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Factors Affecting Farm-specific Production Efficiency in the Savanna Zones of West Africa

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Agricultural intensification involving greater crop–livestock interactions and integration is emerging as the most promising strategy for improving agricultural production and productivity in much of Sub-Sahara Africa. In West Africa, where this process is at various stages of evolution, 559 farm households from the Sudan Savanna (SS) and Northern Guinea Savanna (NGS) zones were studied to examine the factors affecting production efficiency. The farms in each zone were divided into four socio-economic domains using a combination of population density and market access as criteria. Estimation of stochastic frontier production function indicated the need to include ecological and socioeconomic variables in both the production function and the accompanying inefficiency equation, failing which such models may suffer from omitted variables bias. The results showed that inefficiency effects of a stochastic nature existed among the sample farms and average efficiency was 76%: 68% in the SS and 86% in the NGS zones. Further, increased resource use associated with agricultural intensification was not always accompanied by an increase in production efficiency; and while agricultural intensification based on high external input strategies yields higher marginal returns in the NGS, a similar strategy is not critical to success in the SS given

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current use levels and the biophysical endowments of the latter ecological zone.

1. Introduction

Africa is often cited as the only developing region where agricultural output and yield growth are lagging seriously behind population growth (Savadogo *et al.*, 1994; Islam, 1995). In Sub-Sahara Africa (SSA), for example, population doubles every 25 years while the annual rate of increase in agricultural productivity has, in fact, declined from 1.9 to 1.5% during the past 15 years (World Bank, 1997). One way of solving the problem of food shortage being created by the widening gap between food output growth and population growth is through increasing agricultural productivity via technical change and/or improving the efficiency of farmers in utilising available resources. Achievement of these objectives will require the development of efficient markets, investment in rural infrastructure and the distribution of agricultural inputs, e.g., seeds and fertilisers. It is also conceivable, however, that technical change could be considered a more appropriate option when efficiency in utilising existing resources is very high among users thus limiting the scope for increasing productivity through reallocation of current resources.

The food production potentials of the sub-humid and wetter part of the semi-arid agroecological zones of SSA have been recognised and given research priority (Winrock, 1992). These zones correspond to the Northern Guinea Savanna (NGS) and Sudan Savanna (SS) zones of West Africa, where some new agricultural technologies have been introduced, e.g., improved animal traction implements, fertilisers, herbicides, pesticides, improved seeds, including improved maize, and dual-purpose cowpea for food and feed. These technological packages are often very similar, yet they are targeted at farms and communities in different ecologies and at different levels of development of infrastructure and human capital, e.g., access to markets, education, experience and technical skills. Consequently, they perform differently in different locations and the overall outcomes fall short of the potential.

In the dissemination of new technologies, farmers in the region are treated as though their constraints and opportunities are similar. Such an approach is also adopted in applied research, where a majority of farm productivity studies generally stratify farms only by farm characteristics, e.g., farm size, tenure and level of income, and measure efficiency for the average farm. Such methods presume that all farms produce under similar conditions, and as such the differences in output and productivity among farms are mostly due to the scale of operation. A methodology that ignores the production environment of farms — biophysical conditions, population pressure and market access — and their implications on farmers' resource allocation and consequent productivity, could be misleading. In fact, Sherlund *et al.* (2002) clearly show that neglecting the heterogeneity in environmental production conditions leads not only to obvious omitted variables bias in the estimated parameters of the production frontier, but also to significantly inflated estimates of plot-specific inefficiency and to bias in estimates of the correlates of technical inefficiency. It is also known that ecology, population pressure and market access induce agricultural intensification[2] and crop–livestock interactions in the savanna zones of West Africa (Jabbar, 1996; Smith *et al.*, 1997). The next question is: do these forces also induce higher productivity and efficiency in resource use? This study attempts to answer this question through incorporating environmental and socioeconomic variables affecting production into a traditional stochastic frontier production (inefficiency) model.

This paper reports the results of a study in the NGS and SS zones of Nigeria — representative of those of West Africa. The study tested the hypotheses that (i) productivity of farms is higher in the NGS than in the SS and in mixed farms than in crop or livestock farms; and (ii) efficiency of farms is higher in NGS than in SS, especially where human population density interacts with high market access than in areas where the interaction is between low human population density and low market access.

In Section 2 of this paper, the study area and the sampling procedure for data collection are described followed in Section 3 by a brief review of literature on the measurement of production efficiency and the econometric model used for this study. In Section 4, the descriptive and econometric results are presented and discussed followed by summary and conclusions in Section 5.

[2] For this paper, agricultural intensification has been defined as increased use of farm inputs like labour, animal traction, manure, chemical fertilisers, crop residues, improved seeds, pesticides and herbicides and other capital expenditure in order to increase the total value of output per hectare of farm land.

2. The Study Area and Sample

2.1 The Study Area

The study was conducted in northern Nigeria covering two agroecological zones — the NGS and the SS. These zones lie roughly between latitudes 8° and 13.5° north of the equator and represent more than 50% of the total land area of SSA (Winrock, 1992). Mean annual rainfall ranges from 500 mm in its northern fringes to 1600 mm along its southern boundary. This rainfall is unimodal, and allows 100–180 days growing period usually followed by a long (7–9 months) and harsh dry season, which limits the amount of available grazing for livestock and makes crop residues an important component of the farming systems. The NGS has a higher cropping potential while the SS has a higher number of livestock per person but a lower cropping potential. The dominant rain-fed crops which provide these residues are maize, sorghum, millet, cowpea and groundnuts, grown as cereal–legume intercrops in various combinations on a number of separate farm plots with a combined size ranging from 3 to 6 ha per farm household (Ogungbile *et al.*, 1999). During the dry season, vegetables, wheat and more recently cowpea are grown along inland valleys (*fadamas*) using residual moisture, and also using private or public irrigation. In addition to growing crops, a majority of the farmers rear cattle, sheep and goats in varying degrees of combination for milk, meat, traction, manure and cash. Herders from the SS traditionally use the NGS as a dry season grazing area.

There are three types of farmers: namely, crop-based, livestock-based and mixed farmers. Crop-based farmers are traditional landowners with two to four work bulls and a number of small ruminants. Their main activity is crop production; they depend on inorganic fertilisers and manure (from own stock and from purchases) to maintain soil fertility (Manyong *et al.*, 2001). Crop-based farmers with large land holdings have an abundance of crop residues, so the tendency for them is to acquire more livestock to utilise the excess residue and save them the cost of purchasing manure — even though they could afford purchases from the proceeds of selling the crop residues. There are also crop farmers who keep only a limited number of small ruminants because they lack the requisite skill for large ruminant rearing. This latter group is often involved in crop residue and manure exchange contracts with pastoralists, and so maintain soil fertility mostly through crop–livestock interaction rather than crop–livestock integration. An emerging trend is that the manure market has extended beyond farmer-to-farmer, as frequently described, to abattoirs. At the time of this study, manure at abattoirs (and this used to constitute a disposal nightmare) was already selling for the equivalent of US$8.2/tonne and indications are that the price will continue to rise given the tendency for contemporary government policies to withdraw subsidy on chemical fertilisers. Another source of manure, outside farmer-to-farmer exchanges, is major livestock markets. There are a growing number of entrepreneurs who originally sold forage to livestock traders and also served as brokers for livestock purchases. As an additional business, this group now gathers manure from the market for sale. Access to manure from abattoirs and livestock markets is logically limited to farmers who are able to afford transport facilities or absorb associated transportation costs, as well as paying for the actual manure.

Livestock-based farmers are mostly former transhumant pastoralists who acquire small farm plots, as they begin to settle, to produce cereals for home consumption and for processing some milk products that they sell. These small farms produce too little residue for their large herds to survive on but they benefit from relative surplus of manure deposited around the homestead — usually part of the farm — by their livestock after extensive grazing on rangelands. Exploiting their comparative advantage, they exchange manure for crop residue with crop farmers through paddocking on the crop farmers' plots. As encroachment on rangelands by crop farming occurs due to increasing human population density, this group would have to depend more and more on production, exchange and purchase of crop residue as feed. Sale of livestock allows them to meet family expenses. Once settled, they tend to acquire more land and produce as much of their cereal and crop residue requirement as possible.

On the whole, therefore, crop–livestock integration for crop-based farmers in the savanna regions of West Africa involves acquiring more animals and sometimes leasing less fertile parts of their farmlands. On the other hand, livestock-based farmers sell some animals and acquire these plots knowing they have the resource — manure — to restore and sustain their fertility. Thus, for crop- and livestock-based farm types, crop–livestock integration means land-for-livestock and livestock-for-land exchanges, respectively, to arrive at fairly stable, single-household-owned, mixed crop–livestock systems with more than two work bulls and an easily manageable size of both land and livestock.

2.2 Sampling and Data Collection

This study was designed to measure farm-specific efficiency along the biophysical gradient involved in moving from the NGS to the SS and in moving from low to high resource use situations. Theoretically, each of the biophysical or socioeconomic gradients is a continuum, which could be studied in an infinite number of ways. Nonetheless, based on human population density and access to wholesale market as principal drivers of agricultural intensification and following Manyong *et al.* (1996) and Okike (2000), a two-by-two matrix of low and high human population density and market access corresponding to four delineated resource use domains in the study area was adopted for data collection. Thus, four villages each from the two agroecological zones were purposively selected representing (i) low population density and low market access (LPLM); (ii) low population density and high market access (LPHM); (iii) high population density and low market access (HPLM); and (iv) high population density and high market access (HPHM) situations. Quantitatively, these correspond approximately to less than 150 persons per km^2 for low population domains and a 'market tension' of less than 5 for low market access domains on the scale of 1–10 developed by Brunner *et al.* (1995). The market tension score essentially accounts for travel time to wholesale market, decreasing with distance from the market and decreasing faster on dirt roads than on paved road. The reverse is also the case, as high population domains have 150 or more persons per km^2 and high market access domains have market tension scores ranging from 6 to 10.

A human population density GIS layer from Deichmann (1996) was combined with a spatial market access layer from Brunner *et al.* (1995) to produce a map of the study area, which then guided the selection of the eight study villages. From the eight villages, 559 households were selected using a stratified random procedure. Data were collected during February–March 1998 through a single visit survey using a detailed questionnaire.

3. Measuring Farm-specific Efficiency

3.1 The Frontier Production Function

Farrel (1957) distinguished between technical and allocative efficiency and this kindled interest in the measurement of economic efficiency leading to the development of a variety of ways of accounting for more than one factor of production in the production process. Among the various econometric methods that evolved, stochastic frontier functions and Data Envelopment Analysis are currently in the forefront. In analysing farm level data where measurement error, some missing information, weather, etc. are likely to play a significant role, the stochastic frontier method is recommended (Coelli, 1995).

Early frontier production functions that followed Farrel (1957) were deterministic, in that they assumed a parametric form of the production function along a strict one-sided error term (Aigner and Chu, 1968; Afriat, 1972; Schmidt, 1976). Such forms take no account of the possible influence of measurement errors and other causes of distortion upon the shape and positioning of the estimated frontier, since all observed deviations from the estimated frontier are assumed to be the result of technical inefficiency. These problems were subsequently addressed to open the way for the numerous adaptations that represent the stochastic frontier function of the present day (Aigner *et al.*, 1977; Meeusen and van de Broeck, 1977).

Currently, the stochastic frontier production function is basically specified as a composed error model of the general form

(1) $$\ln(Y_i) = F(X_i;\beta) + \varepsilon_i \qquad i = 1, 2, \ldots, N$$

where Y_i is the output of the ith farm; X_i is the vector of input quantities used by the ith farm; β is a vector of unknown parameters to be estimated; $F(.)$ represents an appropriate function (e.g., Cobb–Douglas, transcendental–logarithmic, etc.), and ε_i, the error term, equals $v_i - u_i$. The term u_i is a non-negative variable representing inefficiency in production relative to the stochastic frontier. The term v_i is a symmetric error which accounts for random variations in output due to factors beyond the control of the farmer, e.g., weather and disease outbreak, and it is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$. The distribution of u_i is also assumed to be independent and identical as $|N(0, \sigma_u^2)|$, which could be half-normal at zero mean, truncated half-normal (at mean μ), and based on conditional expectation of the exponential ($-u_i$). Greene (1990) also offers a two-parameter gamma distribution model. Jondrow *et al.* (1982) and Ali and Flinn (1989) specify a method for decomposing the error term ε into u and v using the conditional distribution of u given ε. Finally, the stochastic frontier equation irrespective of its functional form is usually estimated using the Maximum Likelihood Estimation (MLE) technique.

In some studies, the efficiency indices obtained for individual farms were subsequently regressed in a second stage against some socioeconomic variables, e.g., education level of farmer, age of farmer, farm size, to estimate the contributions of these variables to inefficiency (Ali and Flinn, 1989; Deb and Hossain, 1995; Parikh *et al.*, 1995). However, Kumbhakar *et al.* (1991) and Reifschneider and Stevenson (1991) noted a significant problem with this two stage approach, i.e., the assumption of independent and identical distribution of the inefficiency effects is violated in the second stage when they are made to be a function of a number of farm-specific factors with non-identical distribution. The above authors specify stochastic frontier models in which the inefficiency effects are made an explicit function of the farm-specific factors, and all parameters are estimated in a single stage MLE procedure as in the computer software — FRONTIER Version 4.1 (Coelli, 1994) — which has been used in this study.

3.2 Specification of the Empirical Model

The model employed for the stochastic production function analyses of individual farm efficiencies in this study is in the form of the Coelli and Battese (1996) inefficiency model. However, the effects of inputs on productivity in the various socioeconomic domains were explicitly incorporated in the production function using fixed-effects methodology where each stratum has a dummy variable measuring the effect in the specific domain (Hoch, 1958). The binary dummies used to represent the socioeconomic domains also replace the panels used by Coelli and Battese (1996) and thus enables the application of cross-sectional data in this study as an important difference. Moreover, the eight socioeconomic domains span the two agroecological zones, and as such their inclusion captures not only the effects of population density and market access on input productivity but also the implicit gradient of agroecological potential, which possibly improves the estimates of the effects of all other variables in the model, given that the production environment is also an input into agriculture. With the above modifications, the final models were derived by, first, fitting Ordinary Least Squares models experimentally before eventually estimating by maximum likelihood methods. This procedure also alerted us if econometric problems e.g., endogeneity and multi-collinearity, existed. The estimated frontier production function and inefficiency models were of the form:

(2) $$\ln(Y_i) = \Sigma\phi_j D_j + \Sigma\beta_j \ln(X_{ji}) + v_i - u_i$$

(3) $$|u_i| = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \ldots + \delta_n Z_{ni}$$

where D are intercept dummies; the subscript i refers to the ith farmer and j refers to the jth stratum, i.e., the socioeconomic domain; Y_i is the total value of farm output of the ith farmer in Naira; X are input variables and Z are factors influencing inefficiency, to be discussed below; andϕ, β and δ are parameters to be estimated.

The v_is in equation (2) are assumed to be identically and independently distributed random errors, having $N(0, \sigma_v^2)$ distribution, and the u_is are non-negative random variables, called technical inefficiency effects, associated with the technical inefficiency of production of the respondent farmers. The Coelli and Battese (1996) inefficiency model assumes that the inefficiency effects are independently distributed and u_i arises by truncation (at zero) of the normal distribution with mean μ_i, and variance σ^2, where μ_i is defined by its absolute value as specified in equation (3), and Zs represent factors contributing to inefficiency.

The β-coefficients in equations (1) and (2) are unknown parameters to be estimated along with the variance parameters, which are expressed in terms of equations (4) and (5):

(4) $$\sigma_s^2 = \sigma_v^2 + \sigma^2$$

(5) $$\gamma = \sigma^2/\sigma_s^2$$

where the γ-parameter has value between 0 and 1. The technical efficiency of a farmer is defined as the ratio of the observed output to the frontier output that could be produced by a farm operating at 100% efficiency, in which case the inefficiency is zero. When the dependent variable is expressed in log, Battese and Coelli (1992, 1993) have shown that this is determined mathematically as:

$$\mathrm{TE}_i = \exp(-u_i). \tag{6}$$

The transformation in equation (6) constrains the technical efficiency of each farmer to values between zero and one and this is related in inverse proportion to the inefficiency effect.

3.3 Variables in the Empirical Model

We used two specifications of the models — one with socioeconomic domains only in the production function and another with these domains in both the production function and inefficiency models. The first one captures only the productivity differences between the domains while the second captures both productivity differences as well as inefficiency effects of the domains. Intercept dummies have been used to measure differences in input use on output across four domains in the two agroecological zones, three farm types, users and non-users of manure and animal traction. The domains were arranged as follows: LPLM, LPHM, HPLM and HPHM domains of the SS; LPLM, LPHM, HPLM and HPHM domains of the NGS. These socioeconomic domains are as previously defined to represent population pressure and access to market in the two agroecological zones. It is noteworthy that it is often the case that settlement patterns follow environmental differences, with more dense population and greater market access following more favourable environments and, therefore, confounding population density with agroecological potential. Snrech (1994) finds that in West Africa, population density correlates rather highly with market attractiveness and provides a better explanation of settlement pattern than agroecological criteria. As either of the above, i.e., agricultural potential or market access, or various complex combinations of them, could influence settlement patterns, this study did not attempt to isolate their individual effects on productivity and efficiency.

Some of the farms did not use animal traction and some did at varying but not so widely differing rates, so a dummy was incorporated into the production function to determine whether such input use decisions led to significant differences in output between users and non-users of traction.

The input variables used in the model are farm size in hectares, labour in person-days, chemical fertilisers used in kilograms, and other costs to cover expenditure on seeds, crop residue, animal traction implements, herbicides, pesticides and other miscellaneous costs.

Labour was calculated in standard person-days by converting different age and sex groups into a single unit to account for differences in quality using conversion factors developed by Norman (1970) for similar areas. Children (7–14 years) were rated as 0.5 person-days; active adult males (15 years and above) as 1 person-day; active adult female (15 years and above) as 0.75 person-days. Although older adults might have exerted lesser energy per time unit than younger adults, this could not be fully accounted for in this variable due to lack of suitable converting factor. Instead, age of the household head has been used as a factor in the inefficiency model to account for such differences in quality and also longer experience in management decisions (see below).

'Other costs' was included to capture the effect of the level of investment (liquidity status) of the household on productivity. It is to be noted that 81% farms used chemical fertilisers; non-users were credited with applying 1 kg of chemical fertiliser to their fields to allow log-transformation and still retain such cases within the model. Seventy-two per cent of farms applied manure, but the quantities applied could not be estimated accurately as it was applied in different forms and at different times, e.g., by kraaling animals by rotation in the field, by collecting at home and transporting to the field, by purchasing from other farmers. The productivity of manure is also known to be related to length of time of storage, season of production, soil type, timing of application, etc. (Murwira *et al.*, 1995; Reynolds and de Leeuw, 1995; Schlecht *et al.*, 1995, 1998; Eghball *et al.*, 1997; Powell and Valentin, 1998), which could not all be controlled for across the study area. Manure is measured with a binary variable (user = 1, 0 otherwise) in the model.

The variables included in the inefficiency model include age of the farmer (years), land use intensity (number of years of continuously cropping a farm plot), obtaining credit for farming (1 = yes, 0 = no), livestock owned (TLU), and membership of farmers' cooperative society. Education levels of the sample household heads did not differ significantly and its inclusion in the inefficiency equation did not improve the model fit, so it was dropped. Age of the farmer was taken as a proxy for farming experience, which may affect farming efficiency because of expected acquisition of dexterity in doing the same task over a period of time. Age may also negatively affect efficiency, as older farmers may be experienced in using traditional technology but may be slow in adopting new technology and learning its management. Shortening fallow periods is a major indicator of agricultural intensification. Including the number of years of continuous cropping of a plot of farmland was meant to relate the agricultural intensification process to production efficiency. In other words, does the process of agricultural intensification also lead to increased efficiency in production?

The best fit model was the one in which socioeconomic domains were used in both the production function and the inefficiency equation as stated earlier. The domains are an embodiment of agro-ecological or production potential of land and the availability of infrastructure to facilitate the acquisition of farm inputs, farm and market information, sale of farm products, etc. The impact of production potential is captured by the domain dummies in the production function while the effects of market access and other socioeconomic dimensions that influence production decisions leading to efficiency levels are captured by the domain dummies in the inefficiency equation.

4. Results and Discussion

4.1 General Characteristics of the Farms

The socioeconomic characteristics of sample farm households in the study area are summarised in Table 1. On the average, active farmers in the NGS were about 42 years of age and generally 3 years younger than their counterparts in the SS. There was no significant difference in age of farmer across domains although young people from LPLM domains generally migrate to HPHM domains in search of farm employment so the composition of the labour force may be slightly different between these zones. Households depend on farms with a combined size ranging from 5.2 ha in the NGS to 6.3 ha in the SS to produce food and earn some cash income. As expected, the area devoted to cash crops out of the total farmland, the quantity of hired labour, the amount of fertilisers applied per unit land, expenditure on crop residues and other costs incurred through purchase of herbicides, pesticides, improved seeds, etc increased as one moved from areas where low population interacted with low market access to areas where the interaction was between high population and high market access (Table 1). The increasing gradient in input application correlates positively with gross revenue per hectare and tallies with a working

Table 1: *Socioeconomic Characteristics of the Sample Households, by Socioeconomic Domain and by Ecology*

	Socioeconomic domain[a]				Ecology	
Variable	LPLM	LPHM	HPLM	HPHM	NGS	SS
Age of farmer (years)	44.2	43.3	43.7	44.1	42.4	44.9
	(0.9)[b]	(0.9)	(0.8)	(1.0)	(0.7)	(0.6)
Farm size (ha)	4.8	7.8	5.0	5.8	5.2	6.3
	(0.5)	(1.1)	(0.6)	(0.7)	(0.6)	(0.4)
Cash crop area	14.6	20.1	26.8	32.1	21.0	34.6
(% of farm size)	(2.0)	(1.7)	(1.8)	(2.1)	(1.3)	(1.3)
Household size	8.5	11.4	11.7	11.4	9.9	11.5
(No.)	(0.3)	(0.5)	(0.8)	(0.6)	(0.3)	(0.5)
Hired labour	55.4	85.4	72.1	161.7	94.4	88.8
(person days)	(9.2)	(11.6)	(11.4)	(21.0)	(9.8)	(9.8)
Animal traction	12.7	11.6	2.3	7.6	11.5	6.1
(days)	(3.4)	(2.3)	(0.7)	(1.3)	(2.2)	(0.9)
Livestock (TLU)	4.9	7.6	5.1	7.8	5.4	7.0
	(0.7)	(1.1)	(0.7)	(2.0)	(0.7)	(0.9)
Fertilisers	111	75	162	440	176	206
(kg/ha)	(46)	(19)	(39)	(233)	(29)	(100)
Expenditure on	600	654	50	1087	462	894
crop residues	(157)	(122)	7 (89)	(285)	(101)	(132)
Other costs	2,806	3,454	4,059	2,766	3,781	2,893
(N[c]/ha)	(1,314)	(1,046)	(1,301)	(554)	(944)	(683)
Crop income	5,005	6,993	10,752	29,253	16,481	9,462
(N/ha)	(1,164)	(2,606)	(1,910)	(13,387)	(6,096)	(2,995)
Gross revenue	12,246	13,263	30,770	43,569	29,270	21,169
(N/ha)	(1,930)	(2,993)	(4,707)	(14,646)	(6,498)	(4,221)

[a]Corresponding domains in the NGS and SS have been merged to make table more readable. Though differences in resource use intensity exist between both ecologies, important trends in moving from one domain to the other have been captured in many cases. NGS stands for Northern Guinea savanna, SS for Sudan savanna, LPLM for Low population low market, LPHM for Low population high market, HPLM for High population high market, and HPHM for High population high market.
[b]Standard errors of the mean are given in parentheses.
[c]The exchange rate current at the time of the field survey was 85 Naira = US$1.

definition of agricultural intensification as the application of more inputs to obtain more output per unit land. This being the case, Table 1 shows an increase in agricultural intensification related to increases in human population density and access to market. In an ecological sense, this increase is from the SS towards the NGS. The difference in crop income per ha between the NGS and the SS and the fact that crop income contributes more to gross revenue in the NGS than in the SS confirm the comparative advantage of the NGS in crop production over the SS, which has a comparative advantage in livestock production. Nonetheless, the question still remains whether the increases in input use are associated with corresponding increases in requisite skills for input management, resulting in higher efficiency among farmers along the same gradient as for agricultural intensification.

4.2 Econometric Results

Variables in the main production function were tested formally for the endogeneity of the error term before proceeding with MLE. We found, using the Davidson and MacKinnon (1993) augmented regression test, that a null hypothesis of endogeneity is rejected at over 24% level of significance (LOS) for fertiliser, other costs and labour. So, for the variables in the main production function, if we ignore potential endogeneity when input use is optimised in the MLE procedure, the results obtained are still consistent.

Productivity of Farm Inputs

The estimated coefficients of the two versions (with and without socioeconomic domains included in the inefficiency effects model) are shown in Tables 2 and 3.

The values of σ^2 and γ indicate that inefficiency effects exist and are stochastic in nature. Causes of inefficiency in farms were determined with the production frontier in a single-stage maximum likelihood estimate. The estimated coefficients of all the domains and input variables in the production function have similar patterns in both the equations though absolute values are somewhat different. However, in the model without the socioeconomic domains in the inefficiency equation, average efficiency was 60% (Table 2), compared with 76% in the model where socioeconomic domains were included in the inefficiency equation (Table 3). The results shown in Table 3 indicate that without the socioeconomic domains in the inefficiency model, the

Table 2: *Maximum Likelihood Estimates for Parameters of the Stochastic Frontier Production Function and Inefficiency Model for the Savanna Zones of Northern Nigeria (Without the Socioeconomic Domains in the Inefficiency Model)*

Variables in production function	Coefficients (SE)	Variables in inefficiency model	Coefficients (SE)
Intercept[a]	6.825*** (0.495)	Intercept	–1.810** (0.814)
Farm size (ha)	0.192*** (0.072)	Age of farmer	0.045*** (0.013)
Labour (person-days)	0.220*** (0.047)	Continuous cropping (years)	–0.025** (0.011)
Fertilisers (kg)	0.163*** (0.055)	Credit	0.899*** (0.281)
Other costs (N[b])	0.182* (0.118)	Livestock owned (TLU)	–0.015*** (0.002)
Manure (user = 1)	0.304*** (0.128)	Coop. soc. member (yes = 1)	–0.482*** (0.183)
Animal traction (user = 1)	0.135*** (0.125)		
Farm type		Other parameters	
Crop	0.0	$\sigma_s^2 = \sigma_v^2 + \sigma^2$	1.387*** (0.089)
Livestock	0.219 (0.162)	$\gamma = \sigma_s^2/\sigma^2$	0.056*** (0.012)
Mixed	–0.099 (0.139)	Log likelihood function	–885.4
Domains		Average efficiency	62.80
SS LPLM	0.0	ANOVA between domains	$F_{7,551} = 5.153$ (0.000)
SS LPHM	0.157* (0.232)		
SS HPLM	1.411*** (0.237)	ANOVA between NGS and SS	$F_{1,557} = 12.5$ (0.000)
SS HPHM	1.502*** (0.254)		
NGS LPLM	0.607** (0.228)		
NGS LPHM	1.099*** (0.229)		
NGS HPLM	1.231*** (0.224)		
NGS HPHM	1.375*** (0.243)		

See Table 1 for a definition of the socioeconomic domains.
Statistically significant at the *10%, **5% and ***1% levels.
[a]The reported intercept is based on SS LPLM domain, crop farms and non-users of animal traction.
[b]The exchange rate current at the time of the field survey was 85 Naira = US$1.

average efficiency of farmers in the study area would have been underestimated. The above support the findings of Sherlund *et al.* (2002) about the relevance of inclusion of ecology in both production function and inefficiency models. Therefore, the rest of the discussion is based on the results in Table 3.

The coefficients of input variables are positive, and they show

Table 3: *Maximum Likelihood Estimates for Parameters of the Stochastic Frontier Production Function and Inefficiency Model for the Savanna Zones of Northern Nigeria (With the Socioeconomic Domains in the Inefficiency Model)*

Variables in production function	Coefficients (SE)	Variables in inefficiency model	Coefficients (SE)
Intercept[a]	6.339*** (0.389)	Intercept	–2.381***(0.824)
Farm size (ha)	0.194*** (0.065)	Age of farmer	0.038*** (0.013)
Labour (person-days)	0.243*** (0.045)	Continuous cropping (years)	–0.017* (0.010)
Fertilisers (kg)	0.133*** (0.053)	Credit	1.337*** (0.353)
Other costs (N[b])	0.125*** (0.039)	Livestock owned (TLU)	–0.017*** (0.006)
Manure (user = 1)	0.267** (0.133)	Coop soc member (yes = 1)	–1.592** (0.692)
Animal traction (user = 1)	0.212** (0.106)		
Farm type			
Crop	0.0		
Livestock	–0.049 (0.121)		
Mixed	0.249 (0.149)		
Domains		Domains	
SS LPLM	0.0	SS LPLM	–1.450* (0.852)
SS LPHM	0.721** (0.365)	SS LPHM	2.108** (0.960)
SS HPLM	1.318*** (0.244)	SS HPLM	–0.252 (0.695)
SS HPHM	1.821*** (0.497)	SS HPHM	2.641*** (0.870)
NGS LPLM	0.467 (0.293)	NGS LPLM	–0.817 (0.721)
NGS LPHM	1.019*** (0.327)	NGS LPHM	–0.563 (0.810)
NGS HPLM	1.097*** (0.257)	NGS HPLM	–2.764*** (1.056)
NGS HPHM	1.196*** (0.307)	NGS HPHM	–1.791* (0.937)
Other parameters			
$\sigma_s^2 = \sigma_v^2 + \sigma^2$	1.764*** (0.162)		
$\gamma = \sigma_s^2/\sigma^2$	0.250*** (0.088)		
Log likelihood function	–887.7		
Average efficiency (%)	75.9		
ANOVA between domains		$F_{3,555} = 101.8$ (0.000)	
ANOVA between NGS and SS		$F_{1,557} = 152.0$ (0.000)	

See Table 1 for a definition of the socioeconomic domains.
Statistically significant at the *10%, **5% and ***1% levels.
[a]The reported intercept is based on SS LPLM domain, crop farms and non-users of animal traction.
[b]The exchange rate current at the time of the field survey was 85 Naira = US$1.

decreasing returns to scale in farm operations in the sample areas, given that the sum of the gross revenue elasticities of the inputs in the production function is significantly less than unity. An increase in farm size by 10% could result in increase in gross output by about 2% while a similar increase in person-days of labour is expected to result in an increase in gross output by 2.4%. Also, application of chemical fertiliser, and expenditure on seeds, pesticides, herbicides, crop residues and other miscellaneous inputs i.e., other costs, led to significant increases in productivity. Higher expenditure on seeds resulting from buying higher quality seeds, combined with expenditure on pesticides and herbicides is an example that confirms the notion that higher input use could lead to higher productivity resulting from positive interactions among inputs, especially when they are of improved quality.

Manure users had significantly higher productivity than non-users. In the SS HPHM and SS HPLM domains, land, labour and manure use intensities are among the highest. Also, livestock management is more intensive than elsewhere, and the grazing of all crop residues is done on the farm, particularly in the SS HPHM domain. This may provide additional benefits from urine in concert with manure leading to better quality manure to the soil (Jahnke, 1982; Anonymous, 1998), and considerable savings in resources required first to gather and transport crop residues to the homestead, and later to gather and transport manure back to the farm.

The users of animal traction have reached a significantly higher production frontier over non-users. Animal traction technology remains somewhat profitable and attractive partly because of the revenue obtained when retired work bulls are fattened and sold. This is an expected outcome and is in line with the evolutionary pathway for agricultural energy intensification (Jabbar, 1996).

The physical environment in which agriculture takes place is an important input and this is reflected in this study by the two agroecological zones and the socioeconomic domains within them. The results show highly significant differences in the parameters across the socioeconomic domains. The coefficient for input productivity varied and increased substantially from the SS LPHM (0.721) through the SS HPLM (1.318) to the SS HPHM (1.821) domains (Table 3). The same trend is repeated in moving from NGS LPLM to NGS HPHM domains. Thus, these results show (econometrically) that within each agroecological zone as resource use intensity increased with increases in population pressure and market access, productivity also increased and such increase was more pronounced where high population density interacted with high market access. When productivity differences among the domains were tested formally, it was found that they were significant at the 1% level among domains in the NGS and at the 10% level when corresponding domains, e.g., NGS LPLM vs. SS LPLM or NGS LPHM vs. SS LPHM, were compared. In effect, marginal productivity differences among domains were higher within the same ecological zone than when similarly defined domains were compared across ecological zones.

Overall, the results of this section indicate that differences in input productivity exist along the LPLM to HPHM gradient. With these results for socioeconomic domains within the SS and NGS, there was the need to investigate if the same marginal productivity differences existed between the NGS and SS, for which input factors and to what extent.

This was done by estimating the same model but replacing the socioeconomic variable with an ecology variable (NGS = 1, SS = 0). The sign and magnitude of the coefficient of the ecology variable (0.796 significant at 1%) clearly confirmed, as a first step, that marginal productivity of input factors was higher in the NGS than in the SS (detailed results not shown for brevity). Following this confirmation, separate functions were then estimated for the NGS and SS households to see if and which input coefficients were different for the two ecological zones. The results summarised in Table 4 show, judging by the magnitude and level of significance of the different coefficients, that marginal productivity was higher in the NGS compared with the SS for farm size, quantity of chemical fertilisers applied and other costs representing expenditure on improved seeds, herbicides, pesticides, animal traction equipment, etc. Conversely, there was higher return to labour and the use of livestock manure in the SS compared with the NGS. In other words, considering that fertilisers, improved seeds, pesticides, herbicides and animal traction equipment constitute the bulk of external inputs in the study area, higher external input application in the NGS is a better strategy for agricultural intensification than in the SS.

The above results show that strategies for addressing agricultural productivity constraints of the NGS and SS of West Africa should be different not only for the ecological zones but also within the

Table 4: *Separate Maximum Likelihood Estimates for Parameters of the Stochastic Frontier Production Function and Inefficiency Model for the Northern Guinea Savanna (NGS) and the Sudan Savanna (SS) Zones of Northern Nigeria*

Variables	Coefficients (SE) by ecological zone NGS	SS
Production function		
Intercept	0.635*** (0.729)	0.787*** (0.500)
Farm size (ha)	0.259*** (0.093)	0.144 (0.928)
Labour (person-days)	0.250*** (0.064)	0.282*** (0.064)
Fertilisers (kg)	0.191*** (0.065)	0.105 (0.078)
Other costs (N[a])	0.236*** (0.065)	0.109** (0.053)
Manure (user = 1, 0 otherwise)	0.301 (0.241)	0.507*** (0.186)
Animal traction (user = 1, 0 otherwise)	0.052 (0.033)	0.040 (0.045)
Inefficiency effects		
Intercept	1.383** (0.680)	–1.719 (2.376)
Age of farmer	–0.012 (0.017)	0.040 (0.027)
Continuous cropping (years)	–0.064** (0.031)	0.003 (0.017)
Credit	0.784*** (0.344)	0.428 (0.509)
Livestock owned (TLU)	–0.008 (0.015)	–0.048*** (0.019)
Cooperative society membership (1 = yes, 0 no)	–0.080 (0.075)	–0.074 (0.067)
Other parameters		
$\sigma_s^2 = \sigma_v^2 + \sigma^2$	1.343*** (0.296)	2.500*** (0.933)
$\gamma = \sigma_s^2/\sigma^2$	0.063 (0.317)	0.545*** (0.207)
Log likelihood function	–391.7	–511.3

See Table 1 for a definition of the socioeconomic domains.
Statistically significant at the *10%, **5% and ***1% levels.

ecological zones following the gradient defined by various socio-economic domains.

Inefficiency Effects

The results summarised in Table 3 indicate that inefficiency increased with aging of farmers and among those that received credit. On the other hand, higher land use intensity, owning more livestock and belonging to farmers' cooperative societies reduced inefficiency.

In West Africa, farming still requires a high level of physical fitness, especially for tilling the soil. In the light of that, the result that aging increases inefficiency is not surprising. The lower efficiency of older household heads might be a reflection of both their lower actual labour input energy per time unit or lower quality of that labour as well as their lower adoption and poorer management of productivity increasing inputs.

There is no direct explanation for the negative effect of formal credit on farmers' production efficiency. The results from separate analysis of the NGS and SS households (Table 4) shows that the inefficiency effect of credit was substantial only on the NGS. There is no clear reason why credit could contribute to inefficiency in the NGS but not in the SS given that the same public institution — the Nigerian Agricultural and Cooperative Bank (NACB) — is primarily responsible for the disbursement of credit to smallholder farmers in both the NGS and the SS. However, the disbursement of credit is usually in cash rather than in kind, so there may be loan misapplication engendered by resource-poverty. In addition, default rate is high in the region as there is neither a clear incentive for repayment nor sanction to serve as deterrent for defaulting. Jabbar *et al.* (2002) studied the supply and demand for institutional credit in sub-Sahara Africa to draw lessons for designing new credit schemes. They found, in general, that available credit does not reach those who need it the most and with whom it could have the greatest impact due to the application of inappropriate screening procedures and criteria to determine credit worthiness. For NACB, in particular, they found recovery rate as very low and highly variable among zones. It is plausible that where recovery rates are low and there are no sanctions for default, loan misapplication would be higher leading to ineffectiveness of credit for increasing productivity. However, any misapplication may have been directed towards other livelihood strategies and consumption goods that improve overall household well-being and indirectly affects current productivity, especially among resource poor farmers, hence it may be difficult to argue against the role of credit in agriculture in poor societies (John Pender, personal communication). The role of credit in production efficiency in the study area requires further investigation.

The reduction of inefficiency through farmers belonging to co-operative societies is linked to cooperatives being a source of good quality inputs, information and organised marketing of products. It could also be that farmers who join cooperative societies are among the best managers of their resources and not necessarily for any direct manner in which membership of cooperative societies reduces inefficiency *per se*.

Higher land use intensity reduced production inefficiency as should be expected with more complete utilisation of resources. In continuous cropping, use of improved crop varieties and external inputs such as inorganic fertilisers are common and the manure collected at homestead especially by mixed farmers is returned to the soil. Since more intensive land use through continuous cropping appears to be more beneficial through the use of crop reside as livestock feed and if more biomass is available from a plot when cropped than when fallow, then more manure is likely to be returned to it from the homestead. Thus incremental net benefits may accrue to both crop and livestock enterprises during continuous cropping. This may be another reason, in addition to population pressure, for the increasing number of cycles of continuous cropping (17 cycles on the average) in the savanna zones of West Africa.

Higher livestock ownership reduced inefficiency both because of direct contribution through livestock and livestock product sales and indirectly through crop–livestock interactions. Larger number of animals may mean larger quantities of manure for crop production and better use of residues as animal feed, both contributing to larger overall output.

Among the socioeconomic domains, the pattern of inefficiency effects did not follow the same pattern as productivity differences. In the SS zone, being in low market domains, especially in the low population density areas, significantly decreased inefficiency, while being in the high market access areas in both levels of population density significantly increased inefficiency. In the NGS zone, being in low population density areas, irrespective of market access level, did not significantly influence inefficiency level but being in high population density areas, in both levels of market access, significantly decreased inefficiency. Thus, in the SS zone, marginal productivities of current input use levels are very low in high market access situations, so scope for further increase in input intensity may be limited without a change in overall technology options. In the NGS zone, marginal productivity of current input use levels in high population density areas are very high and perhaps the input intensity can be pushed further to increase output without sacrificing efficiency.

The above results show first of all that resource use increases associated with agricultural intensification do not necessarily take place simultaneously with an improvement in the skills of farmers in the management of those inputs as to translate automatically to higher production efficiency. Secondly, they indicate that given ecological and socioeconomic variety in the location of farms across a region, no single technological or policy strategy will be sufficient to ensure that agricultural intensification for increased food production takes place along a sustainable, economically efficient pathway. For example, in the SS, except in the LPLM domain, input application rates are high especially in the high population domains. Production inefficiency effects are high in the SS especially in the HPLM domains. This is counter-intuitive though may be related to speculative application of chemical fertilisers by farmers in the face of uncertainty of rainfall. Table 1 shows that on the average 206 kg of chemical fertilisers were applied per ha in the SS compared with 176 kg per ha in the NGS. Given that rainfall decrease along a south-north axis, moisture stress in the SS zone may limit the effectiveness of the applied fertiliser and thus result in less than potential output. Because of this anomaly, it is common to find granules of chemical fertilisers applied to benefit crops for a particular season still lying around not dissolved up to the harvest time. Farmers resort to this 'over application' rather than regret not applying enough in a year that turns out to have good rains. Should rains fail to reach anticipated levels, this decision no matter how well intended leads to resource waste and inefficiency, even in market driven domains. Reliable metrological information and appropriate advice to farmers, well in advance of the farming season, should alleviate this problem. It is obvious that availability of inputs and new technologies without adequate information to farmers on their management should not be expected to lead to sustainable agricultural development. This is supported by the situation in the SS LPLM where input application rates are low but apparently efficient.

Another example is with respect to animal traction technology. Between the NGS and the SS, the same animal traction equipment designs are promoted for the relatively lighter soils of the SS and the heavier soils of the NGS. More biophysically responsive approaches are required to reduce the implicit inefficiencies of inappropriate engineering designs in order to make animal traction more productive and more attractive to farmers. In peri-urban areas, animal traction also faces the challenge from the availability of cheap labour made possible by the large number of able-bodied youths who migrate from rural to urban and peri-urban areas, and are constrained to sell their unskilled labour during their initial period of search for employment. Other challenges faced by farmers' use of animal traction include short growing seasons and animal-tending costs implied in the opportunity cost of labour and capital during off-season, which are different in the different ecological and socioeconomic domains (Ehui and Polson, 1992).

Following from the above, the results point to the fact that in the SS, where agroecological potential is lower than in the NGS, small is efficient. Alternatively, high resource use intensities must be guided appropriately through farmer enlightenment programmes. However, this is lacking because the extension system is weak and failing in some instances in the area (Okike, 2000). Conversely, in the NGS, production efficiency among farmers especially in the low population domains could be significantly improved through higher levels of input use than is currently the case.

Overall, under rain-fed conditions and given current resource application levels, agricultural intensification based on high external input strategies yield higher returns in the NGS compared with the SS. It could be speculated that within the NGS, areas with better access to markets that have already attained high resource use intensity and high production efficiency should be targeted with strategies that encourage the production of high-value crops and vegetables.

Distribution of Economic Efficiency and Characteristics of Most Efficient and Least Efficient Farms

The frequency distribution and probability histogram rating the production efficiency of the 559 farms is presented in Figure 1. The mean efficiency for the sample is 75.9%. Seventy-four farms were less than 50% efficient while 164 farms or 29.3% of the sample were below the average mark of 75.9%. There was no frontier (100% efficient) farm. The implicit frequency curve is mesokurtic (kurtosis = 1.723 ± 0.206, mean ± SEM) and has a significant negative skew (skewness = –1.626 ± 0.103) similar to that found among Indian farmers by Coelli and Battese (1996). Figure 2 depicts the distribution by region and by socioeconomic domains. In the SS, efficiency levels declined from 88% in the LPLM domain to 41% in the HPHM domain. By contrast, in the NGS, there was an increase in efficiency albeit gradual from 85% in the LPLM to 89% in the HPHM. The fact that high external input use

Figure 1: *Distribution of the Production Efficiency of Farms in the Savanna Zones of Nigeria*

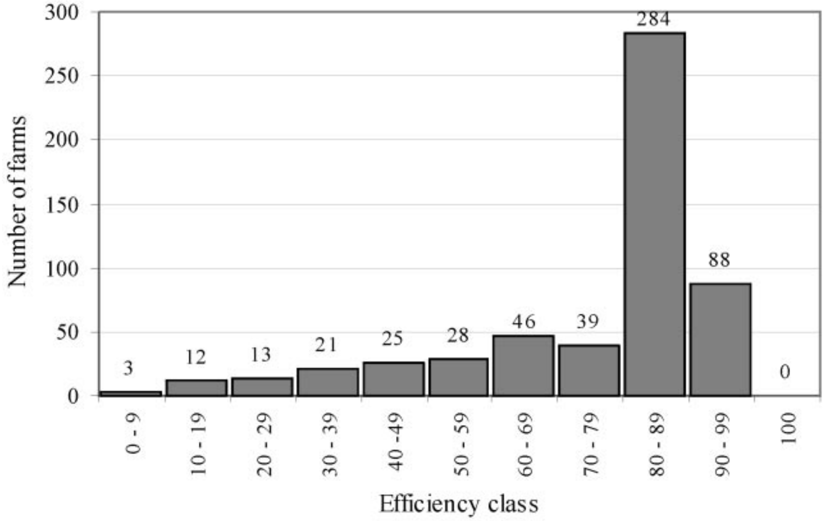
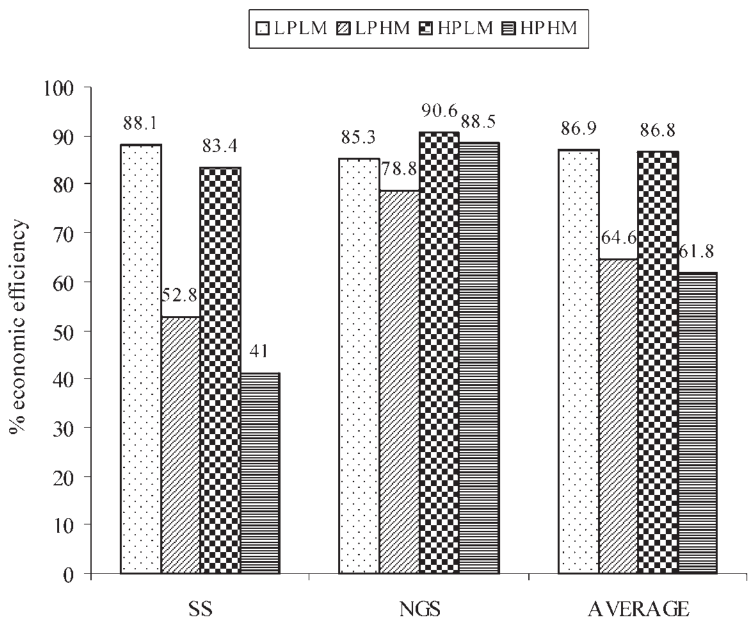


Figure 2: *Mean Production Efficiency of Farms in the Northern Guinea Savanna (NGS) and Sudan Savanna (SS) Zones of Nigeria According to Socioeconomic Domains*



lowered production efficiency among farmers in the SS while the same situation increased their efficiency in the NGS is further illustrated. The overall picture shown by the average of both savanna zones is that high population domains performed better than high market domains, probably implying that, if isolated, the effects of human population density on production efficiency of farmers in the quest for increased food production in the savanna zones of West Africa is less adverse than the effects of access to wholesale markets. Again, the need to incorporate spatial variables that capture agroecological potential, human population density and access to wholesale market in production functions and in enunciating policy for sustainable agricultural intensification is highlighted.

Characterising top-performing farms and worst performing farms is of obvious policy interest. Farms were distributed into the top and bottom 10% in the SS and NGS based on farm-specific efficiency level and were characterised (Table 5). While constructing a thick frontier from up to 10% of the top performing farms may dilute the qualities of the farms operating at the real frontier at 100% efficiency, it reduces the probability of recommending the characteristics of frontier farms that may be considered too optimistic. Results from a thick frontier are more practical and applicable to a wider array of farms. For similar reasons, rather than taking the lowest performing farm, a bottom 10% was also used for poor performing farms.

Table 5 presents the major characteristics of the most efficient farms that differentiate them in a statistically significant manner from the least efficient farms. In the NGS, they are higher gross revenue per hectare; smaller farm size; lower land use intensity (shorter years of continuous cropping); higher area of farm devoted to cash crops; higher labour use intensity; lower number of livestock (TLU) owned; and higher cash expenditure on crop residue while in the SS, the most efficient farms had higher revenue per ha; used more animal traction and devoted more land to cash crops.

5. Summary and Conclusions

The study tested the hypothesis that production efficiency of farms varied according to level of intensification, agroecological condition, population density and market access. To test the hypothesis, a sample of 559 farms in West Africa were selected covering two agroecological zones (Northern Guinea Savanna and Sudan Savanna), four

Table 5: *Selected Characteristics of Least Efficient and Most Efficient Farms*

	SS			NGS	
Variables	Least efficient farms (n = 31[a])	Most efficient farms (n = 31[a])	Average for all farms (n = 559)	Least efficient farms (n = 26*)	Most efficient farms (n = 26*)
Production efficiency (%)[B]	21	90	75.9	72	92
Gross revenue (N[a]/ha)[A]	7,779	14,018	24,834	9,824	112,867
Farm size (ha)[A]	4.9	5.5	5.8	4.6	3.1
Continuous cropping (years)[A]	17	20	14	11	5
Fertiliser used (kg/ha)	132	179	192	100	159
Cash crop area (%)[AB]	29	59	28	12	35
Crop labour (person-days/ha)[A]	80	92	78	61	99
Animal traction used (days)[B]	2	7	9	5	5
Age of respondent	45	44	44	42	40
TLU owned[A]	6.0	4.6	6.3	9.0	1.6
Expenditure on crop residue (N[b])	400	635	698	1,121	247
Other costs (N/ha)	2,200	3,180	3,300	1,180	1,180

[a]Equal to 10% of the sample from the ecological zone.
[b]The exchange rate current at the time of the field survey was 85 Naira = US$1.
[A,B]*t*-test for equality of means shows difference at 10% level of significance between least and most efficient farms in the SS and NGS respectively.

socioeconomic domains (low-population low-market, low-population high-market, high-population low-market and high-population high-market) in each of the two zones, and three farm types (crop, livestock and mixed). The stochastic frontier production function technique was used to examine the differences in production efficiency of the farms, determine input factor productivity, identify inefficiency effects and characterise the farms according to their efficiency levels.

From the point of view of methodology, the results show the need to include environmental and socioeconomic variables not only in production functions but also in the accompanying inefficiency equation, failing which such models may suffer from omitted variables bias since the environment of production — a major input into agricultural production and which also affects a farmer's input managerial ability — would have been ignored.

The results showed an overall decreasing return to scale in farm operations and demonstrated that differences in input productivity, in the NGS and SS, occured in a pattern related to their biophysical and socioeconomic circumstances. The NGS with a higher agroecological potential had a higher agricultural input productivity than the SS. Within the NGS and the SS, this gradient of resource use intensification and productivity could be traced from the LPLM domains to the HPHM domains in an increasing order. However, production efficiency did not follow a similar pattern: in the SS zone, inefficiency increased in high market domains irrespective of population density, and in the NGS, inefficiency decreased in high population domains irrespective of market access levels.

Controlling for the production environment and agricultural potential, this study shows that the improvement in rural infrastructure and the facilitation of procurement/distribution of agricultural inputs and sale of produce associated with high population and high market access areas led to higher agricultural productivity. However, the requisite skills for the management of inputs did not follow a similar pattern. Especially in the SS, production inefficiency effects were introduced in particular by inefficient extension services and credit delivery systems, which seem to have acted in concert to encourage the application of agricultural inputs beyond the agricultural potential of that ecological zone.

The best performing farms in the SS operated at an average efficiency of 90%, while the least efficient farms had an average score of 21%. The difference of 69% presents the opportunity that agricultural productivity in the SS could be improved through the improvement of production efficiency alone. A strategy of improving production efficiency alone in the NGS will produce less dramatic results since the gap between the least and most efficient farms is comparatively small i.e., 20%, suggesting the need for technical change in approach to farming in that ecology. We are led by these results to conclude that while agricultural intensification and efficient production in the NGS still benefits from high external input use strategies, the same strategy is not critical for achieving similar results in the SS given current levels of resource application in the latter ecology.

Increasing agricultural productivity, even within the framework of the ranges provided by this study, will depend on how seriously extension services are taken and their programmes carried out. Going by recent studies in West Africa on the performance of extension systems, a lot still needs to be done should extension systems be the preferred route of reaching farmers with new technologies including information.

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