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Measurement of technical efficiency of smallholder fish production in Ghana: A stochastic frontier approach

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This paper examines the level and determinants of technical efficiency of smallholder fish production in seven of the ten regions of Ghana. We employ the single-stage stochastic frontier approach in this study. Regional location, feed, fingerlings and labour are found to influence technical efficiency positively and significantly. However, formal education, marital status, membership in fish farmer groups and contact with extension services negatively influence inefficiency. Finally, estimates from the study indicate that the average smallholder fish producer in Ghana is 73.88% technically efficient. We recommend a bottom-up participatory approach to policy formulation which involves grassroots participation as well as the inclusion of aquaculture management in the curriculum of schools.

Key words: Smallholder fish production, technical efficiency, stochastic frontier.

INTRODUCTION

Globally, the contribution of fish farming to national development, both from poverty alleviation and national economic development points of view poses some interesting concerns. These concerns may be attributable to the fact that fish is a significant component of the diet for many people around the world, providing essential nutrition for over one billion people, and fish production also provides livelihood for over 200 million people in developing countries (The WorldFish Centre, 2007). In terms of trade, over 37% (by volume) of world fish production is traded internationally, the value of this being the highest in international trade in all animal proteins (World Bank, 2011). It is therefore not surprising that aquaculture has recently been adopted as a means to increase or supplement other sources to meet the deficit in Ghana's fish supply. In 2003, for instance, Ghana produced about 52% of its fish requirements from its domestic sources; this contribution increased to 68% in 2004 (FAO, 2005).

In Ghana, there are generally six major sources of fish ranging from imports, the open sea or marine fisheries, lagoon fisheries, the Lake Volta, other inland water bodies and pond fish production. In fact, of all these sources most of Ghana's fish supply comes from marine sources (Asmah, 2008), which contributed about 80% of the total quantum of domestic production between 1993 and 2000 (FAO, 2004). According to Braimah (2001) in Asmah (2008) Lake Volta is the single most important source of fish of all inland fisheries, supporting about 140 species of fish. Furthermore, the vast size of the Lake also lends itself to canoe fishing by fisher folk along its banks. It was estimated to have produced over 70,000 tonnes of fish in 2002 which is about 16% of total domestic production and 85% of inland fishery output

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(Asmah, 2008). Fishing along the lake is seasonal: the peak season spans the months of July and August, while the lean season is from January to February. It is necessary to mention that apart from the Volta Lake there are many other water bodies from which fish is obtained for consumption, of which include Bosomtwi, Weija, Barekese, Tano, Vea and Kpong; altogether covering approximately 1,000,000 ha, and over 50 lagoons covering 40,000 ha (ibid). It is generally argued that in terms of fish, Ghana as a country has a self-sufficiency ratio of 60% meaning that the demand of fish exceeds supply by some 40%. According to Adutwum (2001) in Asmah (2008) the nation has over the years tried to meet this deficit through the importation of frozen fish. This raises concern for especially the small holder fish farmer who cannot effectively compete on the basis of prices: the imported frozen fish is cheaper and has increasingly become an important part of the diet of low income urban and rural consumers. Per capita fish consumption in Ghana is between 20 and 25 kg, making it one of the highest in Africa. This is an indication of the availability of a market for fish and fish products.

In spite of the high demand pointed out above available data indicates that the contribution of small-scale pond fish production to total quantum of fish produced in Ghana for local consumption is less than 1% (Abban et al., 2009). This is an interesting discovery and one that calls for some consideration and action especially at a time when aquaculture is poised to fill the gap between dwindling supply from major capture fisheries and the ever-increasing demand for fish and fishery products in several peer countries. For aquaculture to succeed in Ghana and to play its role towards food security and livelihood both the government and private sector must work together. Plausible as the above may be, there is the inherent assumption that fish farmers need more inputs to reach their potential. However, it is known that increase in agricultural production, and by inference fish production, may be attained through improvement in productivity, which can be increased through one or a combination of factors namely, technology, the types and quantities of resources used and the efficiency with which the resources are used. Of the various determinants, improvement in the efficiency of the resources already available to the farmers is most important (Goyal et al., 2006); hence the objective of this study was to determine the level of technical efficiency of smallholder fish production. Taking the above into consideration, this paper measures and analyzes the performance of small-scale fish farming households in Ghana. The paper applies a stochastic production frontier model, which measures the relative technical efficiency in a consistent way while also shedding light on the factors associated with these efficiency differences.

Statement of hypotheses

In this study, three hypotheses are tested. These hypotheses are;

1. $H_0 = \beta_{ij} = 0$, The null hypothesis that identifies an appropriate functional form between the restrictive Cobb-Douglas and the translog production function.
2. $H_0 = U_i = 0$, The null hypothesis specifies that each smallholder fish farmer is technically efficient and that variations in actual fish output (harvest) are due to random effects.
3. $H_0: \gamma = \delta_0 \ldots \delta_6 = 0$, The null hypothesis that inefficiencies are absent from the model at every level.

METHODOLOGY

Theoretical framework

The estimation of technical efficiency has been carried out with many different approaches, but the Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) have been given the most consideration by researchers. The basic difference between these two approaches lies in the method of analysis: the former employs econometrics while the latter uses mathematical programming. The SFA takes cognizance of the presence of stochastic noise-random shocks affecting the production process-outside the control of the producer, as well as technical error and also permits inferences to be drawn from estimation results (Coelli et al., 2005). In fact, the inclusion of the measurement error makes the frontier stochastic, whence the name stochastic frontier model is derived (Koop, 2003). As a consequence the SFA technique is considered appropriate for this study as such factors are expected to abound in smallholder fish farming in Ghana, a developing economy. Coelli et al. (2005) specified, in this case, a Cobb-Douglas Stochastic frontier model as:

$$Y_i = exp(\boldsymbol{\beta_0} + \boldsymbol{\beta}_1 \ln x_{it}) \text{x } exp\,(v_{it}) \text{x } exp\,(-u_{it}) \quad (1)$$

Where: $exp(\boldsymbol{\beta_0} + \boldsymbol{\beta}_1 \ln x_{it})$ is the deterministic component; $exp\,(v_{it})$ is the noise component, and $exp\,(-u_{it})$ is inefficiency. Some assumptions have been associated with the noise term in the existing literature:

1. It is independently and identically distributed (*i.i.d*.)
2. It is symmetric and
3. It is distributed independently of (u_{it})

In the estimation of the effects of the exogenous variables on the technical efficiency of farms, the two main procedures are the one-step and the two-stage modelling. In the two-stage procedure the production function is first estimated and the estimates of the technical efficiency of each farm are obtained. These are then regressed on farm-specific variables known or hypothesised to influence the efficiency. Critics of the two-stage approach -including Kumbhakar et al. (1991) and Reifschneider and Stevenson (1991) argue that this procedure is inconsistent and some of the assumptions of the error term, such as independent distribution are violated in the second stage (Pascoe and Mardle, 2003), and hence it is biased (Wang and Schmidt, 2002) and not as efficient as the single-stage procedure (Reifschneider and Stevenson, 1991). In contrast to this approach is the single-step, which incorporates all the variables affecting either the production function or contributing to inefficiency. In essence the relation between μ_i and z_i is established by this procedure, using the maximum-likelihood estimation (Wang and Schmidt, 2002); hence in this study the one-step modelling procedure is adopted.

Determination of technical efficiency

The technical efficiency (TE) of a given firm is illustrated as the ratio of the output obtained from that firm in comparison to the output of the best producing (frontier) firm using the same technology, as:\

$$TE = \frac{yi}{exp(x_i\boldsymbol{\beta})} = \frac{exp(xi\boldsymbol{\beta} - u_i)}{exp(x_i\boldsymbol{\beta})} = exp(-u_i) \qquad (2)$$

Empirical models

In order to determine the effects of predetermined variables on the value of pond fish production, as well as the efficiency of resources used, the translog stochastic production function is estimated, being motivated by the fact that this functional form has been widely used in frontier production studies and it is also flexible to use (Onyenweaku and Okoye., 2007; Onumah and Acquah, 2010).

The following translog model is used in this study to arrive at the technical efficiency of the smallholder fish farmers in Ghana:

$$\begin{aligned} \ln Q = {} & \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \ln labour + \boldsymbol{\beta}_2 \ln capital + \boldsymbol{\beta}_3 \ln fingerlings + \boldsymbol{\beta}_4 \ln feed + \\ & \frac{1}{2}\boldsymbol{\beta}_5 (\ln labour)^2 + \frac{1}{2}\boldsymbol{\beta}_6 (\ln capital)^2 + \frac{1}{2}\boldsymbol{\beta}_7 (\ln fingerlings)^2 + \frac{1}{2}\boldsymbol{\beta}_8 (\ln feed)^2 + \\ & \boldsymbol{\beta}_9 \ln(labour) * \ln(capital) + \boldsymbol{\beta}_{10} \ln(labour) * \ln(fingerlings) + \\ & \boldsymbol{\beta}_{11} \ln(labour) * \ln(feed) + \boldsymbol{\beta}_{12} \ln(capital) * \ln(fingerlings) + \\ & \boldsymbol{\beta}_{13} \ln(capital) * \ln(feed) + \boldsymbol{\beta}_{14} \ln(capital) * \ln(\ln feed) + \\ & \boldsymbol{\beta}_{15} \ln(fingerling) * \ln(feed) + Reg + v_i - u_i \end{aligned} \qquad (3)$$

Where: Q refers to the total output of fish harvested in kilograms; *labour* is labour (man-hours) employed during the production season *capital* is the area of all ponds used in production of fish in the production season in hectares; *feed* (in kilograms) is feed[1] fed to the fish during the production season; *fingerlings* count) is the number of fingerlings stocked at the start of the production season; *Reg* is a dummy, used as a proxy to capture regional effects on the efficiency of fish production by smallholder fish farmers in the different regions. Seven (7) dummies are constructed from this variable, where for a particular region, say Greater Accra the *Reg* takes on a value of 1, and zero for all other regions. In the estimation of the model, one of the dummy regional variables is excluded to conform to the n *-1* degree of freedom restriction when using dummy variables, and also to avoid the problem of perfect correlation among the dummies and the constant; β_is are regression parameters to be estimated and are as defined earlier.

The empirical technical inefficiency model

The model for various operational and farm-specific variables hypothesised to influence technical inefficiencies of fish farms in Ghana is defined as:

$$\begin{aligned} Zi = {} & \boldsymbol{\delta}_0 + \boldsymbol{\delta}_1 land_i + \boldsymbol{\delta}_2 sex_i + \boldsymbol{\delta}_3 techad_i + \boldsymbol{\delta}_4 ffa_i + \\ & \boldsymbol{\delta}_5 edu_i + \boldsymbol{\delta}_6 maristat_i + W_i \end{aligned} \qquad (4)$$

In this inefficiency model, *land* is a dummy, capturing the effect of land tenure on the efficiency of individual smallholder fish farmers. It has a value of 1 if freehold, otherwise 0; *sex* is a dummy, and has a value of 1 if decision maker is male, 0 otherwise; *techad* is a dummy variable and has a value of 1 if farmer was visited at least once by an extension officer, 0 otherwise; *ffa* is a dummy variable indicating whether the farmer/farm is a registered member of the local fish farmers' association. It has a value of 1 if yes, 0 otherwise; *edu* is the maximum level of formal schooling of the farm owner/manager; *maristat* is a dummy and is an indication of marital status of respondent; it takes a value of 1 if married, 0 otherwise; W is the 'error term' in the model; $\delta_0 - \delta_6$ are parameters to be estimated along with the variance parameters σ^2 and γ.

It must be noted that while the σ^2 is an indicator of how well the functional form specified fits the data and also the appropriateness of the assumption underlying the distributional form of the composed error term, the γ tests whether or not the dominant sources of errors are outside the deterministic part of the production function (Umoh, 2006).

Data description

The data set for this study is secondary and it comes from primary information on aquaculture development in Ghana obtained via questionnaires in 7 of the 10 regions, namely the Greater Accra, Eastern, Ashanti, Volta, Western, Central and Brong-Ahafo Regions. The list of smallholder fish farmers in each region was obtained from the Fisheries Directorate's regional offices. From the list respondents were then randomly sampled and interviewed with structured questionnaires. To facilitate data collection, questionnaires were completed with the farm owner or manager, whichever was available, at the time of visit. Where none was present, the farmers were traced to their homes where the data was gathered. Collection of data by phone was done only in one instance, which was to the owner of a commercial farm whose manager was not ready to give out any information. The surveys were conducted between June 2006 and December 2006. Primary data from134 fish farms were obtained, 124 of which are purposively selected (based on intensity of production) from seven of the ten regions (Greater Accra, Ashanti, Volta, Brong Ahafo, Central, Eastern and Western) for this study. This was motivated by the fact that the remaining three northern regions had no record of pond fish farms, and that these seven regions had 966 pond fish farms, spanning more than half of the entire country. Ecologically, the seven regions fairly represent the climatic conditions of the country.

A limitation to this secondary data set was the inconsistency in data entry and incomplete records (especially for costs and outputs). This may be due to the fact that the farmers did not know the basic booking-keeping methods or were afraid to release financial information for fear of taxation (Hiheglo, 2008).

RESULTS AND DISCUSSION

Summary statistics

This study was conducted to provide baseline information for subsequent monitoring of smallholder fish production efficiencies to assess the impacts of changes in the agricultural policy environment on selected socio-economic factors in the study area. Table 1 shows the summary statistics for the variables used in the stochastic frontier model. The mean harvest (output) per hectare was 266.10 kg. This was obtained by using: 0.39 ha of

[1]Feed is a composite term for all food items given to the fish during the production season.

Table 1. Summary statistics of quantitative variables used in the Stochastic Frontier Model.

Variable description	Unit	Mean	Standard deviation
Harvest (Output)	Kg/ha	266.10	706.00
Pond area	ha	0.39	1.05
Fingerlings	Num/ha	1018.64	3629.32
Feed	Kg/ha	400.80	557.60
Labour	Man - hours	464.38	302.43
Years of education	Years	9.06	5.17

Source: Authors' Computation from FAO dataset (2005).

pond area, 1018 fingerlings, 400.8 kg of feed and 464.8 man -hours of labour, by fish farmers with an average of about 9 years of formal education.

In this study we adopted the single-stage modeling technique and Table 2 is a descriptive statistics of the demographic variables used in this study. There were more male fish farmers than female fish farmers. The result also indicates that about 71% of the sample were members of FFA, while more (89.52%) of them had contacts with extension agents. Having more males is no indication of male dominance in the industry as workers, but rather as the main decision makers and heads of family businesses. It is interesting to note that membership of FFAs is on the higher side, with more extension contacts. From the perspective of policy intervention, policy makers may have to consider reaching farmers with new innovations and better ways of improving efficiencies through their farmer associations using a participatory approach.

Technical efficiency measurement of smallholder fish production in Ghana

Table 3 shows the estimation of the maximum likelihood estimates for parameters of the general translog stochastic production frontier and technical inefficiency effect models for smallholder fish production in Ghana.

Whereas labour and capital had positive and significant coefficients at 1%, fingerlings had a positive and significant coefficient but at 10%. This is an indication that stocking a pond with fish does not necessarily determine the yield obtained but rather the optimum combination of other relevant input factors. Feed, however, had a negative and significant coefficient at 1%; hence excess feeding regime may have been detrimental to the growth and development of the fish stocked.

From the results in Table 3, the output of fish would increase by about 1.3 kg with every 10% increase in man-hours. A 1% increase in the number of fingerlings and capital will result in 18 and 62.75% respectively in the output of fish produced.

The input variable that should be of greatest interest to policy makers is feed. Optimum amounts of feed and the adoption of the most effective feeding regime during the production cycle would help improve output of fish and hence efficiency. Thus to improve productivity primary interest should be on research to determine the optimum amount of feed and the right combination of feed nutrients. Interaction between variables resulted in some important findings. Feed alone as an input had a negative significant effect on the output, but an interaction between feed and capital had a positive significant effect on output. On the other hand a combination of feed and labour as well as feed and fingerlings were significantly negative. This confirms the previous assertion that the right proportion and composition of feed had a very important role to play in the output of fish and hence the efficiency of fish production

Inefficiency model estimates

The estimates for the inefficiency model are reported in the lower section of Table 3. Estimated coefficients of formal education, gender, membership in ffa, technical advice and the dummies for the regions were all significantly negative. These imply that fish farmers who have formal education were more technically efficient than those who had none; female farmers/farm owners were more efficient; members of ffas were more efficient, and farmers in all the regions under consideration except the Brong Ahafo Region, were relatively more efficient than their counterparts in the Ashanti Region. Crentsil (2009), however, in his study concluded that the Ashanti Region was the best fish producing region in Ghana. The point to note here is that the output of a farm does not necessarily correlate with its efficiency, because technical efficiency simply relates the output to the input used. Onumah and Acquah (2010), however, found regional differences to be insignificant in the variation of technical efficiency among smallholder fish producers in Ghana. We therefore conclude that the right combination of inputs bear much more on the output and hence efficiency rather than the location of the farmer, even though the latter cannot be ignored as a determinant of the variation in efficiencies among respondents in this study.

Battese et al. (1996) also found a positive significant

Table 2. Descriptive statistics on other demographic features of the smallholder fish farmers.

Variable names	Frequency	Percentage
Gender (1 = Male; 0 = female)		
Male	93	75.00
Female	31	25.00
Marital status (1 = married; 0 = single)		
Married	108	82.10
Single	16	12.90
FFA membership (1 = member; 0 = non – member)		
Member	88	70.97
Non - member	36	29.03
Land tenure (1 = owner; 0 = tenant)		
Owner	82	66.13
Tenant	42	33.87
Access to technical advice (1 = yes; 0 = no)		
Yes	111	89.52
No	13	10.48
Western region (1 = yes; 0 = no)		
Yes	12	9.68
No	112	90.32
Eastern region (1 = yes; 0 = no)		
Yes	9	7.26
No	115	92.74
Central region (1 = yes; 0 = no)		
Yes	20	16.13
No	104	83.87
Brong Ahafo (1 = yes; 0 = no)		
Yes	26	20.97
No	98	79.03
Greater accra (1 = yes; 0 = no)		
Yes	3	2.42
No	121	97.58
Volta region (1 = yes; 0 = no)		
Yes	22	17.74
No	102	82.26

Source: Authors' Computation from FAO dataset (2005).

relationship between education and technical efficiencyof farmers. Chiang et al. (2004) and Onumah and Acquah (2010), on the contrary found a negative correlation between education and technical efficiency, but indicated that technical know-how had greater influence on productivity than general formal education. It was not surprising to discover that members of ffas were more efficient, because as indicated elsewhere in this study members of a group learn from each other and get assistance from other members of the team, hence could be expected to be more efficient than the non-member, generally.

Technical advice in Ghana takes various forms. It includes informal meeting with an extension agent by a single farmer or as a group of farmers to discuss issues regarding their operations. In this study farmers who had access to technical advice were generally more efficient than those who did not. This has policy implications, because by this outcome, therefore, it may be suggested that more contacts with extension agents could further increase the efficiency of smallholder fish farmers.

γ is a measure of level of the inefficiency in the variance parameter, it ranges between 0 and 1. For the translog model, γ is estimated at 0.7992. This is an indication that about 80% of the random variation in fish production is attributable to inefficiency and the remaining 20% to stochastic factors. In other words, the variation in the output of fish is attributable to factors under the control of farm units much more than stochastic factors. The implication of these findings is that in formulating policy to help boost productivity of farmers, policy makers should

Table 3. Maximum-likelihood estimates of parameters of the Translog Frontier production function for smallholder fish farmers in Ghana.

Variable	Coefficient	Std. Error	t – Value	P - Value
Stochastic Frontier				
Constant	0.4433	0.0613	7.23	0.000
lnlabour	0.1310***	0.0450	2.91	0.004
lncapital	0.6275***	0.1201	5.22	0.000
lnfingerlings	0.1790*	0.0993	1.80	0.071
lnfeed	-0.5077***	0.1445	-3.51	0.000
½(lnlabour)^2	-0.1848***	0.0392	-4.71	0.000
½(lncapital)^2	0.0966***	0.0278	3.47	0.001
½(lnfingerlings)^2	0.4008	0.4018	1.00	0.319
½(lnfeed)^2	0.1181	1.3679	0.09	0.931
ln(lab)*ln(cap)	0.0614	0.0407	1.51	0.132
ln(lab)*ln(fing)	0.1887*	0.1130	1.66	0.061
ln(lab)* ln(feed)	-0.0513***	0.0105	-4.89	0.000
ln(cap)* ln(fing)	-0.3099**	0.1410	-2.20	0.026
ln(cap)*ln(feed)	3.3906***	1.0899	3.11	0.002
ln(fing)*ln(feed)	-1.9822***	0.7342	-2.70	0.007
Inefficiency Model				
Constant	-4.1868	1.5033	-2.79	0.005
Formal education	-0.1251***	0.0251	-4.98	0.000
Gender	-0.4348***	0.1801	-2.41	0.007
Marital status	0.2688	0.6921	0.39	0.698
FFA membership	-0.8930***	0.3196	-2.79	0.006
Land tenure	0.2730	0.2682	1.02	0.309
Technical advice	-0.3396***	0.1208	-2.81	0.003
Western region	-1.8439**	0.7300	-2.53	0.012
Eastern region	-2.0078*	1.0453	-1.92	0.055
Central region	-2.1514**	1.0227	2.10	0.035
Brong Ahafo Reg.	0.6034	0.9764	0.62	0.537
Greater Accra Reg.	-0.8092*	0.4648	-1.74	0.052
Variance parameter				
Sigma squared	0.1803***	0.0292	6.17	0.000
Gamma	0.7992***	0.2508	3.19	0.000
Lambda	1.9949	0.4768		
Log likelihood	-56.24704			
Mean TE	73.88%			

***Significance at 1%; **significance at 5%; *significance at 10%.

not merely think about increasing inputs or making credit available but that a means should be found to conduct efficiency monitoring and evaluation at the farm level with the view to creating awareness about the causes of farm level inefficiency. This finding is also a major indicator of how future policy interventions should be formulated and implemented: not top-down but bottom-up by employing participatory methods. Thirdly, it suggests the need for a follow-up on qualitative research to seek to understand qualitative underpinnings for inefficiency in Ghanaian smallholder fish production in greater depths. The σ^2 value of 0.18, highly significant at 1% is an indication of quite a good fit of the translog model for the data.

Distribution of the technical efficiency of smallholder fish farmers in Ghana

The overall mean technical efficiency of the sample was 73.88%. Stating this figure alone without further analysis of the performance of individual farms could be misleading, to say the least. It may be seen from Table 4 that most farms (43.5%) had technical efficiency scores

Table 4. Distribution of the overall technical efficiency of smallholder fish farmers in Ghana.

T.E Class	No. of fish farmers	Percentage
≤0.50	43.5	54
0.51 - 0.60	11	8.8
0.61 - 0.70	17	13.7
0.71 - 0.80	14	11.4
0.81 - 0.90	21	16.9
0.91 - 1.00	7	5.7

Source: Author's computation.

Table 5. Regional technical efficiency distribution of smallholder fish farmers in Ghana.

T.E Class	WR (%)	ER (%)	CR (%)	BA (%)	GA (%)	VR (%)
≤0.50	74.0	33.1	55.0	21.9	0.0	50.0
0.51 - 0.60	0.0	0.0	10.0	11.5	0.0	13.5
0.61 - 0.70	9.3	22.2	5.0	7.7	0.0	4.5
0.71 - 0.80	0.0	44.7	10.0	15.4	33.1	9.2
0.81 - 0.90	16.7	0.0	20.0	26.1	66.9	18.2
0.91 - 1.00	0.0	0.0	0.0	17.4	0.0	4.6

Source: Author's computation. Number of Fish Farmers: WR = 12; ER = 9; CR = 20; BA = 26; GA = 3 and VR = 22; Mean TEs: WR = 49.5%; ER = 61.0%; CR = 55.4%; BA = 66.0%; GA = 81.2% and VR = 59.5%; TE ranges: WR = 0.1375279 to 0 .8998032; ER = 0.2428515 to 0.7899342; CR = 0.0911026 to 0.8977706; BA = 0.1799706 to 0.9317483; GA = 0.809598 to 0.8621432 and VR = 0.0777726 to 0 .933502

below 50%. However, about 6% of farmers operated on or very close to the frontier. The results also indicate that the least efficient farm needs to improve its technical efficiency by some 23.9% to attain the mean efficiency score and the average farmer needs to adopt the best technology of the frontier farmers to increase its efficiency score by at least 26%.

The outcome of this study also brings to the fore the fact that only a small percentage of farmers is near the frontier and therefore policies to improve efficiency need to critically identify the factors responsible for the discrepancy in technical efficiency among farmers. Could regional differences contribute to these differences? This is considered in Table 5.

Regional technical efficiency distribution of smallholder fish farmers in Ghana

In Table 4 it was concluded that most farms operated below the mean technical efficiency score. We therefore assessed the technical efficiency of the sample based on the region within which they operated. From Table 5 it may be seen that on average the Greater Accra and the Western Regions were the most and least technically efficient regions respectively. However, considering the frontier most farmers (17.4%) in the Brong-Ahafo for instance, operated closest to or on the frontier, though in the same region majority of farmers (21.9%) operated at efficiency levels below 50%. This is an indication that even within the same region variation in efficiency could be observed among farmers. Consequently, though regional differences could explain some of the differences in technical efficiency, much more importantly the operations of individual farmers are very critical in this distinction. Onumah and Acquah (2010) however, concluded that region of production played no significant role in explaining the differences in technical efficiency.

Technical efficiency distribution of smallholder fish farmers in Ghana by gender

On average female respondents were more technically efficient than their male counterparts; however about 4.8% of males had efficiency scores between 0.91 and 1.00 (Table 6), an indication that males operated closer to the frontier than females. In a similar study to measure technical efficiency of maize farmers in the Mfantseman Municipality in Ghana, Essilfie et al. (2011) discovered that female maize farmers were more technically efficient, stating that males were more likely to be involved primarily with the production of cash crops.

In their study of aquaculture in Southern Ghana, Onumah and Acquah (2010) also concluded that males were generally more technically efficient, citing the strenuous and laborious nature of fish farming as a reason. The implication of these varied findings is that

Table 6. Gender technical efficiency distribution of smallholder fish farmers in Ghana.

T.E Class	Male (%)	Female (%)
≤0.50	44.2	35.0
0.51 - 0.60	9.6	15.0
0.61 - 0.70	10.6	20.0
0.71 - 0.80	12.5	10.0
0.81 - 0.90	18.3	20.0
0.91 - 1.00	4.8	0.0

Source: Authors' Computation from FAO dataset (2005). Mean TE: Male = 56.9% and Female = 60.6%.

Table 7. Likelihood ratio tests.

Variable description	Chi^2	Df	P > | Z |	Decision
$H_0 = \beta_{ij} = 0$	42.01	17	0.000	Reject H_0
$H_0 = U_t = 0$	50.23	10	0.000	Reject H_0
$H_0 : \gamma = \delta_0 ... \delta_6 = 0$	36.49	13	0.000	Reject H_0

Source: Authors' Computation from FAO dataset (2005).

gender may not be conclusive in explaining the variations in technical efficiency among smallholder fish farmers in Ghana.

Tests of hypotheses

As was indicated earlier in this paper, to ensure that the estimation procedure and thus the results obtained were as reliable as possible, we carried out tests on the hypotheses stated. For the first null hypothesis, a nested hypothesis test was performed to determine whether the Cobb-Douglas specification is an adequate representation of the frontier production function. This test uses the log Likelihood ratio test.

Table 7 outlines the results of the null hypothesis. The null hypothesis $H_0 = \beta_{ij} = 0$ is rejected in favour of the translog production function. The second null hypothesis explores the test that specifies each smallholder fish farmer is operating on the technically efficient frontier and that the systematic and random technical efficiency in the inefficiency effects are zero. This is rejected in favour of the presence of inefficiency effects. The final null hypothesis determines whether the variables included in the inefficiency effects model have no effect on the level of technical inefficiency. This is also rejected confirming that the combined effect of these variables on technical inefficiency is statistically significant.

Conclusion

The main objective of this paper was to determine the levels and the factors affecting the technical efficiency of smallholder fish production in Ghana. We started off on the premise that different farms would have different levels of technical efficiency owing to farm-specific factors such as the level of experience of the farm owner, the tenure of land, among others; hence these were incorporated in the stochastic frontier in a single-stage modeling procedure. The results of the study showed that the labour employed, the number of fingerlings stocked and the quantity of feed used were positive and significant determinants of technical efficiency among smallholder fish farmers.

Furthermore, interaction between some exogenous variables were found to have significant and positive effects on the endogenous variable and hence efficiency. For instance it was demonstrated that if pond area simultaneously increased with number of fingerlings feed and labour, *ceteris paribus*, the total output of fish would increase (Table 2). This indicates a holistic approach is needed to improve efficiency.The effect of geography on the efficiency of production as captured by the coefficients of the regions indicates that the region within which a farmer operates does have an effect on technical efficiency. On the average the most technically efficient region was the Greater Accra Region (81.2%); a further study to find out how farmers in this region attain such technical efficiency scores is recommended, to serve as the basis for improving the efficiencies of the other regions. The overall average technical efficiency among smallholder fish producers was estimated to be 73.88%. This means that there is the possibility of increasing the efficiency level by some 26.12% if the best practices of the frontier farmer could be emulated and the necessary support given by the government. The average efficiency scores are however, not very representative of the sample since the standard deviations are high and therefore the distribution of farmers according to efficiency indices is tabulated, from which it is concluded that inefficiency among the respondents does not lie only in over-utilization, but also underutilization of significant inputs.

These findings have very important policy implications. Since technical advice enhances efficiency, training members of fish farmer associations by extension agents could help reduce over-feeding and improve on the technical efficiency and hence output. Formal education should be encouraged in the study area, and where possible fish production should be included in the agriculture and integrated science syllabi in the primary and secondary schools, since this may help improve efficiency of fish production in the future. Increases in pond areas will result in the reduction of output, but membership in FFAs could improve output, therefore the formation of more fish farmer cooperative societies is hereby recommended so that the more highly educated and the less educated ones will have the opportunity to learn from each other and members should be encouraged to construct smaller ponds for easier management and hence improve efficiency. Furthermore, membership in fish farmers' associations is a very important determinant of technical efficiency and this medium could be used as the platform for discussing important innovations that could improve efficiency.

Involving fish farmers in the drafting of policies is a recommendation worth noting, especially because most of the variations in technical efficiency result from factors directly under the control of farmers rather than from stochastic factors. A participatory bottom-up - rather than the traditional top-down - approach to solicit the view of farmers before formulating policy interventions would help in the adoption of innovations and hence the sustainability of such interventions.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

The effects of land tenure practices on agricultural output in Agatu Local Government Area of Benue State, Nigeria

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The study examined the agricultural land use of small holders in Agatu Local Government Area of Benue State, Nigeria. It provides both qualitative and quantitative information about the prevailing agricultural land use practices in the study area. Various aspects of the existing agricultural practices (such as land use types, mode of access to land, implements and labour characteristics and agricultural inputs) were examined to ascertain the linkage between the land tenure and agricultural output and income of farmers. The survey covered a sample of 300 farmers drawn from 30 villages using stratified and systematic random sampling procedures. The information on the farming system shows that, a great number of farmers (70%) mostly cultivate small plots using traditional farming implements. The chi-square technique was used to test the relationship between the farmers' prevailing land tenure practices and the agricultural output of the study area. The results (Chi-square calculated 125.3 and table value 7.82) of the study proved that, land tenure practices has greatly constrained agricultural output of farmers in Agatu Local Government Area of Benue State. The study therefore, recommended: the expansion of Fadama (floodplain) farming, land tenure reformation and farm consolidation, improving the techniques of farming, provision of credits to farmers, formation of co-operatives and provision of infrastructural facilities in the area.

Key words: Land tenure, landuse practices, agricultural output, tenure security.

INTRODUCTION

Land is the basis for every form of physical development and constitutes the primary medium for food production, for the provision of shelter and utilities, for the manufacture of goods and the establishment of institutions to support the basic needs of modern communities (Lasun and Olufemi, 2006). Hence, it's the farmers' most important asset and plays essential role in increasing as well as sustaining the agricultural production. Ukaejiofo (2009) noted that land lies at the heart of social, political and economic life of most African countries. He stressed further that, it is the key factor for economic growth and development of every nation and the foundation for shelter in the urban areas as well as the source of livelihood in the rural areas. Therefore, it is

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an indisputable source of empolyment and wealth.

However, ownership of land often interferes with its use as an agricultural asset. The right of people to own, use and control land and its resources are known as land tenure system. The term land tenure is derived from the Latin word tenere which means 'to hold'. According to Ogolla and Mugabe (1996), tenure defines the methods by which individuals or groups acquire, hold, transfer or transmit property rights in land. Subsequently, Land tenure can be conceived as the relationship, whether legally or customarily defined, among people, as individuals and groups with respect to land and other natural resources (Food and Agricultural Organisation of United Nations (FAO), 2005). Doner (1964) defines land tenure as the 'actual legal, contractual or simply understood customary arrangements whereby people in agriculture try to arrange for an initial access to route to the income flow and the way by which these routes are secured'. In Dorner's perception, the level of productivity in the agricultural sector is a factor of the level of agricultural income. He contends that, the levels of agricultural income are affected by the degree of access to rights in land. Consequently, the thrust of his definition is to ensure a system of tenure, which does not only guarantee an initial access to rights in land and income, but also ensures the security of that access.

However, Ouedraogo and Traore (1999) conceive tenure as it relates to land and other natural resources, which has led some people to refer to agricultural tenure, pastoral tenure, forest tenure and even tenure of fishing grounds. It is imperative to note that, the rights of ownership and use of land involve emotions. Hence, Ukaejiofo (2009) opined that, land in Africa has historical, cultural, social and spiritual significance to the communities and to individual holders. Correspondingly, Famoriyo (1977) remarked that, land matters evoke great depth of feelings as a result of economic and socio-political implications attached to its control. People generally guard their land jealously whether it is currently exploited or not. This has far-reaching implications for primary agricultural production.

In Nigeria, land has been subjected to miscellaneous uses such as recreation, wildlife, industries, communication, building, agriculture and other uses. The percentage of agricultural land area in Nigeria according to World Bank Report, published in 2010, was 81.80 in 2009. Hence, agriculture constitutes the largest user of land and to facilitate rural development, high priority has to be given to agricultural sector. Tenure relationships in Nigeria are diversely characterized, which impedes general prescriptions. For instance, Benue State in Nigeria has a large expanse of arable land but many and varied are the land tenure systems. As a result, dealings in land have continued as if the land use act of 1978 which stipulated that, lands belonging to the government has not been passed. This has in no small measure hampered effective land management in the state. Most of the lands in Agatu Local Government Area of the state and other parts of Idoma speaking area are cultivated by small-scale farmers. A substantial amount of agricultural production takes place under the traditional system characterized by primitive production technology, shifting cultivation or rotational bush fallow, wide spread illiteracy among the peasant farmers, and minimal application of improved inputs such as fertilizer, agro-chemical and farm machinery (Adaji, 2000). In addition to the above characteristics, the land tenure institution poses a severe constraint of inalienability, insecurity of tenure, land fragmentation and 'atomization' of holdings due to the customary law of inheritance. Consequently, the agricultural system remains largely subsistence which can no longer meet the food requirement of the present population. Olayide (1980) have pointed out that by increasing yield per hectare and expansion of cultivated areas, food production would be able to keep pace with increasing population. But up till date, the traditional system continues to produce most of the food consumed in the country. Therefore, if production is to be stepped up and if the standard of living of the small farmers is to be improved, an improvement of food production in the traditional sector is necessary. However, only little is known about land holding systems in Agatu Local Government Area. According to Cleave (1974), before any consideration can be given to possible development in African small holdings and the means through which this can be improved, we must determine what farmers are doing, what factors control their activities and what pressures there are to change the pattern of agricultural land that results.

The purpose of this study therefore, is to determine the relationship between systems of agricultural land tenure and output in Agatu Local Government Area with a view to understanding current situation and to proffer solutions for more effectiveness. Hence, the study seeks to provide answers to the following questions:

1. What are the prevailing land tenure systems in Agatu?
2. To what extent has the tenure system in Agatu posed constraints to land acquisition?
3. To what extent has the amount of land owned influenced the farmers' level of output?
4. How has the size of land possessed impacted on the kind of agricultural land use?

Specifically, the study aims at:

1. Determining the characteristics of land tenure types in Agatu.
2. Determining the link between access to land and farmers' level of output in Agatu.
3. Assessing the relationship between land holding and land use practices in Agatu.

The following hypothesis (stated in the null form) guided

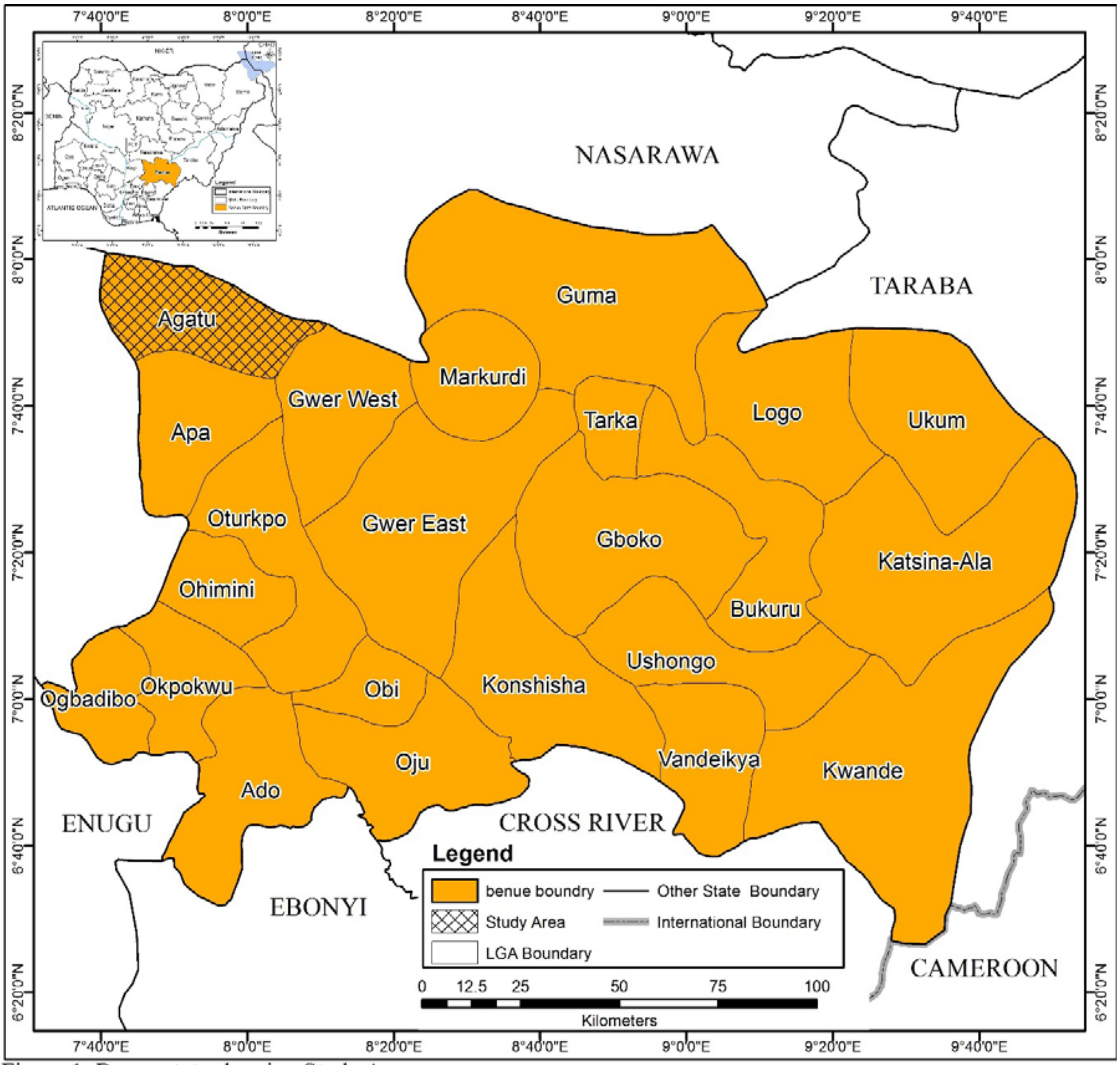

Figure 1. Location of study area; Source: Adapted and modified from administrative map of Benue state.

this study:

Ho: The level of agricultural output would not be significantly affected by the type of tenure systems in Agatu Local Government Area.

Study area

The Study focuses on Agatu Local Government Area of Benue State in Nigeria, which was formally carved out of Apa Local Government on the 1st of October, 1996. Agatu, which consists of 10 wards, stretches from latitude of 7°45' and 8° N and longitude of 7° 50' and 8° E at the North-west of the state (Gbue, 1999). According to Bureau for land and survey, Makurdi has a total area of about 1001km^2, with a population of 115,597 people (2006 census). Agatu is bordered by Nassarawa State in the North, Apa Local Government Area in the South, Gwer West in the East and Omala Local Government (Kogi State) in the west (Figures 1 and 2).

It has 2 distinct seasons, the rainy season (900 to 1200 mm of rainfall) which lasts from April to October and the dry Season which commences from November to March with a dry dust-laden North–easterly trade wind (harmattan).Temperature of the study area is between 23 to 35°C (Ngutsav and Akaahan, 2002)

Agatu Local Government is basically an agrarian community and has the largest Fadama land in Benue State. Its vast fertile land is tilled by the farming population given rise to a variety of agricultural produce. It is endowed with a lot of human and natural resources such as minerals (including limestone, coal, marble, iron ore etc) agricultural, forestry, water and tourist resources. In fact, the agricultural resources of the studied area are enormous that, if well harnessed and utilized, could feed

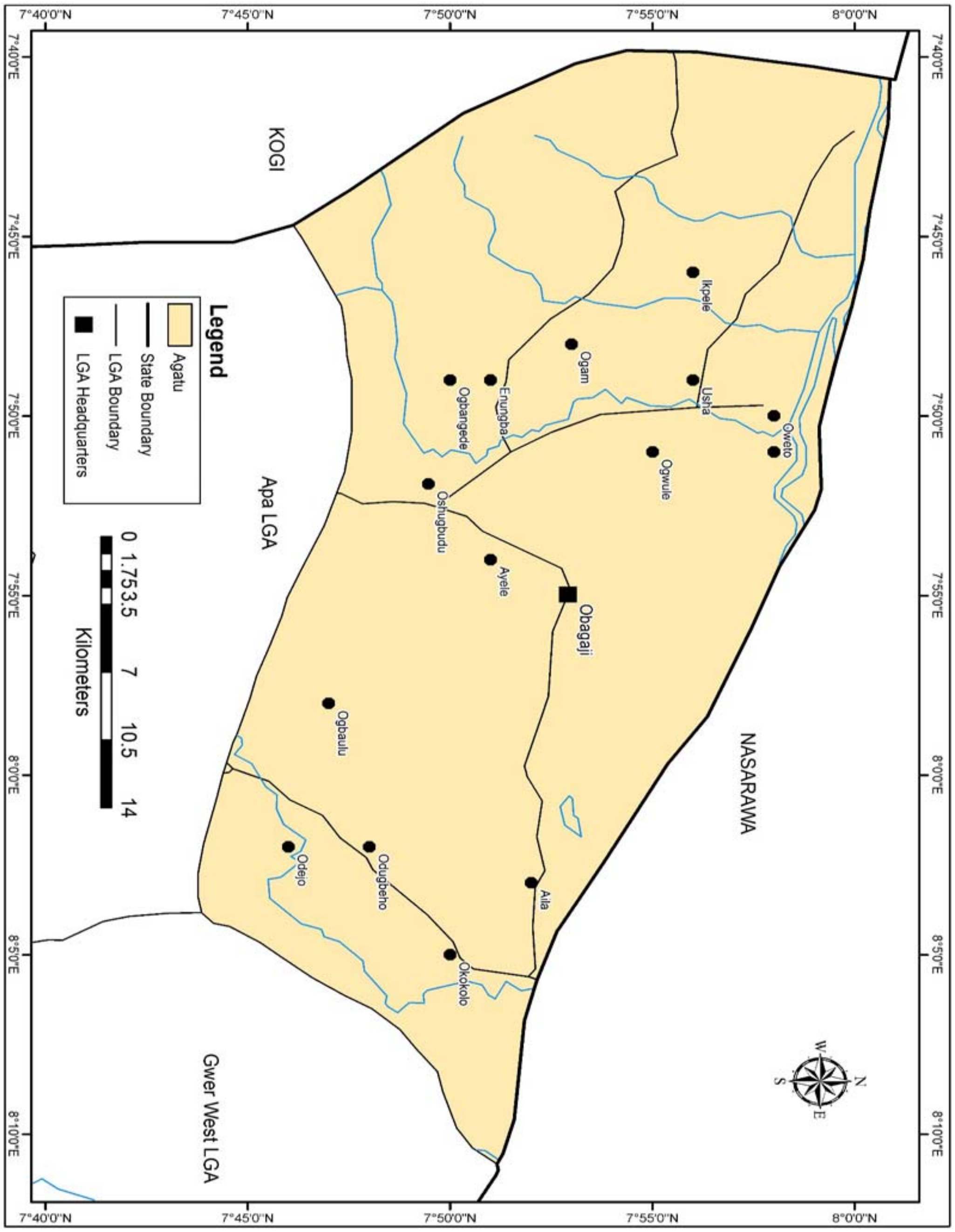

Figure 2. Agatu; Source: Abapted and modified from the administrative map of Benue State.

the whole of Nigeria.

The people of Agatu Local Government are predominantly Christians. There are only a few Muslims and adherents of traditional religions. Despite the differences in religious beliefs the people live in harmony.

METHODOLOGY

In order to achieve the objectives of this study, data were collected on the following variables: the nature of land holdings, the kind of agricultural land use practices, the mode of land acquisition, farmers' level of output and implements, and labour characteristics in Agatu Local Government Area. The research design adopted is descriptive survey method. According to Best (1980), descriptive survey method enables the researcher to obtain the opinion of the representative sample of the target population in order to be able to infer the response of the entire population. For administrative convenience, Agatu Local Government was divided into 3 districts (such as Adogoji, Agbaduma and Achega) based on differences in cultural heritages and practices. One hundred respondents were randomly selected from each of the 3 districts to make a grand total of 300 farmers for the study. To do this, the total population of the

Table 1. Distribution of respondents by gender in agatu local government area.

District	Gender	
	Male (%)	Female (%)
Adogoji	100	-
Agbaduma	94	6
Achega	68	32
Total	262(87.33)	38(12.67)

Table 2. Distribution of respondents by age group in Agatu LGA.

Age group	Number	Percentage
20-30	62	20.67
31-40	60	20.00
41-50	67	22.33
51-60	75	25.00
61-70	34	11.34
71-80	2	0.66
Total	**300**	**100**

farming families was determined from taxable adult register. Each member of this population was numbered serially and then using a portion of the table of random numbers, 300 farmers were selected. Despite differences in the population of the districts, the researcher selected 100 respondents to ensure that the districts were equally represented. This is believed to be an objective selection of sample capable of expressing reality

The instrument for this study was a structured questionnaire designed to elicit information on the demographic structure, socio-economic and labour characteristics of households, area of land under cultivation, total production and receipt by households. The data collection took a period of 2 months. Data were also sourced from Federal Office Statistics (FOS), Benue Agricultural and Rural Development Authority (BENARDA), internet, seminar papers, journals and other academic publications mostly on land use practices and agricultural development.

RESULTS AND DISCUSSION

The generated field data were analyzed using frequency distribution, percentages, tables and mean, while the Chi-square statistics was employed to test H_0 that is, to find out whether significant differences existed between systems of land tenure and agricultural output. The level of significance was set at 0.05.

Table 1 shows gender distribution of respondents 87.33% were males, 12.67% were females. This implies that, a greater percentage of respondents were males, which further indicates that, men have greater control over land than women in Agatu LGA. However, on the basis of districts, it can be deduced from the table that gender disparity in Agatu Local Government is Highest in Adogoji districts as control over land is exclusively dominated by the males; it is high in Agbaduma district and moderately low in Achega district.

Table 2 reveals the age distribution of the respondents. 25% are above the age of 50 whereas 12% are above the age of 60. Thus, only about 63% of the farmers are physically active (the active farming age in Agatu is between the ages of 20 to 50 and this constitutes majorly the youths.)

Table 3 shows distribution of respondents by marital status. It reveals that, 85 representing 28.33% of the respondents are polygamists. This has far reaching implications for agricultural development. The reason being that, high polygamy is advantageous in terms of increase in labour force, which is an index of high productivity. Hence, Agatu Local Government has sufficient labour force to enhance agricultural productivity.

Table 4 presents the distribution of respondents by educational level. It portrays that, over 90% of respondents are literate to varying degrees. Hence, farmers in the studied area could be flexible to agricultural innovations that would result to intensive and improved production techniques.

Table 5 expresses the link between land tenure and nature of agricultural land use in Agatu Local Government Area. It shows that, there is freehold predominates (50% of the farmers) in Agatu Local Government Area and it is only the free holders that engage in tree crop production and fishery. This could be due to the fact that, freeholders have more security of tenure which induces long-term agricultural investment. The table further reveals that, arable cropping is majorly undertaken by farming households who rent land, while livestock farming is undertaken mostly by communal land owners. Arable cropping which is predominantly carried out by communal land owners and renters is probably due to lack of tenure security on their part which impedes long term investment.

Table 3. Distribution of respondents by marital status in Agatu LGA.

Marital Status	Number	Percentage
Single	62	20.67
Polygamy	85	28.33
Monogamy	63	21.00
Widowed	46	15.33
Separated	30	10.00
Divorced	14	4.67
Total	300	100

Table 4. Distribution of respondents by level of education in Agatu LGA**.**

Level of education	Number	Percentage
Never went to school	27	9.00
Primary	55	18.33
Secondary	63	21.00
Diploma/NCE	100	33.34
Degree and equivalent	45	15.00
Post graduate	10	3.33
Total	300	100

Table 5. Land tenure and agricultural land use system in Agatu LGA.

Land Tenure	Nature of land use					
	Poultry	Fishery	Arable	Tree Crop	Livestock	Total
Communal	-	-	45	-	25	70
Freehold	-	30	50	70	-	150
Rented	10	-	60	-	10	80
Total	**10**	**30**	**155**	**70**	**35**	**300**

Table 6 demonstrates the relationships between systems of land tenure and agricultural output in Agatu Local Government Area. The table has revealed that, farmers who rent land have higher output of agricultural production than freeholders and communal land owners. This indicates that, renters of lands who usually have small parcels of land go on more intensive agriculture resulting into higher yield. The table reveals further that, 138 farmers (46%) have output of between 1000 to 1500 tonnes. Hence, agricultural output in Agatu Local Government Area is highly appreciable.

Table 7 indicates calculated X^2 table value as 125.31while the degree of freedom df is 4 leaving the X critical to be 7.81 at 0.05 level of significance. Therefore, with the calculated X^2 value at 125.31 and X^2 critical table value at 7.82 less than calculated value, the null hypothesis that, systems of land tenure in Agatu Local Government Area would not significantly constrain farmers' level of output is rejected. Whereas the alternative hypothesis at 95% confident interval which has affirmed a relationship between the mode of land tenure and farmers' level of output in Agatu Local Government Area is accepted. Hence, the land tenure in Agatu Local Government Area has significantly constrained agricultural output of farmers.

SUMMARY OF FINDINGS

This has revealed that:

i) The control of land especially for agricultural uses in Agatu Local Government Area is almost exclusively dominated by the males
ii) Only about 63% of the farmers are physically active, while the remaining 37% are above the age of 50, which are less capable of providing the type of efforts required by using hoe and other local implements to till the soil.

Table 6. Land tenure systems and agricultural output in Agatu LGA.

Land Tenure	Output (tonnes)			
	Less than 500	500-1000	1000-1500	Total
Communal	30	35	5	70
Freehold	20	70	60	150
Rented	2	5	73	80
Total	52	110	138	300

Table 7. Chi-square relationship between land tenure and farmers' level of output in Agatu LGA.

Parameter	N	Df	$\chi^2_{cal.}$	$\chi^2_{crit.}$	Decision
Communal	3				
Freehold	3	4	125.31	7.82	Reject null hypothesis
Rented	3				

iii) Farmers in Agatu Local Government Area are predominantly polygamist.
iv) Over 90% of the farmers in the area are literate to varying degrees.
v) There is a vast land for agricultural uses in Agatu Local Government Area .However, subsistence production predominates.
vi) About 50%, i.e. half of the farmers in the area acquired land for agriculture through inheritance.
vii) The awareness of the importance of documents to support claims over land or plots is on the increase in Agatu Local Government Area. Almost 50% of farmers possessed all sorts of documents to back up their ownership status, while about 40% lacked certificates to validate their claims over land.
viii)40% of the farmers in the local government have less land now than they had five years ago indicating that family land is being fragmented with increase in the family size.
ix) Agatu Local Government Area is an agrarian community in that 100% of the inhabitants practiced arable cropping.
x) 50% of the farmers in Agatu Local Government Area are freeholders.
xi) Farmers who rent land in Agatu Local Government Area have more yield of agricultural production.
xii) A substantial amount of agricultural production in Agatu Local Government Area takes place under the traditional and manual system since more than half of the entire farmers use hoes and cutlasses.
xiii) The dominant source of labour which has been debilitated by rural/urban migration and the influence of formal education. Hence, labour constitute a major constraint to agricultural production in Agatu.
xiv) The major agricultural inputs used by farmers in Agatu Local Government Area are fertilizers and herbicides.
xv) Capital constitutes a major limitation to farmers in Agatu Local Government Area seeing that, over 90% of them survive through meager savings out of profits or profits from farm proceeds.
xvi) About 57% of (more than half) of the farm proceeds in Agatu Local Government Area is sold for money, while a negligible proportion is preserved for future.

CONCLUSION AND RECOMMENDATION

Based on the major findings of this study, it could be readily observed that, the tenure right is a major barrier to the development of agriculture in the study area and to solve the problem, it would sound logical to propose a strategy whereby available land is fairly distributed among the farmers and that would be through the land tenure reformation and land consolidation method. Hence, the following recommendations are made:

i) Attention should be focused on agricultural innovations that are small farmers centered.
ii) Fruit, livestock and fish farming should be encouraged to reduce over dependence on arable cropping.
iii) Dry-season farming and gardening through irrigation should be developed in addition to rain fed agriculture in order boost up agricultural production.
iv) Government is enjoined to assist the farmers with loans and other agricultural inputs to enhance large scale production through mechanized farming.
vi) Farmers are advised to form cooperatives, a medium through which they could be easily reached and their pressing issues of interest handled.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Trend and determinants of multidimensional poverty in rural Nigeria

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Government continues to initiate programmes to address the challenge of poverty in Nigeria.This paper investigates the poverty levels over time using the multidimensional approach and estimates its determinants; using the National Living Standard Survey data of 2004 and 2010. The Alkire-Foster methodology and the Logit model were employed for analysis. The result showed that 70% of rural households are headed by males, are still in their economically active years and practice agriculture. Also, more than one third have no education. The adjusted headcount ratio, headcount ratio and the intensity of poverty increased in 2010 relative to 2004. The absolute and percentage change in poverty reveals that change is higher for the headcount ratio than the intensity of poverty. The health, asset and education dimensions contributed most to poverty. Agriculture has the highest adjusted poverty incidence. Being in a female headed household, increased household size, working in the agriculture sector and residing in the northern zones increase the probability of being poor. Education, working in non-agricultural sector and services, residing in South West and South East zones reduce the probability of being poor. Effort should be targeted at reducing the number of poor households; and the health, asset and education dimensions require special attention; as well as those engaged in agriculture and resident in the northern regions of the country.

Key words: Multidimensional poverty, Alkire-Foster, logit, rural Nigeria.

INTRODUCTION

The Nigerian economy has experienced substantial growth in the last decade. The real GDP growth rate rose from 2.7% in 1998 to 5.3% in 2006 and increased to 7.2% in 2011 (NBS, 2010; CIA, 2012). In spite of improvement in the country's economic growth, Nigeria suffers from high levels of poverty and it is widespread. Poverty incidence has risen over the years and was estimated to be about 69% in 2010 (NBS, 2010). The country retrogressed to become one of the 25 poorest countries at the threshold of the twenty-first century from a ranking among the richest 50 in the early-1970s. Poverty incidence was quite alarming when measured using international poverty line, which is population below $1.00 in terms of Purchasing Power Parity PPP, and was estimated as 61.2% in 2010. Those who live on less than $1.25 a day was 64.41% in 2003/2004 and 68% in 2010 (World Bank, 2011). In Nigeria, poverty is especially severe in rural areas where social services and infrastructure are limited (IFAD, 2012). Poverty incidence rose from 16.2 to 43.1% in the urban sector and from

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28.3 to 63.8% in the rural sector between 1980 and 2004 respectively. For over four decades in Nigeria, all attempts to put the rural areas on course of development have not been successful (Oyeranti and Olayiwola, 2005). Conditions have continued to worsen and poverty has become a major issue in the rural areas of the country in spite of its potentials and rich natural resource endowment.

The Government at various levels has continued to make efforts to transform the economy and reduce poverty. Some of these programmes include: Directorate of Food, Road and Rural Infrastructure (DFRRI), Better Life Programme (BLP), National Directorate of Employment (NDE), Agricultural Development Programme (ADP), National Agricultural Land Development Programme (NALDP), Family Support Programme (FSP), Family Economic Advancement Programme (FEAP), Poverty Eradication Programme (PEP) and National Poverty Eradication Programme (NAPEP). The latest of this is the National Economic Empowerment Development Strategy (NEEDS), State Economic Empowerment Development Strategy (SEEDS) and Local Economic Empowerment Development Strategy (LEEDS). Most of these programmes were bureaucratic and unable to effectively address the needs of the rural people.

Several studies have estimated poverty in Nigeria from the unidimensional approach (World Bank 1996; FOS, 1999; Olaniyan, 2000; Omonona, 2001; Olaniyan and Abiodun, 2005; Okunmadewa et al., 2005). Some employed multidimensional approaches (Oyekale et al., 2007; Oni and Adepoju, 2011; Ataguba et al., 2011). Few studies have also focused on rural poverty using these approaches (Oyekale et al., 2007; Oni and Adepoju, 2011; Ologbon, 2012). These studies on multidimensional poverty in rural Nigeria have employed the Fuzzy set to estimate the capabilities of rural households. While these studies have been able to identify the number of poor, it does not take into account the intensity of deprivations among the poor (Alkire and Roche, 2011); and violates dimensional monotonicity. An exception is the study by Ologbon (2012) which estimated poverty in the riverine areas using the Alkire- Foster method. Following Alkire et al. (2011) and Ologbon (2012), this study attempts to estimate rural poverty over time for the entire country; applying the Alkire- Foster method which is essentially rooted in the capability approach. This methodology will not only give the incidence and intensity of poverty but also identify deprivations driving poverty. This will inform policy makers on possible areas where interventions are required to lift the poor out of poverty.

Objective

1. Estimate the poverty status of rural households over time.
2. Identify factors that influence the poverty status of households.

Measurement of poverty

Alkire and Foster's (2007) methodology includes two steps: An identification method (*ρk*) that identifies 'who is poor' by considering the range of deprivations they suffer, and an aggregation method that generates an intuitive set of poverty measures (*Mα*) that can be broken down to target the poorest people and the dimensions in which they are most deprived.

The notation $y = [y_{ij}]$ denote the *n x d* matrix of achievements, where n represents the number of households, d is the number of dimensions, and $y_{ij} \geq 0$ is the achievement of household *i= 1, 2…..,n* in dimensions *j= 1,2,…d*. The identification method involves considering the vector *c* of deprivation counts obtained from the deprivation cut-off, z (first cut-off); which is then compared against a poverty cutoff *k* (second cut-off) to identify the poor, where *k = 1…d*.
Hence, the identification method ρ is defined as $\rho_k(y_i; z) = 1$ whenever $c_i \geq k$, and $\rho_k(y_i; z) = 0$ whenever $c_i < k$. It means that a household is poor if deprived in at least *k* number of dimensions. When *k*=1, then the identification criterion corresponds to the union approach whereas at *k= d,* the identification criterion corresponds to the intersection approach. A common alternative is to take a cutoff that lies between 1 and *d*. Finally, the set of households that are multidimensional poor is defined as $Z_k = \{i: \rho_k(y_i; z)\}$. The ρ_k is referred to as a dual cutoff method[1] because it first applies the within dimension cutoff z_j to determine which household is deprived in each dimension, and then the across dimension cutoff *k* to determine the minimum number of deprivations suffered by an household to be considered multidimensional poor.

Multidimensional poverty measure

The headcount ratio or the percentage of households that are poor *H= H(y;z)* is defined by:

$$H=q/n \quad (1)$$

Where $q = q(y; z)$ is the number of households in the set z_k, as identified using ρ_k. While it is easy to compute, it violates dimensional monotonicity in which case, if a poor household becomes deprived in an additional dimension, the headcount ratio does not change. Alkire and Foster (2007) proposed a headcount measure that is

[1] For detailed description of the methodology, see Alkire et al. (2011)

adjusted by the average number of deprivations experienced by the poor.

In this regard, a censored vector of deprivation counts c_k is defined so that if $c_i \geq k$, then $c_i(k) = c_i$; and if $c_i < k$, then $c_i(k) = 0$. This means that in $c(k)$, the count of deprivations is always zero for households that are not poor , while households that were identified as poor keep the original vector of deprivation counts c_i. Then, $c_i(k)/d$ represents the shared possible deprivations experienced by a poor household i , and hence the intensity of poverty (deprivations shared across the poor) is given by:

$$A = |c(k)|/(qd) \quad (2)$$

The adjusted headcount ratio $M_0(y;z)$ is given by:

$$M_0 = HA \quad (3)$$

The adjusted headcount ratio has other properties including dimensional monotonicity, deprivation focus, poverty focus and subgroup decomposability in addition to standard properties of a poverty measure. The dimensional monotonicity implies that A rises when a poor household becomes deprived in an additional dimension even though the headcount remains the same. Similar to the headcount ratio H, M_0 satisfies decomposability.

M_0 can be decomposed by population subgroups. The decomposition is expressed as:

$$M_0\ (x,y;z) = \frac{n(x)}{n(x,y)} M_0(x;z) + \frac{n(y)}{n(x,y)} M_0(y;z) \quad (4)$$

Where x and y corresponds to two subgroups with size n(x) and n(y) and total population size $n(x,y)$. The overall poverty is the weighted average of subgroup poverty levels, where weights are subgroup population shares.

It is also possible to break down overall multidimensional poverty measure to reveal the contribution of each dimension j. Once the identification step has been completed, all members of the $M_0(y;z)$ family can be broken down into dimension subgroups. Then, $M_0(y;z)$ can be break-down into dimensional groups as:

$$M_0(y;z) = \sum_{i=1}^{n} \mu\left(g_{*j}^0(k)\right) / d$$

(5)

Where g_{*j}^0 is the j column of the censored matrices $g^0(k)$. Once the identification has been applied, and the non-poor rows of g^0 have censored to obtain $g^0(k)$, , for each j, $\left(\mu\left(g_{*j}^0(k)\right) / d\right) / M_0(y;z)$ can be interpreted as the post-identification contribution of dimension to overall multidimensional poverty.

Changes over time

The change in poverty over two time periods can be due to the effect of changes in the incidence of poverty or intensity of poverty or the interaction between the two (Alkire et al., 2011). This change can be assessed by considering either the absolute change across the two time periods and/or the percentage change across the two time periods. The absolute change is the difference in the level of any focal indicator across two time periods. The percentage change in poverty expresses the change relative to the initial poverty level. For two time periods t_x and t_y where t_x is less than t_y and w is a vector of the relative weights of the indicators; these changes are estimated as:

Annual Absolute Change in Poverty (Mo) is:

$$\Delta M_o\ (X,Y;z,k,w) = \frac{[M_o(Y;z,k,w) - M_o(X;z,k,w)]}{t_y - t_x} \quad (6)$$

Annual percentage change in poverty (Mo):

$$\delta M_o\ (X,Y;z,k,w) = 100 \times \frac{[M_o(Y;z,k,w) - M_o(X;z,k,w)]}{(t_y - t_x)M_o(X;z,k,w)} \quad (7)$$

METHODOLOGY

Scope of study

Nigeria is the most populous country in Africa and the ninth most populous country in the world providing habitation for 1.9% of the world's population as at 2005. The population of the country rose from about 88.5 million in 1991 to 140 million in 2006 (FRN, 2007) and 168.8 million in 2012 (World Bank, 2012). The study area is rural Nigeria with a population of 77,803,783 in 2010 (World Bank, 2012). Nigeria is made up of 36 states and a Federal Capital Territory (FCT), grouped into six geopolitical zones: North Central, North East, North West, South East, South South and South West.

Source and type of data

The study uses secondary data comprising mainly of the National Living Standard Survey (NLSS) data in 2004 and 2010. The NLSS survey data is a national representative data and provides data on household's socio-economic and demographic data. The data used in this paper are age, gender, marital status, primary occupation, household size, educational attainment and geo-political zones. Others are household's type of dwelling, floor material, wall material, roof material, fuel for cooking, source of lighting, toilet type and source of drinking water. In addition, data on if household head ever attended school or has at least six years of formal education, any member suffer any form of illness or activities stopped due to illness, household asset ownership and land ownership were obtained.

Table 1. Dimensions, indicators, deprivation cutoffs and weights of MPI.

Dimension (Weight)	Indicator (Weight)	Deprivation cut-off
Housing (1/5)	Type of dwelling (1/30) Floor material (1/30) Wall material (1/30) Roof material (1/30) Fuel for cooking (1/30) Source of lighting (1/30)	Households living in a single room, house with no flooring (that is, a mud or dung floor) or inadequate roofing and wall material. (United Nations, 2003). Households using firewood, coal as main source of cooking fuel and those without electricity, solar and other improved sources as main lighting material.
Sanitation (1/5)	Toilet type (1/10) Source of drinking water (1/10)	Households using unimproved sanitation facilities such as pit latrine without slab, open pit latrine, bucket toilet and hanging toilet(United Nations, 2003), and households using water from an unimproved source such as open wells, open springs or surface water. (United Nations, 2003)
Education (1/5)	Ever attended school (1/10) Household head with at least six years of formal education.(1/10)	Household head that has not attended any form of schooling and households without household head having at least 6 years of formal education. (United Nations, 2003).
Health (1/5)	Suffer any form of illness (1/10) Activities stopped due to illness. (1/10)	Household heads that suffer from any form of illness and stopped activities as a result of such illness
Assets (1/5)	Asset ownership (1/10) Land ownership (1/10)	The household does not own more than one of the following assets: bicycle, radio, telephone, television, a house and does not own agricultural land

Analytical technique

The Alkire-Foster methodology explained under the measurement section is used to estimate the multidimensional poverty. The dimensions and indicators considered are listed in Table 1.

Dimensions and cut-offs

The determinants of poverty are estimated using the logit model. The model is specified as:

$$z_i = b_0 + \sum_{j=1}^{k} b_k x_{ij} + \varepsilon_i \quad (8)$$

Z_i is the poverty status of the i^{th} household represented with a dummy; 1 if poor and 0 otherwise. j =1, 2, ……k are the vectors of the predictor variables explaining poverty b_0, $b_k$are the parameters to be estimated while $\varepsilon_k$is the error term.

The predictor variables X, are: Gender of household head, age of household head, marital status, primary occupation of household head, educational attainment of household head, Household size and geo-political zones.

RESULTS AND DISCUSSION

Socio-demographic characteristics

Table 2 presents the socio-demographic characteristics of households. The patterns of distribution of socio-demographic characteristics of households are similar in the years considered (2004 and 2010). The male household heads represent 86% of all households in both years. This agrees with the pattern of household headship in Nigeria. Aigbokhan (2000) reported a similar result with only 13.5% of household heads being female. Similarly, the heads of households are mostly within ages 20 and 59 years representing 76.8% in 2004 and 73.7% in 2010. This means that they are still in their economically active years which enables them engage in diverse means of livelihood. Households with sizes between 4 to 6 persons represent about 40% in each year; followed by those with 7 to 9 persons. Only a quarter has household sizes of seven and above which means that most of the households are not excessively large in size. Over 60% had no education in 2004 but it reduced in 2010 to 44.8%. However, much of the reduction is due to increase among those with primary education in 2010. Although, the reduction is large but over one-third still have no education. There is need for increased literacy among household heads and also access to education beyond primary level. Agriculture remains the primary occupation for about 70% of rural households. This agrees with the description of the rural sector as mostly an agrarian society as stated by Okunmadewa (2002).

Household poverty estimates

The multidimensional poverty estimates are based on five dimensions: Housing, sanitation, education, health and assets as shown in Table 1; with equal weights assigned to all. For each dimension, thresholds were set which is

Table 2. Socio economic Characteristics of Rural Households.

Category	2004 Frequency	Percentage	2010 Frequency	Percentage
Gender				
Male	12552	86.5	21624	86.7
Female	1960	13.5	3317	13.3
Age(years)				
0-19	36	0.2	109	0.4
20-39	4552	31.4	8202	32.9
40-59	6585	45.4	10180	40.8
>= 60	3339	23.0	6450	25.9
Marital status				
Married	11529	79.4	21641	86.8
Divorced	557	3.8	706	2.8
Widowed	1660	11.4	2593	10.4
Never married	766	5.3	1	0.0
Household size				
1-3	4948	34.1	9321	37.4
4-6	6147	42.4	10076	40.4
7-9	2450	16.9	4237	17.0
10 and above	967	6.7	1307	5.2
Educational attainment				
No education	9252	63.8	11184	44.8
Primary education	2837	19.5	7853	31.5
Secondary education	1575	10.9	3890	15.6
Tertiary education	848	5.8	2014	8.1
Primary occupation				
Agriculture	11132	76.7	17444	69.9
Services	1109	7.6	3889	15.6
Non agriculture	2271	15.6	3608	14.5
Region				
North Central	2751	19.0	4217	16.9
North East	2732	18.8	4338	17.4
North West	3122	21.5	6869	27.5
South East	2351	16.2	3583	14.4
South South	2363	16.3	3860	15.5
South West	1193	8.2	2074	8.3
	N = 14512		**N= 24941**	

the first cutoff; to identify if the household is deprived in that dimension. A second cutoff, k was set which states the number of dimensions in which a household can bedeprived to be considered MPI poor.

Table 3 presents the estimated poverty indices based on different cut-offs, k. It can be observed from the table that from 2004 to 2010, the headcount and the adjusted headcount ratio decreased with increase in k. This agrees with the findings of Batana (2008). With the number of deprivations experienced by the households at K equals 1, the head count ratio H is about 100%. This shows that there is no household that is not deprived in at least one

Table 3. Household multidimensional poverty indices.

K	2004			2010		
	M_0 = HA	H	A	M_0 = HA	H	A
1	0.566	0.997	0.568	0.646	0.999	0.647
2	0.552	0.927	0.595	0.640	0.970	0.660
3	0.427	0.615	0.694	0.553	0.750	0.735
4	0.210	0.252	0.833	0.342	0.400	0.855
5	0.040	0.040	1.000	0.108	0.108	1.000

Table 4. Changes in MPI, headcount ratio and intensity of poverty at K=3.

	M_0		H		A	
Year	2004	2010	2004	2010	2004	2010
	0.427	0.553	0.615	0.750	0.694	0.735
Annual absolute change	0.021		0.022		0.006	
Annual percent change	4.92		3.65		0.984	

Table 5. Relative contributions of dimensions to MPI at K=3.

Year	Housing contribution (%)	Sanitation contribution (%)	Education contribution (%)	Health contribution (%)	Assets contribution (%)
2004	13.56	17.13	19.43	27.49	22.39
2010	13.87	16.77	20.59	25.87	22.90

dimension. At k = 3, 61.5% are estimated poor in 2004 but this increased to 75% by 2010; similarly, the adjusted headcount ratio increased in 2010. However, the intensity of poverty increases with increase in K, that is, the share of dimensions in which the poor are deprived increases with K. Although, the multidimensional household poverty index is decreasing with increase in K, it is because the number of households that are poor is reducing but the intensity of poverty among the poor is increasing.

Following Alkire and Roche (2011), poverty estimates at K=3 over time were compared and all the poverty measures reveal an increase in their estimates. This means that poverty is increasing and is due to both increase in headcount, H (a change in the percentage of people who are poor) and the intensity, A (a change in the share of deprivations in which the poor are deprived) of poverty among the poor. The adjusted headcount increased from 0.427 in 2004 to 0.553 in 2010.

The annual absolute change and percent change in poverty reveals that the change is higher for the headcount ratio than the intensity of poverty as shown in Table 4. Alkire et al, (2011) posited that in Lesotho, Kenya and Nigeria, change in MPI is achieved by reduction in headcount and barely by reduction in intensity of poverty. This implies that while the country increases effort to reduce the intensity of poverty, greater effort should be made to get people out of poverty

The relative contribution of dimensions to poverty is shown in Table 5. The pattern in both years is the same and it reveals that health contributed most to poverty followed by asset and education. The contribution of health to poverty reduced in 2010 relative to 2004; but the opposite was the case for education. In spite of this, it is imperative to tackle rural poverty by giving attention to these priority areas as International Fund for Agriculture Development, IFAD (2001) emphasized that increasing access to assets. They defined assets to include education, health, land, and housing and considered it crucial for broad–based growth and poverty reduction.

Change in poverty indices by geopolitical zones (GPZ)

The change in poverty indices over time by GPZ is shown in Table 6. Arranging in order of decreasing poverty is North West, North East, North Central, South East, South South and South West. North West records the highest poverty rate and the annual percentage change in all the indices. It also records an increase in poverty from 2004 to 2010. However, North East has the highest intensity of

Table 6. Changes in MPI, headcount ratio and intensity of poverty at K=3 by GPZ.

Geo-political zones	Year	M_0	H	A
North Central	2004	0.170	0.173	0.983
	2010	0.182	0.181	1.006
Annual absolute change		0.002	0.001	0.004
Annual percentage change		1.176	0.771	0.389
North East	2004	0.205	0.192	1.068
	2010	0.216	0.212	1.019
Annual absolute change		0.0018	0.003	-0.008
Annual percentage change		0.894	1.736	-0.765
North West	2004	0.259	0.268	0.966
	2010	0.292	0.295	0.990
Annual absolute change		0.0555	0.0045	0.004
Annual percentage change		2.124	1.679	0.414
South East	2004	0.170	0.173	0.983
	2010	0.118	0.122	0.967
Annual absolute change		-0.0086	-0.0085	-0.0026
Annual percentage change		-5.098	-4.913	-0.271
South South	2004	0.162	0.157	1.032
	2010	0.139	0.136	1.022
Annual absolute change		-0.0038	-0.0035	-0.0016
Annual percentage change		-2.366	-2.229	-0.161
South West	2004	0.053	0.052	1.019
	2010	0.053	0.053	1.00
Annual absolute change		0.000	0.0002	-0.0032
Annual percentage change		0.000	0.321	-0.310

poverty though it reduced in 2010. The North West and North East are worst affected by poverty in the country. Studies have reported that northern regions of the country have high poverty levels relative to the southern regions (Odusola, 1997; Okunmadewa et al., 2005; NBS, 2009). Over time, in the South East and South South, the headcount and the intensity reduced. The South East recorded the highest annual percentage reduction in poverty. Although, the South West is the least poor, there is still increase in incidence. This means that the interventions in the zone have not impacted positively to reduce poverty in the zone, although there is a decline in intensity.

Decomposition by gender

In Table 7, poverty indices increased for both gender over time. While more female headed households were poor in 2004; equal number was poor in 2010. This reflects that a higher proportion of male headed households became poor in 2010. The annual percentage change in headcount and intensity increased for male headed households but only the percentage change in headcount increased for female headed households. In all, irrespective of gender, there is annual percentage increase in headcount and adjusted headcount ratio. However, the percentage change in the intensity of poverty reduced for female and is estimated as -0.179.

Decomposition by occupation

With respect to occupation, poverty was highest among those engaged in agriculture, followed by services and lastly by those engaged in Non-agriculture related occupation in both 2004 and 2010. In Agriculture, poverty incidence was very high at 0.663 in 2010. Southgate et al. (2007) asserted that the impact of the household head being primarily involved in agriculture is linked with high poverty rates, hunger, and malnutrition and also recent analysis of poverty has shown that poverty is disproportionately concentrated among households whose primary livelihood lie in agricultural activities (Federal

Table 7. Changes in MPI, Headcount Ratio and Intensity of Poverty at K = 3.

Variable	Year	M_0	H	A
Occupation				
Agriculture	2004	0.628	0.739	0.985
	2010	0.663	0.671	0.988
Annual absolute change		0.006	-0.011	0.003
Annual percentage change		0.928	-1.533	0.051
Non-agriculture	2004	0.156	0.148	1.057
	2010	0.166	0.161	1.031
Annual absolute change		0.002	0.002	-0.004
Annual percentage change		1.068	1.464	-0.409
Services	2004	0.196	0.186	1.054
	2010	0.171	0.168	1.018
Annual absolute change		-0.004	-0.003	-0.006
Annual percentage change		-2.126	-1.613	-0.569
Gender				
Male	2004	0.408	0.618	0.660
	2010	0.553	0.751	0.736
Annual absolute change		0.024	0.022	0.013
Annual percentage change		5.923	3.587	1.919
Female	2004	0.429	0.579	0.741
	2010	0.553	0.754	0.733
Annual absolute change		0.021	0.029	-0.001
Annual percentage change		4.817	5.037	-0.179

Republic of Nigeria, 2007). In a similar finding, Amao and Awoyemi (2009) reported an inverse relationship between non-agriculture activities and poverty. Nonetheless, agriculture recorded a decrease in annual percentage change in headcount (-1.53) but the intensity of poverty increased (0.05). More attention must target reducing intensity of poverty while enhancing effort to continue to reduce its incidence. This shows that if poverty is reduced substantially in the agricultural sector, rural poverty will fall since over half of rural households are engaged in the agricultural sector. This contrasts the situation for those in services where both the incidence and intensity is reducing over time. It should be noted that the intensity of poverty for those in services and non-agriculture is higher than those in agriculture; therefore intervention should be made to further reduce these intensities.

Determinants of household poverty in rural Nigeria

Multivariate analysis

Table 8 shows the Logit regression estimates of the determinants of household poverty. The MPI obtained for poverty cut-off (k) equals three (0.427 in 2004 and 0.553 in 2010) was taken as the poverty line to classify households into poor and non- poor. Results from the analysis of logistic regression model shows that the chi square value is significant at 1% level which confirms that the model is a good fit for the data.

The factors that increase the probability of being poor are female headed households, household heads that are more than 60years old, household sizes that are four or more, households in north-west, north-east, south-south and year 2010. Those that decrease the probability of being poor are having household heads between ages 20 and 59 years, being practitioners in the non-agriculture or services sector, having household head that have no education or belonging to south west and south east geopolitical political zone.

Households headed by females have a higher probability of being poor. A female headed household increases the likelihood of being poor by 0.019 and is significant at 1%. Similar findings have been reported by Apata et al. (2010), Bastos et al. (2009) and World Bank (1999). The presence of discrimination against women in the labour market, or that women tend to have lower education than men and hence they are paid lower salaries as opined by Bastos et al. (2009). Also, females are not as privileged as their male counterparts in terms of asset ownership and accumulation (World Bank, 2001;

Table 8. Determinants of household poverty in rural Nigeria.

Predictor variables	Coefficients	Marginal effects
Gender of household head		
Male	0.0819*	0.0199*
Female	(0.0490)	(0.0118)
Age of household head (years)		
0-19	1	1
20-39	-0.0890***(0.0182)	-0.0218***(0.0459)
40-59	-0.0574***(0.0100)	-0.0141***(0.0459)
>=60	0.0025** (0.0011)	0.0006**(0.0460)
Marital status		
Not Married	1	1
Married	-0.0611(0.0890)	-0.0149(0.0216)
Divorced	0.1164(0.1089)	0.0282(0.0261)
Widowed	-0.0518(0.1007)	-0.0127(0.0248)
Household size		
1-3	1	1
4-6	0.1591***(0.0277)	0.0390***(0.0068)
7-9	0.2000***(0.0362)	0.0493***(0.0089)
>9	0.2159***(0.0532)	0.0534***(0.0133)
Primary occupation		
Agric. related	1	1
Non-agriculture	-0.6128***(0.0327)	-0.1518***(0.0080)
Services	-0.4666***(0.0358)	-0.1157***(0.0089)
Educational level		
No education	1	1
Primary education	-1.1159***(0.0264)	-0.2718*** (0.0061)
Secondary education	-1.9482***(0.0352)	-0.4368***(0.0060)
Tertiary education	-2.7548***(0.0559)	-0.5261***(0.0054)
Geo-political zone		
North Central	1	1
North East	0.2936***(0.0395)	0.0706***(0.0089)
North West	0.0562*(0.0351)	0.0137*(0.0085)
South East	-0.0877*(0.0407)	-0.2157*(0.0100)
South South	0.2094***(0.0046)	0.0516***(0.0096)
South West	-0.1261***(0.0482)	-0.0310***(0.0119)
Year		
2010	0.3843***(0.0252)	0.0944***(0.0061)
Constant	1.1254***(0.2000)	
Number of observations	39,453	
LR chi^2 (21)	7691.35	
Log likelihood	-23126.895	
Prob>chi^2	0.0000	
Pseudo R^2	0.1426	

*** P < 0.01 **P < 0.05 *P < 0.1; *Standard errors in parenthesis.

Olorunsanya, 2009). Such differential access to productive asset and inputs leads to inequality in welfare. Consequently female headed households continue to suffer in poverty.

Being between the ages of 20 to 59 years reduces the probability of being poor relative to the base category of 0 to 19 years; while being above 60 years increases the probability of being poor. The marginal effect estimates show that the greatest reduction in the probability of being poor is between ages 20 and 39 years. The marginal effect of the age group 20 to 39 years is -0.022, indicating that a change in age category from the base category (0 to 19 years) to 20 to 39 years category significantly reduce poverty by 0.022. Studies carried out in Nigeria by Nzenwa and Oboh (2005), Olubanjo et al. (2007) reported that age of household head had a positive effect on poverty. Babatunde et al. (2008) also posited that prevalence of poverty is higher among the older age group. These studies show that it is difficult to make a general conclusion on the effect of the age of household head. However, this study shows that while increase in age reduces probability of being poor initially, at a threshold, it increases it.

Generally, large household size reduces welfare in most regions of the country. The larger the household size, the poorer the household. Results show that household size had positive correlation with the probability of a household being poor for household sizes from four and the coefficients are significant at 1%. The marginal effect increases with increased household sizes. The estimates are 0.0390, 0.0493 and 0.0534 for households with sizes of 4 to 6 persons, 7 to 9 persons and greater than 9 persons, respectively. Thus, household poverty increases with increasing size of the household. This position is consistent with Omonona (2010) who posited that large household size are associated with poverty and Lipton (1999) also maintained that small households are less likely to be poor than others. Also, similar findings were reported by Schoummaker (2004), Aassve et al. (2005), Kates and Dasgupta (2007). The absence of well-developed social security systems and low savings in developing countries (especially those in Africa) tends to increase fertility rates, particularly among the poor, in order for the parents to have some economic support from children when parents reach old age. This is one of the rationales for parents to increase the number of children as children serve as a form of informal insurance for their parents when old.

Relative to agriculture, other occupations reduce the probability of being poor. The marginal effects for non-agricultural activities[2] and services are -0.1518 and -0.1157, respectively. This implies that non-agricultural activities have the highest probability of reducing poverty followed by services. This position is similar to the findings of Anyanwu (2010) that occupation has a high correlation with poverty in Nigeria. Also, past studies have also identified that most of the poorest households in Sub Saharan Africa are found working in agriculture (Ikpi, 1989; Ayoola et al., 2000; Okunmadewa, 2002; Spencer, 2002; Alayande and Alayande, 2004; Poulton et al., 2005; Apata, 2006).

Education significantly decreases the probability of being poor. The estimated marginal effects reveal that the likelihood of being poor is further reduced also by increasing levels of education. Apata et al. (2010) and Palmer-Jones and Sen (2003) reported same result for rural South-west Nigeria and India respectively.

Anyanwu (2012) emphasized the importance of regional location in explaining poverty in rural Nigeria. The North East, North West and South South geo-political zones of the country has a statistically significant positive effect on the probability of being poor relative to the North Central zone. On the contrary, the results show that South West and the South East zones decrease the probability of being poor. The marginal effect estimates are 0.0706, 0.0516 and 0.0137 for North East, South South and North West respectively which shows that households in the North East have the highest probability of increasing poverty. Also, households in the South East and South West decrease the probability of being in poverty with estimated marginal effects of 0.2157 and 0.03 respectively. There is an increase in the probability of being poor in 2010 relative to 2004 which means that there is an increase in the probability of becoming poor over time.

Conclusion

Households are mostly male headed and over 70% of rural households are in their economically active years. Although, there is reduction in the number of household heads without education, over one-third are still without any form of education. Household sizes are moderate with only a quarter with more than seven persons. Agriculture remains the primary occupation in rural households. The adjusted headcount ratio, headcount ratio and intensity of poverty increased in 2010 relative to 2004. The absolute change and percentage change in poverty reveals that the change is higher for the headcount ratio than the intensity of poverty. The health, asset and education dimension contributed most to poverty. Both the headcount and the intensity of poverty increased for male headed households while only the headcount increased for women. Agriculture has the highest adjusted poverty incidence in both years, but the incidence reduced in 2010 while the intensity remained high. The significant factors that increase the probability of being poor are being a female headed household, increased household size, working in the agriculture sector, residing in North West, North East and South South geo-political zones. The significant factors that decrease the probability of being poor are working in non-agricultural sector and services, having education, residing in South West and South East geo-political zones.

[2] Non–agricultural activities are paid government employment, international and local cooperatives, private employers, parastatals, NGOs. Services are mainly artisans.

This implies that programmes should be targeted to reducing the number of poor rural households. Targeted programmes in health and education dimensions will reduce poverty substantially. Improving asset of rural households can be achieved by improving access to resources and enforcing policies that define rights to these resources. Educational training should go beyond the primary level. The agricultural sector requires more attention to reduce poverty in the sector. Particularly rural households in Northern Nigeria and South South geo-political zones require more attention to bring them out of poverty.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Analysis of determinants of farm-level adaptation measures to climate change in Southern Africa

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The study examines farmer adaptation strategies to climate change in Southern Africa based on a cross-section database of three countries (South Africa, Zambia and Zimbabwe). A multivariate discrete choice model was used to analyse the determinants of farm-level adaptation strategies. Results confirm that access to credit, free extension services, awareness of climate change are critical determinants of farm-level adaptation options. Policies aimed at easing identified key limits to farmers' capacity to adapt to climate change need to emphasize the critical role of: extension services; provision of improved climate, production and market information as well as the means to implement adaptation through affordable credit and insurance against climate risks (safety nets).

Key words: Climate change, farm-level adaptation, Southern Africa.

INTRODUCTION

Climate change models for southern Africa indicate that the region will face increased challenges due to projected changes in climate (IPCC, 2007; Hulme et al., 2005). Further evidence (e.g. IPCC, 2007; Tadross et al., 2005, 2009) predict reductions in rainfall and increased rainfall variability for most parts of southern Africa. In addition, the predictions point to a higher climate variability and increased frequency and intensity of extreme weather conditions in Africa (Klein et al., 2007). The implications for Southern Africa are that the region would generally get drier and experience more extreme weather conditions, particularly droughts and floods, although there would be spatial variations within the region with some countries experiencing wetter than average climate.

Local ecosystems provide the main source of livelihood for many of the world's poor. Most of the rural poor in sub-Saharan Africa rely for their livelihood and food security on highly climate-sensitive rain-fed subsistence or small-scale farming, pastoral herding and direct harvesting of natural services of ecosystems such as forests and wetlands (IPCC, 2007; Mitchell and Tanner, 2006). The expected long-term changes in rainfall patterns and shifting temperature zones are expected to have significant negative effects on agriculture, food and water security and economic growth in Africa

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(Dinar et al., 2008; Nhemachena et al., 2010; Klein et al., 2007; Kurukulasuriya et al., 2006).

Further changes in climate are unavoidable even under stringent mitigation measures over the next few decades due to high concentrations of greenhouse gasses (higher than pre-industrial levels) and high residual levels of greenhouse gasses in the atmosphere (Klein et al., 2007; Houghton et al., 1996). Mitigation efforts to reduce the sources of or to enhance the sinks of greenhouse gasses will take time. Furthermore, effective mitigation requires collaboration and commitment from many countries (Klein et al., 2007). Adaptation is therefore critical and of concern in developing countries, particularly in Africa where vulnerability is high because ability to adapt is low. Adaptation helps reduce the impacts of climate change in the short to medium term, and is motivated from local priorities or regional risks, without requiring multi-country commitments (Hassan and Nhemachena, 2008; Nhemachena, 2009). The benefits of adaptation are realised in the short term and are felt at the local community level. Adaptation measures are therefore critical in the short to medium term, while in the long run mitigation, efforts are required to reduce risks and create sinks for further greenhouse gas emissions. It is therefore imperative to help identify ways of strengthening adaptation capacity of local communities, local, and national systems to enable them to cope with climate change and variability contributing to social and economic progress of local vulnerable communities.

A better understanding of current farmer climate change adaptation measures and their determinants is key in policy planning for future successful adaptation in the agricultural sector. This paper provides highlights on current farmer adaptation options and their determinants. The study suggests that a better knowledge of the current local adaptation measures that are already being used by farmers provide better ways of building support on farmers' local adaptation measures to enhance use and adoption of adaptation measures in the agricultural sector. Supporting the coping strategies of the local farmers has potential for facilitating widespread use and adoption of adaptation measures and to have great beneficial impacts in reducing the predicted negative effects of changes in climatic conditions on agricultural production. Support for local coping strategies require a better understanding of the local practices that will be important in helping designing focussed policies aimed at enhancing adaptation to climate change in agriculture.

To our knowledge, no studies published to date investigated the determinants of farm-level adaptation options in Southern Africa. Understanding the determinants of household choice of adaptation options may provide policy insights in identifying target variables for enhancing use of adaptation measures in agriculture. The adaptation study that used the same Global Environment Facility/World Bank (GEF/WB) data did not distinguish the determinants of each of the major adaptation options available to farmers, but instead aggregated adaptation options into two options of whether a farmer adapts or not. The decision of not adapting was then used in a sample selection Heckman model to analyse the determinants of not adapting to changes in climatic conditions (Maddison, 2007). Other studies that analysed adaptation using the same data set considered single adaptation options focusing mainly on climate related factors (Kurukulasuriya and Mendelsohn, 2007a, b; 2008) studies on modelling endogenous irrigation and crop choice, respectively and Seo and Mendelsohn (2007) (a micro-economic analysis of livestock choice).

This study adds to these analyses by distinguishing household and other socio-economic factors affecting propensity of use of each of the main adaptation measures available to farmers. In addition, this study uses a different approach to examine the determinants of use of various adaptation measures. The study by Maddison (2007) used a heckman sample selection model in trying to cater for sample selection bias and used no adaptation as the dependent variable. The approach considered factors that affect the decision not to adapt to changes in climatic conditions and did not consider determinants of the multiple adaptation options being used by farmers. This study uses a multivariate probit model to examine the determinants of various adaptation measures while allowing for the correlation across error terms due to unobservable explanatory variables.

The distinguishing feature of this study is that it uses a multivariate discrete choice econometric model to simultaneously examine the relationships between each adaptation option and a common set of explanatory variables. The advantage of using this approach as opposed to univariate (single-equation) technique is that it explicitly recognises and controls for potential correlation among adaptation options and therefore provides more accurate estimates of relationships between each adaptation option and its explanatory variables. The univariate technique on the other hand is prone to biases due to common factors in situations where there are unobserved and unmeasured common factors affecting the different adaptation options.

METHODOLOGY

Analytical framework

A multivariate probit econometric technique is used to analyse the determinants of adaptation measures (relationships between identified adaptation measures and the explanatory variables). The multivariate probit model simultaneously models the influence of the set of explanatory variables on each of the different adaptation measure while allowing the unobserved and unmeasured factors (error terms) to be freely correlated (Lin et al., 2005; Green, 2003; Golob and Regan, 2002). Complementarities (positive correlation) and substitutabilities (negative correlation) between different options may be the source of the correlations between error terms (Belderbos et al., 2004). Another source of positive correlation is the existence of unobservable household-specific factors that affect choice of several adaptation options but are not easily measurable such as indigenous knowledge. The correlations are taken into account in the multivariate probit model.

Another approach would be to use a univariate technique such as probit analysis for discrete choice dependent variables to model each of the adaptation measures individually as functions of the common set of explanatory variables. The shortfall of this approach is that it is prone to biases caused by ignoring common factors that might be unobserved and unmeasured and affect the different adaptation measures. In addition, independent estimation of individual discrete choice models fails to take into account the relationships between adoptions of different adaptation measures. Farmers might consider some combinations of adaptation measures as complementary and others as competing. By neglecting the common factors the univariate technique ignores potential correlations among the unobserved disturbances in adaptation measures, and this may significantly lead to statistical bias and inefficiency in the estimates (Lin et al., 2005; Belderbos et al., 2004; Golob and Regan, 2002).

A multinomial discrete choice model is another alternative to a complicated multivariate model with seven endogenous discrete choice variables. In the multinomial discrete choice model the choice set is made up of all combinations of adaptation measures or 2^7 = 128 available alternatives. With a problem of this size (128 alternatives and 19 explanatory variables) estimating a multinomial logit (MNL) model is possible. The shortfall of this technique is that interpretation of the influence of the explanatory variables on choices of each of the seven original separate adaptation measures is very difficult. The usefulness of a MNL is limited by the property of independence of irrelevant alternatives (IIA). In such situations estimation of multinomial probit (MNP) and "mixed" or random-coefficients MNL are more appropriate and simulation methods both Bayesian and non-Bayesian can be used to estimate parameters of large MNP and mixed logit models (Golob and Regan, 2002). The shortfall of this technique is that all multinomial replications of a multivariate choice system have problems in interpreting the influence of explanatory variables on the original separate adaptation measures.

This study uses a multivariate probit econometric technique to overcome the shortfalls of using the univariate and multinomial discrete choice techniques. Following Lin et al. (2005) the multivariate probit econometric approach used for this study is characterised by a set of *n* binary dependent variables y_i (with observation subscripts suppressed), such that:

$$y_i = 1 \text{ if } x'\beta_i + \varepsilon_i > 0,$$

$$= 0 \text{ if } x'\beta_i + \varepsilon_i \le 0,\ i = 1,2,\ldots,n, \quad (1)$$

where *x* is a vector of explanatory variables, $\beta_1, \beta_2, \ldots, \beta_n$ are comformable parameter vectors, and random error terms $\varepsilon_1, \varepsilon_{2,} \ldots, \varepsilon_n$ are distributed as multivariate normal distribution with zero means, unitary variance and an *n*×*n* contemporaneous correlation matrix $R = [\rho_{ij}]$, with density $\phi(\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_n; R)$. The likelihood contribution for an observation is the *n*-variate standard normal probability.

$$\Pr(y_1,\ldots,y_n \mid x = \int_{-\infty}^{(2y_1-1)x'\beta_1} \int_{-\infty}^{(2y_2-1)x'\beta_2} \ldots \times \int^{(2y_n-1)x'\beta_n} \phi(\varepsilon_1,\varepsilon_2,\ldots,\varepsilon_n; Z'RZ)d\varepsilon_n \ldots d\varepsilon_2 d\varepsilon_1, \quad (2)$$

Where $Z = \text{diag}\ [2y_1 - 1, \ldots, 2y_n - 1]$. The maximum likelihood estimation maximises the sample likelihood function, which is a product of probabilities (2) across sample observations. Computation of the maximum likelihood function using multivariate normal distribution requires multidimensional integration, and a number of simulation methods have been put forward to approximate such a function with the GHK simulator (Geweke et al., 1997; Hajvassilion et al., 1996) being widely used (Belderbos et al., 2004). This study follows the GHK simulator approach that uses Stata routine due to Cappellari and Jenkins (2003) to estimate the model[1].

The marginal effects of explanatory variables on the propensity to adopt each of the different adaptation measure are calculated as:

$$\partial P_i / \partial x_i = \phi(x'\beta)\beta_i,\ i = 1,2,\ldots,n \quad (3)$$

where P_i is the probability (or likelihood) of event *i* (that is increased use of each adaptation measure), $\phi(\cdot)$ is the standard univariate normal cumulative density distribution function, x and β are vectors of regressors and model parameters respectively (Hassan, 1996).

Econometric analysis with cross-sectional data is usually associated with problems of heteroscedasticity and multicollinearity and the effect of outliers in the variables. Multicollinearity among explanatory variables can lead to imprecise parameter estimates. To explore potential multicollinearity among the explanatory variables, we calculated the Variance Inflation Factor (VIF) for each of the explanatory variables. The VIFs ranges from 1.07 to 1.53 which does not reach convectional thresholds of 10 or higher used in regression diagnosis (Lin et al., 2005). In the analysis, multicollinearity does not appear to be a problem. To address the possibilities of heteroscedascticity in the model, we estimated a robust model that computes a robust variance estimator based on a variable list of equation-level scores and a covariance matrix (Stata 9 help robust).

Description of data

This study used cross-sectional data obtained from the Global Environment Facility/World Bank (GEF/WB)-CEEPA funded Climate Change and African Agriculture Project: Climate, Water and Agriculture: Impacts on and Adaptations of Agro-ecological Systems in Africa. The study involved eleven African countries: Burkina Faso; Cameroon; Egypt; Ethiopia; Ghana; Kenya; Niger; Senegal; South Africa; Zambia and Zimbabwe. For the purpose of this paper, only data from the Southern African region (South Africa, Zambia and Zimbabwe) were used for empirical analyses. (For more information on the survey method and the data collected see Dinar et al. (2008) After data cleaning, a total of 1719 surveys were usable for the Southern African region. This paper used part of the large dataset for the project that included farmer perceptions on climate change, adaptation strategies being used by farmers and perceived barriers to responding to perceived climate changes.

Temperature and precipitation data came from Africa Rainfall and Temperature Evaluation System (ARTES) (World Bank, 2003). This dataset created by the National Oceanic and Atmospheric Association's Climate Prediction Center is based on ground station measurements of precipitation.

Dependent and independent variables

The dependent variables for the model were seven dummy variables: using different varieties; planting different crops; crop

[1] "Hajivassilion and Ruud (1994) proved that under regularity conditions the simulated maximum likelihood estimator is consistent when both the number of draws and observation goes to infinity. Gourieroux and Monfort (1996); show that it has the same limiting distribution as the (infeasible) maximum likelihood of the number of observations as the number of draws approaches zero", Belderbos et al. 2004).

Table 1. Main farm-level adaptation strategies in Southern Africa (% of respondents).

Adaptation	Southern Africa	South Africa	Zambia	Zimbabwe
Different varieties	11	5	13	15
Different crops	4	4	6	3
Crop diversification	9	6	9	12
Different planting dates	17	7	5	38
Diversifying from farming to non-farming activity	8	5	11	7
Increased use of irrigation / groundwater / watering	9	18	5	6
Increased use of water conservation techniques	5	6	3	7
Number of observations	1719	236	829	654

diversification; different planting dates (given the high perceptions that the timing of rains is changing); diversifying from farming to non–farming activities; increased use of irrigation and increased use of water soil conservation techniques) equal to one if the household used the adaptation option and zero otherwise. Summary statistics of the identified main adaptation measures are presented in Table 1. The explanatory variables included in the model are based on review of adoption literature studies and our view of theoretical work; however this remains rather explorative given the lack of straight forward available theoretical predictions. The independent variables in this study represent some of the many factors that affect use of adaptation options at the farm-level. Although, there might be many factors affecting farmer use of adaptation options, this study identified seventeen independent variables listed in Table 2 to be most appropriate in explaining use of different adaptation options by farming households. In the empirical model, each explanatory variable is included in all seven equations to help test if the impacts of variables differ from one adaptation option to the other.

Descriptive statistics of the explanatory variables and their expected impacts of adaptation options are presented in Table 2 and a detailed description of the variables is presented in Appendix A. Appendix B presents a correlation matrix of the independent variables. Household socio-economic characteristics like farming experience; access to free extension services, credit; mixed crop and livestock farming systems; private property and noticing climate change are expected to have significant positive impact on use of adaptation measures at the farm-level.

RESULTS AND DISCUSSION

The study estimated a multivariate probit model and for comparison a univariate probit model for each of the seven adaptation options. Results from the multivariate probit model of determinants of adaptation measures are presented in Table 3. The results of the correlation coefficients of the error terms are significant (based on t-test statistic) for any pairs of equations indicating that they are correlated. The results on correlation coefficients of the error terms indicate that there are complementarities (positive correlation) between different adaptation options being used by farmers. The results supports the assumption of interdependence between the different adaptation options which may be due to complementarity in the different adaptation options and also from omitted household-specific and other factors that affect uptake of all the adaptation options. Another important point to note from the results is that there are substantial differences in the estimated coefficients across equations that support the appropriateness of differentiating between adaptation options.

The univariate probit models can be viewed as a restrictive version of the multivariate probit model with all off-diagonal error correlations set to zeros (that is, $\rho_{ij} = 0$ for $i > j$) (Lin et al., 2005; Belderbos et al., 2004). A likelihood ratio test based on the log-likelihood values of the multivariate and univariate models indicate significant joint correlations $\chi^2(21) = 57.867$; probability > χ^2 = 0.0000 justifying estimation of the multivariate probit that considers different adaptation options as opposed to separate univariate probit models and consequently the unsuitability of aggregating them into one adaptation or no adaptation variable as was the case by Maddison (2007).

Female-headed households are more likely to take up adaptation options. The possible reason for this observation is that, in most rural smallholder farming communities in the region, much of the agricultural work are done by women. Since women do much of the agricultural work and men are based in towns, women have more farming experience and information on various management practices and how to change them based on available information on climatic conditions and other factors such as markets and food needs of the households. The important policy message from this finding is that targeting women groups and associations in smallholder rural communities can have significant positive impacts in increasing uptake of adaptation measures by smallholder farmers.

Farmer experience increases the probability of uptake of all adaptation options. Highly experienced farmers are likely to have more information and knowledge on changes in climatic conditions, crop and livestock management practices. Experienced farmers are usually leading and progressive farmers is most rural communities and these can be targeted in promoting adaptation management to other farmers who do not have such experiences and are not yet adapting to changing climatic conditions. Making use of the local successful farmers as entry points in promoting adaptation among smallholder farmers can have significant positive impacts in increasing use of various adaptation options.

Table 2. Summary statistics of independent variables and their expected impacts on adaptation measures.

Variable	Mean	Standard deviation	Minimum	Maximum	Expected impact
Female-headed household	0.82	0.38	0.00	1.00	±
Age of household head	47.41	14.61	16.00	100.00	±
Household size	5.57	2.43	1.00	22.00	±
Farming experience (years)	16.31	12.88	1.00	80.00	+
Farm size	21.16	12.54	0.04	346.00	±
Free extension services	0.64	0.48	0.00	1.00	+
Mixed crop/livestock farms	0.22	0.41	0.00	1.00	+
Household has electricity	0.14	0.33	0.00	1.00	+
Access to credit	0.15	0.36	0.00	1.00	+
Subsistence	0.43	0.49	0.00	1.00	±
Mean annual temperature	21.79	2.57	16.08	26.79	+
Mean annual precipitation	69.47	13.47	20.44	97.88	+
Noticed climate change	0.65	0.48	0.00	1.00	+
Have animal power	0.30	0.46	0.00	1.00	±
Have heavy machines	0.37	0.28	0.00	1.00	+
Have tractor	0.07	0.26	0.00	1.00	+
Income per cap	451.63	131.34	0.00	2892.34	±
Private property	0.52	0.50	0.00	1.00	+

Noticing climate change increases the probability of uptake of adaptation measures. Farmers who are aware of changes in climatic conditions have higher chances of taking adaptive measures in respond to observed changes. It is important that, this is an important precondition for farmers to take responsive measures in adapting to changes in climatic conditions (Madison, 2007). Raising awareness of changes in climatic conditions among farmers would have greater impact in increasing adaptation to changes in climatic conditions. It is therefore important for governments, meteorological departments and ministries of agriculture to raise awareness of the changes in climatic conditions through all possible alternative communication pathways that are available to farmers such as extension services, farmer groups, input and output dealers, radio and televisions among others. This need to be accompanied by the various crop and livestock management practices, farmers can take to respond to the forecasted changes in climatic conditions such as varying planting dates, using irrigation, growing crop varieties suitable to the predicted climatic conditions.

Access to free extension services significantly increases probability of taking up adaptation options except moving from faming to non-farming. Extension services provide an important source of information on climate change as well as agricultural production and management practices. Farmers who have high extension contacts have better chances to be aware of changing climatic conditions and also of the various management practices that they can use to adapt to changes in climatic conditions. Improving access to extension services for farmers has potential to significantly increase farmer awareness of changing climatic conditions as well as adaptation measures in response to climatic changes.

Farmers with access to credit and markets have high chances of adapting to changing climatic conditions. Access to cheap credit increases financial resources of the farmers and their ability to meet transaction costs associated with the various adaptation options they might want to take. With more financial and other resources at their disposal, farmers are able to change their management practices in respond to changing climatic and other factors and are better able to make use of all the available information they might have on changing conditions both climatic and other socio-economic factors. For instance, with financial resources and access to markets farmers are able to buy new crop varieties, new irrigation technologies and other important inputs they may need to change their practices to suit the forecasted and prevailing climatic conditions.

Increasing mean annual temperature increases the probability of farmers to respond to changes in terms of changing management practices. Increasing warming is associated with decreases in water resources (surface and ground), high evapo-transpiration rates and this increases water scarcity and shortages for food production and other uses. In response to increasing temperatures, farmers tend to change their crop and livestock management practices to suit the changing temperature regimes. For instance farmers need to change to growing drought resistant crops; varying planting dates, so that critical crop growth stages do not coincide with peak temperature periods; diversifying crop and non-farming income options; use water and soil conservation techniques to conserve the little rain that is received as

Table 3. Results of multivariate probit analysis of determinants of adaptation measures.

Variable	Different crops	Different varieties	Crop diversification	Different planting dates	Increase irrigation	Increase water conservation	Farming to non farming
Log farmland	0.109**	0.021***	0.004*	0.017*	0.013**	0.304*	-0.102***
Free extension services	0.071***	0.152*	0.287**	0.106**	0.338***	0.476***	-0.370**
Farming experience (yrs)	0.009*	0.014*	0.011*	0.005	0.019**	0.012*	0.011
Total household workers	0.004	0.002	0.015***	0.003*	0.004**	0.014***	0.003
Mixed crop-livestock farm	0.306**	0.185**	0.095***	0.380**	0.018***	0.163*	-0.031
Income per cap	0.001	0.000	0.003	0.001	0.007*	0.000*	0.000*
Female headed household	0.047*	0.464**	0.024*	0.071*	0.058*	0.660**	0.266
Age of household head	0.006	0.001	-0.006	0.005	0.002	0.030**	-0.009
Household has electricity	0.414**	0.157*	0.314*	0.278***	0.321***	0.558***	0.223*
Subsistence	0.230*	0.102*	0.502***	0.488***	0.115	1.362***	0.148*
Log distance to selling market	0.039*	0.562**	0.305*	0.007	0.033***	0.135*	0.764***
Access to credit	0.180*	0.218*	0.288***	0.004*	0.435***	0.254**	0.157*
Noticed climate change	0.776***	0.929***	0.289*	0.005*	0.413**	0.726***	0.508***
Mean annual temperature	0.046*	0.309***	0.175***	0.081*	0.307***	0.093***	0.181***
Mean annual precipitation	0.012*	0.044***	0.001	-0.004	-0.008*	-0.022*	-0.004**
Have tractor	0.045	0.269*	0.086**	0.575*	0.134***	0.431***	0.827*
Have heavy machines	0.092*	0.291**	0.190*	0.167*	0.624***	0.269*	0.547**
Have animal power	0.171**	0.301*	0.558***	0.033*	0.452**	0.750***	-0.154
Private property	0.005	0.058	0.107*	0.219**	0.215*	0.042*	0.354**
Zambia	0.182*	0.371	0.047	0.791	0.829***	0.735*	-0.793***
Constant	-4.345***	-12.237***	-5.435***	1.644	-1.220	-6.208***	1.576
	Rho1	**Rho2**	**Rho3**	**Rho4**	**Rho5**	**Rho6**	
Rho2	0.167*						
Rho3	0.279***	0.051**					
Rho4	0.225*	0.003***	0.163*				
Rho5	0.054	0.039*	0.016***	0.249**			
Rho6	0.202*	0.027	0.315***	0.167*	0.190**		
Rho7	-0.012	0.557***	-0.222*	-0.156	-0.389*	0.247*	
Observations				846			
Log Likelihood				-1249.7669			
Wald $\chi^2(140)$				415.96			
Prob > χ^2				0.0000			

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho32 = rho42 = rho52 = rho62 = rho72 = rho43 = rho53 = rho63 = rho73 = rho54 = rho64 = rho74 = rho65 = rho75 = rho76 = 0: $\chi^2(21) = 59.521$, Prob > χ^2 = 0.0000. *; **; *** Significant at 10; 5 and 1%, respectively.

well as using irrigation technologies to supplement rainwater and increase the crop growing period.

Increasing mean annual precipitation increase, the probability of farmers changing their management practices that include: growing crop varieties that suit the prevailing and forecasted precipitation. Less precipitation increases the probability of farmer to efficiently use water resources for food production and other uses as well as irrigation water and use water conservation techniques. Use of water conservation techniques increases with decreasing precipitation probably because farmers have learnt from drought experiences to conserve rainwater in times of good rains so that it is available for future use in dry periods. Increasing knowledge and empowering communities to use water conservation techniques such as water harvesting can significantly help farmers cope with changing rainfall and temperature regimes.

Private property increases uptake of adaptation measures. Farmers with secure tenure on their farm households have high propensity to invest in adaptation options compared to where tenure is insecure. The implication of this finding is that, it is important for governments to ensure that even in the communal systems that characterise most of the smallholder farming systems in the region, tenure arrangements are secure to facilitate investments in long-term adaptation options by farmers. Secure tenure gives farmers a feeling of ownership of the land and acts as a positive incentive in facilitating farmer investments on their farms that include investments in adaptation and good crop and livestock management practices. Conservation technologies have high chances of being taken where farmers feel secure on their ownership of the land and this can be very important in promoting use of soil and water conservation techniques as important adaptation options for farmers.

Mixed crop and livestock farmers are associated with positive and significant adaptation to changes in climatic conditions compare to specialised crop and or livestock farmers. The results imply that mixed farming systems are better able to cope with changes to climatic conditions through undertaking various changes in management practices. An important reason for this observation is that mixed farming systems are already diversified and they have a number of alternative crops and livestock options that can ensure that if one option fails the other will do well even if there are changes in climatic conditions. Diversification in farming systems is therefore important for farmers to adapt to changes in climatic conditions.

Subsistence farmers are more likely to take variations in planting dates, crop diversification, and use of water conservation techniques as their adaptation options. The important reason for this is that subsistence farmers usually produce one staple food crop, maize, sorghum or millet in most cases and it is easier for them to incorporate other crops in their current options than completely changing to different crops or using expensive irrigation technologies. Promoting cheap adaptation options among smallholder, farmers can positively and significantly increase subsistence farmers' adaptation to climate change.

Households with access to electricity, tractors, heavy machines and animal power are usually mechanised and have better chances of taking up other adaptation options. With access to technology farmers are able to vary their planting dates, switch to new crops, diversify their crop options and use more irrigation and water conservation techniques as well as diversifying into non-farming activities. Farmers with better technologies usually have access to market and they produce for sale which gives them better chances to change their management practices in respond to changing climatic and other conditions such as prices and market chances. Ensuring availability of cheap technologies for smallholder farmers can significantly increase their use of other adaptation options.

Country fixed effects were also included and the results for Zambia are shown. Including either South Africa or Zimbabwe resulted in each being dropped due to multicollinearity. The country effects from Zambia have significant effect on adaptation indicating the importance of national policies concerning adaptation to climate change.

Conclusion

This study was based on micro-level analysis of adaptation that focuses on tactical decisions farmers make in response to seasonal variations in climatic, economic and other factors. These tactical decisions are influenced by a number of socio-economic factors that include household characteristics, household resource endowments, access to information (seasonal and long-term climate changes and agricultural production) and availability of formal institutions (input and output markets) for smoothening consumption. Farm-level decision making occurs over a very short time period usually influenced by seasonal climatic variations, local agricultural cycle, and other socio-economic factors. Adaptation is important for farmers to achieve their farming objectives such as food and livelihood security and high incomes and significantly reduce potential negative impacts that are associated with changes in climatic and other socio-economic conditions (that include: climate variability, extreme weather conditions, volatile short-term changes in local and large scale markets).

This paper explored the determinants of household use of seven different adaptation measures (using different varieties, planting different crops, crop diversification, different planting dates (given the high perceptions that the timing of rains is changing), diversifying from farming to non–farming activities, increased use of irrigation, increased use of water and soil conservation techniques) using a multivariate probit model. The model allowed us to simultaneously model the determinants of all seven adaptation options, thus limiting potential problem of correlation between the error terms. The model help reflect that households simultaneously consider decisions to use various adaptation options. Correlation results between error terms of different equations were significant (positive) indicating that various adaptation options tend to be used by households as complementary, although this could also be due to unobserved household socio-economic and other factors.

Multivariate probit results confirm that access to credit, free extension services, farming experience, mixed crop and livestock farms, private property and perception of climate change are some of the important determinants of farm-level adaptation options. Use of different adaptation measures significantly increase for farming household with more access to these factors among others. Designing policies that aim to improve these factors for smallholder farming systems have great potential to improve farmer adaptation to changes in climate as a way of ensuring food and livelihoods and income objectives of the farmers are achieved among other goals. For example, more access to credit facilities, information (climatic and agronomic) as well as access to markets (input and output) can significantly increase farm-level adaptation. Government policies need to support research and development that prepares the appropriate technologies to help farmers adapt to changes in climatic conditions. Government responsibilities are usually through conscious policy measures to enhance the adaptive capacity of agricultural systems. Examples of these policy measures include crop development, improving climate information forecasting, or promoting and even subsidizing certain farm-level adaptations such as use of irrigation technologies.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Appendix A. Description of independent variables.

Variable	Description of variable
Female-headed household	Dummy variable for household gender (female-headed households)
Age of household head	Age of household head
Household size	Size of the household
Farming experience (years)	Farming experience based on number of farming years
Farm size	Total household farm size
Free extension services	Dummy variable for households with access to free extension services (climate, crop and livestock farming)
Mixed crop/livestock farms	Dummy variable for mixed farming households with both crop and livestock
Household has electricity	Dummy variable for farming households with electricity
Access to credit	Dummy variable for households who have access to credit
Subsistence	Subsistence farming households
Mean annual temperature	Mean annual temperature
Mean annual precipitation	Mean annual precipitation
Noticed climate change	Dummy variable for households who noticed changes in climatic variables
Have animal power	Dummy variable for household possession of animal power
Have tractor	Dummy variable for household possession of a tractor
Have heavy machines	Dummy variable for household possession of heavy machines
Income per cap	Household income per capita
Private property	Dummy variable for tenure system

Appendix B. Correlation matrix of the independent variables.

Variable	Female-headed household	Age of household head	Household size	Farming experience	Farm size	Free extension services	Mixed crop/livestock farms	Irrigation	Access to credit	Subsistence	Mean annual temperature	Mean annual precipitation	Noticed climate change	Have animal power	Number of crops	Head non farm	Private property
Female-headed household	1.0000																
Age of household head	-0.0457	1.0000															
Household size	0.1345	0.1156	1.0000														
Farming experience	-0.0749	0.4996	0.0793	1.0000													
Farm size	0.0426	-0.0344	-0.0709	0.0434	1.0000												
Free extension services	0.0583	0.0739	0.0763	0.0153	-0.0066	1.0000											
Mixed crop/livestock	-0.0805	-0.0178	-0.2062	-0.0941	-0.0265	-0.0191	1.0000										
Irrigation	0.0701	0.0662	-0.0620	-0.0342	0.1528	0.2579	0.1584	1.0000									
Access to credit	0.0320	-0.0118	0.0474	-0.0581	-0.0184	0.1375	-0.0273	0.1457	1.0000								
Subsistence	-0.1166	0.0315	-0.0238	0.0624	-0.0630	-0.1486	0.0583	-0.2290	-0.1246	1.0000							
Mean annual temperature	-0.0471	-0.0620	0.0328	0.0714	-0.1535	-0.0873	-0.0607	-0.4143	-0.0463	0.3081	1.0000						
Mean annual precipitation	-0.0002	-0.0263	0.0657	0.0008	-0.1835	-0.1393	-0.1003	-0.2375	-0.0217	-0.0897	-0.0752	1.0000					
Noticed climate change	-0.0046	0.0087	0.0097	-0.0124	0.0071	0.1626	-0.0163	0.0520	0.0475	0.0699	-0.0264	-0.1723	1.0000				
Have animal power	0.0633	0.0294	0.1230	0.1118	0.0711	0.1718	-0.2015	0.0176	0.0793	-0.0600	0.0565	0.0038	0.0850	1.0000			
Number of crops	-0.0207	0.0791	0.1775	0.0632	-0.0436	0.1654	-0.0890	0.2255	0.2424	-0.2990	-0.0677	0.1268	0.0380	0.1344	1.0000		
Head non farm	0.0375	-0.2261	0.0571	-0.1731	-0.0283	-0.1094	0.0502	0.0171	-0.0171	-0.0091	-0.1582	0.1185	-0.0193	-0.0455	0.0324	1.0000	
Private property	0.0343	0.1346	-0.0091	0.0298	0.0559	0.0865	0.0141	0.0035	-0.0010	0.0246	0.1672	-0.2357	0.0317	-0.0032	-0.0470	-0.2281	1.0000

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