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Full Length Research Paper

Determining the effects of crude oil pollution on crop production using stochastic translog production function in Rivers State, Nigeria

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Effects of crude oil pollution on crop production were determined using stochastic translog production function. Data were collected from 17 local government areas (LGAs) out of 23 LGAs using multistage sampling technique. A total of 296 questionnaires were suitable for analysis. The results showed that the effect of crude oil pollution variables on crop farms reduced the size of farmland (-2.5842), significant at 1%, thereby reducing marginal physical product (MPP) with respect to land by 1.0186 and 1.9016 tons, respectively. They also affected negatively technology inputs, while in non-polluted farms output increased (0.3814 tons). Physical inputs, crude oil pollution variables and their interactions showed strong negative (diminishing) returns to scale in crude oil polluted farms but in non-polluted farms, showed strong positive returns to scale. The technical efficiency results indicated that less than 22% of crop farmers were 81 to 100% efficient in resource use in crude oil polluted farms while in non-polluted farms those with this high efficiency were 33%. Results obtained in this study showed that crude oil pollution on crop farms had negative and detrimental effects on crop output and technical efficiency of resource use in Rivers State, Nigeria.

Key words: Crude oil pollution, stochastic translog production function, crop farms, resource use productivity, technical efficiency, Rivers State, Nigeria.

INTRODUCTION

Crude oil and gas production is the main stay of the Nigeria economy contributing about 90% of the nation's foreign exchange, 80% of total government revenue earning and 25% of the gross domestic product (GDP) (Niger Delta Development Commission, 2006). Crude oil and gas pollution is the major environmental hazard caused by crude oil and gas exploration, exploitation and production in the Niger Delta region of Nigeria and many parts of the world (Ward et al., 2003; Benson and Etesin, 2008; Kuhad and Gupta, 2009; Rashid et al., 2010; Wang et al., 2010). Crude oil and gas pollution can occur in form of spillages due to oil well blowout, corrosion of pipelines, accidental discharges and vandalisation. These oil spillages can lead to underground leakages which have impacts on the environment in the form of underground water pollution (Seitinger et al., 1994), soil pollution (Pernar et al., 2006; Wang et al., 2009; Ikhajiagbe and Anoliefo, 2011), health effect (Chukwu and Lawal, 2010; Jain et al., 2011; Shrivastava, 2011) and destruction of vegetation (Alam et al., 2010). The Niger Delta region occupies the southern tip of Nigeria with the following states; Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo and Rivers States.

Problem of the study

Within Rivers State, oil pollution arising from oil spillages and gas flaring regularly occur (Osuji and Adesiyan, 2005). Therefore, the environment had been destroyed, while the rivers and farmland which the inhabitants rely on for their fishing and farming activities have been rendered unwholesome. This environmental destruction had increased the poverty level of the inhabitants (Benson et al.,2007; Otuya et al., 2008; Patrick–Iwuanyanwum et al., 2011; Onyenekenwa, 2011).

The problem of this study is to determine the effects of crude oil pollution on crop production with special reference to the physical and technological inputs used in crop production using translog stochastic production function approach for analysis. The definition of crude oil and gas pollution in this study embraces oil spillages on crop farms, areas of crop farms occupied by flow stations, oil wells, gas flaring sites, pipeline laying sites, borrow pits and other oil exploration, exploitation and production operations in Rivers State, Nigeria.

Justification of the study

Many researchers have studied the effects of crude oil and gas pollution on crop farms in Nigeria and other parts of the world (Ekundayo et al., 2001; Achuba, 2006; Aade-Ademilua and Mbamalu, 2008; Ibemesim, 2010; Al-Qahtani, 2011).

Ekundayo et al. (2001) studied the effects of crude oil spillage on growth and yield of maize *(Zea mays L.)* in soil of Midwestern Nigeria. Their results showed that in crude oil polluted soils, germination was delayed and the germination percentage was significantly affected by oil pollution. Growth was poor in polluted soils using parameters such as plant height, stem girth, ear height and leaf area at four weeks after planting, leaf area at maturity and average length of primary roots as growth indicators. Grain yield was significantly reduced by as much as 98.6, 96.5 and 58.3% for pre-plant, five weeks after planting and seven weeks after planting treatments, respectively.

Achuba (2006) studied the effect of crude oil contaminated soil at various sublethal concentrations (0.25, 0.5, 1.0 and 2%) on the growth and metabolism of cowpea *(Vigna unguiculata)* seedlings. The results showed that crude oil induced environmental stress in the seedlings. Aade–Ademilua and Mbamalu (2008) investigated the growth and development of French beans (*Phaseolus vulgaris L.* var. Ife Brown) under petrol and diesel – oil polluted water irrigation in Ijora – Lagos, Nigeria. The results showed that the seeds germinated at the same time and rate when compared with the control. The heights of plants treated with the polluted water were significantly higher ($p = 0.05$) than those of the control plants but the former plants had little or no sprawl. There was significant ($p = 0.05$) increase in the growth of treated plants in terms of total area and dry weight during vegetative stage but the growth of the plants decreased significantly ($p = 0.05$) during flowering stage due to early leaf senescence. The study concluded that an overflow of the polluted water on plant vegetation overtime would endanger the growth and development of plants.

Ibemesim (2010) studied the tolerance and sodium ion relations of *Paspalum conjugatum Bergins* (sour grass) to water soluble fractions of crude oil. The results showed that apart from the decrease in tiller numbers, water soluble fraction had no significant ($p > 0.05$) effect on growth parameters of *Paspalum conjugatum*. However, 30% artificial sea water and sea water soluble fraction significantly ($p < 0.05$) decreased tiller numbers, height, shoot moisture content, shoot and root dry weight and mortality. The results further suggested that the polycyclic aromatic hydrocarbons (PAHs) present in water soluble fraction modified the availability, absorption and/or passive uptake of Na^+ in *Paspalum conjugatum.*

Al-Qahtani (2011) carried out an experiment to determine the effects of oil refinery sludge on plant growth and soil properties. The results of the effect of oil refinery sludge on *Vinca rosea (Catharonthus roseus)* and soil chemical composition showed that the dry matter yield decreased significantly with increasing application of sludge and the decrease in yield was significant. Soil salinity and sodicity showed slight increases with the application of oil refinery sludge. Mineral elements of plants such as N and P decreased significantly with the application of oil refinery sludge than in control treatment.

There is dearth of literature on the use of translog stochastic production function in crude oil polluted crop farms in Rivers State, Nigeria. However, some studies related to the current topic exist from other parts of the world (Vlist et al., 2007). Studies relating to the use of stochastic translog production function in agriculture are many and include Chavas and Aliber (1993), Ogundari (2008), Belloumi and Matoussi (2006), Obasi (2005), Maiya et al. (2008), Fleming (2008), Kaream et al. (2008), Baten et al. (2009), Rahman and Rahman (2009), Otitoju and Arene (2010), Oleke and Isinika (2011) and Essilfie et al. (2011). Some authors had also studied the use of physical inputs and technology variables using other functional methods (Latruffe et al., 2005).

Obasi (2005) evaluated the impact of technology on productivity, and identified the factors limiting the use of improved agricultural technologies in Imo State, Nigeria using stochastic translog production function. Results of the analysis of data showed that land and labour had significant negative impact on productivity, while planting materials and fertilizers had significant positive impact on productivity. The results also revealed that there were significant positive interactions between land and labour, land and fixed capital inputs, land and fertilizer, labour and planting materials, labour and fertilizer, fixed capital inputs and fertilizer, and planting materials and fertilizer in Imo State. The study concluded that improved agricultural technologies had significantly impacted on agricultural productivity in Imo State.

Rahman and Rahman (2009) analysed the impact of land fragmentation and ownership of resources on productivity and technical efficiency in rice production in Bangladesh using farm level survey data. The results revealed that land fragmentation has a significant detrimental effect on productivity and efficiency as expected.

The elasticity estimates of land fragmentation revealed that a 1% increase in land fragmentation reduced rice output by 0.05% and efficiency by 0.03%. On the other hand, ownership of key resources (land, family labour and draft animals) significantly increased efficiency. The mean elasticity estimates revealed that a 1% increase in family labour and owned draft animal improved technical efficiency by 0.04 and 0.03%, respectively. Also, a 1% increase in the adoption of modern technology improved efficiency by 0.04%.

Baten et al. (2009) in modeling technical inefficiencies effects in a stochastic frontier production function for panel data observed that stochastic translog production function was more preferable compared to stochastic frontier Cobb-Douglas production function. They observed that there was a negative relationship (interaction) between size and yield. Otitoju and Arene (2010) used translog stochastic frontier model to estimate the determinants of technical efficiency of the soybean farmers in Benue State, Nigeria. The determinants of technical efficiency that were statistically significant were sex, age and experience. Sex and age had inverse relationship with technical inefficiencies of the farmers while experience had a direct relationship.

Objectives of the study

The main objective of the study is to determine the effects of crude oil pollution on crop production using stochastic translog production functions in Rivers State, Nigeria. The specific objectives are to:

(i) Determine the maximum likelihood estimates of physical, crude oil pollution and technology variables in the state, crude oil polluted and non-polluted crop farms in Rivers State, Nigeria.
(ii) Determine the resource productivity estimates in the state, crude oil polluted and non-polluted crop farms in Rivers State, Nigeria.
(iii) Estimate the technical efficiency of individual farm-specific resource use in the study area.
(iv) Suggest policy statements to amend the negative effects of crude oil pollution on crop farms in Rivers State of Nigeria.

MATERIALS AND METHODS

Data collection

This study which was conducted in Rivers State of Nigeria, started on 5th August, 2002 and ended on 28th April, 2003. Rivers State is located in the Niger Delta region of Nigeria. Geographically, the state is located approximately between latitudes 6°E to 7°E and longitudes 4°N and 6°N. The sampling technique used was multi-stage. There was selection of 17 local government areas (LGAs) from a total of 23 LGAs existing in Rivers State, Nigeria and this represented the first stage. The 17 LGAs were selected based on the fact that they were more crop farming oriented than the others.

The second stage focused on the stratification of farmland in a selected LGA into two sampling groups, that is, crude oil polluted and non-crude oil polluted. This stratification of farmland into two sampling groups was used on the ground that information were needed from both crude oil polluted and non-crude oil polluted (non-polluted) areas. The third stage comprised of the random sampling of 10 crop farmers from crude oil polluted areas in a chosen LGA and a corresponding number of 10 crop farmers from non-polluted areas in the same community (locality) in that LGA. This summed to 20 crop farmers interviewed per selected LGA in Rivers State, summing up to 340 questionnaires distributed in these 17 LGAs chosen. Out of the 340 questionnaires distributed, due to difficult terrain, the politicking of oil pollution issues and youth restiveness in the state as at 2003 when the survey was conducted, only 326 questionnaires were retrieved (that is, about 95.9%). Furthermore, 30 questionnaires were found to be inconsistent with the set objectives of the study. Hence, only a total of 296 (about 87.1%) questionnaires were retained as suitable for analysis, with 169 questionnaires been received from the crude oil polluted crop farms and 127 questionnaires from non-polluted crop farms. The unequal weighting in the data analysed arose because most of the discarded and unretrieved questionnaires belonged to the non-polluted farms category.

Stochastic frontier production function

A regression model based on stochastic frontier production function (parametric) was used to measure the effect of crude oil pollution on crop production and technical efficiency of resource use among crop farmers on the state, crude oil polluted and non-polluted farmland. The stochastic frontier production function is stated as (Battese, 1992; Udoh, 2000; Key and McBride, 2003):

$$Y = f(X, P, T, \beta)\, e^{(vi-ui)},\ i = 1, 2, \ldots, N \qquad (1)$$

where, Y = crop output (in tones); X = vector of physical inputs used (land area cultivated in hectares; available family and hired labour in man days; fixed and operating capital in dollars); P = vector of impact of crude oil pollution index; T = vector of level of technology index; β = vector of parameters to be estimated; vi = random error due to misspecification of the model; -ui = ratio of actual value to maximum possible output, that is, inefficiency components of error terms; F(.) = the suitable function (in this study, translog function).

The stochastic frontier production function given in Equation (1) is estimated for the state and crude oil polluted farms only, while the estimation of non-oil polluted farms did not include the P variables. To capture the negative effects of crude oil pollution on farmland polluted, the impact of crude oil pollution index was estimated following the methods of Udo and Fayemi (1975), Mubana (1978), and Canter and Hill (1979). This is expressed as follows:

$$P = \frac{\sum_{i=1}^{n} \left[\frac{q_{2i}}{q_1} X_i \right]}{n} \qquad (2)$$

where, P = impact of crude oil pollution index; q_{2i} = land area affected by crude oil pollution; indicating the farm's degree of crude oil pollution (ha); q_1 = total land area cultivated (ha); X_i = percentage of crop yield (crop output) foregone due to oil pollution (where, i = degrees of pollution: 93 to 100%, 31 to 92% and 0 to 30%); n = type of crude oil pollution affecting in individual farm: ni = heavy oil pollution and/or acquired land; n_2 = medium oil pollution; n_3 = light oil pollution.

The types of negative effects of oil pollution were categorized as follows:

Category A (n_1): (i) Heavy oil spillage which lead to 93 to 100% crop yield (output) loss. (ii) Acquired land for oil well-head sites, flow stations, drilling sites, oil field locations, borrow pits, gas flaring sites, pipeline laying operations and other oil related activities which leads to 100% crop output loss (Udo and Fayemi, 1975; Mubana, 1978).

Category B (n_2): medium oil spillage which leads to 31 to 92% crop yield (output) reduction.

Category C (n_3): Light oil spillage which leads to 0 to 30% crop yield (output) reduction.

The level of technology index was captured using a modified chain index method by Harper (1971) and Mubana (1978). It is expressed mathematically as

$$T = \frac{\sum_{i=1}^{n} \left(\frac{\alpha_{2i}}{\alpha_{1i}} . 100 \right)}{k} \tag{3}$$

where, T = level of technology index; α_{2i} = quantity of each technology type used in current yeat t, (2003) measured in bags of fertilizers, pockets of pesticides, number of implements purchased, improved seeds, machinery hired and seed dressing. These inputs were converted into percentage before the summation; α_{1i} = Quantity of each technology type used in year t = l, (2002) measured as above. i = 1, 2, …. 296. k = number of types of technology adopted by the farmer in t, (2003) and t – l years (2002). The types of technology used include fertilizers, pesticides, implements purchased, improved seeds, machinery hired and seed Dressing.

Measurement of technical efficiency of resource use

The measurement of farm level technical efficiency, e^{-u} requires first the equation of the non-negative error u, that is, decomposition of E into its two index components, u and v. The technique of into its two index components, u and v. The technique of decomposition as suggested by Jondrow et al. (1982) involves the conditional distribution of u given ε expressed as

$$E\,(u/\varepsilon i) = \sigma^* \left(\frac{f^*\ (\varepsilon_i\ \lambda/\sigma)}{1 - F\,(\varepsilon_i\ \lambda/\sigma)} - \left\{ \frac{\varepsilon_i d}{\sigma} \right\} \right) \tag{4}$$

where, $\sigma^* = \sigma u \,.\, \sigma v / \sigma$ or f (.) – u $\equiv$ Y – u; ε_i = u + v; σ = standard deviation of the total error term. $\lambda = \sigma u / \sigma v$; f* (.) = the standard normal density function (PDF); F (.) = the standard distribution function (C D F)

The population average technical efficiency is given as:

$$E\,(e^{-u}) = 2e^{\sigma 2u/2}\ [\ I - F\ (\sigma u)\ ] \tag{5}$$

where, F = the standard normal distribution function. It should be noted that by taking the natural logarithm of –u, the farm specific resource use efficiency index is measured and I – e^{-u} will give resource use technical inefficiency.

Stochastic translog production function

Implicitly, an unrestricted transcendental logarithmic (translog) production function which is general, flexible and allows analysis of interactions among variables was estimated. This was in line with the studies of Christensen et al. (1973), Ali (1996), Baten et al. (2009) and Otitoju and Arene (2010). However, it is necessary to note that the estimates of translog may be invalid because of the violation of regularity conditions at extreme sample value of the inclusion of the second – order terms, especially in small samples. But in this study, the problem is partially solved with the large total sample size (N = 296) with high degrees of freedom. Also at the subgroup level (crude oil polluted and non – polluted farms), the samples are still large at n = 169 and 127 respectively, therefore the problem of small sample does not exist.

The general form of stochastic translog production function is:

$$\begin{aligned} \ln Y_J = {} & \alpha_0 + \sum_{i=1}^{n} a_i \ln X_{ij} + ½ \sum_{i=1}^{n} \sum_{g=1}^{n} b_{ig} (\ln X_{ij} \ln X_{ij}) + \sum_{k=1}^{m} c_k \ln P_{kj} + \sum_{t=1}^{p} d_t \ln T_{tj} \\ & + \sum_{i=1}^{n} b_{ii} (\ln X_{ii})^2 + ½ \sum_{i=1}^{n} \sum_{k=1}^{m} e_{ik} (\ln X_{ij} \ln P_{kj}) + ½ \sum_{i=1}^{n} \sum_{t=1}^{p} f_{it} (\ln X_{ij} \ln T_{tj}) \\ & + ½ \sum_{k=1}^{m} \sum_{k=1}^{m} h_{kk} (\ln P_{kj}\ \ln P_{kj}) + ½ \sum_{k=1}^{m} \sum_{k=1}^{p} r_{kt} (\ln P_{kj} \ln T_{tj}) + ½ \sum_{t=1}^{p} \sum_{t=1}^{p} s_{tt} (\ln T_{tj} \ln T_{tj}) \\ & - u_j + v_i \end{aligned} \tag{6}$$

where, j = 1, 2 …….. 296 for all farms, 169 (for the crude oil polluted crop farms) and 127 (for non-polluted crop farms); i, g = 1, 2, 3 are physical inputs; Y, X, P, T, v, u are as previously defined.

The definitions of other variables are as follows:

ln = logarithmic sign,
α = parameter of intercept (constant),
a_i = parameter of physical inputs used,
b_{ig} = parameters of interaction across ith and gth physical inputs,
c_k = parameters of crude oil pollution variables in indices,
d_t = parameters of level of technology variables in indices,
b_{ii} = parameters for squared terms of physical inputs,
e_{ik} = parameters for interaction between physical inputs and oil pollution variables,
f_{it} = parameters for interaction between physical inputs and technology variables,
h_{kk} = parameters for interaction among oil pollution variables,
r_{kt} = parameters for interactions between oil pollution and technology variables,
s_{tt} = parameters for interaction across technology variables.

It needs to be stated that Xi and T are conventional physical and technology variables normally considered in transformation process. But P is conditioning variables whose inclusion into the model was to capture the negative effects of crude oil pollution on the value of crops outputs. The list of factors responsible for production may not be exhaustible and the categorization of the factor may also not be generalized. However, to quantify how crude oil spillage and pollution affect crop output, this study had built upon these three sets of variables.

The parameters (β_i) of Equations (1) and (4), and the density function of vi and ui are estimated by maximizing the log-likelihood function given as:

$$\ln Q = {}^{N}/_{2} \ln ({}^{2}/_{\Pi}) - N \ln \sigma + \sum_{i=1}^{N} \ln \left[1 - F\left\{ \frac{\varepsilon i \lambda}{\sigma} \right\} \right] - \frac{1}{2}\sigma^2 \sum_{i=1}^{N} \varepsilon i^2 \quad (7)$$

where, N = the number of observations (296) crop farms; σ = the standard deviation of the total error term; $\lambda = \sigma u / \sigma v$; F (.) the standard distribution; εi = component error term; $\pi = 3.1415$

Measurement of productivity

The production elasticities of the variable physical inputs (land, labour and capital) were estimated by taking the first partial derivative of Equation (6) with respect to each input, and evaluating them at farm specific input use.

The farm specific productivities (MPi) were estimated as farm specific elasticities multiplied by farm – specific average output, approximated as (Yi / Xi) (Ali, 1996; Udoh, 2000). Generally, for finite level of Xi input, MPi can be positive for a range of values of Xi, but can be negative if $b_{ij} > 0$.

RESULTS

The results of the maximum likelihood estimation (MLE) for stochastic translog production function in Rivers State, in crude oil polluted and non – polluted crop farms are given in Table 1.

Physical inputs (a_i)

The coefficient of (β_1) land in Rivers State was -1.2039, crude oil polluted crop farms was – 2.5842, which were statistically significant at 1% and were negatively correlated to expectation. In non- polluted crop farms it was 0.4025, though not statistically significant but positively correlated as expected.

Crude oil pollution index (ai)

The crude oil pollution index in Rivers State was -1.9575, significant at 10%, in crude oil polluted farms, it was -7.0463 and was statistically significant at 1%.

Crude oil pollution variables (c_k)

The coefficient of farmland acquired for flow station (β_6), was -0.1813 in Rivers State, in crude oil polluted farms it was -0.3023, both statistically significant at 1% respectively. The coefficient of farmland acquired for digging borrow pits (β_8) was 0.2864 in Rivers State, in crude oil polluted farms it was -0.3969 both statistically significant at 1% level. Coefficient of farmland acquired for pipeline laying (β_9) was -0.1116 which was not statistically significant in crude oil polluted farms but was 0.2340 and statistically significant at 1% in all farms in Rivers State. The coefficient of farmland acquired by oil companies for gas flaring (β_{10}) was -0.1893 which was statistically significant at 5% in crude oil polluted farms and was -0.1035 though not statistically significant in Rivers State. Heavy oil pollution (β_{11}) on crop farms had -0.7664 in crude oil polluted farms and -0.5883 in Rivers State, both statistically significant at 1% respectively. The coefficient for heavy crude oil spillage (β_{12}) on crop farms was -3.9917 which was statistically significant at 5% in crude oil polluted farms, and was 0.1728 in Rivers State though not statistically significant. The estimated coefficient for medium crude oil spillage on crop farms (β_{13}) in crude oil polluted farms was 5.6217, while in Rivers State it was 1.8029, both statistically significant at 5 and 1% respectively. The estimated coefficient of light crude oil spillage on crop farms (β_{14}) was 5.9032, statistically significant at 5%, in crude oil polluted crop farms. Surprisingly most coefficients obtained in degrees of spillage had positive signs instead of the expected negative correlation.

Technology variables (d_t)

The coefficients of fertilizer usage (β_{15}) in Rivers State were 2.5817, in crude oil polluted crop farms it was 7.4792, and in non-polluted farms it was 2.7707 all statistically significant at 1 and 5% respectively. Estimated coefficients of the quality of improved seeds used by crop farmers (β_{17}) was -0.4460; it was -1.0485 in crude oil polluted farms, level and -2.1943 in non-polluted farms all statistically significant at 5 and 1% respectively.

Interactions among physical inputs (b_{ig})

The coefficient of interactions between land and labour (β_{22}) was 0.0849, in Rivers State, 0.1425 in crude oil polluted farms and 0.2190 in non-polluted farms, all statistically significant at 5%. Coefficients of the interaction terms of land and capital (β_{23}) in crude oil polluted farms was 0.2537 and -0.1410 in non-polluted farms which were statistically significant at 1 and 5% levels respectively. The interaction terms of labour and capital (β_{24}) had coefficient of -0.0810 in Rivers State while in non-polluted farms, it was -0.2113, both statistically significant at 1% level respectively.

Interaction between physical inputs and crude oil pollution variables (e_{ik})

Coefficient of the interaction terms of land and medium oil spillage (β_{26}) was -1.2512, in crude oil polluted farms and

Table 1. Maximum likelihood estimates of stochastic translog production frontier function in crude oil polluted and non polluted crop farms in Rivers State, Nigeria.

Variable	Parameter	Rivers State farms translog MLE		Crude oil polluted translog MLE		Non-polluted translog MLE	
		Coefficient value	Standard error (S.E.)	Coefficient value	Standard error (S.E.)	Coefficient value	Standard error (S.E.)
Constant	α_0	1.7234	1.9549	7.3777***	2.6911	9.3684**	3.9078
Physical inputs (a_i)							
Land (ha)	β_1	-1.2039***	0.3445	-2.5842***	0.4705	0.4025	0.6496
Labour (mandays)	β_2	0.4271	0.3840	0.2421	0.5254	0.0089	0.7888
Capital (s)	β_3	0.9786***	0.3654	0.1447	0.4945	0.7314	0.6348
Indexes (a_i)							
Technology index	β_4	0.0481	0.1500	0.2202	0.1912	-0.0477	0.3139
Crude oil pollution index	β_5	-1.9575*	1.0362	-7.0463***	2.4783		
Crude oil pollution variables (c_k)							
Farmland acquired for:							
Flow station	β_6	-0.1813***	0.0548	-0.3023***	0.0926		
Oil well	β_7	0.1174*	0.0733	-0.2261	0.1660		
Borrow pits	β_8	-0.2864***	0.0844	-0.3969***	0.1275		
Pipelines laying	β_9	-0.2340***	0.0447	-0.1116	0.7108		
Gas flaring	β_{10}	0.1035	0.0661	-0.1893**	0.0815		
Heavy pollution	β_{11}	-0.5883***	0.1227	-0.7664***	0.2239		
Degrees of spillage							
Heavy crude oil spillage	β_{12}	0.1728	0.7292	-3.9917**	1.9827		
Medium crude oil spillage	β_{13}	1.8029***	0.5748	5.6217**	2.6263		
Light crude oil spillage	β_{14}	0.2992	0.5464	5.9032**	2.4879		
Technology variables (d_k)							
Fertilizers	β_{15}	2.5817***	0.5728	7.4792***	1.1187	2.7707**	1.1673
Pesticides	β_{16}	0.1387	0.3918	-1.7509	1.2527	2.6939	0.8164
Improved seeds	β_{17}	-0.4460**	0.2042	-1.0485***	0.2760	-2.1943***	0.6526
Implements purchased	β_{18}	0.4293	0.3733	-0.3957	0.4848	0.4928	0.9923
Squared terms (b_{ii})							
Land x Land	β_{19}	0.1592***	0.0322	-0.0926	0.0580	0.0514	0.0736
Labour x Labour	β_{20}	0.0007	0.0276	-0.1124***	0.0425	0.1502***	0.0587
Capital x Capital	β_{21}	-0.0351	0.0204	-0.0401	0.0287	0.1143***	0.0348

Table 1. Contd.

Interactions across inputs (b_{ig})							
Land x Labour	β_{22}	0.0849**	0.0396	0.1425**	0.0668	0.2190**	0.0910
Land x Capital	β_{23}	0.0098	0.0292	0.2537***	0.0436	-0.1410**	0.0704
Labour x Capital	β_{24}	0.0810***	0.0295	-0.0332	0.0511	-0.2113***	0.0579
Interaction of physical inputs and crude oil pollution variables (e_{ik})							
Land x Heavy oil spillage	B_{25}	-0.0053	0.0730	-0.2553	0.1605		
Land x Medium oil spillage	β_{26}	-0.3091***	0.0881	-1.2572***	0.3409		
Land x Light oil spillage	β_{27}	-0.1586**	0.0764	-1.0273**	0.4937		
Interaction of physical inputs and technology variables (f_{ik})							
Land x Fertilizers	β_{28}	0.3086***	0.0616	0.3630***	0.1098	0.0585	0.1280
Land x Improved seeds	β_{29}	-0.1537***	0.0248	-0.0579	0.0482	-0.2405***	0.0581
Labour x Fertilizers	β_{30}	-0.0889***	0.0497	-0.2831***	0.0999	0.0674	0.0795
Labour x Improved seeds	β_{31}	0.0595***	0.0242	-0.0406	0.0421	0.0984*	0.0579
Labour x Implements purchased	β_{32}	-0.1382***	0.0291	-0.1713***	0.0562	0.0593	0.0644
Capital x Fertilizers	β_{33}	-0.1394***	0.0562	-0.5525***	0.1038	0.1048	0.0950
Capital x Improved seeds	β_{34}	0.0581***	0.0170	0.1524***	0.0277	0.1968***	0.0509
Interactions across crude oil pollution variables (h_{kk})							
Heavy oil spillage x Medium oil spillage	β_{35}	0.2404	0.1830	-1.2444*	0.7091		
Heavy oil spillage x Light oil spillage	β_{36}	-0.1236	0.1618	-1.0420*	0.6468		
Medium oil spillage x Light oil spillage	β_{37}	-0.0584	0.0410	-0.3260**	0.1531		
Interaction between crude oil pollution and technology variables (r_{kt})							
Heavy oil spillage x fertilizers	β_{38}	-0.2022**	0.0932	-0.8051***	0.2240		
Medium oil spillage x fertilizer	β_{39}	-0.0608*	0.0369	-0.5861***	0.2103		
Light oil spillages x fertilizer	β_{40}	-0.1012*	0.0561	-0.7292*	0.3895		
Pollution index x Technology index	β_{41}	0.0242**	0.0105	-0.0008	0.0186		
Interaction across technology variables (s_{tt})							
Fertilizers x Improved seeds	β_{42}	-0.0721**	0.0317	-0.1026*	0.0619	0.0445	0.0618
Improved seeds x Implements purchased	β43	0.0751***	0.0210	0.1366***	0.0367	0.2372***	0.0619
Fertilizers x pesticides	β44	0.1586***	0.0414	0.4443***	0.0888	0.1438*	0.0754
Pesticides x improved seeds	β_{45}	0.0500***	0.0172	0.6557***	0.0021	0.0596	0.0417
δ		0.9062	-	0.8625	-	0.99997	-
λ		2.5041***	0.3601	3.1091***	0.9499	190.6337	698.571

Table 1. Contd.

σ	0.8204***	0.0287	0.6214***	0.0301	0.8834***	0.0281
σu^2	0.58053	-	0.34993	-	0.78038	-
σv^2	0.09258	-	0.03620	-	0.00002	-
log likelihood function	-2104.1920	-	-658.2523	-	-733.2056	-

Source: Field survey, 2003; ***, **, * indicates significant levels at 1%, 5% and 10%, respectively.

-0.3091 in Rivers State, both statistically significant at 1% respectively. The land and light crude oil spillage interaction terms coefficient (β_{27}) in Rivers State, was 0.1586 and in crude oil polluted farms it was -1.0273, both statistically significant at 5% level.

Interaction of physical input and technological variables (f_{it})

The interaction between land and fertilizer variables (β_{28}) was 0.3086 in Rivers State, 0.3630 in crude oil polluted farms and was both statistically significant at 1% level. The interactions between land and improved seeds (β_{29}) had coefficients of -0.1537 and -0.2405 in Rivers State and in non-polluted farms, respectively, which were both statistically significant at 1% level.

Interaction between crude oil pollution and technology variables (r_{kt})

The interactions between heavy crude oil spillage and fertilizers usage (β_{38}) in Rivers State was -0.2022, in crude oil polluted farms the coefficient was -0.8051, both significant statistically at 5 and 1% levels respectively.

Coefficient of the interactions between medium crude oil spillage and fertilizers usage on crop farms (β_{39}) in Rivers State was -0.0608 and, in crude oil polluted farm it was -0.5861, both significant statistically at 1%. The coefficient of the interaction between light crude oil spillage and fertilizers usage on crop farms (β_{40}) in crude oil polluted farms was -0.7292, and in Rivers State it was -0.1012, both statistically significant at 10% respectively.

Interaction across technology variables (s_{tt})

The interaction between fertilizers usage and improved seeds (β_{42}) had a coefficient of -0.0721 in the state, significant at 5%, -0.1026, in crude oil polluted farms, statistically significant at 10%. Interactions between fertilizers and pesticides usage (β_{44}) in Rivers State was 0.1586, in crude oil polluted farms it had inelastic coefficient of 0.4443, and 0.1438 in non – polluted farms, statistically significant at 1 and 10% respectively.

Coefficient of interactions between pesticides and improved seeds (β_{45}) was 0.0500 in Rivers State; it was 0.0557 in crude oil polluted farms, both statistically significant at 1%.

Distribution of stochastic translog production elasticities among the variables

The coefficient values estimated in Table 1 are sometimes interpreted as the elasticities of output values with respect to the inputs at the data point as in Table 2. Table 2 shows the distribution of stochastic translog production elasticities among variables in the study area.

The sum of elasticities of output with respect to conventional (physical) inputs used in crop production gave an estimated scale elasticity of 0.2018, with respect to oil pollution variables it was -1.1935, technology variables gave 2.2518 and interaction terms had -1.1848 in all farms surveyed in Rivers State, Nigeria. The sum of elasticities of output with respect to physical inputs used in crop production in crude oil polluted crop farms was -2.1974, oil pollution variables had -1.2825, technology variables had -1.2825, technology variables had 4.5044 and interaction terms were estimated as -4.9927. The total estimated values for crude oil polluted farms were-3.9682 and 0.5753 in all farms surveyed in the state. The sum of elasticities of output with respect to physical inputs in non polluted crop farms was 1.1428, with respect to technology variables it was 1.7154, interaction terms had 0.8424 and the total estimated values was 3.7006.

Resource – use productivity of crop farmers

Having estimated the elasticities of output with respect to the physical inputs, it becomes necessary to evaluate their resource – use productivities. This is done by estimating the marginal and average physical productivities of the physical (conventional) inputs used by the crop farmers in Rivers State, Nigeria. Table 3 presents the resource –use productivities and their

Table 2. Distribution of production elasticities among variables in the study area.

S/N	Sets of variable	Estimated values	Remark
	Rivers state farms		
1	Physical inputs	0.2018	SR – Decreasing positive returns to scale
2	Crude oil pollution	-1.1935	SR – Decreasing negative returns to scale
3	Technology	2.7518	SR – Increasing returns to scale
4	Interaction terms	-1.1848	SR – Decreasing negative returns to scale
	Total estimated values	0.5753	SR – Decreasing positive returns to scale
	Crude oil polluted farms		
1	Physical inputs	-2.1974	SR – Decreasing negative returns to scale
2	Oil pollution	-1.2825	SR – Decreasing negative returns to scale
3	Technology	4.5044	SR – Increasing returns to scale
4	Interaction terms	-4.9927	SR – Decreasing negative returns
	Total estimated values	-3.9682	SR – Deceasing negative returns to scale.
	Non polluted farms		
1	Physical inputs	1.1428	SR-Increasing returns to scale
2	Technology	1.7154	SR – Increasing returns to scale
3	Interaction terms	0.8424	SR – Decreasing positive returns to scale
	Total estimated values	3.07006	SR – Increasing returns to scale

Source: Computed from MLE values in Table 1.

respective values in all crop farms surveyed, crude oil polluted crop farms and non-polluted crop farms respectively. Table 3 shows that the marginal physical productivity (MPP) of land was -10186 in farms surveyed in Rivers State, Nigeria, while the average physical productivity (APP) was 0.8461. The MPP and APP obtained for labour were 0.002 and 0.0047 respectively in all farms surveyed. The resource use productivity estimates of capital showed MPP was 0.0218 and APP was 0.0223 respectively.

In crude oil polluted farms, the resource use productivity estimate of land gave the result of MPP as -1.9016 and APP as 0.7359. With respect to labour, the estimated values of MPP were 0.9617E-03 and 0.3973E-02 for APP. The resource use productivity estimate with respect to capital for MPP was 0.0024 and 0.0165 for APP.

The resource use productivity in non-polluted crop farms with respect to land showed the marginal physical products (MPP) estimate to be 0.3814 and the average physical products (APP) to be 0.9475 as shown in Table 3. With respect to labour, the MPP was 0.4834E-04 and 0.0054 for APP, while the resource use productivity in relation to capital was 0.0189 for MPP and 0.0259 for APP respectively.

Technical efficiency of resource use among crop farmers

The level of technical efficiency of each individual farm, e^{-ui} was estimated using the one sided error component ui from Equation (4). Instead of presenting the technical efficiency for every individual farm, the frequency distribution of these efficiencies for all types of farms studied is presented in Table 4. These results showed a wide variation in the level of technical efficiencies across all farms studied in Rivers State,

Nigeria, crude oil polluted crop farms and non-polluted crop farms respectively. The average (population) technical efficiency and its indices were also calculated in Table 4.

The table demonstrates that 8.78% of the farmers had technical efficiency levels between 0.81 and 0.90; 25% of the farmers had technical efficiency indices level between 0.71 and 0.80, while 19.93% had between 0.61 and 0.70. The average technical efficiency of resource use in all farms studied in Rivers State was 0.6082; minimum level of technical efficiency calculated was 0.0887, while maximum level was 0.9034 in all farms surveyed.

Table 4 also shows that only one farmer had a technical efficiency indices level between 0.91 and 1.00, about 21.30% of the farms had technical efficiency level between 0.81 and 0.90, while 30.77% had technical efficiency interval of 0.71 -0.80 respectively in crude oil polluted crop farms. The average technical efficiency calculated was 0.5859; minimum level of technical efficiency obtained was 0.1328 while the maximum technical efficiency obtained was 0.9284.

In non-polluted crop farms, 25.98% of the farmers had technical efficiency within the indices of 0.91 to 1.00; 7.87% were technically efficient at the interval of 0.81 to

Table 3. The resource use productivity estimates in the study area.

Resources	Elasticity	Average unit	MPP	APP
Land (ha)	-1.2039	1.54	-1.0186	0.8461
Labour (mandays)	0.4271	275.0	0.002	0.0047
Capital ($)	0.9786	58.40	0.0218	0.0223
Average output per ha (ton)	-	1.3030	-	-
Crude oil polluted farms				
Land (ha)	-2.5842	1.45	-1.9016	0.7359
Labour (mandays)	0.2421	268.59	0.9617E-03	0.3973E-02
Capital ($)	0.1447	64.62	0.0024	0.0165
Average output/ha (ton)	-	1.0670	-	-
Non-polluted farms				
Land (ha)	0.425	1.60	0.3814	0.9475
Labour (mandays)	0.0089	279.10	0.4834E-04	0.0054
Capital ($)	0.7314	58.59	0.0189	0.0259
Average output per ha (ton)	-	1.5160	-	-

Source: Computed from stochastic translog MLE results in Table 1.

0.90 and 4.72% were technically efficient within the range of 0.71 to 0.80. The average technical efficiency was 0.6637; minimum level of technical efficiency obtained was 0.0967, while the highest level of technical efficiency in non-polluted farms was 0.9913.

DISCUSSION

Distribution of stochastic translog production elasticities among the variables

In all crop farms surveyed in Rivers State, Nigeria, the sum of elasticities of output with respect to physical (conventional) inputs used for crop production was 0.2018 which signified the presence of short run (SR) decreasing positive returns to scale as shown in Table 2. The diminishing (decreasing) positive returns to scale meant that each additional unit of physical input used in crop production resulted in a smaller increase in output compared to the preceding unit. The sum of elasticities of out put with respect to crude oil pollution variables (- 1. 1935), indicated short run (SR) decreasing negative returns to scale. The sum of elasticities of output with respect to technology variables (2.7518) indicated the presence of short run increasing returns to scale. This means that each additional unit of input used resulted in 2.8 units of increase in output produced than the preceding unit used in the state. This means that there was still room to increase crop production by applying more technological inputs, which further implied that a good number of the crop farmers sampled in the state were zero technological inputs users.

There was a short run decreasing negative returns to scale (-1.1848) estimated with respect to the sum of elasticities of output with respect to interaction terms in the state. This could be due to the negative effects of crude oil pollution variables on most production variables considered in this study as shown in Table 1. This indicated that the continuous pollution of crop farms by crude oil reduced the farm output by 1.2 units. This result confirmed the results of Ekundayo et al. (2001) and Al-Qahtani (2011). Total estimated value of production elasticities among the various variables in all farms surveyed in Rivers State, Nigeria, 0.5753, showed the presence of decreasing positive returns to scale in the short run. This brought the stage of production to stage II, where the marginal product is more than zero.

Table 2 also presents the distribution of stochastic translog production elasticities among variables used in crude oil polluted crop farms in Rivers State, Nigeria. The table showed a strong negative (decreasing) returns to scale in the physical inputs (-2.1974) used in production. This simply means that even if additional inputs were added into production, the output of the farm will decrease rather than increase. This confirmed the negative effects of crude oil exploration, exploitation and production activities. The result confirmed the results of Aade-Ademilua and Mbamalu (2008) and Wang et al. (2009).

From Table 1, it was observed that while the coefficients of labour and capital was positive (though not significant), the coefficient of land was negative and significant at 1%. This goes to say that crude oil pollution has a direct negative effect on reduction of size of farmland available, thereby affecting the output of the

Table 4. Frequency distribution of individual farm-specific resource use efficiency indices in Rivers State.

Class interval of technical efficiency indices	Rivers State farms		Crude oil polluted		Non-polluted	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
0.01 - 0.10	1	0.34	1	0.59	1	0.79
0.11 - 0.20	5	1.69	1	0.59	14	11.02
0.21 - 0.30	25	8.45	7	4.14	12	9.45
0.31 - 0.40	23	7.77	8	4.73	10	7.87
0.41 - 0.50	42	14.19	15	8.88	12	9.45
0.51 - 0.60	41	13.85	23	13.61	17	13.39
0.61 - 0.70	59	19.93	25	14.79	12	9.45
0.71 - 0.80	74	25.00	52	30.77	6	4.72
0.81 - 0.90	26	8.78	36	21.30	10	7.87
0.91 - 1.00	0	0	1	0.59	33	25.78
Total	296	100	169	100	127	100
Average technical efficiency indices						
Average technical efficiency	0.6082		0.5859		0.6637	
ATE standard deviation	0.2895		0.1850		0.1749	
Minimum value	0.0887		0.1328		0.0967	
Maximum value	0.9034		0.9284		0.9913	
Skewness	0.5265		-0.9381		-0.0610	
Kurtosis	2.2801		3.2206		1.6543	
C.V. %	47.60		31.58		26.35	

Source: Computed from Equation (4).

farm (Achuba, 2006; Pernar et al., 2006). However, it is important to note that land is a principal input in crop farming in Rivers State, Nigeria, therefore its reduction means, reduction of output.

Table 2 further showed that the sum of production elasticities of output with respect to crude oil pollution variables was -1.2825 and interaction terms (-4.9927) which indicated the presence of short run decreasing negative returns to scale in all cases. However, the sum of elasticities of output with respect to technology variables used gave strong increasing returns to scale (4.5044), meaning that if more technological inputs were employed by the farmers, output could increase for more than four times in every unit of extra technology input used.

These results go to confirm the fact that crude oil pollution variables negatively affected the other variables they interacted with, thereby causing reduction in output. This could be so because further addition of production inputs was not necessary as crop farms had either been completely acquired for exploration, exploitation and production of oil and gas or completely abandoned due to crude oil spillages. These results are similar and in line with the results of Osuji and Adesiyan (2005); Igwo-Ezikpe et al. (2010); Wang et al. (2010). The total estimated values in crude oil polluted farms category showed a short run decreasing negative returns to scale (-3.9682), which brought the stage of production to stage III, where the marginal products are negative.

The distribution of the production elasticities among variables in non-polluted farms is also shown in Table 2. The sum of production elasticities with respect to physical inputs was 1.1428 and with respect to technology inputs (1.7154), which indicated the presence of an increasing return to scale in the short run respectively. The sum of elasticities of output with regards to interaction terms gave an estimate of 0.8424, which showed the presence of decreasing positive returns to scale in the short run. The total estimated values in non-polluted forms was 3.7006, which showed a short run increasing returns to scale, bringing the production stage to stage I, where additional inputs increased the marginal product and average product respectively.

In comparison, the results of non-polluted crop farms did not portray the decreasing negative returns to scale which characterized the production elasticities estimates obtained in crude oil pollution affected farms. This could mainly be because there were no cases of crude oil and gas spillages, exploration, exploitation, and production activities on these farms. Therefore, the non-polluted farms had the opportunity to increase productivity per additional unit of input used in crop production by 3.7 units as against the 4.0 units reduction in output observed in crude oil polluted crop farms. Therefore, the effects crude oil pollution had on crop production in Rivers State, Nigeria during the period of survey were negative and detrimental as it significantly reduced the area of farmland and crop output respectively.

Resource use productivity of crop farmers

In Table 3, the marginal physical productivity (MPP) estimate obtained (MPP) was negative (-1.0186) which means it had a decreasing negative returns to scale. This negative marginal physical product (MPP) estimate result obtained could be due to the negative effects of crude oil pollution on land in relation to output produced (as previously analysed under distribution of stochastic translog production elasticities among the variables). This means that for any extra hectare (ha) polluted by crude oil, MPP of crop output per ha fell by 1.0186 tons in Rivers State which represented an elastic response. The average physical product (APP) had a positive value (0.8461) while the MPP (-1.0186) was negative, it means that the APP value is greater than zero, while the MPP value was less than zero. Therefore, the production process was in stage III with respect to the land input which had experienced decreasing negative returns to scale in all farms surveyed. Both the APP and MPP values were lower when compared to the average output per ha which was 1.3030 tons (Msuya et al., 2008).

In Table 3, the MPP of labour estimated (0.002) showed that the production process might had been saturated with labour such that any marginal increment in labour input used hard a negligible effect on the output level (Ogundari, 2008). The fact that APP was greater than MPP, MPP and APP are decreasing and APP was still positive, showed that, the production process was in stage II with respect to labour that is, decreasing positive returns to scale in all farms surveyed in the state.

The use of capital had marginal effect on crop output given that the MPP was 0.0218 and APP was 0.0223. This confirmed the fact that in Rivers State, in traditional agriculture, the use of modern farm tools and equipment was minimal and was mostly restricted to simple farm tools and implements whose unit market cost is low and affordable. This result was similar to Msuya et al. (2008). The production process was in stage II with respect to capital use in all farms surveyed.

In crude oil polluted farms, the marginal productivity of land had a negative value (-1.9016) signifying a decreasing negative returns to scale (Table 3). This means that if an extra hectare of farmland was polluted by crude oil, the marginal output per hectare reduced by 1.9016 tons in crude oil polluted farms. This authenticates the fact that crude oil and gas pollution and/or spillages had the capacity of impoverishing the farmers, as output was completely lost. This confirmed the studied of Udo and Fayemi (1975); Mubana (1978), Rashid et al. (2010). The APP was 0.7359, meaning that about 0.7359 tons of output will be produced for every unit of hectare of land increased. The production process was in stage III with respect to land in crude oil polluted farms. The average output per hectare was 1.0670.

The MPP estimate (0.9617E – 03) with respect to labour showed that if there is an extra unit of labour in mandays added, output will increase very marginally in crude oil polluted farms (Ogundari, 2008). This implied that there was a decreasing returns to scale in labour input used. Since APP estimate (0.3973E – 02) was greater than MPP estimate, both MPP and APP with respect to labour, the production process was in stage II. This result is similar to the results obtain in all farm surveyed.

The MPP estimate (0.0024) and APP estimate (0.0165) with respect to capital use were less than those obtained in all farms surveyed in the state. This means that for an extra unit of capital increase, both MPP and APP increases very marginally. This showed that the production process was in stage II, and the estimates manifested decreasing returns to scale in crude oil polluted crop farms.

Table 3 further shows the resource productivity estimates for non-polluted crop farms. The table discloses that the average output per hectare was 1.5160 tons. The MPP and APP of resource use productivity estimates with respect to land in non polluted crop farms were 0.3814 and 0.9475 respectively, which means that for an extra unit increase in the area of land under cultivation, MPP output was expected to increase by 0.3814 tons, while the APP output increased by 0.9475 tons. The decrease in output value of MPP in crude oil polluted farms was exceptionally higher than in all group of farms under study. These points clearly to the negative and detrimental effect of crude oil pollution on crop farms which cannot be over emphasized. This means that land was more productive in non-polluted farms as compared to the crude oil polluted farms where marginal physical productivity of land was negative. Hence, the non-polluted crop farms had higher land productivity than the crude oil polluted farms. Since the MPP value was less than APP value, both MPP and APP were falling (i.e. decreased lower than average output per ha in tons), and the MPP and APP were still positive, the production process was in stage II in non-polluted farms with respect to land.

For any additional increase in labour input in mandays, the MPP estimated (0.4834E.04) affected production output very marginally, that is about 0.05kg only) increased the production output by 5.4 kg, which is also marginal. The results of labour input in all cases of crop farms considered revealed that there was saturation of labour input (in mandays). The production process was in stage II with respct to labour in non-polluted farms.

The MPP and APP estimates with respect to capital use in non-polluted farms were both marginal values (0.0189 and 0.0259) respectively. The production process was in stage II with respect to capital input use in non-polluted crop farms.

Technical efficiency of resource use among crop farmers

Table 4 indicates that about 53.71% of the farmers in all farms surveyed in Rivers State, Nigeria had technical efficiency level between 0.61 and 90.0 (that is, 61 to 90%). No farmer attained the high technical efficiency between 0.91 and 1.00 interval (91 to 100%). The average resource use efficiency in all farms surveyed in Rivers State was 60.82% leaving an inefficiency gap of 39.18%. This expressed the fact that 39.18% increase in production could be achieved without additional resources, or inputs used could be reduced at the same level to achieve the same level of output. The minimum efficiency index observed among the farms was 8.87%, while the maximum value of efficiency index was 90.34%. This result disclosed that the most efficient farmer in terms of resource use was 90.34% efficient, while the least efficient farmer was 8.87% efficient in all farms surveyed in Rivers State, Nigeria.

The figures on Table 4 also showed the results of technical efficiency in crude oil polluted farms. About 67.45% of crop farmers had technical efficiency ranging from 61 to 100%. Less than 22% of the individual farmers interviewed during the study whose farms were polluted by crude oil and gas had technical efficiency indices between 81 and 93%, which revealed that more than 78% of the farmers were less than 80% efficient. The average technical efficiency (58.59%) indicated that about 41.41% increase in production could have been achieved without any additional resources, or that inputs use could be reduced by this same amount to attain the same level of output. The results of minimum and maximum technical efficiencies estimated showed that the most efficient farmer in terms of resource use was 92.84% efficient, while the least efficient one had resource use efficiency of 13.28% in crude oil polluted farms category.

Table 4 shows further the figure for non-polluted farms. The results on the table revealed that about 26% of the individual farmers interviewed in non-polluted farms were 91 to 100% technically efficient. About 33.85% of crop farmers in non – polluted areas had technical efficiency that is above 80%. This level of technical efficiency was not attained in any other farms category and was considerably higher than the technical efficiency obtain in crude oil polluted farms. This could be due to the absence of the negative effects of crude oil pollution on the crop farms that had made more farmers to be more technically efficient with respect to resources use. The average technical efficiency (66.37%) obtained in non-polluted crop farms showed that 33.63% of more crop production could have been achieved without any further additional resources. This average technical efficiency level in non-polluted crop farms was higher than that of crude oil polluted farms (58.59%). In non polluted crop farms, the most efficient farmer had a technical efficiency of 99.13%, while the least efficiency was 9.67%. The level of technical efficiency for most efficient individual farmer was also higher in non-polluted farms (99.13%) when compared. Therefore, crude oil pollution was one of the main factors that reduced the technical efficiency of resource use of most crop farmers in crude oil affected areas. However, the study observed a high level of technical efficiency in Rivers State, Nigeria during the period of survey, despite the negative effects of crude oil pollution on physical and technological inputs. The wide variation of technical efficiency estimated and analysed in this study was similar to results of Ogundari (2008), Msuya et al. (2008) and Kareem et al. (2008).

Conclusion

The distribution of stochastic translog production elasticities among variables used in crude oil polluted crop farms showed strong negative (decreasing) returns to scale in physical inputs, oil pollution variables, their interaction terms and total estimated, values. In non-polluted crop farms, the sum of production elasticities of output with respect to physical inputs, technology variables, their interaction terms and total estimated values showed strong positive returns to scale. These results showed that crude oil pollution on land reduce the size of farm land available, thereby affecting the output; also affected negatively almost all technology inputs they interacted with, therefore causing reduction in crop output.

Considering the resource use productivity of crop farmers in Rivers State, Nigeria, the marginal physical product of land in crude oil polluted farms had a negative value of -1.9016, signifying that marginal physical product of output per hectare of land could be reduced by 1.9016 tons, while in non – polluted crop farms, the marginal productivity increase by 0.3814 tons. The average physical product of output obtained in crude oil polluted crop farms (0.7359 tons) was lower than that obtained in non-polluted crop farms (0.9475 tons). These results confirmed the negative and detrimental effect of crude oil pollution on crops production. This means that land was more productive in non-polluted areas than in crude oil polluted areas of the state.

The results of technical efficiency in crude oil polluted farms showed that less than 22% of the crop farmers had technical efficiency between 81 and 93%, which revealed that more than 78% of them were less than 80% technically efficient in the use of farm resources. In the non-polluted crop farms, about 26% of the individual crop farmers interviewed had 91 to 100% technical efficiency. More than 33% of crop farmers in non polluted farms had technical efficiency of 81 to 100%, while 67% of them were less than 80% technically efficient. These results and other indices of results on technical efficiency had showed that crude oil pollution affected the technical efficiency of resource use of individual crop farmers in Rivers State, Nigeria during the period under survey.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations were made:

(i) Since every additional unit of input used in crop farms (including physical and technology inputs) reduced crop output/yield and any extra farmland cropped reduced crop output because of the negative effects of crude oil pollution, this study recommended comprehensive scientific rehabilitation programmes for polluted farmland in Rivers State, Nigeria. This recommendation is in line with the suggestions of Ward et al. (2003) and Igwo-Ezikpe et al. (2010).
(ii) The study further recommended that crop farmers in Rivers State, Nigeria living in crude oil pollution prone areas should seek additional means of livelihood by diversifying their sources of income or take farming as a secondary occupation as this will help reduce tension and allow land to be allocated for its best alternative uses (in this case crude oil and gas exploration and production).
(iii) Living in the crude oil pollution prone environment, the Rivers State crop farmers strive hard to eke out their living, having suffered from all kinds of crude oil pollution incidents without proper ideas on how to ameliorate the negative effects of crude oil pollution on their farms. The Rivers State crop farmers had lived under this ignorance of measures to improve their farming activities for the past five decades, which unfortunately had constantly deteriorated due to constant crude oil pollution into its environment. This study therefore recommended that there is need to intensity the dissemination of information on benefits accruable from adopting the best farm practices to improve their resource use techniques, their technical efficiencies and soil remediation techniques available (Ward et al., 2003) and educating farmers on what functional measures to adopt in the case of crude oil spillages or if acquisition of farmland occurs (which in most cases, is inevitable), thereby depriving them of their sources of livelihood. This could be done through extension and rural development programmes and on-farm trainings using Niger Delta Development Commission, oil companies farming schemes, Rivers State Ministry of Agriculture and Rivers State Agricultural Development Programmes (ADPs) outfits in the state.

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