"Agricultural Productivity, Efficiency, and Soil Fertility Management Practices of Vegetable Growers in the Upper East Region of Ghana"*

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ABSTRACT

The study examined the relationship among agricultural productivity, technical efficiency, and soil fertility management practices of growers of onion, pepper and tomato in the Upper East Region of Ghana. To solve food insecurity problem, more land should be brought under the cultivation of tomatoes, more labour should be devoted to the production of pepper, and capital-intensive techniques should be adopted for the cultivation of onion. There is relatively more scope for the improvement of technical efficiency of growers of tomato than the growers of onion and pepper. The significant determinants of farm specific technical efficiency of growers of onion are farm experience, distance of the farm from the house of the farmer and extension services. The significant determinants of the farm specific technical efficiency of the growers of pepper seems to be the age of the farmer, distance of the farm from the market, and extension services. The significant determinants of the farm specific technical efficiency of the growers of tomato are the age of the farmer, level of education, distance of the farm from the house of the farmer, and soil fertility management practices. The policy makers should concentrate on these human-capital, institutional and socio-economic variables in order to solve food insecurity problem in West Africa.

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1. INTRODUCTION

The satisfaction of the ever-growing demand for food remains a major challenge to world agriculture. This is particularly true in the developing world such as sub-Saharan Africa (SSA) where tremendous socio-economic transformations and geophysical changes are observed to render traditional farming systems incapable of meeting this ever-growing demand for food. SSA has been experiencing substantial land degradation and declining soil fertility, leading to lower agricultural productivity. Less fertile soils are increasing due to land pressure resulting from rapid population growth. Traditional grazing lands are acquired for arable cultivation and long fallow periods, crucial for soil fertility regeneration, have become rare.

SSA is the only region of the world where per capita food production has steadily declined over the past two decades (FAO, 2000). Agricultural output has grown annually by an average of less than 1.5%, with food production increasing at a rate slower than the population growth (FAO, 2000). This greatly undermines the food security situation of the sub-region. Although unfavourable agricultural policies may be partly responsible for the low agricultural output, the capacity of the natural resource base (especially soils) to sustain increasing production under current farming practices is questionable.

The predominant farming systems in SSA are based on shifting cultivation. Farmers fell and burn the vegetation, cultivate the cleared land for a season or two and abandon the site to fallow. The traditional farming systems are stable and biologically efficient only when there is sufficient land to allow fallow period long enough to restore soil fertility. In recent years, however, rapid demographic and socio-economic changes have caused expansion of the cultivated area onto marginal lands and fallow periods are reduced, resulting in degradation of farmlands and declining yields. In addition, most soils of humid tropical Africa are sandy, highly weathered, low in organic matter content and susceptible to soil erosion and compaction (Bekunda et al., 1997). Thus the challenge faced by decision-makers in many nations of sub-Saharan Africa is how to feed an increasing population without irreparably damaging the natural resource base on which agricultural production depends.

Agricultural performance depends on the productivity of labour, land and capital, and the technical efficiency of the farm-owner in operational management.[1] Oluleye (1991) has argued that increase in output can best be achieved by improvements in productivity rather than by additional labour and capital. Labour productivity may be affected by the quality of hired and family labour on the farm. Quality of labour is influenced by factors such as education and training, working conditions, social attitudes toward work, efficiency of other factors of production, etc. In a period of economic uncertainty characterised by inflation, declining real value of wages and adverse general socio-economic environment, it may be difficult to raise the productivity of hired labour on the farm because they may not work harder. The productivity of land depends on the fertility of soil and other factors. The fertility of soil can be improved through the extensive use of organic manure, crop rotation, and chemical fertilisers. Farmyard manure is the most commonly used and readily available fertiliser worldwide.[2] However, soil fertility can be maintained only through the recycling of organic materials such as crop residues and manure in combination with chemical fertilisers. Moreover, the efficiency of fertiliser increases dramatically when combined with crop residues and manure.

Increasing the technical efficiency of the farm-owner in operational management can also raise agricultural productivity. The idea of technical efficiency/inefficiency implies measurable performance, and output is one of such measures. In such a framework, the factors that may explain efficiency/inefficiency variations are included in the efficiency/inefficiency part of the model as explanatory variables (Battese and Coelli, 1995). Such factors could include marital status, sex, age, education, and farming experience of the farm owner.[3] The other factors, which could influence the efficiency, include access to credit, extension services, rural infrastructure, soil fertility management practices, and output-input procurement and distribution system.

Thus agricultural productivity can be improved either through the development and adoption of new technologies or through the efficient use of the existing technologies without damaging the natural resource base.[4] The need for improved and modern farm technologies in agricultural production has been highlighted in many studies (Goldsworth, 1965; Falusi, 1973; Akinola, 1979). Moreover, the low productivity of labour and land resources has been associated with low utilisation of advanced technologies like chemical fertilisers, herbicides and pesticides (Ruthenberg, 1976). During the past two decades, the green revolution (or new technology) has been recognised by policy makers as an important tool to increase agricultural productivity. Agricultural technology needed for more efficient use of fertilisers, higher yielding and insect resistant crop varieties include engineering or mechanical, chemical and biological inputs, and improved production processes and management practices.

The policy-makers have been trying to identify and suggest ways to eliminate the constraints on the adoption of new technologies (Ajibefun et al., 1996). The importance of the efficient use of available technology is seldom realised by policy makers. It is being assumed, erroneously by policy-makers, that farm-owners can operate the existing technology efficiently, but cannot make a rational choice among the various technologies. Unless the potential of an existing technology is completely exploited, benefits from new technologies may not be realised to the full extent. Moreover, it has been argued in the literature that efficiency differentials in the use of technology among the farmers will disappear in the long run, when sufficient number of farmers adopts the technology (Obwana, 2000). But, in spite of the successful adoption of new technologies for several years, the existing inadequate food supply in most developing countries, including Ghana, shows that the hypothesis that farmers will exploit the technology fully, once it is given to them, is not valid (Fried et al, 1993). So there is a need to concentrate on the efficiency approach of raising agricultural productivity. Thus, from a long-run policy viewpoint, it is imperative to examine how effectively and efficiently farmers in the Upper East Region (UER) of Ghana, given the current modern technology, apply the technology at the farm level without damaging the natural resource base. Furthermore, knowledge of the factors, that influence agricultural productivity differentials among farmers cultivating various crops, is very important because it can help the policy makers to design appropriate policies to increase agricultural productivity by improving on factor productivity, and on farm-specific and crop-specific efficiencies.

2. CHARACTERISTICS OF THE UPPER EAST REGION AND AGRICULTURAL PRODUCTIVITY RELATED PROBLEMS

The UER, with an area of 8842 Km^2 is the smallest region of Ghana (except Greater Accra), representing slightly more than 3.7% of the total land area. The population density of 136 persons/Km^2 is among the highest in the country. The region is divided into seven administrative districts. These are Bawku West, Bawku East, Binduri, Bongo, Bolgtanga, Kassena-Nankana, and Builsa. The population density varies from 43 in Builsa district to 273 in the Bongo district. About 87% of the population live in the rural areas and it is estimated that about 80% of the active population are employed in agriculture. They are engaged in the production of various crops such as sorghum, millet, maize, rice, groundnut, cowpea, soybean, onion, pepper, and tomato; and the rearing of livestock such as goat, sheep, pig, donkey and poultry. The compound farming is dominant in the region and it is estimated that men own 30% and women own 70% of the farm holdings. The region is described as the poorest because 99% of the population live below the poverty line. The region has pronounced wet and dry seasons. The main rivers of the region are the White and Red Volta, the Sissili, and Kulpawn (Terbobri, 1999).

The UER falls within the Guinea Savannah ecological zone, with a small area north of Bawku representing the Sudan savannah ecology. The natural vegetation is savannah spaced, which include fire resistant trees, shrubs, and grasses of various species. The soils of the region belong to seven groups: Luvisols, Lixisols, Cambisols, Leptisols, Vertisols, Phinthosols and Fluvisols. According to FAO. Report, 85% of the region's soils are classified as class IV-well-drained reddish brown, with shallow patches. The soil analysis indicates that there is low level of organic matter and nutrients' content. Soil degradation is due to high temperatures resulting in the rapid rate of decomposition, the negative authripic effect of recurrent annual burning of vegetation cover, and livestock's overgrazing. Valley soils, which range from sandy clay to silty clay, have higher natural fertility than upland soils, but are difficult to work and subject to seasonal water logging and floods (FAO, 1998).

According to Okorie (1984), any policy on raising the agricultural productivity must emphasise on soil-fertility management practices, liberalised credit facilities, agricultural extension network, rural infrastructure, and efficient output-input procurement and distribution system. Crop yields in many parts of the world have increased substantially due to a combination of inter-related factors, which include the use of improved varieties, better control measures for weeds, pests and disease; improved soil and water conservation practices, and increased use of fertilisers (Ejiga, 1990).

The farmers of UER generally adopt three types of soil fertility management practices, which include organic manure, chemical fertilisers and crop rotations. The organic manure is prepared from household refuse, crop residues and the droppings of the livestock. The crop rotations involve legume-cereal and cereal-cereal rotations. In addition, the chemical fertilisers are also used to improve the soil fertility but their use is restricted only to maize and vegetables that are produced for commercial purposes. Agro-chemicals that could otherwise have helped in raising productivity have become relatively unavailable and/or more expensive.

The agricultural productivity in the UER of Ghana may be low because of lack of research and extension services. In an effort to improve the agricultural productivity, the government of Ghana has set up the Savanna Agricultural Research Institute (SARI) and the Soil Research Institute (SRI). The productivity of land and efficiency of farm-owners depend on the level of infrastructure development (roads and telecommunications) and input-output procurement and distribution system. For instance, how far the farm is located from the output and input distribution points matters for the marketing of agricultural produce as well as for the cost of inputs (especially the chemical fertilisers). Moreover, the status of feeder roads and how far the farm is located from the house of the farmer matters for the transportation of organic manure. The development of telecommunication matters for the exports of these food products to the neighbouring countries. There is about 1574 Km of roads in the UER, which comprise 1000 Km of feeder roads and 574 Km of highways. The rating of the feeder roads is 315 Km good, 180 Km fair, 505 Km poor; whereas the rating of highways is 15 Km good, 186 Km fair, 308 Km poor, and 65 Km under construction (MOFA-PPMED, 1997). The development of rural infrastructure, and input-output procurement and distribution system in the UER needs more attention of the government of Ghana

3. PROBLEM STATEMENT

Dry season farming is a common feature of the people of the UER. In the Bawku East, Bawku West and Binduri districts, the cultivation of onions in large volumes is a major income generating activity during the dry season, from October to April. The onion produced in these areas account for more than half the national production. It is estimated that most households derive more than 50% of their livelihood from the cultivation of onion (Technoserve, 2002). However, the production of onions is not sufficient to meet the national demand. As a result, Ghana has to import onions from abroad. If the production of onions could be increased then Ghana could save some of its foreign exchange. It is in the light of this, we have decided to concentrate on the production of onions in these three districts.

Irrigation Company of the Upper Region (ICOUR) manages two dams; the Tono dam near Navrongo in the Kassena/Nankana district and the Vea dam near Gowrie in the Bongo distict. It is estimated that the Company has developed and manages 2207 hectares of arable land. About 3000 small-scale farmers cultivate on ICOUR's developed land. During the dry season, pepper and tomato are grown by most of the ICOUR farmers in the Kassena/Nankana district (Dere, 2001). That is why we have decided to concentrate on the production of pepper and tomato in the Kassena/Nankana district. In addition, since onion, pepper, and tomato serve as the basic ingredients in the cooking of foods, it is desirable to find ways through which their production could be increased.

In the UER, productivity of the various factors of agricultural production and technical efficiency of the growers of vegetables such as onion, pepper, and tomato, can be improved through the development and adoption of new technologies, the efficient use of the existing technologies without damaging the natural resource base, and the reallocation of resources. Since most of the small farmers are poor and they face credit constraints, they may not be in a position to raise the agricultural productivity by selecting the first and third options. So the only option left to these farmers is to raise their productivity through the efficient use of the existing technologies without damaging the natural resource base. Thus, the challenge to policy makers would be how to improve technical efficiency of the small farmers so that large gains in agricultural output can be attained. The technical efficiency is generally estimated using stochastic production function frontiers. However, to increase factor productivity and efficiency of the vegetable growers require a good knowledge of the level of current efficiency as well as the variations in the level of efficiency in various crops (enables the policy makers to identify the crops on which to concentrate), and the factors on which factor productivity (enables the policy makers to assess the potential gains in output) and efficiency (enables the policy makers to identify the factors on which to concentrate) of the vegetable growers depend.

It can be argued that technical efficiency of the farmers across various crops is determined by individual characteristics of the farmers. Factors influencing such characteristics may be divided into three groups -human capital variables that dominate the decision -making process of the farmers and institutional and socio-economic variables that could influence a farmer's capacity to apply his/her decisions at the farm level. The human capital variables that are being considered are age, education and farming experience of the farmer. The institutional factor could be the extension services. The socio-economic variables comprise distance of the farm from output and input distribution points, distance of the farm from the house of the farmer, and the index of soil fertility management practices.

Once we identify the significant factors on which the agricultural productivity and technical efficiency of the vegetable growers depend, we could increase the production of vegetables by concentrating on them. This in turn could solve the food insecurity problem in the Upper East Region, other regions of Ghana, as well as West Africa. First, if the increased production of vegetables also increases the incomes of these vegetable growers then it could solve the food insecurity problem of these farmers. Secondly, if the marketable surplus of these vegetables also increases and distributed within the Upper East Region then it could solve the food insecurity problem of the other farmers and public in general in this region. Thirdly, if the marketable surplus of these vegetables is distributed in the remaining regions of Ghana then it could solve the food insecurity problem in these regions. Fourthly, if the marketable surplus of these vegetables is distributed in the neighbouring countries of Ghana then it could solve the food insecurity problem in West Africa.

4. OBJECTIVES OF THE STUDY

The general objective of the study is to examine the relationship among agricultural productivity, technical efficiency, and soil fertility management practices of vegetable growers in the Upper East Region of Ghana. The specific objectives are:

- To assess the contribution of various factors of production to agricultural productivity.
- To estimate the level of technical efficiency of farmers engaged in the production of onion, pepper and tomato.
- To identify the factors through which the farm specific and crop specific technical efficiency could be raised.
- To assess the contribution of farmers to food security in UER of Ghana.

5. LITERATURE REVIEW

In the present study, we are interested in the measurement of technical efficiency; we therefore examine the theoretical approaches that are used for the estimation of stochastic production function and cost function frontiers. In addition, we also look at the empirical literature on agricultural productivity and technical efficiency, soil fertility management practices, and status of infrastructure.

5.1 THE THEORETICAL LITERATURE

The existing literature emphasises two broad approaches to the estimation of stochastic production frontier and stochastic cost frontier (Charnes et al., 1994, Coelli, 1994). These are: (a) The non-parametric programming approach and (b) The statistical approach. The estimation of stochastic production frontier provides estimates for the technical efficiency and the estimation of stochastic cost frontier provides estimates for the allocative efficiency. Technical efficiency reflects the ability of a farmer to obtain maximal output for a given set of inputs. Allocative efficiency reflects the ability of a farmer to use the inputs in optimal proportions, given their respective prices. In the case of a stochastic production frontier, the value of technical efficiency lies between zero and one, while the value of allocative efficiency lies between one and infinity in the stochastic cost function case. If the farmer operates below the stochastic production frontier then he/she is considered as technically inefficient (the value of technical efficiency is less than one). On the other hand, if the farmer operates above the stochastic cost frontier then he/she is considered as allocatively inefficient (the value of allocative efficiency is more than one).

The non-parametric programming approach requires one to construct a free disposal convex hull in the input-output space from a given sample of observations of inputs and outputs. This approach can be used where a farmer produces multiple outputs. In this approach, estimates can be obtained for technical, allocative and scale efficiencies (Farrell, 1957; Afriat 1972; Hanoch and Rothchild, 1972; Diewert and Parkan, 1983; Varian, 1985; Charnes et al, 1994).

A major criticism of this approach is that the convex hull, representing the maximum possible output, is derived using only marginal data and not utilising all the observations in the sample. Thus the production efficiency measures are susceptible to outliers and measurement errors (Forsund et.al.,l980). Secondly, the method has very demanding data needs. Finally, this being a non-parametric approach, no statistical inferences from the estimates can be derived.

The statistical approach can be sub-divided into the neutral-shift frontiers and the non-neutral shift frontiers. The former approach provides estimates for the technical and allocative efficiencies by specifying composed error formulations to the conventional production and cost functions (Kumbhakar, 1990; Fried et al , 1993; Coelli, 1995; Battese and Coelli, 1995). The latter approach uses a varying coefficients production function formulation (Kalirajan and Obwona, 1994; Obwona, 1995). A major criticism of the statistical approach is that it cannot provide estimates for the technical and allocative efficiencies for those farmers that produce multiple crops.

5.2 THE EMPIRICAL LITERATURE

The empirical literature on the measurement of technical and allocative efficiency in the agricultural, manufacturing and services' sectors of sub-Saharan African countries is very limited. Croppenstedt and Demeke (1997) have estimated the technical efficiency of private farmers engaged in the cereal crop production in Ethiopia and observed that education is weakly correlated with farm efficiency. Admassie and Asfaw (1997) have also estimated the technical and allocative efficiency of farmers in Ethiopia and observed that educated farmers are relatively and absolutely more efficient than those without education, and the mean profit efficiency of farmers is 54 percent. Croppenstedt and Muller (1998) have noted that the average farm specific efficiency of farmers in Ehiopia ranges from 51 to 76 percent depending on the assumed distributional form of the one-sided error.

Njikam (1998) has examined the impact of trade liberalisation on the technical efficiency of electrical industry of Cameroon and found a positive effect of trade policy liberalisation on this technical efficiency. Weir (1999) has observed that the farm-level efficiency in Ethiopia is approximately 55 percent and increased schooling reduces inefficiency of farmers. It has been established by Ajibefun and Daramola (1999) for the Block Making, Metal Fabricating and Sawmill industries of Nigeria that the age of operator, level of education and the level of investment are the most significant determinants of both technical and allocative efficiency. In another study Obwona (2000) has shown for the Tobacco growers of Uganda that the most significant determinants of technical efficiency are the family size, level of education, health status, hired workforce, credit accessibility, fragmentation of land and extension services. Weir and Knight (2000) have observed for farmers in Ethiopia that a one year increase in average schooling attained in the household reduces measured farm inefficiency in the production of cereal crops by 2.1 percentage points. Thus, if educational attainment is raised from zero to four years of primary schooling on average in the household, mean efficiency could increase by 15 percent. Njikam (2000) has estimated pre and post trade reform stochastic frontier production functions for seven Cameroonian industrial sub-sectors, namely, food, beverage & tobacco, textile & leather, wood & furniture, paper & printing, chemical and rubber, and observed that the mean technical efficiency of the manufacturing sector in the pre-trade reform period was 83.78 and the mean technical efficiency in the post-trade reform was 81.87. The firm-specific technical efficiencies in the post-trade reform period are significantly higher than those of the pre-trade reform period. Bigsten et al (2000) have estimated simultaneously an efficiency function and a dynamic discrete choice equation of export function for the manufacturing sector of four African countries, Cameroon, Kenya, Zimbabwe, and Ghana, and observed that firms improve their efficiency because of exporting and efficient firms become exporters. While examining the technical efficiency of micro enterprises located in Cape Coast, Bhasin and Akpalu (2001) have shown that the significant determinants of technical efficiency of women entrepreneurs engaged in hairdressing are age of operator, business experience, credit and contact with the lender. In dressmaking, the significant determinants of technical efficiency of women entrepreneurs are age of operator, level of education and credit. However, the significant determinants of technical efficiency of male wood processors are age of operator, business experience, training programs, credit and contact with the lender.

The literature on the agricultural productivity and the soil fertility management practices is also voluminous. The empirical evidence on the relationship between agricultural productivity and the procurement, distribution and pricing policy of fertiliser can be found in Pinstrup-Anderson (1976), Mudahar (1980), Falusi and Olayide (1981), Idachaba (1981, 1991), Okorie (1984), Adamu (1990), Ejiga (1990), Ogunfowora (1990, 1996), Fabiyi and Ogunfowora (1991), Subramanium (1992), Mijindadi et al (1993), Olupkmobi et al (1993), Ikpi and Olayemi (1995), and Firdausy (1997), among others. The empirical literature on organic manure emphasises the crucial role of corralling, green manure, crop-residues and composting in raising the soil-fertility and agricultural productivity. The empirical literature on the relationship between agricultural productivity and crop rotations emphasises the importance of lay farming, natural grasslands, integration of forage legumes with cereal crops, and alley cropping.

Linking infrastructure investment and productivity is part of the broader goal of understanding the "institutional structure of production" (Coase, 1992). Most of the studies, which link infrastructure investment with productivity, have been conducted at the macro level. The empirical evidence on the relationship between productivity and infrastructure can be found in Aschauer (1989a, 1989b, 1993), Holtz-Eakin (1992), Fernald (1993), Canning and Fay (1993), Easterly and Levin (1994), and Polenske (1994), to mention a few. Linkage among the agricultural productivity, technical efficiency of the vegetable growers, and the development of rural infrastructure is an area yet to be explored.

There are virtually no empirical studies in Ghana, which examine the inter-link among agricultural productivity, technical efficiency and the soil-fertility management practices of the vegetable growers at the crop level, while emphasising the role of rural infrastructure and extension services.

6. RESEARCH METHODS

6.1 THEORETICAL FRAMEWORK

In this study, we have used the stochastic frontier, also called "Composed error" model of Aigner et al (1977) and Meeusen and van den Broeck (1977). Consider a farmer using k inputs (x_1, x_2, …,x_k) to produce a single output Y. Efficient transformation of inputs into output is characterised by the production function, which shows the maximum output obtainable from various input vectors. The stochastic production function is defined as

$$Y_i = x_i \beta + (V_i - U_i) , i = 1, 2,\ldots N \qquad (1)$$ [5]

where Y_i is the production (or the logarithm of the production) of the i -th farmer;

x_i is a k X 1 vector of input quantities of the i -th farmer;

β is a vector of unknown parameters;

V_i are random variables; and

U_i are non-negative random variables, which are assumed to account for technical inefficiency in production.

The random errors, V_i, are assumed to be independently and identically distributed as N $(0,\sigma_V^2)$ independent of U_i's. The U's are also assumed to be independently and identically distributed as, for example, exponential (Meeusen and van den Broeck, 1977) and half normal (Aigner et. al., 1977). In the present study, we assume that U's follow half normal distribution and use mixed chi-square distribution (Likelihood Ratio Test) to test for the one-sided error.

Technical efficiency (TE) of an individual farmer is defined as the ratio of the observed output to the corresponding frontier output, conditional on the levels of inputs used by the farmer. Thus the technical efficiency of farmer i in the context of the stochastic frontier production function (1) is

$$TE_i = Y_i/Y_i^* \qquad (2)$$

Where Y_i is the actual output and Y_i^* is the frontier output (potential output). For the non-log version of equation (1), the technical efficiency is defined as $(x_i \beta - U_i)/(x_i \beta)$. For the log versions (Cobb-Douglas and Trans-log), the technical efficiency is defined as $\exp(-U_i)$. The value of the technical efficiency lies between zero and one. The most efficient farmer will have value one, whereas the less efficient farmers will have their efficiencies lying between zero and one. The maximum likelihood estimates for the parameters of the Stochastic frontier and the predicted technical efficiency/ inefficiency of the farm-owner for each crop will be obtained by using the Computer program, FRONTIER 4.1 (Coelli, 1994), in which the variance parameters are expressed in terms of

$$\sigma^2 = (\sigma_U^2+\sigma_V^2), \text{ and}$$

$$\gamma = \sigma_U^2/(\sigma_U^2+\sigma_V^2) \qquad (3)$$

The term γ represents the ratio of the variance of inefficiency's error term to the total variance of the two error terms defined above. The value of γ can range between 0 and 1. The significance of the γ parameter can be used to test whether the stochastic frontier production function is preferred to the average production function. If the null hypothesis, that γ equals zero, is accepted, this would indicate that σ_U^2 is zero and hence that the U_i term should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least squares.

We estimate the technical inefficiency model by regressing the predicted technical efficiency on a vector of human capital variables (age of farmer, level of education, and farming experience), institutional variable (extension services) and socio-economic variables (distance of the farm from the house of the farmer, distance of the farm from the market, and index of soil fertility management practices) for the three selected crops. The soil fertility management index is constructed by assigning weights to the three types of soil fertility management practices prevalent in the Upper East Region of Ghana. The technical inefficiency model can be specified as

$$TE_i = \delta_0 + \sum_{j=1}^{m} \delta_j H_{ij} + \varepsilon_i \qquad (4)$$

where H is a vector of exogenous variables and the parameters of this equation are estimated by OLS. The statistical significance of δ's will help us in identifying the variables which are causing technical inefficiency among the vegetable growers of Upper East Region of Ghana. Thereafter, we re-estimate the preferred model by deleting the insignificant policy variables. These variables are referred to as policy variables because they depend on the policies of private and public institutions. The two-stage estimation procedure has been long recognised as one that is inconsistent in its assumptions regarding the independence of the inefficiency effects in the two estimation stages. The two-stage estimation procedure is unlikely to provide estimates that are as efficient as those that could be obtained using a single-stage estimation procedure (Reifschneider and Stevenson,1991).

6.2 RESEARCH HYPOTHESES

The following hypotheses are tested in the present study

H_0 : Factors of Production do not contribute to agricultural productivity.

H_1: Factors of Production contribute positively to agricultural productivity.

H_0 : There is no difference between the composed error model (two error terms) and the standard production model (one error term).

H_1: Composed error model is more appropriate in comparison to the standard production model.

H_0 : Human capital variables do not have any impact on the technical efficiency of vegetable growers.

H_1: Human capital variables do have some impact on the technical efficiency of vegetable growers.

H_0 : Institutional and Socio-economic variables do not have any impact on the technical efficiency of vegetable growers.

H_1: Institutional and Socio-economic variables do have some impact on the technical efficiency of vegetable growers.

6.3 SAMPLING PROCEDURE AND DATA COLLECTION

The farmers selected for this study are those growing onion, pepper, and tomato. The data collection process required pilot surveys in order to construct the sampling frames and draw various samples. Three pilot surveys were therefore conducted for this purpose. In the first pilot survey, estimates for the populations of growers of onion located in the villages of Binduni, Zumi, and Navrongo of Bawku East, Binaba of Bawku West, and Gumyoko, Kuloku, and Zaago of Binduri districts of the Upper East Region were obtained from the Agricultural Extension Agents and Technoserve. Proportional random sampling procedure was adopted to select a sample of fourty growers of onion (around 8%). The population and sample sizes of the growers of onion are indicated in Table 1. In the second pilot survey, estimates for the populations of the growers of pepper located in the villages of Bisawoo, Bomia, Buru Navio, Kugwania, Paga Bisawoo, Paga Gwari, Paga Navio, Punyoro, Navia, Namolo, nyangua, Nakolo, Yigwania, Yogbania, Wuru of Kassena/ Nankana district of the Upper East Region were obtained with the help of Agricultural Extension Agents. Again, Proprtional random sampling procedure was adopted to select a samples of fourty growers of pepper (around 8%). The population and sample sizes of the growers of pepper are indicated in Table 1. In the third pilot survey, estimates for the populations of the growers of tomato located in the villages of Gongnia, Kazina-Line, Paga Bisawoo, Pungu, Nangalikinia, Namolo, Nogsinia, Saboro, Vunania, Yigwania, and Wuru of Kassena/Nankana district of the Upper East Region were obtained with the help of Agricultural Extension Agents. Proportional random sampling procedure was adopted to select a sample of fourty growers of tomato (around 8%). The population and sample sizes of the growers of tomato are indicated in Table 1. The size of the sample for each crop was chosen to be the same for comparison purposes.

Enumerators who were very proficient in the local language were selected and trained for one week so that they could interpret the questionnaires to the farmers. Before the final questionnaires were administered, questionnaire testing was conducted on five respondents from each crop. The testing revealed some weaknesses in the structure of some of the questions in original questionnaire. The questionnaire was therefore modified accordingly and was administered by the enumerators. Information was collected on value of output, physical quantities of inputs, human capital variables, institutional variables and socio-economic variables. There was a follow up to confirm some of the responses provided by the respondents.

Table 1: Population and Sample size of farmers by crop and district/village.

District/Village	Onion Farmers Population	Onion Farmers Sample	Pepper Farmers Population	Pepper Farmers Sample	Tomato Farmers Population	Tomato Farmers Sample
Bawku East	**192**	**23**				
Binduni	100	12				
Zumi	60	7				
Navrango	32	4				
Bawku West	**92**	**10**				
Binaba						
Binduri	**56**	**7**				
Gumyoko	26	3				
Kuloku	14	1				
Zaago	16	3				
Kassena/Nankana						
Bisawoo			34	4	-	-
Bomia			9	1	-	-
Buru Navio			17	2	-	-
Kugwania			15	2	-	-
Gongnia			-	-	9	1
Kazina-Line			-	-	8	1
Paga Bisawoo			16	2	10	1
Paga Gwari			25	3	-	-
Paga Navio			9	1	-	-
Punyoro			10	1	-	-
Pungu			-	-	8	1
NangaliKinia			-	-	10	1
Navia			8	1	-	-
Namolo			33	4	143	18
Nogsinia			-	-	82	11
Nyangua			15	2	-	-
Nakolo			9	1	-	-
Saboro			-	-	25	3
Vunania			-	-	8	1
Yigwania			17	2	9	1
Yogbania			98	12	-	-
Wuru			16	2	10	1
TOTAL	**340**	**40**	**331**	**40**	**322**	**40**

Source: From the Survey

6.4 EMPIRICAL FRAMEWORK

Descriptive statistics are used to analyse the primary data. In the estimation of production functions, value of output is the dependent variable. Volume of output should be preferred to value of output. However, we could not use the volume of output because farmers use different measurement units for the volume of output (crates of different sizes, buckets of different sizes, sacks of different sizes, head panes, etc.). The inputs that are included in the estimation of production functions are man-hours worked, area under cultivation, expenditure on equipment, expenditure on fertilizers and expenditure on seeds. The maximum likelihood method is used to obtain estimates for the parameters of production functions. The likelihood ratio test is used to test the appropriateness of stochastic frontier production function (which includes two error terms) in relation to the standard production function (which includes only one error term). Once it is found that the stochastic frontier production function is more appropriate, estimates for the farm specific and crop specific technical efficiencies are obtained. The distribution of technical efficiency for each crop is examined to know the scope for improvement in the technical efficiency of vegetable growers. Technical efficiency is regressed on human capital, institutional and socio-economic variables. The Ordinary Least Squares (OLS) method is used to obtain estimates for the parameters of the inefficiency model. The preferred model is arrived at after deleting the insignificant variables (because of multi-colinearity). The significant variables are identified for each crop and compared with the other studies.

7.0 DESCRIPTIVE DATA ANALYSIS

The age composition of the farmers is indicated in Table 2. Male farmers dominate in the production of the three crops. This may be because males do not allow their wives to work on the farm. In the event of husband's death, women become insecure and therefore women should be encouraged to become farmers in these districts. The modal age group for the growers of onion and tomato is 36 to 45 years, whereas the modal age group for the growers of pepper is 26 to 35 years. The age composition suggests that younger people should be encouraged to become growers of onion and tomato.

Table 2: Age Composition of the Farmers by crop and sex.

Age (Years)	Onion Farmers			Pepper Farmers			Tomato Farmers		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Less than 25	2	0	2	6	0	6	2	0	2
26-35	6	2	8	11	1	12	15	1	16
36-45	7	4	11	10	1	11	17	1	18
46-55	4	1	5	7	0	7	1	1	2
56-65	4	3	7	2	0	2	1	1	2
Above 65	5	2	7	1	1	2	0	0	0
TOTAL	28	12	40	37	3	40	36	4	40

Source: From the Survey

The educational background of the farmers engaged in the production of onion, pepper and tomato is presented in Table 3. Majority of the growers of onion and pepper do not have any formal education. One reason for this could be that the villages situated in these districts do not have proper schooling facilities. Secondly, since these farmers are mostly illiterate, they cannot find employment in other occupations and therefore had to rely on farming. There is a need for these farmers to acquire some level of formal education. The situation was different for the growers of Tomato. Majority of the tomato farmers have at least primary level education. It seems that educated people are attracted to tomato cultivation. In the Kassena/Nankana district, educated farmers prefer growing tomato rather than pepper. This may be because the cultivation of tomato is more remunerative or requires some technical knowledge that only educated farmers can acquire.

Table 3: Educational Background of Farmers

Level of Formal Education	Onion Farmers Frequency	%	Pepper Farmers Frequency	%	Tomato Farmers Frequency	%
Nil	28	70.0	20	50.0	8	20.0
Primary	6	15.0	10	25.0	5	12.5
Middle/J.S.S.	1	2.5	6	15.0	6	15.0
Secondary	2	5.0	4	10.0	7	17.5
College/Polytecnic	1	2.5	0	0.0	12	30.0
University	0	0.0	0	0.0	2	5.0
Adult Education	2	5.0	0	0.0	0	0.0
TOTAL	40	100.0	40	100.0	40	100.0

Source: From the Survey

The sources of organic manure used by the farmers are indicated in Table 4. Majority of the growers of onion, pepper, and tomato get their organic manure from livestock droppings. Compost is the least popular source of organic manure for the growers of onion and pepper. On the other hand, crop residue and black soil are the least popular source of organic manure for the growers of tomato.

Table 4: Sources of Organic Manure

Type of Manure	Onion Farmers Frequency	%	Pepper Farmers Frequency	%	Tomato Farmers Frequency	%
Compost	17	42.5	1	2.5	3	7.5
Livestock Droppings	33	82.5	37	92.5	21	52.5
Crop Residue	31	77.5	15	37.5	1	2.5
Black Soil	0	0.0	4	10.0	1	2.5

Source: From the Survey

The different types of fertilizers that are used by the vegetable farmers are indicated in Table 5. Sulphate Ammonia is the most popular fertilizer among the growers of onion and tomato. On the other hand, N.P.K. is the most popular fertilizer among the growers of pepper. The least popular

Table 5: Type of Fertilizer Used

Fertilizer	Onion Farmers Frequency	%	Pepper Farmers Frequency	%	Tomato Farmers Frequency	%
Compound	17	42.5	10	25.0	14	35.0
Sulphate Ammonia	18	45.0	33	82.5	26	65.0
N.P.K.	10	25.0	35	87.5	22	55.0
Ammonia	6	15.0	8	20.0	13	32.5
Super Fol	0	0.0	0	0.0	2	5.0

Source: From the Survey

Table 6: Type of Crop Rotation

Type of Rotation	Onion Farmers Frequency	%	Pepper Farmers Frequency	%	Tomato Farmers Frequency	%
Vegetable-Vegetable	12	30.0	5	12.5	32	80.0
Onion-Pepper-Tomato	1	8.33	0	0.0	8	25.0
Onion-Pepper	2	16.66	2	40.0	0	0.0
Onion-Tomato	1	8.33	0	0.0	4	12.50
Pepper-Tomato	0	0.00	2	40.0	6	18.75
Onion- Other Vegetables	8	66.66	0	0.0	0	0.0
Pepper-Other Vegetables	0	0.00	1	20.0	0	0.0
Tomato-Other Vegetables	0	0.00	0	0.0	14	43.75
Vegetable- Cereal	17	42.5	2	5.0	30	75.0
Onion-Pepper-Cereal	2	11.75	0	0.0	0	0.00
Onion-Tomato-Cereal	6	35.30	0	0.0	12	40.0
Pepper-Tomato-Cereal	0	0.00	1	50.0	7	23.33
Onion-Cereal	9	52.95	0	0.0	0	0.00
Pepper-Cereal	0	0.00	1	50.0	0	0.00
Tomato-Cereal	0	0.00	0	0.0	11	36.66
Vegetable-Legume	1	2.5	1	2.5	10	25.0
Onion-Tomato-Legume	0	0.00	0	0.00	2	20.0
Pepper-Tomato-Legume	0	0.00	0	0.00	3	30.0
Onion-Legume	1	100.00	0	0.00	0	0.0
Pepper-Legume	0	0.00	1	100.00	0	0.0
Tomato-Legume	0	0.00	0	0.00	5	50.0

Source: From the Survey

fertilizer among the growers of onion and pepper is Ammonia; whereas the least popular fertilizer among the growers of tomato is Super Fol (may be brand name).

Different types of crop rotation that are practiced by the growers of onion, pepper, and tomato in the Upper East Region of Ghana are indicated in Table 6. The most popular crop rotation among the growers of onion is vegetable-cereal, i.e. onion-cereal. On the other hand, the most popular crop rotation among the growers of pepper is vegetable-vegetable, i.e. Pepper-onion, Pepper-Tomato. The most popular crop rotation among the growers of tomato is vegetable-vegetable, i.e. Tomato-other vegetables (Okro, Cabbage,etc.) The least popular crop rotation among the growers of onion, pepper, and tomato is vegetable-legume. The vegetable growers have been practicing different types of soil fertility management practices in order to sustain the soil fertility.

8.0 ANALYSIS OF ESTIMATED RESULTS

8.1 Maximum Likelihood Estimates of Frontier Production Functions

The maximum likelihood estimates of preferred frontier production functions are indicated in Table 7. The non-log version of the frontier production function is more suitable for all the three crops in comparison to the log versions (Cobb-Douglas and Translog). First of all it is important to note that the Likelihood Ratio test statistics for all the three crops are statistically significant at the 5% level of significance, which imply that the frontier production function fits the data better than an average production function.[6] This point is also buttressed by very significant Variance Ratios for all the three crops. It is evident from the estimated frontier production function for the growers of onion that land, man-hours worked and equipment are significant determinants of value of output. The marginal effects of land, man-hours worked and expenditure on equipment on the value of output of growers of onions represent the values of marginal products of these factors of production and these are 802.16, 1.579 and 2.29, respectively. For onion cultivation, the productivity of land is higher than the productivity of labour and capital. Moreover, capital is more productive than labour. The estimated frontier production function for the growers of pepper indicates that the coefficients of land, man-hours worked, fertilizer and equipment are statistically significant. The marginal effects of land, man-hours worked, fertilizer, and equipment on the value of output of growers of pepper represent the values of marginal products of these factors of production and these are 994.14, 3.5478, 0.1178 and 0.7364, respectively. Again, the productivity of land for pepper is higher than the productivity of labour, capital and fertilizer. However, the productivity of labour is higher than the productivity of capital. The estimated frontier production function for the growers of tomato indicates that the coefficients of land, man-hours worked, fertilizer, seed and equipment are statistically significant. The marginal effects of land, man-hours worked, fertilizer, seed and equipment on the value of output of tomato represent the values of marginal products of these factors of production and these are 1224.2, 2.5716, 0.3919,0.7592 and 0.4368, respectively. For tomato also, the productivity of land is higher than the productivity of labour, capital, fertilizer and seeds. However, the productivity of labour is higher than the productivity of capital.

The productivity of land is highest in the cultivation of tomato. This suggests that more land should be brought under the cultivation of tomatoes. The productivity of labour is highest in the production of pepper. This implies that more labour should be devoted to the cultivation of pepper. In addition, the productivity of capital is highest in the production of onion. This suggests that we should adopt more capital-intensive technique for the production of onions.

Table 7: Maximum Likelihood Estimates of Production Functions

Crop / Variable	**Onion** (Non-Log Version)	**Pepper** (Non-log Version)	**Tomato** (Non-log Version)
Intercept[7]	21.175 (80.574)	175.07* (2.5191)	2713.3* (5.1206)
Land	802.16* (198.68)	994.14* (1.8374)	1224.2* (9.2869)
Man-hours	1.5791* (0.8648)	3.5478* (0.0527)	2.5716* (0.2403)
Fertilizer	-	0.1178* (0.0610)	0.3919* (0.0550)
Seeds	0.3017 (0.9482)	-	0.7592* (0.1315)
Equipment	2.2932* (0.9651)	0.7364* (0.0215)	0.4368* (0.0405)
Variance Ratio (γ)	0.6390* (0.1636)	0.9999* (0.0000006)	0.9999* (0.0000007)
Total Variance(σ^2)	69263* (3.8387)	48775* (0.9991)	6312859* (1.0000)
Log-Likelihood Function	-270.15	-248.87	-346.20
Likelihood Ratio Test	1.396*	20.10*	16.27*

Source: From the Computation

Notes: 1. The figures in the parentheses are the standard errors.
2. * indicates that the statistics is significant at 5% level of significance.

8.2 Technical Efficiency Estimates

The value of technical efficiency lies between zero and one. However, we have multiplied the efficiency estimates by one hundred so that we could express the efficiency in terms of percentages. The distribution of these technical efficiencies of growers of onion, pepper and tomato are given in Table 8. The mean technical efficiency of the growers of tomato is 70.4%, which is relatively lower than the mean technical efficiency observed for growers of onion (82.0%) and pepper (88.7%). Fifteen growers of onion (37.5%) operate at the technical efficiency level of less than 80%, with the maximum efficiency being 97.1%. Six growers of pepper (15.0%) operate below 80% technical efficiency. The least efficient and the most efficient growers of pepper operate at 67.4% and 99.9% efficiency levels, respectively. Twenty-one growers of tomato (52.5%) operate at efficiency levels below 80%. The least efficient and the most efficient growers of tomato operate at 12.8% and 100% efficiency levels, respectively. Thus, there are variations of technical efficiencies within and across the three crops. There is relatively more scope for the improvement of technical efficiency of growers of tomato than the growers of onion and pepper.

Table 8: Distribution of Technical Efficiencies

Efficiency (Percent)	Onion Farmers		Pepper Farmers		Tomato Farmers	
	Frequency	%	Frequency	%	Frequency	%
11-20	0	0	0	0	1	2.5
21-30	0	0	0	0	2	5.0
31- 40	0	0	0	0	4	10.0
41 – 50	0	0	0	0	5	12.5
51 – 60	0	0	0	0	1	2.5
61 – 70	3	7.5	1	2.5	1	2.5
71 – 80	12	30.0	5	12.5	7	17.5
81 – 90	20	50.0	15	37.5	7	17.5
91 – 100	5	12.5	19	47.5	12	30.0
TOTAL	40	100.0	40	100.0	40	100.0
Mean	82.0		88.7		70.4	
Minimum	65.6		67.4		12.8	
Maximun	97.1		99.9		100.0	

Source: From the Computation

Our findings on technical efficiencies are similar to the findings of Admassie and Asfaw (1997), Croppenstedt and Muller (1998), Weir (1999), and Obwona (2000). Admassie and Asfaw (1997) estimated the mean profit efficiency of farmers as 54 percent. Croppenstedt and Muller (1998) noted that the average farm specific efficiency of farmers in Ethiopia ranged from 51 to 76 percent depending on the assumed distributional form of the one-sided error. Weir (1999) observed that the farm-level efficiency in Ethiopia was approximately 55 percent. Obwona (2000) observed that the technical efficiency of tobacco growers in Uganda varied between 44.8% and 97.3% with the mean technical efficiency level of 76.2%.

8.3 Determinants of Technical Efficiency

Given a technology to transform physical inputs into outputs, some growers of pepper and tomato are able to achieve maximum efficiency upto 100% while the others are technically inefficient. This discrepancy could be due to the latter group not having adequate technical knowledge compared to the first group. On the other hand, this discrepancy may exist because of human-capital, institutional and socio-economic variables (Bhasin and Akpalu, 2001). The computed technical efficiencies are modelled to depend on certain variables. We expect to observe a negative relationship between the technical efficiency and age of farmer, distance of the farm from the market, and distance of the farm from the house of the farmer. All other variables (farm experience, level of education, extension services, and soil fertility management practices) are expected to be positively related with the technical efficiency. First, we estimate the general model with all the independent variables. Due to the problem of multi-collinearity, coefficients of some of the variables are insignificant. These variables are deleted from the regression equation to arrive at the preferred model. The estimates for the preferred technical inefficiency model are given in Table 9.

In the case of growers of onion, the significant variables are farm experience, distance of the farm from the house of the farmer and extension services. While interpreting the results, we should keep in mind that only one variable changes and other variables are kept constant. The farming experience is positively related to the level of technical efficiency. The farmer learns from experience what is good and what is bad for the crops and this experience certainly enhances the efficiency of the farmer. Those farmers of Bawku East, Bawku West and Binduri districts whose efficiencies are relatively lower should be encouraged to continue their farming activity so that later on their efficiency could increase with experience. The distance of the farm from the house of the farmer is negatively related to the technical efficiency of the farmer. If the farm is located far away from the house of the farmer, this may involve waste of time and additional transportation problems and this could lead to a lower level of efficiency. Efforts should be made to improve the feeder roads so that the efficiency level of the growers of onion could be raised. The extension services are directly related to the technical efficiency. The farmer learns from the extension services and if the farmer decides to follow the advice of extension officers then it can certainly enhance the level of efficiency of the farmer. There is a need to provide more extension services to the growers of onion located in the Bawku East, Bawku West and Binduri districts so that the efficiency level of some of the growers of onion could be raised (on average two contacts are made per farmer per season). The value of R^2 indicates that about 86% of the variability in the efficiency of growers of onion is explained by the relevant variables. The significant value of F indicates that the estimated regression is a good fit.

Table 9: Determinants of Technical Efficiencies

Crop / **Variable**	**Onion**	**Pepper**	**Tomato**
Intercept	0.8147* (0.0242)	1.0483* (0.0420)	0.8629* (0.0759)
Age of Farmer	-	-0.0052* (0.0009)	-0.0038** (0.0014)
Level of Education	-	-	0.0031** (0.0011)
Farm Experience	0.0022*** (0.0012)	-	-
Distance of farm from Market	-	-0.0048* (0.0011)	-
Distance of farm from the house	-0.0100* (0.0020)	-	-0.0198* (0.0045)
Extension Services	0.0163* (0.0052)	0.0064** (0.0025)	-
Soil fertility management practices	-		0.0340* (0.0112)
R^2	0.86	0.96	0.98
F-Statistics	73.91*	312.91*	810.49*

Source: From the Computation

Notes: 1. The figures in the parentheses are the standard errors.

2. * indicates that the statistics are significant at 1% level of significance.

3. ** indicates that the statistics are significant at 5% level of significance

4. *** indicates that the statistics are significant at 10% level of significance.

In the case of growers of pepper, the significant variables are age of the farmer, distance of the farm from the market, and extension services. As expected, age has a negative impact on efficiency of growers of pepper. This is because the older growers of pepper are expected to be less efficient in comparison to the younger ones. Younger people are more agile should be encouraged to do farming of pepper in the Kassena/Nankana district so that the level of technical efficiency could be raised. The distance of the farm from the market also has a negative impact on the efficiency of growers of pepper. If the farm is located far away from the market then this may involve waste of time and additional transportation problems in the procurement of inputs and this could reduce the level of efficiency of the farmer. It is suggested that village markets should be developed in the Kassena/Nankana district, so that the efficiency level of growers of pepper could be raised. The extension services are directly related to the technical efficiency of the growers of pepper. The farmer learns from the extension services and if the farmer decides to follow the advice of extension officers then it can certainly enhance the level of efficiency of the farmer. There is a need to provide more extension services to the growers of pepper located in the Kassena/Nankana district so that the efficiency level of some of the farmers could be raised (on average three contacts are made per farmer per season). The value of R^2 indicates that about 96% of the variability in the efficiency of growers of pepper is explained by the relevant variables. The significant value of F indicates that the estimated regression for growers of pepper is a good fit.

In the case of growers of tomato, the significant variables are age of the farmer, level of education, distance of the farm from the house of the farmer, and soil fertility management practices. As expected, age has a negative impact on efficiency of growers of tomatoes too. This is because the older growers of tomato are expected to be less efficient in comparison to the younger ones. Younger people who are more agile should be encouraged to do farming of tomato in the Kassena/Nankana district so that the level of technical efficiency could be raised. The level of education is positively related to the efficiency of growers of tomato. Education certainly enhances the knowledge of farmer and this could raise the efficiency of the farmer. Educated people should be encouraged to cultivate tomatoes so that the efficiency of the growers of tomato could be raised. The distance of the farm from the house of the farmer is negatively related to the technical efficiency of the farmer. If the farm is located far away from the house of the farmer, this may involve waste of time and additional transportation problems and this could lead to a lower level of efficiency. Efforts should be made to improve the feeder roads so that the efficiency level of the growers of tomato could be raised. The index of soil fertility management practices is positively related to the technical efficiency of the growers of tomato. The frequent use of soil fertility management practices could increase the fertility of soil and which could ultimately raise the level of technical efficiency. Those farmers of the Kassena/Nankana district that are engaged in the farming of tomato should be encouraged to practice more frequently the soil fertility management practices so that their level of efficiency could be raised. The value of R^2 indicates that about 98% of the variability in the efficiency of growers of tomato is explained by the relevant variables. The significant value of F indicates that the estimated regression for growers of tomato is a good fit.

Our findings with regard to the determinants of technical efficiency are in conformity with the findings of other researchers. Croppenstedt and Demeke (1997) estimated the technical efficiency of private farmers engaged in the cereal crop production in Ethiopia and observed that education is weakly correlated with farm efficiency. Admassie and Asfaw (1997) observed that educated farmers are relatively and absolutely more efficient than those without education. Weir (1999) observed that increased schooling increases the efficiency of farmers. Weir and Knight (2000) observed that a one-year increase in average schooling attained in the household reduces farm inefficiency in the production of cereal crops by 2.1 percentage points. Obwona (2000) showed that the significant determinants of the efficiency of tobacco growers in Uganda are the family size, level of education, health status, hired workforce, and credit accessibility, fragmentation of land and extension services.

9.0 CONCLUSIONS AND POLICY RECOMMENDATIONS

The descriptive data analysis indicates that younger people should be encouraged to become growers of onion and tomato. Majority of the farmers engaged in the production of onion and pepper do not have any formal education. There is a need for the farmers of Bawku East, Bawku West, Binduri, and Kassena/Nankana districts of the Upper East Region of Ghana to attain some level of education through adult education. The vegetable growers located in these districts of the Upper East Region of Ghana have been practicing different types of soil fertility management practices to sustain the soil fertility.

On efficiency measurement, hypothesis testing indicates that the stochastic frontier production functions are preferred to average production functions in all the three crops. The productivity of land was highest in the cultivation of tomato. This suggests that more land should be brought under the cultivation of tomatoes. We also noticed that the productivity of labour is highest in the production of pepper. This implies that more labour should be devoted to the cultivation of pepper. In addition, the productivity of capital is highest in the production of onion. This suggests that we should adopt more capital-intensive techniques for the production of onions. We noticed variations of technical efficiencies within and across the three crops. There is relatively more scope for the improvement of technical efficiency of growers of tomato than the growers of onion and pepper. Our findings for technical efficiencies are similar to the findings of Admassie and Asfaw (1997), Croppenstedt and Muller (1998), Weir (1999), and Obwona (2000).

In the case of growers of onion, the significant determinants of the technical efficiency are farm experience, distance of the farm from the house of the farmer and extension services. For the growers of pepper, the significant determinants of the technical efficiency are the age of the farmer, distance of the farm from the market, and extension services. In the case of growers of tomato, the significant determinants of the farm specific technical efficiency are the age of the farmer, level of education, distance of the farm from the house of the farmer, and soil fertility management practices. The policy makers should concentrate on the above-mentioned human-capital, institutional and socio-economic variables in order to solve food insecurity problem. Our findings with regard to the determinants of farm specific and crop specific technical efficiencies are in conformity with the findings of Croppenstedt and Demeke (1997), Admassie and Asfaw (1997), Weir (1999), Weir and Knight (2000), and Obwona (2000).

10. NOTES

1 Technical inefficiency embodies all managerial and organisational sources of inefficiency that Leibenstein (1966) called X-inefficiency. Allocative inefficiency, on the other hand, implies failure to apply cost minimising factor combinations. Scale inefficiency depends on the scale properties of the production function. Considerations of technical efficiencies provide insights into how much more the outputs could be increased without changing inputs (output increasing efficiency) or how much inputs reduction may be feasible without compromising output (input saving efficiency).

2 Fertilisers are inorganic substances applied to soil to increase crop yields by providing one or more of the elements that are essential plant nutrients. It raises soil fertility by increasing the plant nutrients in the cycle of growth and decay.

3 Farming experience refers to the number of years of cultivating the same parcel of land. This

characteristic of farming is important because technical efficiency can be farm-specific and crop-specific.
4 Third way to increase productivity is that by reallocating the resources.
5 The stochastic frontier production function assumes the presence of technical inefficiency of production. The term N represents the size of sample (number of farmers) for each crop.
6. The average production function assumes only one error term that is normally distributed.
7. The intercept takes care of the omitted variables in each equation.

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