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An economic analysis of crude oil pollution effects on crop farms in Rivers State, Nigeria

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This study researched on crude oil pollution effects on crop farms in Rivers State, Nigeria using stochastic translog production function. Data were collected in the state, using multi-stage sampling technique. A total of 296 structured questionnaires retrieved from farmers in crude oil polluted and non-polluted areas of the state were used. Stochastic translog production interaction between land and heavy, medium and light oil spillages resulted in crops output reduction by 0.255, 1.257 and 1.027 units, respectively. Interaction across heavy, medium and light oil spillages and fertilizers usage indicated farm crops output decrease by 0.805, 0.586 and 0.729 units, respectively. This study therefore concluded that crude oil pollution on crops farms reduced crops output significantly, hence detrimental to crop production in Rivers State, Nigeria.

Key words: Crude oil, pollution, stochastic translog production function, crops output, Nigeria.

INTRODUCTION

The petroleum industry is the backbone of the Nigeria economy, accounting for over 90% of total foreign exchange revenue. The daily production of crude oil is slightly above two million barrels from more than 240 producing fields, totaling over 5,284 wells drilled. With over half a century of oil and gas exploration, exploitation and production, Nigeria has built up a considerable hydrocarbon infrastructure with over 7,000 km of pipelines linking over 280 producing flow stations all of which are situated in the Niger Delta region of Nigeria (Niger Delta Development Commission, 2006). The Niger Delta region is situated in the southern part of Nigeria and bordered to the south by the Atlantic Ocean, occupying a surface area of about 112, 110 km^2, which represents 12% of Nigeria total surface area with an estimated population of about 28 million inhabitants in 2006 (NDDC, 2006). Within this region, crude oil pollution such as oil spillages and gas flaring regularly occur (Orji, et al., 2011; Nwaichi and Uzazobona, 2011).

Scholars such as Uzoho et al. (2004) evaluated the influence of crude oil on maize growth and soil properties in Ihiagwa, Imo State, Nigeria. The results of their study showed that seed germination, plant height, leaf area and dry matter yield significantly deceased as the levels of crude oil pollution increased. The primary way in which crude oil pollution reduced crop growth and performance according to their study was through reduction of seedling emergence and direct suffocation of plant and oxygen diffusion rates between soil system and the atmosphere.

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Dung et al. (2008) explored the spatial variability effects of gas flaring on the growth and development of cassava (*Manihot esculenta*), water leaf (*Talinum triangulare*) and pepper (Piper spp.), which are crops commonly cultivated in the Niger Delta. Their results suggested that a spatial gradient exist in the effect of gas on crop development. Retardation in crop development manifested in decreased dimensions of leaf lengths, and widths of cassava and pepper crops closer to the gas flare points. Their statistical analysis confirmed that cassava yield were higher at locations further away from the flare point. In addition, the amount of starch and ascorbic acid in cassava decreased when plant is grown closer to the gas flare. High temperature around the gas flare appeared to be the most likely cause of the retardation and low yield.

Okonwu et al. (2010) investigation showed that the percentage of germination of maize (*Zea mays*) decreased with increase in concentration of crude oil equilibrated with water. Germination rate decreased significantly with increased time of pre-soaking in crude oils. Crude oil spilled soil immediately after planting increased the length of lag phase preceding germination from 100% in the control to 58% in crude oil contaminated soil. Fernandez-Luqueno et al. (2012) studied the ability of various crops to grow and maintain their yield when they are cultivated in contaminated soils, thereby being able to choose the most appropriate crop when suddenly a gasoline-pipeline collapse on soil of subsistence agricultural systems. Their results showed that gasoline contamination reduced seedling emergence, shoot length, root volume, root dry weight, shoot dry weight and abundance of nodules.

Problem statement

Despite the availability and use of advanced technology in the petroleum industry, various forms of accidents such as blow-outs of production wells, explosions and pipeline ruptures still occur, which are worsened by vandalization of oil installations and pipelines (Otitoloju et al. 2007; Iturbe et al. 2008; Li et al., 2011). Farmers in Rivers State are eventually the most affected judging by the death of marine and terrestrial organisms usually involved in oil spill incidents and the hazardous effect of gas flaring (Saier, 2006; Otitoloju and Dan-Patrick, 2010; Huang, et al., 2011). The rivers and underground water which the inhabitants rely on, for their drinking water have been polluted with crude oil, while buildings and agricultural products had been destroyed (Atakpo and Ayolabi, 2009; Ekpoh and Obia, 2010; Nwaichi and Uzazobona, 2011; Onyenekenwa, 2011). Irregularities had been observed in the major livelihood activities of the people of Rivers State of Nigeria due to crude oil pollution (Okoli, 2006; Adoki and Orugbani, 2007; Orogun, 2009).

Ekunwe and Orewa (2007) (examined the technical efficiency and productivity of yam in Kogi State of Nigeria using stochastic frontier production function. The result indicated that the technical efficiency of farmers varied with a mean of 62%, while only about 23% of the farmers had technical efficiencies exceeding 80%. Erhabor and Emokaro (2007) employed the use of the stochastic frontier production function in the comparative economic analysis of the relative technical efficiency of cassava farmers in the three agro-ecological zones of Edo State, Nigeria. The empirical estimates showed mean technical efficiency of 72, 83 and 91% for Edo South, Edo North and Edo Central agro-ecological zones, respectively. Ajani and Ugwu (2008) used a stochastic production frontier model and obtained the result that gamma which is a measure of variance of output from the frontier attributed to efficiency was 0.114.

Heady et al. (2010) presented multi-output, multi-input total factor productivity (TFP) growth rate in agriculture for 88 countries over the 1970 and 2001 period estimated with both stochastic frontier analysis (SFA) and data envelopment analysis (DEA). They found results with SFA to be more plausible than with DEA, and used them to analyze trends across countries. Large volumes of literature still exist that had used stochastic frontier production analysis in crop production (Ali, 1996; Onyenweaku and Okoye, 2007; Nyagaka et al., 2010; Dlamini et al; 2010). Some scholars (Lachaal et al., 2005; Awoyemi and Adeoti, 2006; Managi et al., 2007) have studied some aspects of stochastic frontier production function but they did not study the economic analysis of crude oil pollution effects on crop farms in Rivers State.

Therefore, there is a dearth of literature on the use of stochastic frontier transcendental logarithmic (traslog) production function for an economic analysis of crude oil polluted and non-polluted crop farms in Rivers State, Nigeria. At this juncture one may seek to understand the economic analysis of crude oil pollution effects on crop farms in Rivers State, Nigeria, using the stochastic frontier transcendental logarithmic (translog) production function as analytical tool to bridge this gap in knowledge.

The objectives of the study

The main objective of this study is to estimate economically crude oil pollution effects on crop farms in Rivers State, Nigeria using stochastic translog production function approach. The specific objectives are to:

1. Determine crude oil pollution effects on crop farms in Rivers State, Nigeria using stochastic translog production function analysis.
2. Make policy statements that could ameliorate the effects of crude oil pollution on crop farms in Rivers State, Nigeria.

MATERIALS AND METHODS

Data collection

This study was conducted in Rivers State of Nigeria in 2003. Data were collected from both the primary and secondary sources. The primary data were collected through personal interviews and observation with the farmers, and structured questionnaires were distributed among farmers in crude oil polluted and non-crude oil polluted areas of an affected community in the state. A multistage sampling technique was used to obtain data for the study. The first stage involved the selection of 17 local government areas (LGAs) out of the existing 23 LGAs in Rivers State. The selected LGAs include: Abua/Odual, Ahoada East, Ahoada West, Andoni, Asaritoru, Degema, Eleme, Emohua, Etche, Gokana, Ikwerre, Khana, Obio/Akpor, Ogba/Egbema/Ndoni, Omuma, Oyigbo and Tai LGAs. These 17 LGAs were selected based on the fact that they were more crop farming inclined than others. The second stage involved the stratification of farmland in a selected LGA into two sampling units namely crude oil polluted and non-crude oil polluted. This stratification of the farmland into two sampling units was based on the fact that information were needed from both crude oil polluted and non-polluted areas.

The third stage involved the random sampling of 10 farmers from crude oil polluted areas in a selected LGA and a corresponding number of 10 farmers from non-crude oil polluted farms (non-polluted) in the same locality (community) in the given area. This gave a total of 20 farmers interviewed per selected LGA in the State, giving a total of 340 questionnaires distributed in the 17 LGAs selected. Out of 340 questionnaires administered, due to difficult terrain, the politicking of oil pollution issues and youth restiveness in the State as at the time of the survey, only 326 questionnaires were retrieved. Furthermore, 30 questionnaires were found inconsistent with the set objectives of the study. Hence, only a total of 296 questionnaires were retained as suitable for analysis. Out of these 296 questionnaires retained as suitable for analysis, 169 questionnaires were retrieved from the crude oil polluted farms and 127 questionnaires from non-polluted farms. The unequal weighting in the data analyzed arose because most of the discarded and unretrieved questionnaires belonged to the non-polluted farms category. Because of the large number of samples retrieved from both polluted and non-polluted crop farms, comparison between the two groups of farms as a measure of efficiency was adequate and not misleading.

Measurement of crude oil pollution and technology indices

To measure the negative effects of crude oil pollution on each farmland polluted, the impact of crude oil pollution index was estimated following the methods specified by Mubana (1978), and Canter and Hill (1979) modified as follows:

$$P = \left(\frac{\overset{n}{\underset{i=1}{E}} \dfrac{q_{2i}}{q_1}}{n} \blacksquare \; X_i \right) \tag{1}$$

where, P= crude oil pollution index per farmer in the crude oil polluted areas;

q_{2i} = land affected by the 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 foregone due to oil pollution (where, i = farmers degrees of pollution, 93 to 100%, 31 to 92% and 0 to 30%).

n = types of crude oil pollution affecting individual farm: n_1 = heavy oil pollution (acquired land); n_2 = medium oil pollution ; n_3 = light oil pollution

X_i was adopted from Udo and Fayemi (1975) and Mubana (1978), which categorized the types of negative effects of oil pollution: Category A (ni): (i) Heavy oil spillage which leads to 93 to 100% crop yield loss.

(ii) Acquired land for oil well – head sites, flow stations, drilling sites, oil field location, borrow pits, gas flaring sites, pipeline laying operations and other oil related activities which leads to 100% crop yield loss (Mubana, 1978);

Category B (n_2): Medium oil spillage which leads to 31 to 92% crop yield reduction;

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

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

$$T = \frac{\overset{n}{\underset{i=1}{\Gamma}} \left(\dfrac{\forall_{2i}}{\forall_{1i}} \times 100 \right)}{K} \tag{2}$$

Where, T = level of technology index, $\%_{2i}$ = quantity of each technology type used in current year t, (2003) measured in bags of fertilizers, packets of improved seeds and dressing of seeds. These inputs were converted into percentages before the summations;

$\%_{1i}$ = quantity of each technology type used in year t - 1, (2002) measured as above, i = 1,2, …. 296,

K = number of types of technology adopted by the farmer in t (2003) and t-1 (year (2002) 2.3

Stochastic translog production function

Christensen et al. (1973) studied translog production function which is general, flexible and allowed analysis of interactions among variables. Ali (1996) used stochastic translog production function to analyse socio-economic determinants of sustainable crop production in Nepal. This study will apply the stochastic translog production function with moderation from Christensen et al. (1973) and Ali (1996) to estimate economically crude oil pollution effects on crop farms in Rivers State, Nigeria. The stochastic frontier translog production function given in equation (3) was estimated for the crude oil polluted crop farms only, while the estimation of non-polluted crop farms did not include the P variables. The general form of the translog stochastic production function used in this study is:

$$\begin{aligned} \ln\ Y_j = {} & \forall_0 + \overset{n}{\underset{i=1}{\Gamma}} a_i \ln X_{ij} + ½ \overset{n}{\underset{i=1}{E}} \overset{n}{\underset{g=1}{\Gamma}} b_{ig} \ (\ln X_{ij} \ln X_{ij}) \\ & + \overset{m}{\underset{i=1}{E}} c_k \ln P_{kj} + \overset{p}{\underset{t=1}{\Gamma}} d_t \ \ln T_{tj} + \overset{n}{\underset{i=1}{E}} b_{ii} (\ln X_{ii})^2 \\ & + ½ \overset{n}{\underset{i=1}{E}} \overset{m}{\underset{k=1}{\Gamma}} e_{ik} \ (\ln X_{ij} \ln P_{kj}) + ½ \overset{n}{\underset{i=j}{\Gamma}} \overset{p}{\underset{t=1}{\Gamma}} f_{it} \ (\ln X_{ij} \ln T_{tj}) \\ & + ½ \overset{m}{\underset{k=1}{\Gamma}} \overset{m}{\underset{k=1}{\Gamma}} h_{kk} \ (\ln P_{kj} \ln P_{kj}) + ½ \overset{n}{\underset{k=j}{\Gamma}} \overset{p}{\underset{t=1}{\Gamma}} r_{kt} \ (\ln P_{kt}\, l_n T_{tj}) \\ & + ½ \overset{p}{\underset{t=1}{\Gamma}} \overset{p}{\underset{t=1}{\Gamma}} s_{tt} \ (\ln T_{tj} \ln T_{tj}) + u_j + v_i \end{aligned} \tag{3}$$

where, j = 1,2,3, ……… 169 for crude oil polluted crop farms and

127 for non-polluted crop farms
$i = 1,2,3$, are physical inputs.

Parameters used include:
Y = Crop output in ton/ha per farmer (crops here refer to different types of crops because of the subsistence nature of production – mixed cropping).
X = Vector of physical inputs used (land area cultivated in hectares, available family and hired labor in man days; fixed and operating capital in dollars).
P = Vector of effect of crude oil pollution index on the farmer;
T=Vector of level of technology index;
vi=Random error due to misspecification of the model;
ui =Ratio of actual value to maximum possible output, that is inefficiency component of error terms.
ln = logarithmic sign
$\forall$ = parameter of intercept,
a_i = parameters of physical inputs,
b_{ijg} = parameters for interaction across ith and gth physical inputs,
c_k = parameters of crude oil pollution variables in indices,
dr = parameters for level of technology variables indices,
b_{ii} = parameters for squared terms of physical inputs.
e_{ik} = parameters for interaction between physical inputs and crude oil pollution variables
f_{it} = parameters for interaction between physical inputs and technology variables.
h_{kk}= parameters for interaction among crude oil pollution variables,
r_{kt} = parameters for interaction between oil pollution and technology variables,
s_{tt}= parameters for interaction across technology variables

It is important to note that Xi and T variables are some conventional physical inputs and technology variables normally considered in transformation process. However, the P variables are the conditioning variables which had been included into the model to capture the negative and detrimental effects of crude oil pollution on crops output or yield.

Translog model specifications

The model specifications for the translog stochastic production function retained in Equation (3) for the crude oil polluted crop farms is as given in Equation (4). As earlier mentioned, the specification for the non-polluted crop farms category excluded the crude oil pollution variables, that is X_5 to X_{12}, and their various interactions.

$$
\begin{aligned}
\ln Y = {} & \forall_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 \\
& + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \beta_8 \ln X_8 + \beta_9 \ln X_9 + \beta_{10} \ln X_{10} \\
& + \beta_{11} \ln X_{11} + \beta_{12} \ln X_{12} + \beta_{13} \ln X_{13} + \beta_{14} \ln X_{14} + \beta_{15} (\ln X_1)^2 \\
& + \beta_{16} (\ln X_2)^2 + \beta_{17} (\ln X_3)^2 + \beta_{18} (\ln X_1 \cdot \ln X_2) \\
& + \beta_{19} (\ln X_1 \cdot \ln X_3) + \beta_{20} (\ln X_2 \,.\, \ln X_3) + \beta_{21} (\ln X_1 \cdot \ln X_{10}) \\
& + \beta_{22} (\ln X_1 \cdot \ln X_{11}) + +\beta_{23} (\ln X_1 \cdot \ln X_{12}) + \beta_{24} (\ln X_1 \cdot \ln X_{13}) \\
& + \beta_{25} (\ln X_1 \cdot \ln X_{14}) + \beta_{26} (\ln X_2 \cdot \ln X_{13}) + \beta_{27} (\ln X_{10} \cdot \ln X_{11}) \\
& + \beta_{28} (\ln X_{10} \cdot \ln X_{12}) + \beta_{29} (\ln X_{11} \cdot\cdot \ln X_{12}) + \beta_{30} (\ln X_{10} \cdot \ln X_{13}) \\
& + \beta_{31} (\ln X_{11} \cdot \ln X_{13}) + \beta_{32} (\ln X_{12} \cdot \ln X_{13}) + \beta_{33} (\ln X_4 \cdot \ln X_{13}) \\
& + \beta_{34} (\ln X_4 \cdot \ln X_{14}) + \beta_{35} (\ln X_{13} \cdot \ln X_{14}) + u + v
\end{aligned} \tag{4}
$$

It is necessary to explain here that the total number of possible interactions were 75 but these had been drastically reduced to 21 interactions only. In addition to the 14 sets of variables considered in this analysis, the number of parameters estimated increased to 36 (including the intercept). This was done in order to ensure that only economically meaningful and theoretically plausible interactions were retained for the analysis, and also to reduce and ease the computation burden, as well as reduce the risks of multicollinearity.

RESULTS AND DISCUSSION

Table 1 shows the results of maximum likelihood estimation (MLE) for stochastic translog production frontier function in crude oil polluted and non-polluted crop farms in Rivers State, Nigeria. The results will be analyzed following the various types of variables and interactions obtained according to the translog model specification as shown in equation (4).

Stochastic translog production variables interactions

The discussions concentrated on the interactive actions of the translog variables used in the analysis

Squared terms of physical inputs (b_{ii})

Doubling the physical inputs means, using these inputs once again after the initial usage on crude oil spilled farms with the intension of increasing productivity after the application of proper remediation techniques in crude oil polluted crop farms, while in the non–polluted crop farms, it means doubling the usage of these inputs with the sole purpose of increasing production. Therefore, squaring (doubling) the amount of farm land (β_{15}) available for farming in crude oil polluted farms decreased the crop output by 0.093 units, though marginal.

There was an increase of 0.051 units per unit of output experienced in non-polluted crop farms when farmland was doubled (squared), though also marginal inelastic and not significant. These results showed that when amount of farmland available was doubled, there was an increase in output in non-polluted crop farms, and a decrease in farm output in crude oil polluted crop farms category. This could be due to the environmental stress or negative effects of crude oil pollution on crops (Achuba, 2006).

Squaring the labour variable (β_{16}) (labour x labour) in crude oil polluted crop farms reduced output by 0.112 units, and at the same time led to increased cost of production, whereas, if labour was doubled in non-polluted crop farms, crop output increased, though marginally by 0.150 units (significant at 1% level) despite the increased cost of production. Squaring of capital

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

S/N	Variables	Parameters	Crude oil polluted, Translog MLE		Non-polluted Translog MLE	
			Coefficient value	Standard error	Coefficient value	Standard error
1	Constant (intercept)	∀	7.378***	2.691	9.368***	3.908
			Physical input (ai)			
2	Land (ha)	β_1	-2.584***	0.471	0.403	0.650
	Labour (Mandays)	β_2	0.242	0.525	0.009	0.798
	Capital ($)	β_3	0.145	0.495	0.731	0.635
			Indexes (ai)			
3	Technology index	β_4	0.220	0.191	-0.048	0.314
	Crude oil pollution index	β_5	-7.046***	2.478		
			Crude oil pollution variables (c_k)			
4	Farmland acquired for:					
	Flow station	β_6	-0.302***	0.093		
	Borrow pits	β_7	-0.397***	0.128		
	Gas flaring	β_8	-0.189**	0.082		
	Heavy pollution	β_9	-0.766***	0.224		
	Degree of spillage					
	Heavy crude oil spillage	β_{10}	-3.992***	1.983		
	Medium crude oil spillage	β_{11}	5.622**	2.626		
	Light crude oil spillage	β_{12}	5.903***	2.488		
			Technology variables (d_t)			
5	Fertilizers	β_{13}	7.499***	1.119	2.771**	1.167
	Improves seeds	β_{14}	-1.049***	0.276	-2.194***	0.653
			Square terms (b_{ii})			
6	Land x land	β_{15}	-0.093	0.058	0.051	0.074
	Labour x labour	β_{16}	-0.112	0.043	0.150***	0.059
	Capital x capital	β_{17}	-0.040	0.029	0.114***	0.035
			Interaction across inputs (b_{ig})			
7	Land x labour	β_{18}	0.143**	0.067	0.219**	0.091
	Land x capital	β_{19}	0.254***	-0.044	-0.141**	0.070
	Labour x capital	β_{20}	-0.033	0.051	-0.211**	0.058
			Interaction of physical inputs and crude oil pollution variables (e_{ik})			
8	Land x heavy oil spillage	β_{21}	-0.255	0.161		
	Land x medium oil spillage	β_{22}	-1.257***	0.341		
	Land x light oil spillage	β_{23}	-1.027**	0.494		
			Interaction of physical inputs and technology variables (f_{it})			
9	Land x fertilizers	β_{24}	0.363***	0.110	0.059	0.128
	Land x improved seeds	β_{25}	-0.058	0.048	-0.241***	0.058
	Labour x fertilizers	β_{26}	-0.283***	0.100	0.067	0.080
			Interaction among crude oil pollution variables (h_{kk})			

Table 1. Contd.

10	Heavy spillage x medium spillage	β_{27}	-1.244*	0.709		
	Heavy spillage x light spillage	β_{28}	-1.042*	0.647		
	Medium spillage x light spillage	β_{29}	-0.326**	0.153		
Interaction between crude oil pollution and technology variables (rkt)						
11	Heavy spillage x fertilizers	β_{30}	-0.805***	0.224		
	Medium spillage x fertilizers	β_{31}	-0.586***	0.210		
	Light spillage x fertilizers	β_{32}	-0.792*	0.389		
Interaction across technology variables (S_{tt})						
12	Technology index x fertilizers	β_{33}	-0.312***	0.094	-0.547***	0.109
	Technology index improved seeds	β_{34}	0.656***	0.202	0.060	0.042
	Fertilizers x improved seeds	β_{35}	-0.102*	0.062	0.045	0.062
	Υ		0.863	-	0.9999	-
	λ		3.109***	0.950	190.634	698.59
	σ		0.621***	0.030	0.883***	0.028
	δ_u^2		0.350	-	0.780	-
	δ_v^2		0.03620	-	0.00002	-
	Log likelihood function		-658.252	-	-733.206	-
	Average technical efficiency		0.586	-	0.664	-
	F-test		26.37***	-	16.21***	-

Source: Field survey, 2003. Asterisks indicate significant level: ***1%; **5%; *10%.

(β_{17}) decreased output in crude oil polluted crop farms by 0.040 units, with a possible increase in cost of production.

However, in non-polluted crop farms output increased when capital was squared by 0.114 (significant at 1%) though marginally regardless of the increase in cost of production expected. These results confirmed the negative effects of crude oil pollution on physical inputs usage in crude oil polluted crop farms (Aade – Ademilua and Mbamalu, 2008).

Interaction among physical inputs (b_{ig})

The interaction between land and labour (β_{18}) showed that for a unit increase in land with corresponding unit increase in labour, crop output level increased by 0.143 units and 0.219 units in crude oil polluted and non-polluted crop farms both significant at 5% level, respectively. This relationship means that in the presence of adequate labour, land productivity could be improved leading to higher output level, especially where the labour is knowledgeable in using remediation techniques in remedying crude oil polluted farmland. The interaction between land and capital (β_{19}) showed that a 10% increase in land area with a corresponding increase in capital resulted in a less than proportionate (inelastic) increase in output by 2.5% (significant at 1%) in crude oil polluted crop farms, whereas in non-polluted crop farms, it lead to a reduction in output by 1.4% (significant at 5%). This reduction in output in non-polluted crop farms could be caused by inadequate supply or even lack of fertilizers and planting materials.

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

The relationship between land and heavy crude oil spillage (β_{21}) showed that a unit of heavy crude oil pollution on land, resulted in 0.255 units reduction in crop output (though not statistically significant). The interaction between land and medium crude oil spillage (β_{22}) indicated that a unit of medium crude oil spillage on land, resulted in 1.257 units reduction in crops output, which is more than proportionate (elastic) reduction and was statistically significant at 1%. The interaction between land and light oil spillage indicated that a unit of light crude oil spillage on farmland resulted in a proportionate decrease in crops output of 1.027 units and was statistically significant at 5%. These results obtained in these relationships confirmed that crude oil spillage on farm land had detrimental effects on crops production in Rivers State, Nigeria and affirmed that crude oil spillage reduces land productivity (Ekundayo et al., 2001; Saier, 2006; Okonwu et al; 2010).

Interaction across physical inputs and technology variables (f_{it})

Land and fertilizers interaction (β_{24}) indicated that a unit increase in fertilizers usage resulted in 0.363 units increase in output in crude oil polluted crop farms, significant at 1% level and a very marginal increase of 0.059 units increase in non-polluted crop farms. The interaction between land and improved seeds (β_{25}) showed expected result of negative value (that is, decrease in outputs) in crude oil polluted crop farms by 0.058 units, and also a surprising reduction in output of 0.241 units in non-polluted crop farms for a unit increase in the inputs of production, statistically significant at 1%. The interaction between labour and fertilizers (β_{26}) indicated that a unit increase in the inputs, resulted in a reduction in output by 0.283 units in crude oil polluted crop farms, which was statistically significant at 1%. This could be that on a crude oil spilled crop farm any increase in land, labour, and fertilizers or improved seeds are wasted because of the detrimental effects of crude oil pollution (Uzoho et al., 2004; Dung et al., 2008; Okonwu et al., 2010; Fernandez-Luqueno et al., 2012).

Interaction among crude oil pollution variables (h_{kk})

The interaction among heavy crude oil pollution (spillage) and medium crude oil spillage (β_{27}) showed that a unit increase in medium crude oil spillage on already heavy crude oil spilled land resulted in a more than proportionate (elastic) decrease in output by 1.244 units(significant at 10%). The relationship between heavy spillage and light spillage (β_{28}) showed that a unit increase in light crude oil spillage on the farmland that had been heavily spilled resulted in reduction of output by 1.042 units which was also a proportionate (elastic) decrease in output and also significant at 10%. The relationship between medium crude oil spillage and light crude oil spillage (β_{29}) indicated that a unit increase in light spillage upon farmland that a medium spillage had already occurred resulted in decrease of output by 0.326 units which was statistically significant at 5%. The results of these interactions among crude oil pollution variables stressed the fact that all forms of crude oil spillages on crop farms reduced and/or led to complete lost of crop yield/output on crop farms. These results were similar to the results of Udo and Fayemi (1975); Mubana (1978); Iturbe et al., (2008); Onyenekenwa (2011).

Interactions between crude oil pollution and technology variables r_{kt}

Heavy crude oil spillage and fertilizers (β_{30}) interaction showed that a unit increase in the use of fertilizers on an already heavily crude oil spilled farmland resulted in a 0.805 unit decrease in output of crops significant at 1%. The interaction between medium crude oil spillage and fertilizers usage (β_{31}) indicated that a unit increase in the quantity of fertilizers used on an already medium crude oil spilled farmland, led to a reduction of output by 0.586 units, also (significant at 1%) (Udo and Fayemi 1975; Mubana, 1978). The relationship between light crude oil spillage and fertilizers usage on cropped farmland (β_{32}) indicated that an increase by a unit of fertilizers usage on light crude oil spilled crop farms resulted in a reduction of output by 0.729 units (statistically significant at 10%). These results showed that fertilizers usage had no expected positive effects on crops production on crude oil polluted areas and hence did not lead to expected increase in yields/output (Uzoho et al., 2004; Dung et al., 2008; Okonwu et al., 2010; Fernandez Luqueno et al., 2012).

Interaction across technology variables (S_{tt})

The interaction across fertilizers and improved seeds (β_{35}) showed that a unit increase in the inputs in the crude oil polluted crop farms, resulted in a reduction of output by 0.102 units (significant at 10%), and increase in output by 0.045 units (marginal increase) in non-polluted crop farms. Again, the negative effect of crude oil pollution was felt on the interaction of fertilizers and improved seeds usage in crude oil polluted crop farms. This goes to confirm the negative and detrimental effects of crude oil pollution on crops (Udo and Fayemi, 1975; Mubana, 1978; Achuba, 2006)

The lambda (λ) figure obtained in crude oil polluted farms (3.109) which was statistically significant at 1% and in non-polluted crop farms (190.634) were by far greater than unity. This implies that the one-sided error component, u dominated the symmetric error v as sources of variation. In other words, the discrepancy between actual (observed) output and the maximum (frontier predicted) output in crop farms in Rivers State, Nigeria was primarily due to factors that were within farmers control. The Lambada (λ) result obtained in crude oil polluted crop farms was close to earlier results of Xu and Jeffrey (1998) who had 2.117; Bagi (1984) had $\lambda = 2.438$.

Gamma (Υ) which is the measure of variance of output from the frontier attributed to efficiency was 0.863 in crude oil polluted crop farms and 0.999 in non-polluted crop farms. The random (stochastic) variability accounted for about 13.7% of the variability in crop output in crude oil polluted crop farms and virtually no random variability 0.001 (0.01%) in non-polluted crop farms. From the results obtained in this study, it means that crude oil pollution on crop farms in Rivers State, Nigeria had accounted for about 14% variation in actual output as against the frontier predicted. Therefore, this random variability could have been caused by crude oil pollution on crop farms in Rivers State, Nigeria. This confirmed the fact that crude oil pollution on crop farms is detrimental to crop output, yield and/or production.

Conclusion

The interaction between land and heavy oil spillage resulted in 0.255 units reduction in output, interaction between medium oil spillage and land resulted in 1.257 units reduction in crops output, while interaction between land and light oil spillage resulted in a decrease in crops output by 1.027 units. The interaction between land and improved seeds resulted in decrease in crop output by 0.058 units, while the interaction between labour and fertilizers showed a reduction in output by 0.283 units in crude oil polluted crop farms respectively.

The interactions among crude oil variables showed that heavy oil pollution interacting with medium oil spillage reduced output of crops by 1.244 units, heavy oil spillage and light oil spillage also reduced output by 1.042 units, while medium oil spillage and light oil spillage reduced crops output by 0.326 units. The interaction between heavy oil spillage and fertilizer showed a reduction in output by 0.805 units, medium oil spillage and fertilizers showed a reduction of 0.586 units in crops output, while the interaction between light oil spillage and fertilizers showed crops output reduction by 0.729 units. The interaction between fertilizers and improved seeds showed crops output decrease by 0.102 units in crude oil polluted crop farms. Therefore, crude oil pollution reduced crops output significantly, hence detrimental to crop farms output and production in Rivers State of Nigeria (Achuba, 2006; Aade – Ademilua and Mbamalu, 2008; Dung et al; 2008; Okonwu et al., 2010).

RECOMMENDATIONS

This study therefore, recommends that there is the need to spread widely information on benefits derived from adopting the best and suitable farm practices available in case of crude oil pollution and educating farmers on what functional measures are adoptable incase crude oil spillages or acquisition of farmland for crude oil exploration, exploitation and production occur (which in most cases is inevitable in Rivers State, since Nigeria derives more benefit from the petroleum industry than the agricultural sector). Thus, land will be used for its best and economically viable purposes.

This recommendation could be enforced through extension and rural educational programmes existing in various oil companies' demonstration farms. The Rivers State crop farmers need adequate knowledge and information about farming activities in a crude oil pollution prone environment which may improve their production capacity and thereby productivity (yield/output), farm income and revenue (Okoli, 2006; Adoki and Orugbani, 2007; Orji, et al., 2011).

Conflict of Interests

The author(s) have not declared any conflict of interests.

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