SIMULATION MODELING OF THE EFFECT OF CRUDE OIL SPILLAGE ON THE YIELDS OF CASSAVA AND YAM SPECIES WITHIN THE OGONI ENVIRONMENT: BEYOND HARVESTING TIME SCENARIO

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Abstract

Within the crop science ideology and the basic theory of agricultural science near and beyond harvesting time scenarios are standard construction that have received elaborate investigations in the absence of simulation modeling which is the language of the present computational era. The effect of crude oil spillage on the yields of cassava and yam species within the Ogoni environment has the potential to create some degree of environmental perturbations. This environmental perturbation can affect the extent of biodiversity gain in which the yam species tend to have a higher quantified magnitude of biodiversity gain than the cassava species. The full novel results that we have obtained which has not been seen elsewhere are presented and discussed quantitatively.

Introduction

From both mathematical and scientific perspectives, the devastating effect of crude oil spillage on two competing crops such as cassava and yam species for limited resources within the Ogoni ecological system makes the inclusion of crude oil spillage to act as an inhibiting factor on the yields of cassava and yam species and also introduces some elements of environmental perturbation in the form of a random noise intensity that ranges from the value of 0.01 mimicking a low environmental perturbation to mild environmental perturbation value of 0.02 and followed by a relatively severe environmental perturbation value of 0.1

For the purpose of this study, we are interested to find out the differential effect of these three types of environmental perturbations on the type of biodiversity in the scenario of beyond harvesting time.

Other research contributions in related area of study can be seen in the works of the following:

Crude oil spillage on the surface of the soil reduces the yields of crops and causes low land productivity in Ogoni land. Some causes of crude oil spillage in Ogoni land were due to oil well blowouts, corrosion and vandalization of pipelines, accidental discharges, and sabotage popularly known as bunkering. These crude oil spillages can lead to underground leakages which have impacts on the environment in the form of underground water pollution, soil pollution (Ikhajiagbe and Anoliefo, 2011), health effect (Chukwu and Lawal, 2010) and destruction of vegetation (Alam *et al*., 2010).

Crude oil spillage on the surface of the soil causes poor soil aeration, destruction of soil structure and total crop failure. Other effects included poor yield, rotting of the cassava and yam tubers, stunted growth of cassava and yam, yellowing of the cassava and yam leaves, wilting of cassava and yam, reduction of soil fertility, degradation of farm land, increased soil temperature/toxicity and bad taste of produce.

Many researchers have studied the effects of crude oil spillage 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).

Inoni *et al.* (2005), have conducted a survey to measure the qualitative effect of oil spillage on crop yields and farm income in Delta State of Nigeria and observed that oil spillage can reduce crops yield, land productivity and greatly deplete farm income.

Ojimba (2012) conducted a research on determining the effects of crude oil pollution on crop production using stochastic translog production function in Rivers State. The result reviewed that crude oil spillage has negative and detrimental effects on crop yields.

Ahmadu and Egbodim (2013) did a study to examine the effect of oil spillage on cassava farm land, yield and land productivity at Niger Delta region of Nigeria and the result shown poor yield of cassava.

Ekaka-a *et al.* (2013) conducted a stability analysis for a system of interacting populations with a dis-similar carrying capacity, a research work that evaluated the yields of cowpea and groundnut using various model parameters.

Ekundayo *et al*. (2001), studied the effects of crude oil spillage on growth and yield of Maize (Zea Maysl) in soil of mid western Nigeria. Their results showed that in crude oil polluted soils, germination was delayed and poor.

Ahmadu and Egbodim (2013) did a study to examine the effect of oil spillage on cassava farm land, yield and land productivity at Niger Delta region of Nigeria between January and October, 2012. A random sampling technique was employed to select 17 cassava farmers each from three oil spillage communities (Otor-Udu, Olomoro and Uzere) and three non oil spillage communities (Egini, Aradhe and Echi), giving a total sample size of 102 respondents for the study. Data analysis was done using descriptive statistics, t-test and regression analysis. The results of the study shows that the major significant effects of oil spillage 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.

Achuba (2006) examined the impact of crude oil spillage affected soil at different concentrations (0.25, 0.5, 0.1 and 2%) on the yield of cowpea (Vigna unquiculata) seedlings. The results testified that crude oil caused environmental stress in the seedlings.

Gbadebo and Adenuga (2012), conducted a study to examine the effect of crude oil on the germination and growth of cowpea in two different kinds of soil (Westland/Fadama and Upland Soils). The study was conducted around the planting period suitable at January in the tropical rain forest, the soil particle size using the hydrometer method; pH of the soil solution which look out for soil and water ration and the growth parameter which measures the growth rate and the leaf area ratio. The key result from the test indicates that cowpea strives in low fertility soil with a pH between 5.5 and 6.5; increase in soil concentration from 0- 75mls significantly decreased seedlings emerging in the cowpea; and the result obtained reveals that the growth rate of cowpea decrease in sterm height, numbers and percentage protein content with increasing crude oil contaminations.

Eze *et al*. (2013) conducted a research to evaluate the effects of different levels of Bonny light crude oil contamination on the germination, shoot growth and rhizobacterial flora of cowpea and groundnut grown in sandy loan soil samples in Nsukka, Nigeria. Collection of soil sample and testing method was used on Bonny light crude oil (specific gravity = 0.81; API gravity = 43.2^0) was obtained from Nigerian National Petroleum Corporation (NNPC), Port Harcourt refinery, Alesa-Eleme, Rivers State, Nigeria. The crude oil was un-weathered, having been obtained fresh from the production plant crude oil at a level of 2.5% increased germination time in cowpea by 24h but at higher doses (5 to 20%) germination of cowpea seeds was totally inhibited. Alternatively, germination of groundnut seeds occurred at different rates. The germination time was 7 days in soils with 0.5 to 2.5% oil concentration and an average of 9 days in those with 5 to 20% levels of the pollutant. Despart groundnut germinated and grow in all concentrations of crude oil tested, significant ($p<0.05$) shoot growth retardation still occurred in both legumes consequent on crude oil toxicity. Cowpea population also diminished with increase in crude oil concentration.

The study shows that both the vulnerability of cowpea and the resistance of groundnut to crude oil, marking groundnut out as a promising phytoremediation candidate.

Abii and Nwosu (2009) collected soil samples at the top surface 0- 15cm and sub-surface 130cm- depth and the soil nutrient content and fertility status (K, Ca, Mg, C, P, Ph, cation Exchange capacity (CEC) and structure) from Ogali and Agbonchia areas of Eleme LGA to determine the oil spillage on the soil. Key result of the study shows that oil spill has adversely affected the nutrient level and fertility status of Eleme soil.

Fayemi A. A. (1975) conducted a research work on the Effect of crude oil pollution on Germination, Growth and Nutrient uptake of Corn. Corn (Zea Mays L) was planted on a soil polluted by crude oil at different levels from 0 to 10.6% by weight of soil, using three corn crops to rise in succession, each for a period of 6 weeks, in the same soil. Germination and yields were drastically reduced as the level of pollution increased.

De Jong (1980) conducted a research on the Effect of Crude Oil Spill on cereals. This research examined that the break in an oil pipeline in mid-winter caused oil to travel underground one, a distance of about 850m; that oil moved upwards through cracks in the frozen soil, especially during recovery attempts and that the contamination in the affected area varied considerably both horizontally and vertically. The result of this work, showed that grain yield were affected by oil pollution and water uptake by wheat from contaminated layers or from below such layers.

Al-Qahtani (2011), carried out an experiment to determine the effects of oil refinery sludge on growth and soil properties. The results of the effect of oil refinery sludge on virica rosea and the soil chemical composition showed that the dry matter yield decreased significantly with increasing application of the oil.

Tilman (2000), discussed the causes, consequences, and the ethnics of biodiversity, one of the key contributions of this work is that human activities hinder the sustainability of biodiversity gain should be halted with the appropriate mitigation measures in order to mitigate the devastating consequences of biodiversity loss on the ecological services.

Kisic *et al.* (2009), carried out a research on the effect of crude oil crops and some chemical characteristics of soil. In the work a four-year pot trial was set up to determine, as precisely as possible, the influence of increased levels of total petroleum hydrocarbons (TPH) upon soil and crops grown. The method was to apply eight treatments, clean soil and different doses of crude oil, and the changes in some chemical parameters of soil, plant density and crop yields were investigated. The influence of the studied indicators on the achieved plant density and crop yield was strongest in the first trial year. The work shown the result that plant density and yield were strongly affected by crude oil.

Mathematical Formulations

For the purpose of this study, we have considered the following dynamical system of nonlinear first order ordinary differential equation with crude oil spillage pollution levels and environmental perturbation effects.

$$\frac{dC(t)}{dt} = \alpha_1 C(t) - \beta_1 C^2(t) - r_1 C(t)Y(t) - P_1 C^2(t) Y(t) + 0.01 (\text{rand}(1)) \quad 1$$

$$\frac{dY(t)}{dt} = \alpha_2 Y(t) - \beta_2 Y^2(t) - r_2 C(t)Y(t) - P_2 Y^2(t)C(t) + 0.01 (\text{rand}(1)) \quad 2$$

C(0) = 0.12 grams per area of plant cover of cassava.

Y(0) = 0.12 grams per area of plant cover of yam.

where the model parameters:

$\frac{dC(t)}{dt}$ represents the growth of cassava specie with respect to time t.

$\frac{dY(t)}{dt}$ represents the growth of yam specie with respect to time t.

α_1 represents the intrinsic growth rate for cassava specie in the absence of self-interaction and inter-competition interaction (birth rate- death rate) provided birth rate > death rate.

α_2 represents the intrinsic growth rate for yam specie in the absence of self-interaction and inter-competition interaction (birth rate- death rate) provided birth rate > death rate.

β_1 is the intra-competition coefficient between cassava specie and itself. That is, the contribution of cassava specie to inhibit cassava specie due to their self-interaction.

β_2 is t he intra-competition coefficient between yam specie and itself. That is, the contribution of yam specie to inhibit yam specie due to their self-interaction.
r_1 is the inter-competition coefficient of cassava. That is the contribution of the yam specie to inhibit the growth of cassava specie due to interaction between the cassava and yam species.
r_2 is the inter-competition coefficient of yam. That is the contribution of the cassava specie to inhibit the growth of yam specie due to interaction between the cassava and yam species.
P_1 represents the crude oil pollution level on the cassava specie.
P_2 represents the crude oil pollution level on the yam specie.
0.01 is the random poisson probability law environmental perturbation due to human activities.

C(t) denotes the cassava biomass at time t.
Y(t) denotes yam biomass at time t.

Remarks

For the purpose of this study and analysis, we have considered the following inclusions:

1. The original length of the growing season for the growth of cassava and yam species is taken to be 13 months.
2. Near harvesting time is conceptualized into three scenarios namely:
   11 months; $\frac{11}{13}(100) = 84.60 = 85\%$ (2 s.f).
   11.6 months; $\frac{11.6}{13}(100) = 89.23 = 89\%$ (2s.f).
   12 months; $\frac{12}{13}(100) = 92.31 = 92\%$ (2 s.f).
3. Beyond harvesting time is similarly conceptualized into three scenarios namely;
   14 months; $\frac{14}{13}(100) = 107.69 = 110\%$ (2 s.f).
   18 months; $\frac{18}{13}(100) = 138.46 = 140\%$ (2 s.f).
   19.6 months; $\frac{19.6}{13}(100) = 150.77 = 150\%$ (2 s.f).
4. Crude oil spillage pollution levels are considered as follows:
   $p_1 = 0.004$ on the cassava specie.
   $p_2 = 0.0035$ on the yam specie

Method of Analysis

If $\beta_1, \beta_2, r_1, r_2, P_1, P_2 \neq 0$, the following semi-stochastic first order non-linear ordinary differential equations:

$$\frac{dC(t)}{dt} = \alpha_1 C(t) - \beta_1 C^2(t) - r_1 C(t)Y(t) - P_1 C^2(t)Y(t) + 0.01\,(rand(1)) \quad 3.9$$

$$\frac{dY(t)}{dt} = \alpha_2 Y(t) - \beta_2 Y^2(t) - r_2 C(t)Y(t) - P_2 Y^2(t)C(t) + 0.01\,(rand)(1) \quad 3.10$$

C(0) = 0.12 grams per area of plant cover of cassava
Y(0) = 0.12 grams per area of plant cover of yam,
are difficult to solve analytically,

Hence, we have used a MATLAB numerical simulation analysis called ODE of order 45 to model the differential effects of crude oil spillage pollution levels and environmental perturbation effects on the yields of cassava and yam species near and beyond harvesting times scenarios.

For the purpose of model parameter simulation, we have considered the following model parameter values as derived by Ekaka-*et al*. (2013);
$\alpha_1 = 0.0225, \alpha_2 = 0.0446, \ \beta_1 = 0.006902$
$\beta_2 = 0.0133, \ \ r_1 = 0.0012, \ \ r_2 = 0.0012$
Next, we have considered the assumed crude oil pollution levels on cassava and yam species as follows: $P_1 = 0.004 \ and \ P_2 = 0.0035$ and 0.01 random poisson probability law environmental perturbation.

For beyond harvesting time scenarios, the length of growing season is varied by approximately 110% (14 months), 140% (18 months) and 150% (19.6 months) for 0.01, 0.02 and 0.1 environmental perturbations.

Results

Beyond Harvesting Time Scenarios

Table 4 shows fourteen months (approximately 110%) variations of the length of the growing sea of the growing season with crude oil spillage levels (0.004) on cassava and (0.0035) on yam yields undergoing 0.01 low environmental perturbation.

Table 4. Evaluating the differential effects of crude oil spillage levels (0.004) on cassava and (0.0035) on yam yields undergoing 0.01 low environmental perturbation: scenario four.

Example	Time (Months)	Cassava yield (old)	Cassava yield (new)	Effect 1 (%)	Yam yield (old)	Yam yield (new)	Effect 2 (%)
1	1	0.1200	0.1200	0.0000	0.1200	0.1200	0.0000
2	2	0.1226	0.1229	0.2447	0.1253	0.1258	0.3990
3	3	0.1253	0.1258	0.3990	0.1307	0.1318	0.8416
4	4	0.1280	0.1288	0.6250	0.1364	0.1382	1.3196
5	5	0.1308	0.1319	0.8410	0.1424	0.1448	1.6854
6	6	0.1336	0.1350	1.0479	0.1485	0.1517	2.1549
7	7	0.1365	0.1382	1.2454	0.1550	0.1590	2.5806
8	8	0.1394	0.1415	1.5065	0.1617	0.1665	2.9685
9	9	0.1424	0.1449	1.7556	0.1686	0.1744	3.4401
10	10	0.1455	0.1483	1.9244	0.1759	0.1827	3.8658
11	11	0.1486	0.1518	2.1534	0.1835	0.1913	4.2507
12	12	0.1518	0.1554	2.3715	0.1913	0.2003	4.7047
13	13	0.1551	0.1591	2.5790	0.1995	0.2097	5.1128
14	14	0.1584	0.1628	2.7778	0.2080	0.2195	5.5288

Table 5 shows eighteen months (approximately 140%) variations of the length of the growing season with crude oil spillage levels (0.004) on cassava and (0.0035) on yam yields undergoing 0.02 mild environmental perturbation.

Table 5: Evaluating the differential effects of crude oil spillage levels (0.004) on cassava and (0.0035) on yam yields undergoing 0.02 mild environmental perturbation: scenario five.

Example	Time (Months)	Cassava yield (old)	Cassava yield (new)	Effect 1 (%)	Yam yield (old)	Yam yield (new)	Effect 2 (%)
1	1	0.1200	0.1200	0.0000	0.1200	0.1200	0.0000
2	2	0.1226	0.1229	0.2447	0.1253	0.1258	0.3990
3	3	0.1253	0.1258	0.3990	0.1307	0.1318	0.8416
4	4	0.1280	0.1288	0.6250	0.1364	0.1382	1.3196
5	5	0.1308	0.1319	0.8410	0.1424	0.1448	1.6854
6	6	0.1336	0.1350	1.0479	0.1485	0.1517	2.1549
7	7	0.1365	0.1382	1.2454	0.1550	0.1590	2.5806
8	8	0.1394	0.1415	1.5065	0.1617	0.1665	2.9685
9	9	0.1424	0.1449	1.7556	0.1686	0.1744	3.4401
10	10	0.1455	0.1483	1.9244	0.1759	0.1827	3.8658
11	11	0.1486	0.1518	2.1534	0.1835	0.1913	4.2507
12	12	0.1518	0.1554	2.3715	0.1913	0.2003	4.7047
13	13	0.1551	0.1591	2.5790	0.1995	0.2097	5.1128
14	14	0.1584	0.1628	2.7778	0.2080	0.2195	5.5288

Table 6 shows nineteen and half months (approximately 150%) variations of the length of the growing season with crude oil spillage levels (0.004) on cassava and (0.0035) on yam yields undergoing 0.1 severe environmental perturbation.

Table 6: Evaluating the differential effects of crude oil spillage levels (0.004) on cassava and (0.0035) on yam yields undergoing 0.1 severe environmental perturbation: scenario six.

Example	Time (Months)	Cassava yield (old)	Cassava yield (new)	Effect 1 (%)	Yam yield (old)	Yam yield (new)	Effect 2 (%)
1	1	0.1200	0.1200	0.0000	0.1200	0.1200	0.0000
2	2	0.1226	0.1239	1.0604	0.1253	0.1280	2.1548
3	3	0.1253	0.1280	2.1548	0.1307	0.1364	4.3611
4	4	0.1280	0.1322	3.2813	0.1364	0.1454	6.5982
5	5	0.1308	0.1365	4.3578	0.1424	0.1550	8.8483
6	6	0.1336	0.1409	5.4641	0.1485	0.1651	11.1785
7	7	0.1365	0.1455	6.5934	0.1550	0.1759	13.4839
8	8	0.1394	0.1502	7.7475	0.1617	0.1873	15.8318
9	9	0.1424	0.1551	8.9185	0.1686	0.1995	18.3274
10	10	0.1455	0.1601	10.0344	0.1759	0.2124	20.7504
11	11	0.1486	0.1652	11.1709	0.1835	0.2260	23.1608
12	12	0.1518	0.1705	12.3188	0.1913	0.2404	25.6665
13	13	0.1551	0.1760	13.4752	0.1995	0.2557	28.1704
14	14	0.1584	0.1816	14.6465	0.2080	0.2719	30.7212

Discussion of Results

On the other hand, when we consider the three beyond harvesting time scenarios, as presented in Table 4, we observed that the 0.01 low environmental perturbation with crude oil spillage levels (0.004) on cassava and (0.0035) on yam yields, has predicted a dominant biomass gain in which the yam species benefit more than the cassava species.

In Table 5, showing eighteen months (approximately 140%) variations of the length of the growing season with crude oil spillage levels (0.004) on cassava and 0.0035 on yam yields undergoing 0.02 mild environmental perturbation, we observed that each cassava yields (new) are bigger than each cassava yields (old) and each yam yields (new) are bigger than each yam yields (old). Hence, there are increases in the yields of cassava and yam species.

Yam species increase in yields than cassava species. These illustrate the increase in the biomass of cassava and yam species.

In Table 6, irrespective of the 0.1 severe environmental perturbations, the biomass of cassava and yam species increase ranging from the first month to the 14^{th} month.

The each cassava yields (new) are bigger than the each cassava yields (old) and the each yam yields (new) are bigger than the each yam yields (old). Hence, there are increase in the yields of cassava biomass and yam biomass. The yam species increase in yields than the cassava species.

Conclusion

We have used the method of ODE 45 simulation modeling to show that biodiversity again is dominantly ensured irrespective of the degree of environmental perturbation.

The sustainability of these predicted biodiversity gain in the scenario of beyond harvesting time can vary if the Ogoni ecosystem suffers from some element of semi-stochastic variations. This numerical idea and its implication on the prediction of biodiversity with respect to yields of cassava and yam species will be the subject of future investigations

Recommendations

The present numerical method of predicting a dominant biomass gain from beyond harvesting time scenario can be used to improve crops yields in a crude oil spillage polluted environment if:

1. Harvesting is delayed beyond harvesting time
2. Mitigation measures are taken to reduce crude oil spillage

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Appendix 1

```
functiondN=jona111(t,N)
dN=zeros(2,1);
alpha1=0.0225;
alpha2=0.0446;
beta1=0.006902;
beta2=0.0133;
r1=0.0012;
r2=0.0012;
dN(1)=alpha1*N(1)-beta1*N(1)*N(1)-r1*N(1)*N(2)-0.004*N(1)*N(1)*N(2)*0.01*rand(1);
dN(2)=alpha2*N(2)-beta2*N(2)*N(2)-r2*N(1)*N(2)-0.0035*N(2)*N(2)*0.01*rand(1)
```

Appendix 2

```
clear all
clc
format short
t=0:1:13;
[t y]=ode45(@jona111,[t],[0.12 0.12],'reltol 0.001')
t1=0:1*0.85:13*0.85
[t1,y1]=ode45(@jona111,[t1],[0.12 0.12],'reltol=0.001')
N1=y(:,1)
N2=y(:,2)
%H1=[N1(1) N1(8) N1(15) N1(22) N1(29) N1(36) N1(43) N1(50)]'
%H2=[N2(1) N2(8) N2(15) N2(22) N2(29) N2(36) N2(43) N2(50)]'
N11=y1(:,1)
N21=y1(:,2)
%H11=[N11(1) N11(8) N11(15) N11(22) N11(29) N11(36) N11(43) N11(50)]'
%H21=[N21(1) N21(8) N21(15) N21(22) N21(29) N21(36) N21(43) M21(50)]'
PD1=[1-(N11./N1)]*100
PD2=[1-(N21./N2)]*100
F1=N11-N1
F2=N21-N2
%ANS=[N1 N11 PD1 N2 N21 PD2]
%ANS1=[H1 H11 P1 H2 H21 P2]
%ASN2=[N1 N11 PD1 N2 N21 PD2]
```