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Effects of Soil Erosion on Technical Efficiency of Cassava Farmers in Enugu State, Nigeria

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Abstract
This study investigated the effects of soil erosion on technical efficiency of cassava farming in Enugu State, Nigeria with a view to identifying the effects of erosion on cassava production. A multistage sampling procedure was used to select 200 respondents for the study. Primary data were collected on respondents' socio-economic characteristics such as age, gender, educational level, marital status, farm size, as well as on quantities and prices of inputs and outputs using a pre-tested questionnaire. Technical efficiency (TE) estimates showed that most farmers operated below the production frontier, with a significant difference ($p< 0.05$) between the mean TE of eroded farms (56 ± 0.19) percent and non-eroded (77 ± 0.17) farms. Farm size, labour, cassava stem cuttings, and fertilizer significantly ($p<0.05$) increased the level of TE in non-eroded farms, while only fertilizer significantly affected the TE in eroded farms. Significant ($p<0.05$) inefficiency factors on non-eroded farms were education, age, household size, and extension contact, while education and age were significant ($p<0.05$) in eroded farms. It was concluded that farmers in eroded farms were less technically efficient in their use of resources than farmers in non-eroded farms in Enugu State.
Keywords: Enugu state, Erosion, maximum likelihood, stochastic frontier, technical efficiency

1.1 Background to the study

The importance of land as the primary means for rural livelihood and a main vehicle for accumulating, investing and transferring wealth between generations can not be overemphasized. Land or soil, as defined by Oseomeobo (1992) is also a key to household wealth and agricultural productivity. However, the sustainability of agricultural production systems is becoming a major concern of agricultural researchers and policy makers in both developed and developing countries due to the challenges of land degradation (Yudelman, 1987; Idris, 2006).

According to Barbier (1997) and Eswaran *et al.* (2001), land degradation has adverse impacts on the environment, agricultural productivity, food security and the quality of life. The productivity impacts of land degradation are due to a decline in land quality in areas where degradation occurs (e.g. erosion), and this affects the income generating potentials of the land holders. The key features of the process of land degradation is the failure of rural households to invest in long term land improvements on existing agricultural land, abandonment of this land in favour of migration to the forest and marginal lands and continual expansion of agricultural frontier through more forest and marginal land conversion.

Barbier (1997); Maiangwa *et al.* (2003) and IFPRI (2007) have identified population pressure, increased urbanization, climatic changes and industrialization as major factors responsible for land degradation. These long term driving factors affect agricultural production systems and the environment through desertification, over grazing, as well as soil erosion with a consequent depletion of soil nutrients. Soil erosion, is a natural phenomenon which is as old as the earth itself, and it is the most visible and wide spread form of land degradation which affects man and its environment (Omafra, 2003). Apart from its negative impact on crop output, it reduces both the agronomic efficiency of farm inputs and the expected net returns to farm investments. In Africa alone productivity of some land has declined by 50% due to soil erosion and desertification while yield reduction resulting from soil erosion range from 2 to 40% with a mean loss of 8.2% (Eswaran *et al.,* 2001). Southgate (1994) reported that soil erosion is a naturally occurring process which presently ranks as the most important environmental degradation problem that affects the soil surface in developing countries, particularly in the tropics.

In another dimension, Barbier (1997) and Scherr (1999) argued that by the year 2020, the increasing wave of soil erosion may pose a serious threat to food production in rural areas as well as urban livelihoods particularly in poor and densely populated areas of the developing world including Nigeria. They further claimed that effects of soil erosion on production and profitability largely depends on the extent (spread) and intensity of erosion, the type of crop grown, and the agro-ecological location of the land area. They advocate for policies that would encourage soil nutrient retention strategies if developing countries are to sustainably meet the food needs of their population. Abegunde *et al*. (2006) stated that most of the earth's natural resources are directly linked to or found in the soil, both animate and inanimate as well as three quarters of the world's man-made development. Thus, any threat to the soil is a threat to life. Significant in this regard is that since land (soil) is the most important production input, human beings lose their fundamental sources of livelihood when soil fertility becomes depleted (Titilola, 2001).

The problem is becoming increasingly notable in that land resources are being used beyond their carrying capacities, thereby rendering the land incapable of supporting production under the current low level of technology use (AERLS, 1992). The concern about the effects of soil erosion has led to increased promotion of soil conservation technologies in developed countries (Clark, 1996). There is also need to quantify crop yield losses associated with soil erosion in order to restore crop production into economically competitive levels on eroded farmlands. This is particularly important for cassava that is grown in areas notable for high incidence of soil erosion in Nigeria. It is against this background that it has become necessary to assess the effects of soil erosion on technical efficiency of cassava farmers as this will guide towards effective land management and introduction of corrective measures against soil erosion menace in Nigeria.

1.2 Data collection methods

Primary data was employed for this study. Data was collected from cassava farmers using a set of pre-tested structured questionnaire. Information sought include respondents' socio-economic characteristics such as age, gender, educational level, marital status, farm size, as well as on quantities and prices of inputs and outputs for cassava production in Enugu State. Data were collected in eroded and non-eroded farms in the State in order to analyse the effects of soil erosion.

1.3 The study area

The study was carried out in Enugu State located in the South Eastern part of Nigeria. Cassava is a very important staple food cultivate in Enugu state and Nigeria at large. There is obvious low productivity of cassava despite various efforts by research institutions to improve its production. The low productivity of cassava production is caused by the effects of soil erosion and inefficiency in the allocation of farm resources (Nair, *et al*., 1998; Naiwu *et al*., 2010).

1.4 Sampling procedure

A multi-stage sampling procedure was used to select respondents. First, Enugu State was stratified into three based on the agricultural zones into which the State is classified (ADP, 2009**).** The zones are: Zone A (Enugu North), Zone B (Enugu East) and Zone C (Enugu West). Two of the zones (A & B) are not affected by soil erosion while Zone C is seriously affected by soil erosion. Secondly, based on the number of Local Government Areas (LGAs) in each zone, proportionate random sampling was selected 33% and 40% of the LGAs in zones A and B respectively, while 66% of the LGAs was selected from zone C. Thirdly, one village/community that are known for high cassava production were selected in each LGA. Finally, twenty five cassava farmers were selected from each village to give a total sample of 200 respondents. Information sought include respondent's socio-economic characteristics such as age, educational level, marital status, farm size, as well as on quantities of inputs and outputs for cassava production in Enugu State. Data were collected in eroded and non-eroded farms in the State in order to analyse
the effects of soil erosion.

1.5 Empirical model

The Cobb-Douglas frontier production function was used in the study. The major advantage of the stochastic frontier production function model is the introduction of disturbance term representing noise, measurement error and exogenous factors beyond the control of the production unit in addition to the inefficiency component. This property of the stochastic frontier model accounts for its appropriateness for efficiency measurement in agricultural production owing to agriculture's inherent characteristic (Shehu and Mshelia, 1994).

The model is specified as:

$$\text{In}Y_1 = \beta_0 + \beta_1 \text{In}x_1 + \beta_2 \text{In}x_2 + \beta_3 \text{In}x_3 + \beta_4 \text{In}x_4 + Vi - \mu_i. \qquad \text{(i)}$$

Where,

Y_i = Output (kg)

X_1 = Size of cultivated farm land (ha).

X_2 = Labour (man days)

X_3 = Value of stem cutting (₦)

X_4 = Fertilizer and other agrochemicals (₦)

β_0 = Intercept.

$\beta_0 - \beta_4$ = parameters to be estimated,

V_1 = Random error which accounts for the random variations in value of cassava output by factors which are beyond the control of the farm such as disease outbreak, weather, measurement errors and is assumed to be independently and identically distributed ($V_1 \sim [0, \sigma^2]$ independent of U_1.

μ_i = Non – negative variable associated with technical inefficiency in production and is assumed to be independently and identically distributed as half normal, $U_1 \sim (N/[0, \sigma^2])$.

In order to determine the factors that contributed directly to technical efficiency, the following model was estimated and jointly used with the stochastic frontier model (Coelli, 1996).

$TE = \propto_0 + \propto_1 z_1 + \propto_2 z_2 + \propto_3 z_3 + \propto_4 z_4 + \propto_5 z_5 + \propto_6 z_6 + \propto_7 z_7 + \propto_8 z_8 + \propto_9 z_9$

Where:

TE = Technical efficiency of cassava farmer (ii)
Z_1 = Education level of the farmer (years)
Z_2 = Age of the farmer (years)
Z_3 = Marital status (Married, otherwise = 0)
Z_4 = Membership in farmers association (Dummy: yes, 1; otherwise, 0)
Z_5 = Extension contact (Yes, 1; No, 0)
Z_6 = Access to credit (Dummy: Yes, 1; No, 0)
Z_7 = Incidence of soil erosion (Yes 1, No, 0)
Z_8 = Household size (No of persons)
Z_9 = Use of improved cassava variety (Yes 1, No, 0), and
$\propto_{1} - \propto_9$ are parameters to be estimated.

1.5 Results and Discussion

The stochastic frontier and the inefficiency model were estimated simultaneously. Table 1 presents the estimated parameters for the production function. Among four production variables considered in the estimation of technical efficiency model of cassava farms (eroded and non-eroded). Farm size, labour, value of stem cutting and fertilizer were found to be positive among eroded and non-eroded farms. The results are similar to the findings of Bravo-Ureta and Evenson (1994); Onyenweakue *et al.,* (2004) and Onyenweaku and Ohajiaya (2005). However, farm size, labour, value of stem cutting and fertilizer were found to be statistically significant among non-eroded farms while only fertilizer is significant at 1 percent probability level among eroded farms, this indicates that if farmers on eroded land use more of fertilizer, it will serve as replacement for lost nutrient due to the effects of soil erosion.

The estimates of the overall variance (δ^2) and gamma (γ) give adequate information on the efficiency of the explanatory variables on farm output. The overall model variance (δ^2) for non-eroded farms is 0.17, gamma (γ) is 0.09 and the mean technical efficiency is 77%. This implies that the efficiency of the inputs used is high; many of the respondents produced closer to their production frontier where profit is maximized and that technical efficiency in cassava production could be increased by 23% through better use of available resource. Also, the overall model variance (δ^2) of eroded farms is 0.63, the gamma (γ) is 0.002 and the mean technical efficiency is 56%. This implies that the efficiency of input used is low due to the effects of soil erosion and there is under utilization of production resources. Hence, the technical efficiency of cassava production on eroded farms could be increased by 46% through the better use of available resources, given the level of current state of technology.

The estimated elasticities of mean output with respect to farm size, labour, value of stem cutting and fertilizer on non-eroded farms were 0.02, 0.38, 0.48 and 0.04. This means that for a 10 percent increase in farm size, labour, stem cutting and fertilizer cost, cassava output on non-eroded farms will increase by 0.2, 3.8, 4.8 and 0.4 respectively. But with a 10 percent increase in farm size, labour, value of stem cutting and fertilizer cost, cassava output on eroded farms will increase by 0.72, 0.4, 0.2 and 1.14 respectively (Table 1).

Table1: Stochastic production frontier estimate on eroded and non-eroded cassava farms

Production frontier parameter	Eroded coefficient	Non-eroded coefficient
Constant	1.19 (1.344)	-2.44 (-1.464)
Farm size	0.07 (0.68)	0.02 (3.23)***
Labour	0.040 (0.70)	0.38 (5.94)***
Value of stem cutting	0.02 (0.327)	0.48 (6.18)***
Fertilizer	0.11 (3.984) ***	0.04 (6.303)***
Sigma squared (δ^2)	0.63 (6.080) *	0.17 (7.352)**
Gamma (γ)	0.02 (5.6) *	0.09 (5.40)**
Log likelihood function	-118.34	-49.066
LR test	16.27**	19***

Source: Field survey, 2012
***Significant at 1% ** Significant at 5% * Significant at 10%

Table 2: Frequency distribution of technical efficiency among cassava farms

Efficiency Range (%)	Eroded (100)	Non-eroded (100)	t-value
10 – 20	-	-	
21 – 30	8	-	
31 – 40	17	-	
41 – 50	18	3	
51 – 60	23	18	
61 – 70	11	23	
71 – 80	6	14	
81 – 90	11	13	
91 – 100	6	29	
Mean (%)	56.48	77	1.65***
Std Devi.	0.19	0.17	
Minimum (%)	24.76	43.73	
Maximum (%)	99	99	

Source: Field survey, 2012
Figures in parentheses are the corresponding t-ratio values
*** Significant at 1%, ** Significant at 5%, Significant at 10%

Table 3: Estimated determinants of technical efficiency

Production frontier parameter	Eroded coefficient	Non-eroded coefficient
Constant	0.11 (0.132)	0.01(2.558) ***
Education	-0.22 (-2.23) ***	-0.148 (-3.69)***
Age of the farmer	-1.97 (-1.71) ***	0.01(4.048)***
Marital status	0.13 (1.33)	-0.12 (-0.85)
Association	0.24 (0.62)	-0.08 (-0.46)
Extension contact	-0.55 (-1.06)	0.36 (3.324)***
Access to credit	0.17 (0.429)	-0.26 (-1.23)
Incidence of soil erosion	0.11 (0.132)	-
Household size	4.40 (0.92)	-0.05 (-1.83)**
Improved cassava variety	0.70 (1.39)	-0.42 (-0.833)

Source: Field survey, 2012
***Significant at 1% ** Significant at 5% * Significant at 10%

1.6 Estimation of the technical efficiency

A crucial characteristic of the stochastic production frontier model is its ability to estimate individual farm specific technical efficiencies. Table 2 shows the decile range of the efficiency in eroded and non-eroded farms. The result revealed that the highest efficiency range was recorded within the range of 50-60 (23%) and 90-100 (29%) on eroded and non-eroded farms respectively. Predicted technical efficiencies range between 25 percent and 99 percent with the mean technical efficiency of 56 percent among eroded farms; 44 percent and 99 percent with mean technical efficiency of 77% on non-eroded farms. There was a decrease in technical efficiency among farmers on eroded land.

This means that, if the average farmer on eroded land was to achieve the technical efficiency level of his most efficient counter part, then the farmer could realize a 44 percent cost saving [i.e.1-(56.48/99)x 100]. Also, for farmers on non- eroded farms to achieve the technical efficiency level, then the farmers could realize a 22.7percent cost saving [i.e 1-(76.54/99) x 100. Hence, about 44% and 23% on eroded and non eroded farms respectively are lost to technical inefficiency in the production system. However, variation in the predicted technical efficiency/ inefficiency among cassava farms can be explained by the variation in the level of education, farmers' age, marital status, membership of cassava production association, extension contact, access to credit, and incidence of soil erosion, household size and use of cassava variety.

1.7 Determinant of technical inefficiency

The estimated determinants of technical efficiency are summarized in Table 3

The inefficiency function shows that, the coefficients for the level of education, age of the farmers, extension contact were negatively related to technical inefficiency while marital status, membership of association, access to credit, and incidence of soil erosion, household size, and improved cassava variety were positively related to technical inefficiency among eroded farms.

Among non-eroded farms; level of education, marital status, membership of association, access to credit, household size and improved variety were negatively related to technical inefficiency while age of the farmers and extension contact were positively related to technical inefficiency. It should be noted that a negative signs of the parameters in the inefficiency functions means that the associated variable have a positive effect on technical efficiency while a positive significant variables indicate the reverse. For instance, the negative coefficients of the level of education among eroded and non-eroded farms showed that cassava farmers with greater years of schooling were less inefficient. Erhabor and Emokaro (2007) reported that education is negatively related to technical inefficiency.

The estimated coefficient of age with respect to eroded farms had negative sign and significant at 10 percent. This implies that increasing age would lead to low productivity as a result of ageing farmers who would be less energetic to work on the farm (Chinaka *et al*., 1995 and Anyaegbunam *et al.* (2006). Also, the estimated coefficient of age among non-eroded farms had positive sign and significant at 1 percent. This means that age has positive effect on technical inefficiency of farmers, indicating that the older ones are less inefficient than the younger ones. The finding supports Ahika (2002), who stated that age has positive effect on technical inefficiency of farmers; he attributed this trend to the fact that older people are less willing to adopt new ideas of doing things.

In addition, the coefficient of extension contact among non-eroded farms had a positive sign and significant at 1 percent. This implies that extension contact would lead to decline in technical inefficiency. This may be due to the fact that extension agent advice them to change traditional system of farming to modern system which might lead to the loss of interest in farming enterprise. This finding agrees with Feder *et al*. (2004). Although agricultural extension on farmers education programmes are important to improving productivity, they are being hampered by bureaucratic inefficiency and some generic weaknesses inherent in public operated and staff intensive system leading to their poor performance.

More so, the coefficient of household size had a negative and significant at 5 percent levels of probability. It shows that as household increases technical inefficiency increases. This means that value of farm products that could be sold are consumed directly by household. This agrees with Yusuf and Malomo (2007); Okike (2000) who reported that family size have negative influence on farmer's technical inefficiency.

The result of t-ratio on non-eroded farms shows that all the variables are statistically significant at one percent level of significance while on eroded farms only fertilizer is significant. Hence, these variables are important determinants of technical efficiency of cassava production in the study area.

1.8 Conclusion

The study showed the technical efficiency of cassava farmers in eroded and non-eroded farms of Enugu State. The mean efficiencies varied from 57 and 77 percent among eroded and non-eroded farms respectively. The variation was due to the effects of soil erosion and the extra cost spent by farmers to control soil erosion menace .The result reveals that education and extension contact were negatively related to technical inefficiency while marital status, membership of association, access to credit, incidence of soil erosion, household size and improved cassava variety were positively related to technical inefficiency among eroded and eroded farms.

Therefore, policies that will enable farmers to improve their level of education, extension contact, improved cassava variety, free access to credit facilities and provision of fertilizer at affordable price in right time should be implemented by various governments and agencies. As these are important for increasing the farmers' efficiency and income.

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