A Model Application to Assess Resource Use Efficiency for Maize Production in Soils of Northcentral Nigeria: Counseling Implications for Sustainable Land Use Optimization

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Abstract
Maize constitutes a major agrarian production setting in Nasarawa State, northcentral Nigeria but the production level is not matching domestic demand. The study assesses scientifically the resource use efficiency of this crop for future production optimization. Data from 2009/2011 maize production yearswere used. Socio-economic (qualitative) data were collected from administered questionnaire on ninety farmers from three communities (Doma, Ayaragu, and Shabu) in Lafia.Data was statistically analyzed usingdescriptive statistics and multiple regression analysis. Soil samples were analyzed for lithological similarity of the soils. Result showed that soil properties varied within the locations but were of similar lithology. 72 % respondents constituted active farming age (32-50 years) and about 30 % over 50 years in age.Regression analysis showed that quadratic factorial form was best fitted with R^2 = 92.0% and adjusted R^2 = 91.4%. Yield increased by 0.17, 0.08 and 78.2 Kgha^{-1} for every unit of seed, labor and land used. Maximum yield estimate (2.34 tha-^{1}) was obtained based on optimal levels of input. All the inputsshowed decreasing returns to scale, except fertilizer. There is need to reduce the use of variable inputs, which returns are less than the cost so as to increase present level of production profitability by the farmers. The scope of higher production lies in adequate availability of inputs.Educating and training the farming community to adopt innovative technology is important for efficient useand sustainable management of their farm soils and crops.
Keyword: Model, Resource Use, Production, *Zea mays* , Nigeria

1.1. Introduction

Small scale farming constitutes an important and invaluable component of Agriculture andlargely the foundation upon which Nigerian economy rests. Literature showed that over 12million farmers, scattered in different ecological zones, engage intraditional subsistence production of a wide variety ofcereal and arable crops (Olayemi, 1980).Furthermore, 90 percent of Nigeria's total food production comes from small-scale farms and at least60 percent of the country's population earns their living from these farms. This implies thateffective development strategy is critically needed to promote productivity and outputgrowth in the agricultural sector, particularly among small-scale maize crop growers.

Farming communities in northcentral region of Nigeria are crop production oriented. Maizeproduction,as the most important land use, constitutes a key component of the farmers' locallivelihood. Currently, production of food cropsin the region does not meet the domestic demand.Thus, the race between increasing population and food supply is a real grim.

Inadequate food production was blamedon the share of agricultural products in total exports thatdeclined from over 70 percentin 1960 to less than 2 percent in 1999 resulting from phenomenal rise of oil shipments (Fakorede*et al.,* 1993). Abdullahi (2001) showed thatdecreasing agricultural productivity wasdue to decline inagricultural focus because of discovery of oil. Iken*et al.* (2004) and Oniah (2005) also reported thatgeneral lack of scientific and technological capacities severely limit actual crop production in spite ofgreat inherent land resources potentials. Also, poor resource base, coupled with competing demands for otherdevelopmental needs, makes public funding for agriculture grossly inadequate. Other factors limiting agricultural growth (Fajemisin, 1985; Olayemi, 1980) include poor prioritization, mismanagement of limited resources, lack of credit andmarket access, and lack of sufficient political will by successive governments.

Inefficiency in the use of available scarce resources could be the cause for decreasing foodproduction and thus low income among the cream of farmers across the region and nation. In view ofthe growing gap between the demand for and supply of food against the background ofan increasing pressure on land, the efficiency with which available resources and technology areused by the farmers becomes a priority subject of investigation. Iken*et al*., (2004) posit that for agriculturalproduction to increase, it must be based on efficient use of traditional technology andpractices, or through the introduction of a package of improved technologies like fertilizer,improved seeds and cultural practices ((Abdallahi, 2001).

Maize (*zea mays, L*) generally has been in the diet of Nigerians for centuries and its production derives mainly from three factors: firstly, maize can be easilyprepared into a variety of meals and this accounts for about 65% of the total daily caloric intake ofrural people (Fajemisin, 1985); secondly, the rising income realizable from the production of maize, and thirdly,that maize not only thrives in intercropping and relay cropping of farmers' cropping system but hasquicker biomass recovery with low economy of production (Ezeaku *et al.,*2002). With all these attributes including the fact thatmaize provides good source of raw materials for industries make the demand on maizeto continue to increase.

However, the uncertaintities and risks associated with agricultural production and in particularthe scarce nature of the required inputs for maize production pose serious problem in meeting theoutput levels. Olabode(1992) reports poor morph-agronomic characteristics of varieties grown; inadequate agro-techniques, high production costs, poor producer prices andpoor marketing system, and importantly poormineral nutrition thatcontribute to low yield of crops. Ezeaku, (2006) associated decline in crop yield to constant cultivation thatnegatively affects soil fertility through degradation of the soil properties by wind and/or water erosion.

Ascertaining the level of input combinations that maximize output of maize and minimize cost over time remains an issue of interest.Providing empirical evidence of relationships between resource inputs and maize production was attempted elsewhere (Battese *et al.,* 1995; Farrel, 1997; Iken *et al*., 2004). Currently, there is paucity of information regardingresource inputs relationship with maize production in the study location.With this scarcity of evidence, there is need for on-farm research to fill gaps in knowledge.

This study aims to: (i) applyquadratic model in order to examine the resource use efficiency in maize production, (ii) determine the optimallevels of input usage by farmers, (iii) obtainreturns to scale for the inputs; (iv) ascertain if the soilshave similar lithology, and v) propose strategies for farmers to improve the level of profitabilityin maize farm production enterprise.

The study intends to provide background knowledge of resource use efficiency and further more contribute to effective utilization and management of soil landscape ecologies so as to boost the nation's food production capacity and income growth.

1.1.2. Literature Review of Production theory, Farm efficiency and Soil

1.1.2.1. Production theory and Farm efficiency:

Production is the process of transforming inputs suchas capital, labor, and land into goods and services called output. These resources can beorganized into a farm-firm or producing unit whose ultimate objectives could be profitmaximization, output maximization, cost minimization or utility maximization or a combinationof the four. In this production process, the farm-firm or entrepreneur may be concerned withefficiency in the use of inputs to achieve a goal i.e. the technological versus economic efficiency (Olabode, 1992; Oniah, 2005). Furthermore, economic efficiency occurs when the cost of producing a given output is as low as possible.The objective of the efficiency is to provide some basic rules about the manner in which firmsshould utilize inputs to produce outputs.

The basic theory of production is simply an application of constrained optimization, the firmattempts to either minimize the cost of producing a given level of output or to maximize theoutput attainable with a given level of costs. Both optimization problems lead to the same rulefor the allocation of inputs and choice of technology since alternative means of attaining theproduction goals exist i.e. the theory of production presents the theoretical and empiricalframework that facilitates a proper selection among alternatives so that any one or a combinationof the famer's aims can be attained. However, in order for the farmer to make decisions that willenable him attain goals above, certain parameters of interest must be known and this is derivedthrough the production function (Farrell, 1997; Battese *et al.*, 1995).

A production function stipulates the technical relationship between the inputs and outputinvolved in production. Usually denoted as:

$$Q = f(x)$$

$$AP = \frac{Q}{\mathrm{x}} = \frac{F(x)}{\mathrm{X}} \ldots\ldots\ldots..Average\ product$$

$$MP = \frac{dQ}{\mathrm{dX}} = \mathrm{f}^1(x) \ldots\ldots\ldots\ldots.Marginal\ product$$

These parameters (AP, MP) help the farmer in determining the use of resources and the patternof outputs which maximize farm-firm profits. These parameters can be derived from the variousforms of production functions: Exponential, Semilog, Quadratic, Linear, etc and can be appliedto both short- and long-run productions. However, efficiency analysis is an issue of interest inrecent times, given that the overall productivity of an economic system is directly related to theefficiency of production of the components within the system (Kyi *et al*., 1998). As such,agricultural productivity is said to be a measure of efficiency.

Also, the maximum resource productivity will imply obtaining the maximum possible outputfrom the minimum possible set of input. In this context, optimal productivity of resourcesinvolves an efficient utilization of resources in the production process (Kyi *et al*., 1998).

1.1.2.2. *Farm efficiency*:

Agricultural productivity is defined as a measure of efficiency with which an agricultural production system employs land, labor, capital and other resources(Farrell, 1997). Two types of efficiency(technicalefficiency and allocative efficiency) have been defined. While technical efficiency was defined as the ability of a farm-firmto extract the maximum output from a given level of input (Idiong, 2007),allocative efficiency was explained asthe farmer's ability to achieve the optimal mix i.e. having the right and efficient combination of inputs that gives optimal output (Kyi and Oppen, 1998;Khumbhaka *et al.,*2000).

These reports indicate thattechnical efficiency is one component of overall economic efficiency and for a farm-firm to beeconomically efficient it must be technically efficient.Furthermore, profit maximization requires a firm to produce the maximum output giventhe level of inputs employed (i.e. be technically efficient), use the right mix of inputs in the lightof relative price of each input (i.e. be input allocative efficient) and produce the right mix ofoutput given the set of prices (i.e. be output allocative efficient).

Several other reviews on production function for analysis of resource use efficiency, technicalefficiency and determinants maize output (Battese *et al.,*1995) show that OrdinaryLeast Square (OLS) is used to obtain the determinants maize output. Production frontier model isused to determine the resource use efficiency of the farmers. The production frontier modelusually used is the stochastic production frontier model of the form:

$$Y = f(X1 \dots Xn)$$

$$\boldsymbol{Y = \beta 0 \ + \beta 1X1 + \beta 2X2 + \beta 3X3 \dots + \beta nXn + et}$$

$$\boldsymbol{\alpha + \beta X1 + BX2 + \beta X3 ... + BnXn + Vt - Ut}$$

Where :

et = Vt-Ut

Vt = A symmetric random error which captures the effect of weather, luck and other factorsoutside the control of the farmer.

Ut = Technical inefficiency i.e. what is left for the farmer to reach the outer bound of theproduction frontier or operate in the frontier.

Y = Output in kilograms

Xn = Vector of inputs

X1 = Quantity of seeds ($kgha^{-1}$)

X2 = Quantity of fertilizers ($kgha^{-1}$)

X3 =Amount of labor used (man $hours^{-1}$)

X4 = Farm size in hectares

In the frontier model, to estimate β as a vector of parameter, the stochasticproduction frontier model is linearised thus;

$$\boldsymbol{InY = \beta 0 \ + \beta 1Inx1 + \beta 2In + \beta 3Inx \dots + \beta nInxn}$$

$$\boldsymbol{InYt = \alpha \ + \beta 1nX1 + \beta InX2 + \beta InX2 \dots + \beta InXn + Vt - Ut}$$

Where In = Natural Logarithm

Y = Output

Vts = Assumed independency distributed random errors

Ut = Technical inefficiency effects, usually outlined by the equation

Xn = Vector of inputs

Also, the technical inefficiency effects in a stochastic frontier above are expressed in terms ofvarious explanatory variables, which include the socio-economic characteristics such as maritalstatus of the farmers, age, gender, education, etc (represented as Z). This is given by:

$Vt\sigma = \sigma n + \delta 1Z1 + \delta 2Z2 ... + \delta nZn$

Where,

Vt = Technical efficiency

δ1..n = Coefficients of the variables

Z1 = Marital status of the family as dummy

Z2 = Age of the farmer, etc.

In the two objects in stochastic frontier analysis, the first serves as the benchmark against whichto estimate technical efficiency of producers (Battese *et al.*, 1995). Its goal is to estimate theefficiency level of each producer. The second aims at incorporation of exogenous variableswhich are neither inputs to the production process nor output of it but which nonetheless affectproducer performance with the intent to identify the determinant of efficiency.

1.1.2.3. *Soil information*:
Land use negatively affects soil fertility and productivity. Constant cultivationresults to soilproperty changes, resulting to depletion of nutrient contents: (e.g. N, P, K, Ca, Mg, S), pH, organic matter, CEC and structure (Akinrinade *et al.,* 2002). However, Akamigbo and Asadu (2001) associatedmarkedchanges in morphological, physical and chemical properties to acceleratedpedogenic processes and decline in fertility of soils under traditional than forest land use. As soilfertility declines, the soil becomes susceptible to erosion and this reduces soilproductivity potential.
If agriculture is to be sustainable, it must feed the growing population. Higher crop yields must be obtained and will be the result of improved management. Improved agricultural production demandshigher input and resource use efficiencies, including nutrient balance, efficient nutrient application ratesand appropriate land use, adequate crop conservation with an appropriate mix of cultural practices,judicious use of chemical inputs (fertilizers, pesticides, and herbicides) and use of genetically enhancedcrops.

2.1. Material and Method
2.1.1. Study Site Description
Lafia is a location in Nasarawa State, northcentral Nigeria. It is located by6^o 15'N and 9^o
30' E and 11^o 00' E with a mean altitude of 600 m above sea level. Lafia is anagricultural area characterized by gentle and undulating plains. The area is drainedby many rivers and streams. The general climate is tropical, having distinct rainy with clear anddry seasons. The mean temperature ranges between 23.5 and 30.9^{o}C, while mean annual rainfallranges between 1270 and 1530 mm with a 3-4 month dry season. The main land use is cerealcropping systems (Ezeaku *et al.,* 2005).
The study area (Lafia) was particularly chosen for this study because of its prime place in staplefood crops production in Nasarawa State, the latter depicting a true agrarian setting in Nigeria.The State has the acronym 'Food basket' of Nigeria. The data for the study was collected fromfarmers that are mainly engaged, for decades, in sole maize production. A two-stagerandom sampling technique was employed in selecting the studied farmers. First stage wasrandom selection of three out of five major maize production locations. These are Doma,Ayaragu,and Shabu communities. Second stage involved random distribution of well structuredquestionnaire to maize farmers in each of the three locations. A total of ninety farmerscomprising thirty farmers from each location were purposely and randomly selected. The maizelocations were identified through the assistance of three resource persons as the sample frame.
2.1.2. Statistics (Analytical framework):
In this study, descriptive statistics and regression analysis wereemployed as analytical tools.
2.1.2.1. Descriptive statistics: Percentage and frequency tables were used in the analysis of the socioeconomiccharacteristics.
2.1.2.2. Regression analysis: In the present study, regression analysis was used to determine the factorsthat affect maize output in the three selected areas. The variables were fitted intodifferent functional forms: - Linear, Semi-log, Double-log and Quadratic forms. The variablestested include farm size, quantity of seed, quantity of fertilizers and amount of labour.
Based on conditions of choice of functions, which include expected signs of the coefficients, t-values,magnitude of R^2 adjusted coefficients and number of significant variables, Quadratic model was the best fittedfunctional form and then selected for use in the study. The model was calibrated using optimal levels of input.
The model specification has an explicit form as follows:
$Y = a + bx_1 - cx^2 + dx_2 - ex_2^2 + fx_3 - gx^2{}_3 + hx_4 - ix^2{}_4$……… (1)
Where;
Y= Maize yield (kg/ha)
A = intercept; b…I = Parameter coefficients
X1 = Quantity of seeds (kg/ha)
X2 = Quantity of fertilizers (kg/ha)
X3 =Amount of labor used (man hours^{-1})
X4 = Farm size (ha)
A,b,c,d,e,f,g,h,and i = parameters
The technical optimum levels of input used were determined by equating the marginal physical product (MPPx) of resource inputs to zero and then solve for:
MPP of $x_1 = 0$, $x_2 = 0$, $x_3 = 0$, $x_4 = 0$, respectively.
MPP of $X_1 = 0$…….. (2)
MPP of $X_2 = 0$….. …(3)
MPP of $X_3 = 0$ …… (4)
MPP of $X_4 = 0$ … …(5)

The values of equations 2 to 5 (X1…X4) were substituted into equation (1) to determine themaximum yields (kgha-1).To obtain the most profitable levels of input used, the first derivative of Y with respect to X1…X4,respectively, was taken. These were equated to the price ratio (quotient of input unit prices tooutput unit prices to get estimated economic optimum input level) as follows:

MPPx = $\frac{Px}{Py}$ ……. (6)

Where;
MPPx – MPPx4 = Marginal physical product of inputs
Px_1 – Px_4 = unit prices of inputs
Py = Unit prices of output.

The estimated economic optimum input level was substituted in equation (1) to obtain the most profitable level of output (i.e. economic optimum output level or profit maximization output levels).

To obtain the returns to scale, the elasticity of production for individual input was calculated:

$EP = MPPx1 = \frac{1}{APPx1-x4}$……… (7)

Where;
EP = elasticity of production
MPP = as defined in equation (6)
APP = average physical product of inputs

Note that the parameter representing these returns to scale is the degree of homogeneity.

2.1.3. Soil sampling

Soils of the three selected locations were sampled with a view to knowing theircharacteristics and then relating them to a parent material. Thirty random auger (of 86 mm internal diameter) samples were collected within the two crop years. Fifteen were taken from surface (0-15cm) and another fifteen at subsurface (15-30cm) soils. The soil depth (0-30 cm) was chosenbecausemaize crop is a surface feeder(Ezeaku, 2001).Fifteen (5 from each location) soil core ring (of a known volume - 96.6 cm^3) samples were taken randomly from undisturbed soils at 0-10 cm depth for bulk density determination.

2.1.4. Laboratory methods

Soil samples collected from the field were removed from the steel collection augers and were air-dried in the laboratory. The dried samples were gently disaggregated and mixed with a mortar and pestle. The sample was then passed through a 2-mm aperture and the coarse fraction (>2 mm) separated. The <2 mm soil fraction was then ground in a mill to a fine powder. All samples were stored in suitable polythene receptacles.

The analytical characteristics of the soil samples were determined in the following manner. The percentage by weight of sand, silt, and clay were determined after previous H_2O_2 treatment and samples were dispersed in sodium hexametaphosphate solution using the Bouyoucos densimeter method (Gee and Bauder (1986). Bulk density was measured on an oven-dried weight basis of a 96.6 cm^3 core sample taken at field-moisture conditions (Blake and Hartge, 1986).

Soil pH was obtained in 1:2.5 soil/water extract using a glass electrode pH meter (McLean, 1982) method. Organic carbon (OC) was obtained by the wet dichromate acid oxidation method (Nelson and Sommers, 1982); Organic matter content was obtained by multiplication of OC value with a factor of 1.72. Exchangeable basic cations (that is Ca, Mg, Na and K) were extracted using unbuffered 0.1 M $BaCl_2$ (Hendershot *et al*., 1993) and determined using atomic absorption spectrometry (AAS). Ca and Mg in the extract were determined using ethylene diamine-tetraacetic acid (EDTA) titration, while Na and K was determined colorimetrically using flame photometer. Cation exchange capacity(CEC) was obtained as a summation of exchangeable bases and acidity. Total N was determined by Macro-Kjeldhal method (Bremmer and Mulvaney, 1982). Base saturation was computed as the percentage ratios of exchangeable bases. Available phosphorus (P) was obtained by Bray I extractionmethod (Olsen and Sommers, 1982).

3.1. Results and Discussion

3.1.1. Demographic characteristics of maize farmers

The demographic characteristics of farmers in the study areas are shown in Table 1. Thevariables considered include age, gender, marital status, farming system and education. Theanalysis of the result on age distribution of the farmers shows that majority of the respondentsfall within the age of 31-40 years (39.6%). This represents mostly adults that are within theeconomically active age group. Such group is most likely active in farming.

The gender distribution of the respondents (Table 1) shows that majority are males (58.5%)relative to women (42 %), implying that men are more active in farming compared to women.

This could be associated to religion where women are restricted only to household jobs. Most of the women only engage in farming on their husband's farm on thepremise that a woman should not own a farm of her own when she has a living husband. Onlywidowed women whose husbands' are not living do have farmsthey maintain.

In terms of education, the result shows that the bulk of the farmers received no formal educationand this could be why they rarely adopt modern farming (innovative) technologies believing thatsoils are naturally fertile and do not need fertilizers.

The farming system result (Table 1) indicates that most (43.5%) of the respondents are engagedin sole maize crop farming. Only 25.9 percent of the respondent farmers are engaged in mixed

Table 1: Demographic characteristics of the respondents in the study area. (N = 90)

Demographic variable	Frequency	Percentages (%)
Age group (Years)		
<30	510	8.7
31-40	26	24.6
41-50	34	47.6
>50	32	30.1
Gender		
Male	66	58.5
Female	34	41.5
Marital status		
Married	78	85.3
Single	12	14.7
Education		
No formal education	45	51.5
Primary	31	36.2
Secondary	12	11.0
Tertiary	2	1.3
Farming system		
Sole crop farming	40	43.5
Livestock	12	9.3
Poultry	20	11.8
Mixed farming	20	25.9
All above	10	9.4

Field Survey of 2009/2010 Crop Years

farming (a combination of crop and animal production). These entail that more attention need to be paid tocrop based activities, especially, maize production so as to justify profitability.

3.1.2. Soil information

The results of soil information are presented in Table 2. It reveals that the soils range from loamy sand to sandy loambut predominantly loamy sand. Sandy nature of soils reflects cretaceous sedimentparent materials fromwhich they are formed (Ezeaku *et al.,* 2005). Predominant loamy sand characteristic of the soil shows similarity in lithologicalorigin.

The predominant loam sandy nature of the soils could have contributed to lack of fertilizer effects on the maize output. Syntheticfertilizers, where applied, are highly mobile in sandy soils and thus could easily be washed outof the zone of root concentration by infiltrating water. Secondly, if nitrogenous fertilizer such as ammonium sulphate (NH_4SO_4)is applied, it could easily be leached out of the root zone by infiltrating water or denitrifies when temperature regime is high. All of these compounds the ability of rootuptake of the fertilizer elements thus results to unsubstantial yield realization.

The bulk density of the soils ranged from 1.32 to 1.36 Mgm^{-3}. The values arelow when compared to the critical value of bulk density (1.5 MgM^{-3}) for maize production in tropical soil (Aune and Lal, 1997). The low bulk density of the soils could beassociated to constant cultivation and organic fertility input like green manuring application by farmers in the area.Low bulk density may not be limiting maize production in the area.

Soil pH values show slight acidity (Table 2) of the soils. However, the soil pH inDoma may present conditions limiting maize crop production because of Al toxicity. Al toxicity occurs in soils with pH value of about 5.5 and increases in intensity aspH increases (Enwezor *et al.,* 1990). Optimum pH for most agricultural crops falls between 6.0 to7.0 because nutrients are more available at pH of about 6.5. Liming is therefore necessary toreduce acidity in Doma soils.

The organic matter content (SOC) of the soils ranged from 20.34 to 24.16 g/kg (Table 2). Critical value of 25.0, 30.0 and 35.5 g/kgwas reported forWest, North and Eastern Nigeria, respectively (Akinrinade and Obigbesan, 2002). The locations' mean(22.71 g/kg) (Table 3) fell below the critical value (30.0 g/kg)for northern Nigeria soils. 30.0 g/kgis suggestedas level to which response to N fertilization is not expected. The general low levels of SOC in the study could beattributed to management practices involving burning, continuous cultivation with reducedfallow period (Lal, 1990), and scanty vegetation coverage of the land mass.

Total nitrogen followed a similar trend as SOC since soil nitrogen constitute thebulk of total N for tropical soils (Noma *et al*., 2005). The mean total N (0.71 gkg-1) for thesoils is below 0.15 percent or 1.5 gkg-1, the critical value for tropical soils (Enwezor *etal.,* 1990) and indicates high N deficiencies. Main cause of N deficiency in tropical soils isintense leaching and erosion due to rainfall. This low N level signifies response to N fertilization.

Soil cation exchange capacity (CEC) wasclassified as low (< 6 Cmol/kg), medium (6-12 Cmol/kg) and high (> 12 Cmol/kg) (Ojanuga and Awojuola, 1981). On the basis of thisclassification, values of CEC in all the soils (Table 2) fell within the low and medium range category since their values are between 5.41 and 8.92 Cmol/kgwith a mean of 7.11 Cmol/kg. Low to medium CEC value oftropical soils was attributed to dominance of kaolinitic clays in the fine earth fraction (Ojanuga *et al.*,1981).

Results of the variability of nutrient elements (Ca, Mg, Na and K) across the cultivated soils are presented in Table 2. Calcium (Ca) (2.53 Cmol/kg) and Mg (1.64 Cmol/kg) mean values are higher thanthecritical values of soilnutrients (Ca =2.0 and Mg = 0.4Cmol/kg) reported for Nigerian soils (Adeoye and Agboola, 1984), an indication that these nutrient elements may not be limiting maize production. The mean value of K (0.18 Cmol/kg) was less than the critical value of K (0.20 Cmol/kg) reported by (Adeoye *et al.*, 1984). The low value ofthe K elementcould have contributed to lack of fertilizer effect on the maize output. However, Fasina (2002) reported low exchangeable Ca, Mg and K to controlmaize yield on the field.Akamigbo and Asadu (2001) associated low values of exchangeable cations in soils to the nature oftheir parent material (sandstone), while their ephemeralness contributes to their susceptibility toleaching losses.

Available P ranged from 5.09 to 7.37 mg/kg with a mean of 5.90 mg/kg (Table 2). This shows a high P deficiency as the mean value was less than the critical range (8-12 mg/kg) of P reported for tropical soils (Enwezor *et al*., 1990). The cause of the high P deficiency could be related toleaching by rainfall. On the other hand, Bubba *et al.,* (2003) associated low P concentration in soils to high weatherability of the soils,presence of kaolinitic clay as the dominant mineral and adsorption reaction by soil constituents.

exchange capacity, BS = base saturation, % = percent.

3.1.3. Quadratic model application

Results of the model application to explain the determinants of maize output are shown in Table 3. The result of the regression of the output (Y in kilograms) against the independentvariables using quadratic function shows an R^2 value of 92.0percent and an adjusted R^2 of 91.4 percent, indicating high degree of correlation.

Table 2: Soil physical and chemical properties of the 3 location soils (No = 30) averaged over 2009 and 2010 crop years

Location:	Doma		Agyaragu		Shabu		Average
Soil depth (cm):	0-15	15-30	0-15	15-30	0-15	15-30	0-30
Physical Properties							
Particle sizes distribution:							
Clay (gkg^{-1})	7.92	8.30	12.46	14.53	7.69	8.06	9.83
Silt (gkg^{-1})	24.70	27.55	9.81	10.21	26.10	27.23	20.93
Sand (gkg^{-1})	68.38	64.15	77.73	75.26	76.22	64.71	61.41
Textural class	Loamy sand		Sandy loam		Loamy sand		
Bulk density (MgM^{-3})	1.34		1.36		1.33		1.34
Chemical properties							
Soil pH (H2O)	5.47	5.28	6.32	6.10	6.00	5.80	5.83
Organic matter (gkg^{-1})	23.10	24.16	20.34	23.40	22.19	23.07	22.71
Total N (gkg^{-1})	0.78	0.69	0.88	0.72	0.64	0.60	0.71
Exch. Acidity ($Cmolkg^{-1}$)	0.36	0.34	0.28	0.27	0.30	0.29	0.31
CEC ($Cmolkg^{-1}$)	6.95	8.00	5.41	6.55	6.81	8.92	7.11
BS (%)	72.40	72.62	69.30	68.57	70.18	70.84	70.65
Ca} $Cmolkg^{-1}$)	2.48	2.51	2.35	2.64	2.43	2.79	2.53
Mg} ,,	1.44	1.46	1.34	1.38	2.00	2.20	1.64
Na} ,,	0.32	0.32	0.26	0.28	0.27	0.31	0.29
K} $Cmolkg^{-1}$)	0.19	0.20	0.14	0.18	0.19	0.19	0.18
Available P ($Mgkg^{-1}$)	5.09	6.74	4.49	5.11	6.60	7.37	5.90

NB: N = nitrogen, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, CEC = cation

The response function from data was estimated as follows:

$$Y = 936.04 + (0.170\, x_1 x_1^2) + (0.001 x_2 - x_2^2) + (0.081 x_2^3) + (78.2\, x_{4\text{-}X4})$$

The analysis of the functional relationship above shows that maize yield increased quadratically by0.17 $kgha^{-1}$ for an every unit (kg) of seed used;0.08 kg/ha for every unit of labor used(Man-hour), and 78.2 $kgha^{-1}$ yield increasefor every unit of land (ha) used. The resultindicates that farm size (in hectares) has positive relationship with the output (significant at10%). Similar observation was made for labor (family or hired) and seed with the latter beingsignificant ($P<0.05$).

The positive relationships suggest that they are significant determinants of output and thisfollows the a priori expectation that increase in farm size and labor use as well as use of improved variety of maize could result to increases in output. The larger the farm size, efficientthe labor and more improved the seeds, the higher the farm yield obtained. Suffice to say thatavailability of labor is important for timeliness of operations and for obtaining the desired outputbut most farmers interviewed say they cannot increase the size of their maize farms because ofinsufficient labor. Most of their growing children are attending schools and colleges and someare at university level. This is a feature that may affect substantially future agriculturalproductivity in the area.

Use of inorganic fertilizers was found to significantly increase maize crop yields (Fajemisin, 1985; Fakorede *et al*., 1993). They reported 95-99 percent fertilizer effect on maize farms but contrary to yield increase withrespect to fertilizer was the case in this study (Table 3). Lack of significant fertilizer effecton the cropped maize could be associated to some reasons:

Table 3: Regression analysis using quadratic function on varying inputs in maize production

Parameter	Variable estimate	SE ±	t-value	Significant level
Intercept (a)	925.07	87.610	0.001	0.01*
Seeds (x1)	0.170	0.068	0.053	5.30**
Fertilizers (x2)	-0.001	0.003	0.781	78.1 Ns
Labour (x3)	0.081	0.020	0.100	10.100***
Farm size (x4)	78.20	41.134	0.089	8.9***
F-value = 111.25; R^2 = 0.9201; Adjusted R^2 = 0.9142				

NB: *, **, *** and Ns – significance at 1%, 5%, 10% and not significant, respectively.

Source: Authors' computation from Survey Data (2009/2010 crop years)

Response from the interviewees shows that fertilizers are unavailable in the locality during theearly cropping season and where available the prices are beyond the reach of an average farmer at a subsistence farming level. The problem is further compounded by lack of credit facility to purchasethe right kind of fertilizers at the right time. Late procurement of fertilizers leads to untimely applications and could affect yield substantially. In this regard, government intervention in form of subsidy is expedient and timely too so as to maximize farm productivity.

Prejudice was mentioned by farmers in terms of choice for fertilizer application. Some of thereasons they mentioned are: chemical inputs, especially fertilizer reduces the lifeshelf of their stored produce such as root crops e.g. yam and cassava (*Diascorea spp* and*Manihot esculenta*, respectively); it causes acidification of their soils. Cropsproduced with fertilizers are not as tasty as those grown without fertilizer. These perceptions necessitate need for training and adequate awareness creation for the farmers to embrace and use improved technologies for farming even though few regard chemical inputsas a pre-requisite for enhanced crop production.

The maximum yield estimate, based on values of optimal levels of input, was found to be 2318 $Kgha^{-1}$ (i.e. 2.32 tha^{-1}). This is significant improvement compared to farmers' average yield (1.7 ha^{-1}) without optimal levels of input application.However, based on the use of innovative technology and at experimental level elsewhere, maize yield of 2.51 tha^{-1} was reported (Ezeaku, 2001).

The economic optimum level of input and output were determined against the prevailing inputprices at the period of study, which were;

Seed = #50.00 kg/ha

Labour = #100.00 man hr^{-1}

Land rent = # 1500.00 per haper cropping season, while output price = #600 kg/ha.

The result of applying equation (6): MPPx = Px/Py, to obtain economic optimum input showsthat economic optimum for seed = 0.05 $kgha^{-1}$, labor = 0.012 man hr^{-1} and land = 23.4 ha.

An estimate of the level of profitability based on these values shows that MVP<MFC for maizeare MVP = #9.00 and MFC = #50.00 in Lafia. (Note: MVP = marginal value product; MFC =marginal factor cost).

The returns to scale from the input are as follows:

EPx1 = 0.002 suggests that it is < 1. This implies decreasing returns to scale for seed input,

EPx2 (fertilizer) is very insignificant (-0.001),

EPx3 = 0.001 is also <1, indicating decreasing returns to scale for labour,

EPx4 = 0.042 (also <1) and suggests decreasing returns to scale for farm size.

The degrees of homogeneity in this production are all less than 1 based on the elasticity ofproduction results: $X_1 = 0.002$, $X_3 = 0.001$, and $X_4= 0.042$, respectively. These variables arefound significant. Summation of the values of the entire variables ($X_1 – X_4$) gives 0.045representing the degree of homogeneity of less than 1 in the production.

Conclusion and Recommendation

In this paper, the production problems of small-scale farmers, resources available and their useefficiency have been discussed. From all indications, it is clear those maize farmers in the studyarea operate majorly on small-scale farm enterprise because of inherent problems of availabilityof farming resource inputs. The study revealed that most of the farmers do not use chemical inputssuch as fertilizers and they obtain low yields. This reflects the fact that major technicalinnovations are not getting to the grassroots and that diffusion rate is low. The study showedthat labor was not always available due to small family sizes, sometimes at high costs because of high demand, and phenomenal rural-urban migration.These impact overall crop outputs in the area.

In terms of resource use efficiency, the study revealed that relationship exists between somerequired variable inputs of maize and achievement of yield. However, decreasing return to scaleimplied that resources were inefficiently utilized despite the amount of profits made.

This study, therefore, confirms that the potential for increasing production through improvedperformance with available resources and traditional technology is limited. Given the weakinstitutional support services such as extension, education and credit, the finding of considerableinefficiency in improved maize production is as expected and thus an efficient use of improvedtechniques of production coupled with better management of land through increased institutionaland infrastructural support will help enhance maize production.

Further strategies based on the findings are recommended as follows:

- Considering the scarcity of resource inputs, mixed cropping system should be adopted tomaximize the available resources for more yields, especially crops that can support maize interms of nutrient supply. Cultivation of different and more suitable crops that is more resilientto climate change impacts encourages diversification of current livelihood options for thefarmers.
- As part of intervention measures, Government should improve rural financial markets so as togrant credit facility to farmers and which would enable them to afford technological innovations.

Government needs to subsidize the cost of agro-inputs such as fertilizers, herbicides, pesticidesand seeds for easy affordability by farmers and also improve rural infrastructure (e.g. feederroads). The fall in the resource use efficiency for maize production, as shown in the study, isexpected to attract policy attention. In this regard, highest priority attention should be given sincemaize is a widely consumed staple food by man and his animals. This will assure secure foodsupply.

- Since the optimum level of input is the amount of input that maximizes profit in order forfarmers to make more profit under decreasing returns to scale position of the farms, it is betterfor farmers to reduce the use of variables since marginal factor cost (MFC) was greater thanmarginal value product (MVP). This will make variable input returns less than the cost.Farmers should target to produce where total physical product (TPP) is maximum and MVP isequal to zero because as inputs increase the farm will continue to have less profit until MFCbecomes tangent to the peak of MVP. The highest profit condition is where MVP/MFC = 1.
- Soil information revealed lithological similarity of the soils.These soils are inherently lowin fertility due to the cretaceousnature of their parent material. This necessitates farmers' adoption ofinnovative technology in managing their farm soils and crops. Such technology includes organic agriculture that not onlybuilds up the fertility (nutrient) status but improves the structural stability of the soil and enhances the optimization of maize crop yield.
- Education as part of counseling implication is in the form of awareness creation about potentialoptions, particularly to increasing effectiveness of new crops and techniques in efficient resource use. This is important as part of enhancing adaptation capacity to the current climatechange conditions. Education need to promote diversification and also attract greater privatesector investment and improve market access links. In line to this, there is need to co-optGuidance Counsellors, complimentary to extension services, to enlighten farmers in abroader adaptation relevant to agricultural sector.

Net impact of education of farmers willenhanceagricultural husbandry techniques: efficiency in limited resource use, utilization and value-addingto crops and products in the production process. This can be achieved by training of communities byextension agents,Agriculture officers andGuidance Counsellors. Others includeinstitutions, industries and NGOs.Dissemination of relevant information could be during workshops and seminars as well as radio and television programmes.

Importantly, an appraisal of the activities of theextension services and Guidance Counsellors in the region is suggested so as to discover and improve on weak points, orbetter still modify their plans of operations to bring about better technology diffusion to farmers.Faster technological and innovative adoptions by farmers through knowledge (education) based approach should form important part of current farmers' reality.

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