# “Oil pollution and agricultural productivity in the Niger Delta of Nigeria,”

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## Abstract

Oil pollution has degraded agricultural lands leading to an increase in poverty levels and turning productive areas into waste lands in the Niger Delta region of Nigeria. This paper examines the effects of oil spillage as a catalyst in accelerating deforestation and reducing agricultural productivity in the Niger Delta from 1985 to 2013. In doing this, the authors estimated the effects of levels of oil spillage and forest loss, which reduced forest biomass as factors of agricultural production and tested the hypothesis that agricultural land and forestland were degraded more efficiently as a result of oil spillage. The empirical analysis derived a unique estimable production function based on Ramon Lopez's Cobb Douglas production function model. The new model included an oil extraction variable – oil spillage as an externality; land degradation as a proxy for deforestation and forest biomass as the proportion of cultivated and forest or fallow land affected by oil spills, while secondary data for land and labor were sourced from FAOSTAT and FAO yearbooks and the Nigerian Bureau of Statistics (NBS) databases respectively. The findings established that increasing levels of oil spills and forest loss negatively affect agricultural productivity, while land, labor and capital positively improved agricultural production in the Niger Delta.


**Keywords:** oil pollution, oil spillage, land degradation, deforestation, agricultural productivity, Niger Delta.
**JEL Classification:** Q5, Q23, Q24, Q32, Q52.

## Introduction

The Niger Delta is a development paradox characterized by endemic poverty in the midst of abundant natural and financial resources. The region's ecosystem has therefore been declared one of the most endangered ecosystems in the world (Anejionu et al., 2015). To some extent, the Niger Delta is a microcosm of the broader Nigerian nation state – which has considerably poorer developmental outcomes than much less successful economies in Sub-Saharan Africa (World Bank, 2011). However, the Niger Delta is a good example of poverty in the midst of plenty. Poverty is pervasive and yet the revenues generated from oil and gas extraction in the delta are responsible for 90% of Nigeria's export earnings and 80% of public revenues.

According to the 2006 National Population Census, the population of the Niger Delta is estimated at 31 million inhabitants (Nigeria Bureau of Statistics, 2006) and predominantly depend on the environment – principally agriculture and fisheries for their source of livelihood (Salami and Balogun, 2006). The National Bureau of Statistics (2004) further indicated that 50% of the active labor force in the Niger Delta predominantly cultivates food crops such as cassava, yam, plantain, maize, cocoyam and vegetables. The Niger Delta environment is highly degraded due to the intensive exploitation of oil and gas resources caused by oil spills, gas leaks, gas flares, and land degradation, flooding and erosion (UNEP, 2011). According to Anejionu et al. (2015), over 10,000 oil spill and pipeline explosion incidents have been recorded and more than 350 billion cubic metres of gas have been flared in the region in the last 14 years. In addition to not receiving an appropriate share of the proceeds of oil and gas extraction, many traditional livelihoods activities have been undermined by these negative externalities of the extractives sector.

The location of the Niger Delta region in the rainforest and mangrove forest vegetative zones of Nigeria makes it possible to have all-year-round agricultural production activities. With high levels of involvement in agriculture and increasing revenues from oil exploration, the Niger Delta region is expected to have high levels of agricultural production and very low poverty levels, but the reverse is the case.

According to the Nigerian Bureau of Statistics (2004), the incidence of poverty in the Niger Delta increased from 15.4% in 1980 to 52.2% in 2004 and is connected to the constant incidence of oil spills which has destroyed sources of income and productive activities in the region. Furthermore, Manby (1999), Nnabuenyi (2012) observed the negative effects of oil spills on agriculture and lamented that most of the destroyed farmlands and polluted rivers have contributed to the frustration and lack of livelihoods for farmers and fishermen. Chindah and Braide (2000) indicated that oil spills cause great damage to Niger Delta communities due to the high retention time of oil in the soil occasioned by limited flow. This prevents proper soil aeration and affects soil temperature, structure, nutrient status and pH, and


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ultimately, crops are destroyed. The negative impacts on agricultural practices by oil extraction activities have contributed to the abject poverty and conditions of social deprivation experienced by communities in the region (Effiong et al., 2012).

## 1. Literature review

The extent and consequences of environmental degradation due to oil spillage in the developing world has become the subject of considerable debate and concern especially the incidence of increased tropical deforestation resulting from oil explorations activities. This has led to heavy impacts on the environment and livelihoods of communities inhabiting around these natural resources (Southgate, 1990). Although, there is an agreement that the quest for agricultural land is a major function in the depletion of tropical forests (Ehui et al., 1989; Ehui et al., 1990). However, oil spillage increases the rate of deforestation and related environmental degradation on agricultural land because of its negative effects on forest or fallow land and also agricultural land. According to Egbe and Thompson (2010), the environmental and economic externalities of oil spills on the livelihoods of communities include marine contamination, soil contamination, reduced crop production, increased incidences malnourishment related diseases and general socio-economic effects.

Ojimba (2012) examined the effects of oil pollution on crop production in Rivers State, Nigeria using a stochastic translog production function. A total of 296 questionnaires were administered in 17 out of 23 Local Government Areas using a multi-stage sampling technique. 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, while in non-polluted farms output increased by 0.3814 tons. Physical inputs, crude oil pollution variables and their interactions showed strong negative (diminishing) returns to scale in oil polluted farms, but in non-polluted farmlands showed strong positive returns to scale. The technical efficiency results indicated that less than 22% of crop farmers were over 80% efficient in resource use in oil polluted farmlands, while technical efficiency in non-polluted farmlands indicated a high efficiency were 33%.

Ahmadu and Egbodion (2012) examined the effect of oil spills on cassava farm land, yield and land productivity in Delta State. Seventeen (17) cassava farmers each from 3 oil spill communities and 3 non-oil spill communities were randomly selected to give a total sample size of 102 respondents for the study. Data were analyzed using descriptive statistics, Likert scale, t-statistics and regression analysis. The results showed that the major significant effects of oil spills on cassava production perceived by the farmers included crop failure, poor yield, rotting tubers, and stunted crop growth with mean scores of 4.80, 4.78, 4.75 and 4.75 respectively. Others included increased soil temperature and toxicity (mean: 4.73), reduction of soil fertility (mean: 4.70), degradation of farm land (mean: 4.70) and low land productivity (mean: 4.70). The results further indicated that the cassava farm size, yield and land productivity in oil spill affected communities were significantly ($p < 0.01$) lower than those of the non-oil spill affected communities by 0.61 ha, 6119 metric tonnes (MT) and 1447 MT/ha respectively. These represent significant reduction of 36%, 48% and 20% of these variables in the oil spillage affected communities respectively. About 45% of the variation in land productivity in cassava production was influenced by oil spill and the farmers' farming experience. The productivity increased with increase in farming experiences, but decreased with increase in oil spills.

Inoni et al. (2006) examined the environmental degradation of the oil-rich Niger Delta region of Nigeria using a sample of 262 crop farmers drawn randomly from 10 communities and 5 Local Government Areas (LGAs) in the oil producing agro-ecological zones of Delta State. The result showed an accentuated negative impact of oil spills on crop production. Oil spills reduced crop yield, land productivity and greatly depressed farm income. A 10% increase in oil spill reduced crop yield by 1.3%, while farm income plummeted by 5%.

**1.1. Negative environmental externalities in the Niger Delta.** Oil spillage exacerbates the process of deforestation, which indirectly affects forest biomass and agricultural productivity of the land. Oil spillage also affects agricultural productivity directly through direct impacts of an oil spill on arable land, which destroys both, cultivated and fallow land. The impact of an oil spill on both cultivated and forest or fallow land is measured using forest biomass. The forest biomass is referred to as the proportion of total fallow and forested land affected by oil spillage.

As noted by the World Bank (1995), resource degradation in agrarian economies is directly related to agriculture. In the context of the Niger Delta, this problem is exacerbated by oil spillage, which destroys the forest biomass. In conclusion, there is a linkage between land degradation activities and oil production and distribution activities, as they affect the agricultural productivity and production of the Niger Delta of Nigeria.

**1.2. Objective of the paper.** The objective of this paper is to empirically assess the impacts of oil spillage on agricultural productivity and land degradation for the period – 1985-2013. In evaluating the extent of oil spill impacts, we estimated the impacts of land degradation (fallow or forestland) as a factor of agricultural production and tested the hypothesis that oil spillage efficiently degrades both agricultural land and agricultural production. This result will be used to establish a unique link between oil spillage, land degradation and agricultural productivity.

## 2. Methodology

The model follows the framework of Lopez (1997). In the paper, the author showed the importance of biomass as an input in agricultural production and that increasing levels of deforestation, which depletes the level of biomass, will affect agricultural productivity and production. Following Lopez's model, this present model also assumes that biomass is an important input in agricultural production in the Niger Delta area of Nigeria. However, in this model it is not only increasing levels of deforestation that depletes the biomass but also the increasing level of oil spillage. This model derives an estimable production function with the amount of oil spilled as a variable influencing agricultural production.

**2.1. The model.** We assume the existence of a well-behaved production function ($Q_i$), relating agricultural output of an individual farmer to the given forest biomass ($\theta$) and the conventional inputs ($L_i$, $x_i$, $K_i$) used by the farmer.

$$Q_i = F^i\left(L_i, x_i, K_i, \theta\right), \qquad (1)$$

where: $Q_i$ = output of farmer $i$ in the village; $L_i$ = labor input used by the farmer $i$; $x_i$ = level of cultivated land that farmer $i$ uses; $K_i$ = fixed factors; $\theta$ = forest biomass in the village where farmer $i$ is located.

The measure of total biomass can be given as the area and density of forest matter. It is easiest to capture area and density of the forest matter through biomass in practise; although there are a few data on density (crown cover), area dominates the measure of biomass. Therefore in this paper, the total biomass will be referred to as forest biomass.

With the assumption that forest biomass in a given village is influenced by both cultivated land and the level of spillage, the forest biomass in a given village can be expressed as[1]:

$$\theta = \eta.\left\{\left(\bar{x} - \sum_{i=1}^{N} x_i\right)(1-\lambda)\right\} \qquad (2)$$

$0 \le \lambda \le 1,$

where,

$\eta$ = average forest biomass density or average "crown cover";

$\lambda$ = reflecting the effect of access of forest land; indirect and direct effects of oil spillage;

$\bar{x}$ = total land area in the village;

$\sum x_i$ = total cultivated land area in the village;

$N$ = total number of farmers in the village;

$\left(\bar{x} - \sum x_i\right)(1-\lambda)$ = proportion of fallow or forested land not affected by oil spillage.

Forest biomass can therefore be expressed as the proportion of total fallow and forestland $(\bar{x} - \sum x_i)$ not affected by oil spillage $(1-\lambda)$. It follows also that as oil spillage ($\lambda$) increases forest-biomass ($\theta$) falls. That is, the level of oil spillage affects not only productivity of cultivated lands $\left(\sum x_i\right)$ but also total land area $\left(\bar{x}\right)$ and negatively affects the productivity of the total fallow land or forestland $(\bar{x} - \sum x_i)$.

The average forest biomass density, $\eta$, following Lopez (1997) can be postulated as a single specification for the dynamics of $\eta$.

$$\dot{\eta}_t = \tilde{\alpha} - \left[\frac{d}{dt}\sum x_i(t) + \lambda(t)\left(\bar{x} - \sum x_i(t)\right)\right]\eta, \qquad (3)$$

where,

$\alpha$ = rate of growth of the natural vegetation in a steady state;

$\tilde{\alpha} > 0$ represents natural growth of vegetation;

$\frac{d}{dt}\sum x_i(t)$ is the rate of change of the total cultivated land;

$\lambda(t)\ \left(\bar{x} - \sum x_i(t)\right)$ = fallow land or forest land affected by oil spillage.

[1] López assumes that the village biomass decreases as the number of farmers increase and clear more land. In this model our interest is on the level of oil spillage, so assuming a given level of farmers, and a given level of deforestation due to land clearance the differences in the level of production will be determined by differences in the level of oil spillage. Moreover, since oil extraction also takes place in the Niger Delta, it should be reasonable to include an oil extraction production function in the model, which will act as an externality in the agricultural production function, $Q_i$. However for simplicity of the model, this is not included, rather this externality is assumed to work through the oil spillage variable ($\lambda$).

For the level of biomass to be stable, $\dot{\eta}_t = 0$, and $\frac{d}{dt}\sum x_i(t) = 0$. In the long run, the rate of change in average forest biomass density and cultivated land should be equal to zero. The level of biomass is stable.

It means that, $\dot{\eta} = \tilde{\alpha} - \left[\bar{x}\lambda\left(1 - \frac{\sum x_i}{\bar{x}}\right)\right]\eta_t = 0$

which follows that:

$$\eta_t = \tilde{\alpha}\left[\frac{1}{\lambda}\left(1 - \frac{\bar{x}}{\sum x_i}\right)\right]. \tag{4}$$

Therefore, the average forest biomass density in the long run is inversely related to the proportion of cultivated land area $(1/\sum x_i)$ and the level of oil spillage $(1/\lambda)$.

Substituting equation (4) for $\eta$ in equation (2) we have:

$$\theta = \tilde{\alpha}\left(1 - \frac{\bar{x}}{\sum x}\right)\left(\frac{1}{\lambda} - 1\right) \tag{5}$$

That is the total forest biomass volume is decreasing with the proportion of cultivated land and total land with oil spillage ($\lambda$), but increasing with the rate of growth of natural vegetation ($\tilde{\alpha}$).

**2.2. Maximization problem.** Assuming that the village is a price taker in the output and input markets and the villagers also have an opportunity cost for their time (the wage rate), that is exogenous to the village the maximization of the aggregate village wealth would then require:

$$\max_{x_i, L_i} \int_0^{\infty} \left\{ \sum_{i=1}^{N} pF^i\left(L_i, x_i, K_i, \theta\right) - wL_i - cx_i \right\} e^{-rt} dt. \tag{6a}$$

$$s.t.\ \ \theta = \eta.\left\{\left(\bar{x} - \sum_{i=1}^{N} x_j\right)(1-\lambda)\right\},$$

$$\dot{\eta} = \tilde{\alpha} - \left[\frac{d}{dt}\sum x_i(t) + \lambda(t)\left(\bar{x} - \sum x_i(t)\right)\right]\eta, \tag{6b}$$

$$\eta(0) = \bar{\eta}_0,$$

where $p$ = output price; $w$ = wage rate; $c$ = private cost of clearing land; $r$ = discount rate; $\bar{\eta}_0$ = initial level of average forest biomass density per acre in fallow land; $N$ = total number farmers that share the common land of the village.

Maximization of equation (6) is equivalent to maximizing the current value Hamiltonian or the current income function at each point in time.

$$\begin{aligned} \max Y^A \equiv & \sum_{i=1}^{N} \left\{ pF^i\left[L_i, x_i, K_i, \eta\left(\bar{x} - \sum_i x_i\right)(1-\lambda)\right] - wL_i - cx_i \right\} \\ & + \mu\left\{\tilde{\alpha} - \left[\eta\left(\frac{d}{dt}\sum x_i + \lambda\left(\bar{x} - \sum x_i\right)\right)\right]\right\}, \end{aligned} \tag{7}$$

where $\mu$ = current value co-state variable measuring the shadow value of $\eta$; $Y^A$= corresponds to the total true income of the village.

The control variables in the model are labor input ($L_i$) and the level of land ($x$), while the state variables are proportion of land with oil spill ($\lambda$) and the average forest biomass density ($\eta$). The first order conditions assuming an interior solution are the following:

$$\frac{\partial Y^A}{\partial L_i} = pF_L^i(\cdot) - w = 0, \quad i = 1,\ldots.., N \tag{8a}$$

$$\frac{\partial Y^A}{\partial x_i} = pF_{x_i}^i(\cdot) - c - \left\{\sum_i pF_\theta^i(\eta)(1-\lambda)\right\} - \mu\eta\lambda = 0, i = 1,\ldots, N, \tag{8b}$$

$$\dot{\mu} = \left[r + \frac{d}{dt}\sum x_i + \lambda\left(\bar{x} - \sum x_i\right)\right]\mu - \left(\bar{x} - \sum x_i\right)(1-\lambda)\sum pF_\theta^i, \tag{8c}$$

$$\dot{\eta} = \tilde{\alpha} - \left[\frac{d}{dt}\sum x_t + \lambda\left(\bar{x} - \sum x_i\right)\eta\right], \tag{8d}$$

$$\eta(0)=\eta_0\,;\lim_{t\to\infty}e^{-rt}\mu(t)\eta\left(\bar{x}-\sum_i x_i\right)(1-\lambda)=0, \quad (8e)$$

where the subscripts of the $F^i(\cdot)$ function denote the partial derivatives with respect to the corresponding terms. In equation (8d), the symbol of the rate of growth of natural vegetation, $\bar{\alpha}$ is replaced by the symbol $\alpha$ in the dynamic state.

Equation (8a) is the usual profit maximization condition, which denotes that the farmer $i$ should employ labor until the marginal demand for labor ($L_i$) on the total current income $Y^A$ is equal to the wage rate ($w$). Equation (8b) indicates the farmer $i$ should adjust his/her level of land under cultivation until the marginal effect of cultivated land ($x_i$) on the total current income $Y^A$ is zero.

This occurs at the point where the additional revenue of an acre of land cultivated $\left(pF^i_{x_i}\right)$ is equal to the private cost of incorporating fallow land or forest land into production, ($c$) (the land clearing cost), plus the instantaneous loss of revenue for all the producers in the village caused by the reduction of fallow area or forested area not affected by oil spillage, $\sum_i pF^i_{\theta_i}(\eta)(1-\lambda)$, plus the future income losses for all the farmers $(\mu\eta\lambda)$ due to the reduction of the average forest biomass density ($\eta$) that increasing cultivated land ($x_i$) and proportion of land with oil spillage causes. As the effects of a shortened fallow cycle are manifested through time and oil spillage increases $(\mu\eta\lambda)$, it therefore follows that at each point in time the rate of change in income due to a change in cultivated land is reduced due to continuous increased cultivated land which shortens the fallow period and also due to oil spillage effects which reduces the productivity of the land. Since without those two effects:

$$\frac{\partial Y^A}{\partial x_i}=pF^i_{x_i}(\cdot)-c>\frac{\partial Y^A}{\partial x_i}\,pF^i_{x_i}-c-\left\{\sum pF^i_\theta\eta(1-\lambda)\right\}-\mu\eta\lambda.$$

Equation (8c) is the well-known no-arbitrage condition indicating that the marginal social return of the average forest biomass density ($\eta$) should be equal to its marginal social cost. The total marginal social return is equal to the contribution of the average marginal density ($\eta$) to the revenue of all farmers in the village plus the capital gains (or losses) associated with changes in $\mu$. The marginal cost of $\eta$ is equal to the opportunity cost, $r\mu$, plus the value of the stock depleted $\left[\frac{d}{dt}\sum x_i+\lambda\left(\bar{x}-\sum x_i\right)\right]\mu$.

Finally equation (8d) is just a reinstatement of the control constraint.

In a steady state, $\dot{\mu}=\dot{\eta}=0$, and given also that $d/_{dt}\sum x_i=0$, it implies that $\mu$ and $\eta$ are given as,

$$\mu*=(1-\lambda)\sum pF^i_\theta/r+\lambda \quad (9a)$$

$$\eta*=\alpha/\lambda\left(\bar{x}-\sum x_i\right) \quad (9b)$$

Also using equation (9a) in equation (8b), we can therefore derive the following equation:

$$\frac{\partial Y^A}{\partial x_i}=pF^i_{x_i}(\cdot)-c-\left[\sum pF^i_\theta(\eta)(1-\lambda)\right]-\left[\frac{(1-\lambda)\sum pF^i_\theta}{r+\lambda}\right]\eta\lambda=0,\ i=1\ldots N. \quad (10)$$

The first order conditions equations (8a), (8b), (8c), (8d) and (8e) correspond to the case when the village is able to exert perfect controls on the use of the common property land resources by individual farmers. That is, it implies that land and labor are efficiently allocated. If social controls over individual farmers are non-existent or not perfect, the land allocation will not, in general follow the rule indicated by equation (8b) or, in the steady state, by equation (10). Since the land clearing costs ($c$) are entirely private, a farmer is likely to fully consider this cost in his land cultivation decision but unless he is forced by regulation or transaction, he will not take into account the full extent of the marginal cost of the rest of the village farmers. That is, in equation (10) for example farmer $i$ may only consider a fraction of the cost:

$$\left[\sum pF^i_\theta(\eta)(1-\lambda)\right]-\left[(1-\lambda)\sum pF^i_\theta/r+\lambda\right]\eta\lambda,$$

which is made worse by the oil spillage.

In the extreme case where there is no social regulation (or taxation) whatsoever, the individual farmer will only consider approximately 1/$N$th of the latter cost. Thus, in general we have $\partial Y^A/\partial x_i\le 0$. If $\partial Y^a/\partial x_i<0$ for at least some $i$ = 1…N, the social controls are imperfect and thus the community's income is less than its maximum due to excessive land cultivation. If $\partial Y^A/\partial x_i=0$, for all $i$ = 1…$N$ the community's income is maximised.

Table 1 provides a summary of the differences between Lopez's model and the adopted model by Akpokodje (2000) for this paper.

Table 1. Summary of differences between López's and the present model

| | López's model | Present model |
|---|---|---|
| Objective function | $Max\ Y^A = \sum_{i=1}^{N} \left\{ pF^i \left[ L_t, x_i, K_i, \eta\left( \bar{x} - \sum_j x_j \right) \right] - wL_t - cx_t \right\}$ $+\mu \left[ \gamma - \frac{\sum x_j}{\bar{x}} \eta \right]$ | $Max Y^A = \sum_{i=1}^{N} \left\{ pF^i \left[ L_t, x_i, K_i, \eta\left( \bar{x} - \sum_i x_i \right)(1-\lambda) \right] - wL_t - cx_t \right\}$ $+\mu \left[ \tilde{\alpha} - \left[ \bar{x}\lambda\eta \left( 1 - \frac{\sum x_i}{\bar{x}} \right) \right] \right]$ |
| Production function | $\ln Q_{jt} = \beta_0 + \beta_x \ln x_{ijt} + \beta_L \ln L_{ijt} + \beta_\theta \ln \theta_{jt}$ $+ Intercept\ Dummies + \varepsilon_{ijt}$ | $\ln Q_{jt} = \beta_o + \beta_x \ln x_{ijt} + \beta_l \ln L_{ijt} + \beta_\lambda \ln(1-\lambda_{jt})$ $+ \beta_{\bar{x}} \ln(\bar{x} - \sum x_i) + \beta_K \ln K_{ijt} + \varepsilon_{ijt}$ |
| Control variables | Labor, $L_i$ and Land, $x_i$ | Labor, $L_i$ and Land, $x_i$ |
| Static variable | Biomass density, $\eta$ | Biomass density, $\eta$ and land with oil spillage, $\lambda$ |
| Endogenous variable | Labor, $L_i$; Land, $x_i$; farm capital, $K_i$, total biomass, $\theta$ | Labor, $L_i$; Land, $x_i$; farm capital, $K_i$, forest biomass, $\theta$ |
| Equations of motion | $\dot{\mu} = \left( r + \frac{\sum x_j}{\bar{x}} \right)\mu - \left(\bar{x} - \sum x\right) \sum_j pF_4^j(\cdot)$ | $\dot{\mu} = \left[ r - \bar{x}\lambda \left( 1 - \frac{\sum x_i}{\bar{x}} \right) \right]\mu + pF_\eta$ |

**2.3. Production function estimation.** We can specify a Cobb-Douglas functional form from the production function.

$$\ln Q_{jt} = \beta_o + \beta_x \ln x_{ijt} + \beta_l \ln L_{ijt} + \beta_\lambda \ln\left(1-\lambda_{jt}\right) + \\ + \beta_{\bar{x}} \ln\left(\bar{x} - \sum x_i\right) + \beta_K \ln K_{ijt} + \varepsilon_{ijt}, \tag{11}$$

where,

$Q_{ijt}$ = output of farmer $i$ in village $j$ at time $t$.

$x_{ijt}$ = land cultivated by farmer $i$ in village $j$ and time $t$.

$L_{ijt}$ = labor used farmer $i$ in village $j$ at time $t$.

$\left(x - \sum x_i\right)$ = forest land.

$\lambda_{ijt}$ = quantity of spills (barrels).

$K_{ijt}$ = farm capital (i.e. the tools).

$\varepsilon_{ijt}$ = the disturbance term.

In the econometric specification above, forest land and oil spill variables are used to account for the environmental factors that affect agricultural production. The use of the fallow or forested land as a factor of production is appropriate under the assumption of the steady state. This occurs when the stock of biomass is constant, the proportion of fallow land or forestland determines the fertility of the cultivated land (Ehui et al., 1989; Ehui et al., 1990). Outside the steady state, the relationship between the cultivated land fertility and the proportion of fallow land or forestland is less direct and is also affected by the rate of forest biomass accumulation. Besides the fertility effect, the level of forest biomass in the areas surrounding the cultivated land patches help to protect against flooding and other physical damages. This positive effect on agricultural productivity is not dependent on whether or not steady state prevails. Furthermore, land and capital, labor and capital were respectively interacted to avoid possible collinearity between land and capital, since land is equally regarded as a capital asset.

**2.4. Sources of data.** These data were obtained from the FAO yearbook from 1994 to 2013. The data on agricultural output are based on agricultural production in Nigeria and it is measured using the FAO indices for agricultural production which shows the relative level of agricultural production for each year in comparison with the base period 2001. Land is derived from the data on arable land and permanent crop, while labor is derived from the agricultural population in Nigeria, defined as all persons depending for their livelihood on agriculture. The forest data were derived from forest-land and woodland area in Nigeria. It is worthy to emphasizes here that the above data on Nigeria are used as a proxy for the Niger Delta area. However, the data on oil spill are based directly on data for the Niger Delta.

## 3. Summary of results

Table 2 provides various estimates from a log-linear production function over a period of twenty-nine years (1985-2013).

Table 2. Summary of regression results

| Variables | Coefficients | t-statistic |
|---|---|---|
| Constant | 20.772 | 2.18 |
| Land & capital | 0.551 | 2.55** |
| Labor | 0.701 | 2.98*** |
| Labor & capital | -0.388 | -1.6 |
| Forest | -2.780 | -3.87*** |
| Oil spills | 0.002 | 0.06 |
| Number of years | 29 | |
| R-squared | 0.820 | |
| Adj-R-squared | 0.780 | |
| F-statistics | 81.21 | |
| Probability > F | 0.000 | |

Notes: (***), (**), (*), significant at 1%, 5%, and 10% respectively.

The estimates of the production function appear to be plausible. Several attempts were made to assess the performance of the variables before the interaction terms were introduced but a recurring collinearity between land and capital were observed hence the need for the introduction of interaction terms. The goodness-of-fit is good; this can be seen from the coefficient of determination $\overline{R^2}$, which states that the explanatory variables in the model explain almost 80% of the variation in the dependent variable while barely 20% of the variation in the dependent variable was due to error term. In observing the F-statistics, the variables in the model were found to be jointly significant at 1% degrees of freedom. Moreover, the signs are as expected; but oil spillage which is a major target in this paper is insignificant, this could be attributed to the dynamics of managing oil exploration activities in the Niger Delta. However, forest or fallow land, and labor were significant at 1% degree, while the interaction of land and capital was significant at 5%.

Given the results, increases in levels of oil spills and increasing levels of forest loss, which reduces the forest biomass, would negatively affect agricultural production. While, labor, land and capital would positively affect agricultural production in the Niger Delta.

## Conclusions

This paper addressed the trade-off between agricultural land and forestland, taking into account the interactions between deforestation, agricultural production and oil spillage. However, variables such as population growth and forest access via pipelines have strengthened this link, but not captured as variables in the model in this paper. Using empirical findings, this paper has demonstrated that, increases in levels of oil spillage and increasing levels of forest loss negatively affect agricultural production or productivity in the Niger Delta. Although, the incidence of vandalism has reduced drastically in recent times and the response to clean up has improved, the rate of bio-degradation of spillage and the recovery rate of the deforested land still negatively affects agricultural output/production in the Niger Delta. However, future studies could improve the robustness of these findings by quantifying in monetary terms the losses due to farmers from oil spillage and deforestation.

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