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Environmental burden of fungicide application among cocoa farmers in Ondo state, Nigeria

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Abstract:

The use of copper based fungicide in the control of black pod disease caused by Phytophthora megakarya is a common practice among cocoa farmers. Copper based fungicide has detrimental effect on the environment as well as the output of cocoa production in Ondo State, Nigeria. Deviation from the recommended quantity of fungicides by cocoa farmers is not uncommon. Several studies on cocoa production often ignore these externalities. The objective of the study was to determine the environmental efficiency of cocoa farmers using detrimental variable (deviation from the recommended quantity of fungicide on cocoa farm) and traditional inputs within the framework of stochastic frontier approach. The averages of fungicide used per cropping season per hectare were 2,230 grams, 5,820 grams 10,555 grams for respondents that used below, actual and above the recommended doses respectively while average cocoa outputs were 0.92, 3.35 and 1.32 metric tons for farmers that used below, actual and above recommended doses of fungicide respectively. The low environmental efficiency did not only raise the cost of production but also affirmed that the wrong use of fungicide in cocoa farm constitutes environmental burden and make the environmental unsustainable. The study recommended that farmers should be educated on the significance and mode of application of recommended dose of fungicide on cocoa plantation.

Keywords: Environmental efficiency, detrimental input, stochastic frontier, cocoa production.

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1.0 Introduction

Agriculture remains a major sector in the Nigerian economy with over 70% of the population depend on farming as a major source of livelihood (Balogun and Obi-Egbedi, 2012). It provides the bulk of employment, income and food for the rapidly growing population as well as the supply of raw materials for agro-based industries. Crop production constitutes the most important sub-sector of agriculture providing cocoa, cotton, groundnut, palm oil products and rubber as the principal export crops. Among these crops, cocoa ranked first amongst the agricultural export crops in its contribution to foreign earnings (Olajide *et al.,* 2012).

Cocoa is of economic importance with more than 650,000 ha being cultivated in Nigeria (Sanusi and Oluyole, 2005). As observed by International Cocoa Organization (2003) and Folayan *et al*. (2006), cocoa output in Nigeria peaked at 308,000 tons in 1970s dropped significantly to 155,000 tons in the 1980s and further reduced to 110,000 tons during 1990 and 1991 farming season. Therefore, the country's market share reduced to about 6%. Bulk of Nigeria's cocoa output is produced by small scale farmers predominantly in the southern cocoa belt. About 60-70% of cocoa production and processing activities are located in the south west Nigeria and 20% in southern Nigeria. Annual cocoa production in Nigeria was estimated at an average of 181,000 to 260,000 tonnes between 2000 and 2010 (World Cocoa Economy: Past and Present, 2010). The country produced 350,000 tons of cocoa in the 2013-2014 seasons, according to the report from the Agricultural Ministry. The increase in cocoa output in recent years has placed Nigeria in the fourth place among world cocoa producer after Ivory Coast, Ghana and Indonesia (IFPRI, 2010).

However, literature on cocoa production indicates that several factors have contributed to decline production. These factors include; the infestation of black pod disease, shortage and high cost of farm labour, non-availability and low utilization of fertilizers, poor access roads to the major producing areas, inadequate government subsidies on input, small farm holdings and poor farmers' education (Global Agricultural Information Network (GAIN), 2014; Freud *et al.,* 1996; CRIN 2003; CDU, 2003; Aikpokpodion, 2010). Aikpokpodion, *et al.* (2013) opined that the most effective and popular means of controlling black pod disease of cocoa among Nigerian farmers is the use of copper based fungicides.

Nonetheless, its use tend to be excessive thereby potentially endangers the environment, particularly if residues persist in the soil or migrate off-site and enter waterways (example; due to spray drift, run-off) (Kookana *et al*., 1998; Wightwick and Allinson, 2007; Kibria *et al*., 2010; Komarek *et al*., 2010). If this occurs it could lead to adverse impacts to the health of terrestrial and aquatic ecosystems. According to Aikpokpodion *et al*. (2010), in a situation where higher concentration above the recommended rate of fungicide is used, the unabsorbed copper on the pod surface will eventually get into the soil either by rainfall or when broken pods are left on the farm after removal of beans. Concerns have been raised over the wrong use of copper-based fungicides, which can result in an accumulation of copper in the soil (Wightwick *et al.*, 2008; Komarek *et al.,* 2010). This in turn can have adverse effects on soil organisms (e.g. earthworms, microorganisms) and potentially pose a risk to the long-term fertility of the soil (Wightwick *et al.,* 2008; Komarek *et al.,* 2010). The excessive and irrational consumption of resources has direct negative consequences on the state of the natural capital, which will not be able to fulfill its role as a main provider of economic resources as well as on the economic and social development (Mioara, 2014).

To ensure the sustainability of cocoa production systems, a balance needs to be found between controlling fungal disease risks to cocoa and protecting terrestrial and aquatic ecosystems. The need for production processes to take into account environmental sustainability principles is imperative. However, the complex interrelationships between agricultural production and the natural environment make it extremely difficult to determine which methods and systems in different locations will actually lead to sustainability (Ikerd, 1993). According to Oluyole *et al.* (2013), one of the strategies for increasing agricultural production is a combination of measures designed to increase the level of farm resources as well as make efficient use of the resources already committed to the farm sector. Mioara (2014) opined that the need to increase productivity is specific for numerous reference environments and it is much obvious as it is more correlated with efficiency. Recent studies prove the existence of the compatibility between wealth creation and mitigation of environmental pressure, hence, the concept which ties together the notions of efficiency and sustainability. The strategy allows the balanced at a reduced scale exploitation of environmental factors.

Daramola *et al.* (2003), characterize resources into variable and fixed resources. Variable resources include labour, seeds, fertilizers, pesticides among others, which are normally used up in one production process. Fixed resources are more durable resources, which contribute to the production process over several production periods. These include land, machinery, and farm building, among others. Efficiency measurement is important because it leads to a substantial resource savings (Bravo-Ureta and Rieger, 1991). In the literature of efficiency study, (Reinhard *et al.,* 1999) propose an indicator of environmental efficiency, which is defined as the ratio of minimum feasibility to the observed use of an environmentally detrimental input at a given output level. Environmental efficiency is perceived as a mechanism aiming to reduce the negative impact of human actions on environment while the natural capitalism has the capacity to account for the resources and underline the natural efficiency in order to produce more with less (Hawken and Lovins, 1999). According to Mioara (2014), environmental efficiency (eco-efficiency) aims to identify the products and services which satisfy the human needs and the ongoing increase in life quality, reducing at the same time the impact on environment.

Past studies in economics and applied economics (Obatolu *et al.,* 2003; Adetunji *et al.*, 2007; IITA 2007; Oyekale *et al*., 2009; Nkang *et al.,* 2009; Ajewole *et al.*, 2010; Ajetomobi, 2011; Agom *et al.*, 2012; GAIN Report, 2014 and Taphee *et al.,* 2015) on production, efficiency, processing, marketing, consumption, cost and benefits of cocoa did not account for the effect of fungicide application (environmentally detrimental input) on cocoa production. In this study, copper-based fungicide is treated as an environmentally detrimental input. The effect of wrong use of fungicide on cocoa production as well as how this important agricultural sub-sector has been fairing in terms of conventional input utilization have not been given much consideration in cocoa research. The study is aimed at addressing this knowledge gap by not only considering the effect of the conventional inputs on cocoa production but also the effect of the wrong use of fungicide. Hence, the objective of the study is to determine the environmental efficiency of cocoa farmers in the study area. The following research questions are raised, viz: What proportion of the cocoa farmers use below, exact, and above the quantity of fungicide recommended? What is the average cocoa output for each of these farmers? What is the environmental efficiency of each sampled cocoa farmer in the study area? What are the factors influencing cocoa farmers' environmental efficiency in the study area? The research hypotheses are:

(i) H_0: There is no significant variation in average cocoa output among farmers based on the dosage of fungicide applied.

(ii) H_0: Environmental efficiency of cocoa farmer is not influenced by years of experience of cocoa farmer.

2.0 Theoretical framework and literature review

The study is based on theory of production, production technology set and efficiency model. Economic theory of firm begins with theory of production. Neoclassical production theory is based on the explanation of relationship between inputs and outputs by utilizing the appropriate analytical framework. This relationship is determined by the production technology. The idea is simple: Inputs are converted to outputs via the production process. This transformation is constrained by the production technology. Organizational unit of the neoclassical production theory is the firm. Firms are considered as rational agents, which has some behavioral motivations. Farel *et al.* (1989) shows that the analytical framework that lies under the efficiency measurement can be modified to account for different behavioral assumptions. Decision-makers are presumed to be concerned with the maximization of some measure of achievement such as profit or efficiency.

The standard definition of production function is that it gives the maximum possible output for a given set of inputs. The production function therefore defines a boundary or a frontier. All the production units on the frontier are fully efficient. The concepts of efficiency and productivity are commonly used to replace each other in spite of their different meanings. Productivity can be used as the ratio of output to input of a given firm, whereas efficiency is defined as the ratio of the maximum possible output on the production frontier to a given level of input (Coelli *et al.,* 2005). The estimation of efficiency began with the work of Farrell (1957), who explained the concept of a firm's efficiency considering multiple inputs. According to him, efficiency consists of two components: (i) technical efficiency, which gives the capacity of the firm to achieve highest output with the given level of inputs, and (ii) allocative efficiency, which reveals the capacity of the firm to apply the inputs in optimal quantities at given prices. It focuses on the ability of an economic unit to minimize the cost of production for a given set of input prices by substituting or reallocating inputs and is given by the ratio of cost efficiency to technical efficiency (Graham, 2004).

According to Vensher (2001) a firm is said to be technically efficient when it produces as much output as possible with a given amount of inputs or produces a given output with the minimum possible quantity of inputs. It means that given the firm size and the proper mix of inputs, the maximal output for given inputs under the current technology is achieved. A combination of technical and allocative efficiency presents a measure of economic or cost efficiency (Coelli, 1996a). Farrell (1957) gave an example which shows that a firm cannot be 100% efficient economically if it is not 100% efficient in technical and at the same time 100% efficient in allocative means. More recently, and with the increasing interest in environmental sustainability, another aspect of efficiency, Environmental Efficiency, has emerged.

Environmental Efficiency is defined as the ratio of minimum feasible to observed use of an environmentally detrimental input, conditional on observed levels of the desirable output and the conventional inputs (Reinhard, 1999). It is important to measure environmental efficiency as well as to identify its determinants in order to evaluate existing environmental policies and design new policies.

Various analytical tools have been used in studies to determine environmental efficiency based on Reinhard concept. These are Data Envelopment Analysis (Ramilan *et al.*, 2011; Wossink and Denaux , 2006), Bootstrap Truncated Regression (Skevas *et al.*, 2012), Input distance function (Tamini *et al.*, 2011) and Stochastic frontier approach (Guo and Marchand , 2012; Van Meensel et al., 2010; Hoang and Nguyen, 2013; Kamande, 2010; Kumar and Gupta, 2004; Wu, 2009). According to Coelli *et al.* (2005), the DEA approach can be criticized for not accounting for the possible influence of measurement error and other noise in data while in bootstrap truncated regression a subset of population in a sampling scheme is excluded. The distance function approach is a concept which can be quite difficult to visualize since it involves a function where the dependent variable (the distance) is not observable, and for the simplest example of a multi-input, multi-output technology we must think in a minimum of four dimensions (Coelli and Perelman, 1996). SFA distinguishes the effects of noise from the effects of inefficiency unlike DEA. Also, the necessary assumptions with respect to the environmentally detrimental variables can be tested using SFA. It is however prone to specification error unlike DEA. However, this study considered fungicide application below and above the recommended quantity as the detrimental environmental variable. Also, SFA was adopted in this study because necessary assumptions on the environmental detrimental variable can be tested among other advantages.

3.0 Methodology

3.1 Type and sources of data

The study utilized primary and secondary data. The study was carried out in Ondo State. Ondo State is the leading cocoa producing state in Nigeria (IITA, 2007). It is located in the Southwestern part of the country on latitude 7° 10' N and longitude 5° 05' E. A temperature throughout the year ranges between 21 °C to 29 °C and humidity is relatively high (80 – 85%). The annual rainfall varies from 2,000mm in the southern areas to 1,150mm in the northern areas (http://www.cometonigeria.com/region/south-west/ondo-state/). The rain has a bimodal distribution, with peaks in June and September and a period of lower precipitation in August. December to February constitute a major dry season.

A multistage sampling procedure was employed to select the respondents for the study. Two dominant cocoa producing Local Government Areas (LGAs) namely Idanre and Ile-oluji/Okeigbo LGAs were purposively selected out of the 17 LGAs in the state. The cocoa producing communities sampled in the two LGAs are Opa-arapa, Olanikan, Obajare, Iloro 1, Apomu, Gberiwoju, Owena, Onikokoojiya, Oni-panu, Abojupa, Alagoke, Ifetedo, Araromi, and Kokowu. Fifteenn (15) questionnaires were administered in each of the 14 communities that spread across the two local government areas. Data were collected with the use of structured questionnaire. A total of 210 questionnaires were administered in the study area while 198 were returned to time.

Data were collected on socioeconomic characteristics of cocoa farmers, cocoa output, labour (man-day), variable and fixed items used in production and the quantity of copper based fungicides applied by respondents. Grouping of cocoa farmers into under-utilization of fungicide group, recommended dose of fungicide group and over-utilization of fungicide group was based on information obtained from Cocoa Research Institute of Nigeria (CRIN) that cocoa farmer is expected to use 900g (equivalent of 18 sachets) of copper-based fungicide per hectare.

3.2 Analytical framework of Environmental Efficiency (EE)

The environmental efficiency that this study estimated is different from the conventional technical efficiency. Environmental efficiency is defined as the ratio of minimum feasible to observe use of an environmentally unfavourable input (quantity of fungicide used above or below recommended), based on observed levels of output and the traditional production inputs. The environmental efficiency is calculated from TE with the classical approach of Stochastic Frontier Approach (SFA). Determination of environmental efficiency follows Reinhard (1999) two-step approach. Environmental efficiency is first calculated from TE using SFA. This is followed by regressing environmental efficiency on variables that are not used in the estimation of technical efficiency. Following Reinhard *et al*. (2000) and used by Sowunmi *et al.* (2016) and Marchard and Guo (2014), the non-radial environmental efficiency can formally be defined as:

$$EE_i(x,y) = [min\,\theta : F(X_i, \theta Z_i) \geq y_i] \text{..................................}(1)$$

Where:

y_i is the cocoa output per season, using

X_i of the conventional inputs and

Z_i - the environmentally detrimental input.

F(.) is the best practise frontier with *X* and *Z.*

Technical efficiency was measured using an output-expanding orientation, as the ratio of observed to maximum feasible output, conditional on technology and observed input usage. This is defined as:

$$TE = [max\{\phi : \phi Y \leq F(X, Z\}]^{-1} \text{.................................}(2)$$

In SFA (Aigner *et al.,* 1977, Meeusen and van den Broeck, 1977), inefficiency is modelled by an additional error term with a two-parameter (truncated normal) distribution introduced by Stevenson (1980). A stochastic production frontier is defined by:

$$Y_{it} = f(X_{it}, Z_{it}, \beta, \gamma, \zeta) exp\,\varepsilon_{it} \text{.......................}(3)$$

Where all cocoa farmers are indexed with a subscript *i* and period of data collection indexed with a subscript *t*; Y_{it} denotes the output of cocoa per season; X_{it} is a vector of normal inputs (with X_{it1} is the farm size (ha), X_{it2} the labour (manday), X_{it3} the capital (the depreciation value of fixed input), Z_{it} is a vector of environmentally detrimental input (with Z_{it1} is the fungicide dosage), β, γ, and ζ are parameters to be estimated; V_{it} is a symmetric random error term, independently and identically distributed as $N(0, \sigma_v^2)$, intended to capture the influence of exogenous events beyond the control of cocoa farmers; ε_{it} is a composite error term, U_i, is a nonnegative random error term, independently and identically distributed as $N^+(\mu, \sigma_u^2)$.

$$\varepsilon_{it} = V_{it} - U_i \text{........................}(4)$$

The stochastic version of the output-oriented technical efficiency measure (2) is given by the expression:

$$TE_{it} = \frac{Y_{it}}{Y_{it} = f\left(X_{it}, Z_{it}, \beta, \gamma, \zeta\right) exp(V_{it})} = exp(-Ui) ....(5)$$

Since $U_i \geq 0, 0 \leq exp(U_i) \leq 1$. In order to implement (5), technical inefficiency must be separated from statistical noise in the composed error term (V_{it} - U_i). Battese and Coelli (1992) have proposed the technical efficiency estimator as:

$$TE_{it} = E\left[exp\{-U_i\} | (V_{it} - U_i)\right] ....(6)$$

Within the framework developed by Reinhard (1999), TE is calculated using a standard translog production function as shown in equation (7) (Christensen *et al.* 1971)[1].

One of the advantages of translog production function is that, unlike in case of Cobb-Douglas production function, it does not assume rigid premises such as: perfect or “smooth” substitution between production factors or perfect competition on the production factors market (Klacek, *et al.*, 2007). Translog production function can be used for the second order approximation of a linear-homogenous production, the estimation of the Allen elasticities of substitution, the estimation of the production frontier or the measurement of the total factor productivity dynamics (Pavelescu, 2011).

$$\begin{aligned} ln(Y_{i,t}) = \beta_0 + \sum_{j=1}^{m} \beta_j \, ln\left(X_{i,j,t}\right) + \beta_z \, ln\left(Z_{i,t}\right) + \frac{1}{2} \sum_{j=1}^{m} \sum_{k=1}^{m} \beta_{jk} \, ln\left(X_{ji,t}\right) ln\left(X_{ki,t}\right) \\ + \frac{1}{2} \sum_{j=1}^{m} \beta_{jz} \, ln\left(X_{ji,t}\right) ln\left(Z_{i,t}\right) + \frac{1}{2} \beta_{zz} \, ln\left(Z_{i,t}\right)^2 - U_{i,t} + V_{i,t} ....(7) \end{aligned}$$

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[1] The negative sign is used in order to show that the term $-U_{i,t}$ represents the difference between the most efficient fisherman (on the frontier) and the sampled fishermen.

where i = 1,….., n are total sampled cocoa farmers and k = 1, 2,….., m are the applied traditional inputs; $ln(Y_{i,t})$ is the logarithm of cocoa output i; $ln(X_{ij,t})$ is the logarithm of the j^{th} traditional input applied by the i^{th} individual cocoa farmer; $ln(Z_{i,t})$ is the logarithm of the environmental detrimental input applied by the i^{th} individual; and β_j , β_z, β_{jk}, β_{jz} and β_{zz} are parameters to be estimated[2]. The logarithm of the output of a technically efficient cocoa farmer $Y^F_{i,t}$ with $X_{i,t}$ and $Z_{i,t}$ can be obtained by setting $U_{i,t} = 0$ in Equation 7. However, the logarithm of the output of an environmentally efficient cocoa farmer $Y_{i,t}$ with $X_{i,t}$ and $Z_{i,t}$ is obtained by replacing $Z_{i,t}$ by $Z^F_{i,t}$ where $Z^F_{i,t} = EE_{i,t} * Zi,t$, and setting $U_{i,t} = 0$ in Equation 7 as follows:

$$ln(Y_{i,t}) = \beta_0 + \sum_{j=1}^{m} \beta_j \, ln\left(X_{i,j,t}\right) + \beta_z \, ln\left(Z_{i,t}\right) + \frac{1}{2} \sum_{j=1}^{m} \sum_{k=1}^{m} \beta_{jk} \, ln\left(X_{ji,t}\right) ln\left(X_{ki,t}\right)$$

$$+ \frac{1}{2} \sum_{j=1}^{m} \beta_{jz} \, ln\left(X_{ji,t}\right) ln\left(Z_{i,t}\right) + \frac{1}{2} \beta_{zz} \, ln\left(Z_{i,t}\right)^2 + V_{i,t} \text{..................} (8)$$

The logarithm of EE ($lnEE_{i,t} = lnZ_{i,t}$) can now be calculated by setting equations 7 and 8 equal as follows:

$$\frac{1}{2} \beta_{zz} \left(ln \, EE_{i,t}\right)^2 + \left(ln \, EE_{i,t}\right) \left[\beta_z + \sum_{j=1}^{m} \beta_{jz} \, ln \, X_{ij,t} + \beta_{zz} \, ln \, Z_{i,t} \right] + U_{i,t} = 0 \ldots\ldots (9)$$

By solving Equation 9, $lnEE_{i,t}$ is obtained as shown below:

$$ln \, EE_{i,t} = \left[- \left(\overbrace{\beta_z + \sum_{j=1}^{m} \beta_{jz} \, ln \, X_{ij,t} + \beta_{zz} \, ln \, Z_{i,t}}^{A} \right) \right. \qquad \ldots (10)$$

$$\left. \pm \left\{ \left(\overbrace{\beta_z + \sum_{j=1}^{m} \beta_{jz} \, ln \, X_{ij,t} + \beta_{zz} \, ln \, Z_{i,t}}^{B} \right) - 2\beta_{zz} U_{i,t} \right\}^{0.5} \right] / \beta_{zz}$$

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[2] Similarity conditions are imposed, that is, $\beta_{jk} = \beta_{kj}$.

As mentioned by Reinhard (1999), the output-oriented efficiency was estimated econometrically whereas EE (Equation 5) was calculated from parameter estimates (βz and β_{zz}) and the estimated error component ($U_{i,t}$). Since a technically efficient cocoa farmer ($U_{i,t} = 0$) is not necessarily environmentally efficient ($lnEE_{i,t} = 0$). The sign $+\sqrt{\ }$ is ideal.[3]

3.3 Empirical model for environmental efficiency

Three traditional inputs; farm size (ha), labour (manday) and depreciation value on fixed items (capital) and one environmentally detrimental input (copper-based fungicide) were identified for the production function. The translog production function is shown below:

$$\begin{aligned} Quantity_{k,i,t} = {} & \beta_0 + \beta_1.Farmsize_{k,i,t} + \beta_2.Labour_{k,i,t} + \beta_3.Capital_{k,i,t} + \beta_4.Fungicide_{k,i,t} \\ & + \beta_5.Farmsize^2{}_{k,i,t} + \beta_6.Labour^2{}_{k,i,t} + \beta_7.Capital^2{}_{k,i,t} + \beta_8.Fungicide^2{}_{k,i,t} \\ & + \beta_9.Farmsize_{k,i,t}.Labour_{k,i,t} + \beta_{10}.Farmsize_{k,i,t}.Capital_{k,i,t} \\ & + \beta_{11}.Farmsize_{k,i,t}.Fungicide_{k,i,t} + \beta_{12}.Labour_{k,i,t}.Capital_{k,i,t} \\ & + \beta_{13}.Labour_{k,i,t}.Fungicide_{k,i,t} + \beta_{14}.Capital_{k,i,t}.Fungicide_{k,i,t} - U_{k,i,t} + V_{k,i,t} \text{............} (11) \end{aligned}$$

Where the output is the quantity of cocoa harvested last cropping year, three traditional inputs are the farm size, labour and capital and the environmentally detrimental (copper-based fungicide). Note that all the variables are in natural log. The maximum likelihood estimator was used to estimate TE. The estimators of TE were substituted in equation (10) to obtain environmental efficiency for each cocoa farmer in the study area.

In the second stage of this study, factors influencing environmental efficiency were determined as indicated in equation (12). Following Reinhard (1999) approach, only variables that are not considered in stage one were used as shown in the equation.

The Tobit regression, a hybrid of the discrete and continuous dependent variables, is chosen in order to determine the factors influencing the environmental efficiency of cocoa farmers in the study area. Tobit regression has two main advantages which are (a) its easiness of manipulation, (b) the truncated aspect of the score of efficiency which takes values included between 0 and 1 are taken into account (Ouattara, 2012; Ray 2004). The model is expressed

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[3] The sign in front of the term B should be positive. Thus, if $U_{i,t} = 0$, then $lnEE_{it} = 0$,

below following Tobin (1958);

$$y_i^* = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \varepsilon_i \text{..} (12)$$

$$y_i = 0, if\ y_i^* \leq 0 \text{..} (13)$$

$$y_i = y_i^*\ if\ y_i^* > 0 \text{..} (14)$$

Where:

Y_i^* is the limited dependent variable, which represents the environmental efficiency of each cocoa farmer while Y_i is the observed dependent variable;

X_i is the vector of independent variables (factors influencing environmental efficiency);

X_1 = Age of cocoa farmer (years)

X_2 = Household size of respondent

X_3 = Membership of association (member =1, non-member = 0)

X_4 = Sex (male = 1, female = 0)

X_5 = Distance from home to farm (km)

X_6 = Experience in cocoa farming (years)

X_7 = Price of cocoa per metric ton (₦)

X_8= Educational status of cocoa farmer (educated = 1, not educated = 0)

β_i is a vector of unknown parameters;

ε_i is a disturbance term assumed to be independently and normally distributed with zero mean and constant variance δ^2; and

i = 1, 2,…, n (n is the number of observations = 198).

4.0 Results and Discussion

4.1 Socioeconomic characteristics of respondents

The result in table 1 shows that 59.1% of the respondents were less than 58 years in age. The average age of the respondents was 50.5 years. This implied that majority were within the active economic and productive age. This finding is in line with a similar study conducted by Oguntade *et al*. (2011); where the mean age of cocoa farmers was found to be 49 years. Also, 73 % of the respondents were male; this affirmed the dominance male farmers in cocoa farming. Generally, farming activities are dominated by the male in southwest, Nigeria. Women are mainly involved in processing and marketing of agricultural produce. More than two-third (88.4%) of the respondents were married. The average household size was 6.7. This value is greater than the national average household size of 5.2 (NBS, 2012). While farmers keep large family as a source of farm labour, large family size contributes to high population growth which has been implicated as the bane of economic development in developing countries. According to Amjad (2013), high population growth reduces capital-labour ratio and savings. This is in agreement with the findings of Agom *et al*. (2012) in a similar study where the average household size was 7. In addition, 20.1% of the respondents made use of family labour while 37.7% used both hired and family labour in farming activities such as spraying, weeding and harvesting. Most of the respondents (96%) of used fungicide to control black pod disease on their farms. Also, 31.1% had 10-20 years of experience in cocoa farming while the average farming experience was 29years. This is in line with Amos (2007) that the average year of experience of cocoa farmers in Ondo State was 30.5 years. Respondents' farm size showed that 60.4% of the farmers had 1- 5ha of cocoa farm land while only 4% of the respondents had at least 20ha of cocoa farm. The average cocoa farm size was 5.8 hectares. This implies that cocoa farming in the study area was dominated by small-scale farmers. Furthermore, in terms of cocoa output, 53% of the respondents produced less than 1 metric ton of cocoa beans while average cocoa output per cropping season was 1.84 metric tons. This is relatively small compare to the average cocoa output of more than 2.0 metric tons recorded in a study by Agom *et al.* (2012).

Table 1: Socioeconomic characteristics of respondents

Characteristics	**Parameter**	**Frequency**	**Percentage (%)**
Age (years)	18 – 27	9	4.5
	28 – 37	21	10.6
	38 – 47	52	26.3
	48 – 57	35	17.7
	More than 57	81	40.9
	Mean	50.48 (12.13)	
	Total	**198**	**100**
Gender	Male	151	76.3

	Female	47	23.7
	Total	**198**	**100**
Marital Status	Single	11	5.6
	Married	175	88.4
	Divorced	1	0.5
	Widow	11	5.6
	Total	**198**	**100**
Educational status	Not educated	43	21.7
	Primary	63	31.9
	Secondary	69	34.8
	Tertiary	23	11.6
	Total	**198**	**100**
Household size	1 – 4	62	31.3
	5 – 8	85	42.9
	9 – 11	33	16.7
	12 – 15	11	5.6
	More than 15	7	3.5
	Mean	6.65 (3.72)	
	Total	**198**	**100**
Farming experience (years)	Less than10	21	10.5
	10-20	60	31.1
	21 – 30	36	18
	31 – 40	31	15.5
	41 – 50	36	18.9
	More than 50	14	7
	Mean	28.88 (14.91)	
	Total	**198**	**100**
Farm size (ha)	Less than 1	17	8.6
	1-5	120	60.4
	5.5-10	32	16.1
	10.5-15	11	5.5
	15.5-20	10	5
	Greater than 20	8	4
	Mean	5.88 (7.49)	
	Total	**198**	**100**
Characteristics	**Parameter**	**Frequency**	**Percentage (%)**
Labour	Family labour	40	20.1
	Hired labour	84	42.2
	Family and hired	74	37.7
	Total	**198**	**100**
Cocoa output (metric tons)	Less than 1	106	53
	1 - 4.0	76	39
	4.5 - 9.0	11	5
	9.5 - 15.0	2	1
	15.5 - 18.0	1	1
	More than 18	2	1

	Mean	1.84 (3.36)	
	Total	**198**	**100**
Use of fungicide	Yes	189	96
	No	9	4
	Total	**198**	**100**

Source: Author's compilation. Standard deviation in parenthesis.

4.2 Determination of variation in average cocoa output based on the quantity of fungicide applied by cocoa farmers

The determination of variation in average cocoa output based on the quantity of fungicide used per hectare by cocoa farmers in table 3 shows that there was significant difference in the average cocoa output ($p<0.01$) among cocoa farmers based on the quantity of fungicides applied per hectare of farm land. The average output of cocoa farmers that applied the recommended quantity of fungicide was highest. This shows that application of fungicide above the recommended quantity is not only financial burden to farmers but also reduced cocoa farmers' returns.

Table 3: Analysis of variance result

Source of variation	SS	Df	MS	F	P-value	F crit
Between levels of fungicide used	210.42	2	105.21	10.19	0.000***	3.04
Within levels of fungicide used	2012.79	195	10.32			
Total	2223.21	197				

Source: Result of data Analysis (2015).
Note: *** means significant at 1%,

4.3 Determination of environmental efficiency from Stochastic Frontier Approach model

In order to obtain the environmental efficiency of the cocoa farmers in the study area, the coefficients and the residuals obtained from the stochastic production frontier model were substituted in equation (10). The Maximum likelihood estimate of stochastic production frontier model result is presented in table 4.

Table 4: Maximum Likelihood Estimate of Stochastic Production Frontier Model

Dependent variable: Cocoa output				
			Input elasticities	
	(1)	(2)	(3)	(4)
Variables	**Coefficient estimate**	**Standard error**	**Sample mean**	**Sample median**
Farm size	0.1815***	0.0348	0.1066	0.1079
Labour	0.3498	0.4284	0.0182	0.0203
Capital	0.0781**	0.0378	0.1926	0.1901
Fungicide input	-0.2976	0.2429	0.1983	0.2071
Farm size square	0.0122	0.0253		
Labour square	-0.0317**	0.0149		
Capital square	0.0096	0.0261		
Fungicide square	0.0470***	0.0089		
Farm size*labour	-0.0272	0.0366		
Farm size*capital	-0.0127	0.0381		
Farm size*fungicide	0.0318	0.0204		
Labour*capital	-0.0077	0.0510		
Labour*fungicide	0.0159	0.0170		
Capital*fungicide	-0.0042	0.0281		
Sample size	198			
Sigma squared (δ^2)	0.4299***	0.0539		
Gamma (γ)	0.8332***	0.1200		
Log likelihood	-56.2399			

Source: Result of data analysis (2015). Note: *** means significant at 1%, ** means significant at 5% and * means significant at 10%, ns means not significant.

As indicated in table 4, the estimated sigma squared (δ^2) was significant (p<0.01). This showed the presence of inefficiency effect and random error among cocoa farmers in the study area. The gamma (γ) value was significant (p<0.05). The value showed that 83.3% of the variability in cocoa output by farmers in the study area was explained by their technical inefficiency. The result also indicated that the coefficients of farm size and depreciation value on fixed items significantly affected cocoa production in the study area.

4.5 Elasticity of production and returns to scale.

From the result of stochastic frontier model in table 4, the estimation of environmental efficiency was preceded by ascertaining the theoretical consistency of the estimated efficiency model. The environmental efficiency for the marginal productivity of inputs to be positive as stipulated in microeconomic theory is germane. According to Oludimu, (1987), and Oladeebo and Ambe-Lamidi (2007), the magnitude of elasticity of production is one of the economic concepts of measuring efficiency in resource-use. Since translog functional form does not allow for the direct interpretation of the magnitude and the significance of the individual input elasticity as it is done in constant elasticity Cobb-Douglas case (Sharma and Leung, 1999; Manchard and Guo, 2014), the elasticity of each input (farm size, labour, capital and fungicide input) was calculated at sample mean and median (table 4) using formula[4]. The result shows that all the elasticities are positive at sample mean and median. From the table quantity of cocoa output depends more on capital (depreciation cost) and fungicide input at sample mean.

Estimate of the dependent variable of the model presented in table 4 shows that the coefficients of farm size, labour and capital were positive; indicating that the allocation and utilization of the variables was in the stage of economic relevance of production function(stage II). This is in line with a similar study conducted by Danso-Abbeam *et al*. (2012) in which the research result indicated that farm size among other variables had positive significant effect on cocoa output. According to African Development Bank Group (2011), more than 80% of output growth in agriculture since 1980 comes from expansion of crop area rather than from greater productivity of area already cultivated. Furthermore, the returns to scale at sample mean (0.52) and sample median (0.53) were positive. This suggests that cocoa production in the study area had a positive decreasing return to scale and was in stage II of production process. Hence, the economically productive stage of production. The implication is that each additional unit of the inputs will results in a more increase in the value of cocoa output but not more than the preceding unit. This shows that a rational stage of production occurred among cocoa farmers in the study area. Though, the more the inputs used, the higher will be the value of cocoa at a decreasing rate.

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[4] Following Sharma and Leung (1999) and Manchard and Guo (2014), the elasticities of mean output with respect to the jth input variable are calculated at the mean/median of the log of the input variable and its second order coefficients as follows:

$$\frac{\delta \ln Y}{\delta X_j} = \beta_j + 2.\beta_{jj}\overline{\ln X_j} + \sum_{j \neq k}^{k} \beta_{jk}\overline{\ln X_k}$$

The productivity of cocoa can be improved through the use of right quantity of fungicides on cocoa farms which reduces the negative effects of cupper fungicides in the environment. This will enable cocoa production move to the rational stage (stage II) of the production process. The coefficient of fungicide input was negative but not significant. The result is in consonance with the findings of Guo and Marchand (2012) that inserted surplus nitrogen (N) as an indicator variable that was suspected to negatively affect the environment in organic rice farming in China, it turned out that the estimated value of coefficient obtained had no effect on organic rice farming.

4.6 Analysis of technical efficiency and environmental efficiency of cocoa farmers

The results of technical efficiency and environmental efficiency analysis are presented in Table 5. The fact that technical efficiencies of all sampled cocoa farmers were less than one (1) implies that no farm reached the cocoa production possibility frontier.

Table 5: Distribution of technical efficiency and environmental efficiency

Efficiency Interval	Technical Efficiency	%	Environmental Efficiency	%
0.00 - 0.10	1	0.5	49	7.6
0.11 - 0.20	0	0	15	7.1
0.21 - 0.30	1	0.5	14	6.1
0.31 - 0.40	2	1	12	10.6
0.41 - 0.50	9	4.5	21	11.6
0.51 - 0.60	31	15.7	23	6.8
0.61 - 0.70	34	17.2	13	6.8
0.71 - 0.80	50	25.3	13	11.6
0.81 - 0.90	65	32.8	23	7.6
0.91 - 1.00	5	2.5	15	7.6
Mean	0.728		0.441	
Min	0.08		0.005	
Max	0.948		0.994	

Source: Result of data analysis (2015)

From table 5, the predicted farm specific technical efficiencies ranged between 0.08 and 0.95. The average of technical efficiencies in the study area was 0.73. This indicates that cocoa farmers produced 72.8% of their potential output (on the average), given the current available technology. Thus, in the short run, there is possibility of increasing cocoa production by 27.2% by adopting new technologies and lessening the burden of copper fungicide application in the environment. This finding is consistent with findings from other studies (Amos, 2007; Binam *et al.*, 2008). The average of environmental efficiencies of cocoa farmers in the study area was 0.44. Specifically, the result shows that 43.4% of the respondents had at most environmental efficiency score of 50%. This implies that many of the cocoa farmers were not environmentally efficient. This affirmed that wrong use of copper fungicide constituted environmental burden in terms of sustainability as well as increasing farmers' cost of production. The positively skewed environmental efficiency confirmed that most cocoa farmers had less than 0.44 in environmental efficiency.

Generally, the result shows a very low environmental efficiency scores among cocoa farmers in the study area. The standard error of environmental efficiency (0.026) was higher than that of technical efficiency (0.009). This result suggests that most cocoa farmers are not environmentally efficient in terms of fungicide usage. This implies that higher technical efficiency score does not guarantee high environmental efficiency score (Sowunmi *et al.*, 2016; Guo and Marchand, 2012).

Table 6: Descriptive statistics for technical and environmental efficiencies

Parameter	**Technical Efficiency**	**Environmental Efficiency**
Mean	0.728	0.441
Standard Error	0.009	0.022
Median	0.756	0.442
Mode	0.816	0.098
Standard Deviation	0.137	0.310
Sample Variance	0.019	0.096
Kurtosis	-0.099	-1.327
Skewness	-0.729	0.170

Range	0.703	0.990
Minimum	0.245	0.005
Maximum	0.948	0.994
Sum	144.059	87.292
Count	198	198

Source: Result of data analysis, (2015)

Table 7 shows that there were significant differences in technical and environmental efficiencies among cocoa farmers that used different quantities of fungicide input on their farms. Both technical and environmental efficiencies were significantly different ($p<0.01$). The significant difference in environmental efficiency manifested in the economic and environmental burden of the wrong use of fungicides by cocoa farmers. Cost of production will increase and the sustainability of the environment in terms of supporting agricultural production is threatened.

Table 7: Result of Analysis of variance test for technical and environmental efficiencies.

	Total 198		Under-utilization of fungicide (62)		Recommended dose of fungicide (60)		Over-utilization of fungicide (76)		ANOVA
Parameter	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	P-value
Technical Efficiency	0.724	0.138	0.703	0.119	0.819	0.079	0.669	0.148	0.000***
Environmental Efficiency	0.441	0.310	0.387	0.377	0.597	0.278	0.362	0.219	0.000***

Source: Result of data analysis (2015)

4.7 Factors influencing environmental efficiency among cocoa farmers.

In Tobit regression model, environmental efficiency scores was regressed on socioeconomic characteristics of cocoa farmers and other farm characteristics that were not included in the stochastic frontier model estimation. The diagnostic result showed that the log likelihood value is negative while the significance of likelihood ratio test ($p<0.01$) confirmed the appropriateness of Tobit regression.

The result of the Tobit model shows that the coefficients of four of the independent variables significantly influenced environmental efficiency of cocoa farmers in the study area. The significant variables are household size ($p<0.1$), farming experience ($p<0.01$), price per ton of cocoa ($p<0.05$) and educational status ($p<0.05$). The coefficient of household size showed a negative relationship with environmental efficiency. This implies that environmental efficiency of farmers will probably decrease with an increase in household size. The marginal effect showed that the magnitude of the reduction in environmental efficiency is 20.4%. The coefficient of year of farming experience of cocoa farmers was positive and significant ($p<0.01$). This implies that cocoa farmers tend to be more environmentally efficient as years of farming experience increases. The marginal effect shows that for every unit increase in farmer's year of experience, there is likelihood of increasing environmental efficiency by 18%. This may be attributed to the fact that with passing years in farming, cocoa farmer would have known the negative effect of wrong use of fungicides on their farms. Hence, such farmer strictly adheres to the recommended dose of chemical use.

The price per ton of cocoa has negative relationship with environmental efficiency. The result showed that as price of cocoa increases the probability of environmental efficiency decreases. The marginal effect shows that for every 1% increase in price per metric ton of cocoa, the environmental efficiency is expected to reduce by 38.2%. This may be attributed to the desperation of most cocoa farmers to benefit maximally anytime there is increase in the world price of cocoa. Believing that the more fungicide is applied, the higher its effectiveness on cocoa black pod disease. Moreover, the significance of educational status (0.05) affirmed the importance of education which enables farmers to imbibe new technology and adhere strictly to instructions that are contained in such technology given by cocoa experts; most especially the use of fungicides. This result agrees with Sowunmi *et al.* (2016) that education of farmer increases environmental efficiency.

Although, the pseudo R^2 is not exactly R^2, the value shows that 28.9% variation in environmental efficiency is explained by household size, farming experience and price per metric ton of cocoa.

Table 8: Tobit regression result

Variable	Coefficient	Standard error	P > /t/	dy/dx
Age of farmer	0.2465	0.2269	0.279	0.2465
Household size	-0.2039*	0.1205	0.092	-0.2039
Membership of association	0.0515	0.0507	0.311	0.0515
Gender of farmer	0.0781	0.0580	0.179	0.0781
Distance from home to farm	0.0257	0.0388	0.509	0.0257
Experience in farming	0.1820***	0.0268	0.000	0.1820
Price per metric ton of cocoa	-0.3815**	0.0167	0.024	-0.3815
Educational status	0.0612**	0.0219	0.049	0.0612
Constant	0.4898	0.4037	0.227	
Sigma	0.3242	0.0163		
Number of obs.	198			
LR chi2(8)	47.73***		0.000	
Log likelihood	-58.6152			
Pseudo R^2	0.2894			

Source: Result of data Analysis (2015). Note: *** means significant at 1%** means significant at 5% and * means significant at 10%

5.0 Conclusion

Copper fungicides are widely used in cocoa production systems for the control of black pod disease. The accumulation of copper in surface soils following the wrong use of copper fungicides in particular has been reported in many regions of the world, and there is evidence suggesting adverse effects to earthworms and soil micro-organisms. The low environmental efficiency among cocoa farmers in the application of copper based fungicides in the study area confirmed that it is a burden to the environment (both terrestrial and aquatic) and threat to sustainability of natural capital. This was corroborated by the significant variation in average cocoa output among farmers based on the quantity of fungicide applied to cocoa plantation per hectare. Cocoa farmers that applied fungicide based on the recommended quantity, had the highest average cocoa output. In addition, environmental efficiency was significantly influenced by increase in years of experience of farmers, education, household size and price per ton of cocoa.This suggests the need for human capital development among farmers to enhance fungicide application compliance and environmental sustainability. ,

5.1 Recommendation

Based on the empirical findings, below are the following recommendations;

1. Government should pay more attention in the area of chemical input use (fungicide input) on the farms among cocoa farmers, as wrong use (under-use or over-use) of fungicide input has direct effect on the output of cocoa which in turn affect the incomes generated from cocoa production both locally and internationally.

2. Effective sensitization and training of cocoa farmers on the recommended fungicide application. The resultant impact of under or over-utilization on production and he environment should be well communicated to farmers. .

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