming households in the study areas seemed to exhibit similar pattern. This is quite understandable as they are people with the same socio-cultural background and within the same geographicalsetting. For example, while the average farm size in polluted area is 1.5 ha, that of the unpolluted area is 1.59 ha. Also, the average number of mandays used by households in polluted area is 82.8 and those in unpolluted area are 83.8. Meanwhile, farmers in the polluted area appeared to use more of inorganic fertilizer (66.5 kg/ha) than those in unpolluted area (53.5 kg/ha). There is however a marked difference in the average output between farmers in the unpolluted area (1546.7 kg/farmer) and the polluted area (836.5 kg/farmer). A plausible reason is most likely the effects of pollution.

Estimates of the parameters of the inefficiency factors

The estimated parameters and the related statistical tests results obtained from the analysis are presented in the Table 3. All the coefficients in the model have the expected signs and many are statistically significant at 10% or less.

Determinants of technical inefficiency

The coefficient of farm size was significant in the 5% that is, in polluted and non-polluted areas. Family labour was significant at the 10% in both polluted and non-polluted areas. Hired labour was not significant as it was observed that majority of the farmers did not engaged hired labourprobably due to high cost. The coefficient of planting materials, which include seeds, was not significant. Fertilizer was significant at 10% level in both cases. The coefficients of family size years schooling, crop diversification and membership of Farmers Association had negative sign in both polluted and unpolluted areas while family size was significant in both situations; years of schooling was significant in unpolluted area. The significance of these coefficients combined with their negative signs implies that these variables help to reduce inefficiency in the farmers. In other words, crop diversification for example, reduces farmers technical inefficiency (Amaza, 2000) while

Table 3. Maximum likelihood estimates of the parameters of the stochastic frontier production function (technical efficiency model).

Variables	Polluted area		Unpolluted area	
	Coefficient	Standard error	Coefficient	Standard error
Production factor constant	2.8845	0.3239***	2.9395	0.03656***
Farm size (X1)	0.2596	0.0095**	0.2853	0.1257**
Family labour (X2)	0.6544	0.0719***	0.7312	0.0779***
Hired labour (X3)	-0.0624	0.0712	-0.0586	0.0759
Fertilizer (X4)	0.0442	0.0260*	0.0417	0.0263
Planting stocks (X5)	0.0336	0.1384	0.0191	0.1532
Inefficiency factor				
Constant	0.5793	0.9477	0.8368	0.0102***
Sex (Z1)	0.8838	0.6188	1.040	0.5926*
Year of farming (Z2)	-1.500	0.4238**	-1.9574	0.8874**
Family size (Z3)	-0.7574	0.5244	-0.8728	0.7165
Year in schooling (Z4)	-0.2787	0.1367**	-0.3248	0.1492
Crop diversification (Z5)	-7.0753	0.3028**	-1.312	0.4525**
Membership of association (D1)	-0.3749	0.1705**	-0.3913	0.2064*
ownership of land (D2)	0.7839	0.3932**	0.9054	0.5519
Source of fund (D3)	0.8086	0.3559**	0.9591	0.5329*
Pollution (D4)	0.2205	0.0166**	-	-
Diagnostics statistics				
Livelihood ratio	41.73		39.92	
Sigma square (σ^2)	0.1209	0.0331***	0.1593	0.0552**
Gamma (γ)	0.6807	0.0856***	0.7707	0.0784***

Source: Computed from field data, ***1% level of significance, **5% level of significance, *10% level of significance.

membership of Farmers Association affords the farmers the opportunity to share information on new farming practices by interacting with other farmers thereby reducing their inefficiency. These findings are consistent with earlier findings by Bravo-Ureta and Evenson (1994), Ajibefun and Aderinola (2004) and Nwaru (2004). The coefficient of pollution (0.2205) had positive sign to technical inefficiency. In other words, it contributes to technical inefficiency among the farmers. This finding is however contrary to that of Hadri and Whittaker (1999) who assessed the effect of soil pollution on crop technical efficiency and found a positive relationship between technical efficiency and use of contaminants in a sample of farms in South West England.

Pascual (2001) also found out that soil quality affects technical efficiency in Mexico and attributed this to household response to ecological constraints who try to substitute lower soil quality for higher managerial ability. In this study, the effects of pollution on food production can be seen in the output of farmers. Whereas, the total output per farmer in the polluted area was 836.7 kg; that of the unpolluted area was 1546.7 kg per hectare for cassava. The coefficient of source of fund had positive and significant at the 5% level. The significance of this coefficient indicates that where the farmers source for fund for farming affects their efficiency. A situation where farmers depend largely on their personal saving as is the case with majority of the farmers in the area will adversely affect their efficiency.

The diagnostic statistics of the technical efficiency factors

The estimated sigma-squared (σ^2) in Table 3 for both polluted and unpolluted areas are large (0.12 and 0.15) and significantly different from zero at the 5% level. This indicates a good fit and the correctness of the specified distributional assumption of the composite error-term. In addition, the magnitude of the variance ratio defined as $\gamma = \delta u^2/(\delta u^2 + \delta v^2)$ is estimated to be as high as 68% for polluted area and 77% suggesting that systematic influences that are unexplained by the production functions are the dominant sources of errors. It also confirms the presence of one-sided error component in the model, thus rendering the use of the ordinary least squares (OLS) estimating technique inadequate in representing the data. This means that over 65% of the

Table 4. Frequency of technical efficiency in the study area.

Efficiency (%)	Technical efficiency	
	Oil polluted	Unpolluted
10-50	6	3
50-55	0	2
55-60	3	1
60-65	3	0
65-70	9	3
70-75	20	4
75-80	24	10
80-85	65	16
85-90	10	24
90-95	0	67
95-100	0	0
	140	**130**
Minimum value	28	38
Maximum value	86	96
Mean value	77.6	88

variations in output among the farms in both polluted and unpolluted areas are due to difference in technical efficiency. In other word the inefficiency effects indicated by the variance parameter are significant in determining the level and variability of output of farmers in the study area. The livelihood functions are estimated to be 41.73 and 39.92 for polluted and unpolluted areas, respectively. These values represent the values that maximize the joint densities in the estimated model.

Distribution of technical efficiency

The technical indices of farmers are derived from the analysis of the stochastic production frontier function in Equation 4. The technical efficiency of the sampled farmers in both polluted and unpolluted areas is less than 100 indicating that all the farmers are producing below the maximum efficiency frontier as shown in Table 4. A range of technical efficiency is observed across the sampled farmers. The best farmer in the polluted areas has a technical efficiency of 86% while the least efficient farmer has 28% whereas in the unpolluted area the most efficient has a technical efficiency of 96% and least efficient farmers has 38%. The mean technical efficiency is 77.6% for the polluted area and 88.5% for the unpolluted area. This implies that on the average the respondents were able to obtain a little over 77.6% of optimal output in the polluted area and 88.5% in the unpolluted area. Testing for significance difference reveals that the computed z- statistics is statistically significant at 1% level showing that farmers in the unpolluted area are more efficient than those in the polluted area. The hypothesis that states that there is no difference in the technical efficiency of farmers in the two areas is thereby rejected. A plausible reason for this could be the effects of oil pollution given the fact that farmers in the area operate under the same technical condition.

The distribution of technical efficiency group reveals that the highest proportion (46.4%) of the farmers in the polluted area falls between the efficiency ranges of 0.80 to 0.85 while the highest proportion (23.7%) falls between the efficiency ranges of 0.85 to 0.90 in the unpolluted area. The distribution of the technical efficiency shows efficiency at 77.6 and 88.5% for farmers in polluted and unpolluted area respectively implying that in the short-run there is scope for increasing technical efficiency in food crop production in the study area especially those in the polluted area. That is, if the problem of oil pollution is taken care of and if farmers would adopt the technology and production techniques currently used by the most efficient farmers.

Conclusion

Expanding population and economic development have generated a growing demand for various land based products leading to unnecessary pressure on soil, water resources and plants with the attendant consequences of deteriorating land resources, declining productivity and reduced income. This study has been able to quantitatively establish the fact that oil pollution in the area is having negative impacts on the food crop farmers resulting in reduced income from farm activities. In considering the results obtained from the analysis of technical efficiency effects of stochastic frontier production function, it is important to note that the production frontier involved are determined by models and within the sample values. This implies that there may be techniques of production practiced by some of the

farmers in the sample, which yielded much higher output for the same level of inputs. Governments at both the Federal and State levels should ensure increase fund allocation to agriculture in the region as well as the provision of and distribution of farm inputs like fertilizers, chemical, capital, etc. so as to boost food production in that area. Government should also ensure that stringent environmental laws to protect the area are enacted and enforced.

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