RESEARCH ARTICLE OPEN ACCESS

Infinite Optimization Modeling of Water-Oil Fluid Interaction in Niger Delta Soil

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ABSTRACT

Water-oil fluid interaction in soil possess problems which includes, contamination of soil and ground water, destruction of plants and animals, acute and chronic infection of humans living in the contaminated zones, destruction of aquatic lives, ecosystem and extinction of some plants and animals. This research is aimed at developing an infinite optimization model of water-oil fluid interaction in Niger Delta soil. The objectives are to carry out rainfall simulations at varying intensities and contaminant volumes on a given soil depth in Niger Delta soil, determine the accrued benefits of cultivating yam, maize, cassava, oil palm and fishery on five different hectares of diesel oil spill reclaimed land at Ogoni and develop optimization models that will minimize the cost of executing a multipurpose multi objective project and maximize profit of cultivating on reclaimed spill land at Ogoni. Cost/benefit analysis and Game theory was used to obtain the accrued benefits for the multi-purpose/multi-objective farm project and develop a 5 X 5 payoff matrix. The accrued benefits of cultivating on 1000 hectare of land per year for five different crops on reclaimed diesel spill land using cost benefit analysis is ₦87,536,250,001. Optimization models for cost minimization and profit maximization of the benefit accrued in the diesel spill land reclamation projects using game theory showed that player A and B best minimized cost and maximized profit at strategy $0.01_{x1}+0.04_{x2}+0.01_{x3}+0.03_{x4}+0.01_{x5}$ and $0.04_{y1}+0.07_{y2}+0.16_{y3}+0.16_{y4}+1.32_{y5}$ to obtain optimal scores of ₦1,137,390,000 and ₦83, 111,190,000 respectively, with a game value of 0.04. The developed optimization model was validated to have correlation coefficient 0.95. It is suitable for use. Ministry of Environment, Agriculture, and Niger Delta Development Commission should unanimously sponsor bill for the adoption and implementation of the developed reclaim diesel spill land optimization models since it will help fulfill the requirements of ISO 14001:2015 standards and increase the GDP of the Nation.

KEYWORD: Game theory, cost minimization model, profit maximization model, game value, accrued benefit

Date of Submission: 28-05-2022 Date of Acceptance: 10-06-2022

I. INTRODUCTION

The research was done at Bori, located at Latitude: 4°40′34″N Longitude:7°21′54″E, with elevation above sea level: 18 m = 59 ft in Khana local government area of Rivers state in the Niger Delta Zone of Nigeria. Diesel oil spill in Bori has contaminated huge portion of land.. Infinite optimization model of oil water fluid interaction in Bori soil is necessary to be researched on due to the prevalent cases of oil spill and its catastrophic effect on human living in the environment(Sarbatly, Kamin and Krishnaiah, 2016), plants and animals (UNEP report, 2011). Research showed that Bori community is an Agricultural hub, the indigenes are mainly fishers and farmers by occupation (Akpotor ,2019; Bartels , Eckstein , Waller , Wiemann , 2019), with fragile vegetation and ecosystem (Refugee Review Tribunal AUSTRALIA, 2007). Hence, oil spill in the land spell doom and catastrophe (Pegg and Zabbey , 2013). The citizens are likely to suffer from chronic cancerous and mutagenic effects within the nearest 15- 20 years (Ihesinachi and Eresiya ,2014). Crops are dying and some have even gone into extinction (Oshienemen , Amaratungaa and Richard ,2018). Her rich farm produce are no longer yielding well (Senewo, 2015).

Some see food have gone into extinctions (Kadafa, 2012). Hence there is need to reclaim the oil spilled land (Fentimana and Zabbey , 2015).

Oil spill reclamation of the affected area is not the panacea. It is important that the cost of reclaiming the land be recovered, hence an optimization model for cost minimization on investing into a multipurpose multi-objective project was developed. First, the predicted models shall be used to determine the best spill containment method at optimal cost, then the benefit of investing into different farm produce such as cassava, maize, yam, oil palm and fishery would be obtained. Game theory shall be used to develop the optimization model that would help generate enough funds to consequently recover the cost of reclaiming the land and rehabilitate the affected persons in the oil spill area (Archetti, 2013). Cost minimization model of the 5x5 matrix of the benefits shall be developed.

Oil water fluid interactions in the soil are caused when oil spill occurs and is influenced by rainfall. The movements of oil water fluids in the soil are mainly influenced by its contaminant volume and rainfall intensity and soil properties (porosity, density etc.) Increase in the contaminant volume and the rainfall intensity could increase fluid movement in soil. A model that can predict the movement and retention of the fluid in the soil can help in selecting the best reclamation method. An optimization model of the accrued benefit of a multipurpose multi objective project using Game theory is necessary to recover the cost of reclaiming the land.

II. METHODOLOGY

Experiments were conducted to determine the leached and retained concentration in a tipical Bori soil in the Niger delta region of Nigeria as shown in equation 1 and 2 below. The developed diesel leached and retainded cocentration models were used to predict the extent of contamination that would occure when ever there is a spill. Having known the extent of contamination, the best containment method for reclaiming the soil can be optimaly and suitable implemented. Several farm lands in Bori- Ogoni have beeb contaminated with approximately 50,000 liter of diesel. The spilled diesel products affceted approximately 20720 hectres of land used to grow cassava and maize crops (UNEP Report, 2011) and (Amie-Ogan, Petaba, Leyira, Nwikina, Philip-Kpae, and Akpan , 2022). The contamination is caused by pipeline vandalization, poor mantainance of pipline facilities and over presurization of the flowing fluids in the pipe(Akpan, Bob, Badom, Pepple, Nwiyor, and Ndam, 2022).

$$LC = -12458-432.07000* Cv +64936* RI +26287* Cv ^2+60880* RI ^2+1136* Cv * RI \quad (1)$$

$$RC = 138.41111+92.24833* Cv -0.88167* RI +89.00833* Cv ^2-172.19167* RI ^2-1.61000* Cv * RI \quad (2)$$

Firstly, Determination of the leached and retained concentration of the diesel products in the soil following a spill. Bori metropolice has an average rainfall of 10mm/hr (Akpan et al., 2022). The contaminant volume is approximatley 50,000 liters of diesel. (UNEP report, 2022). Hence applying the developed model to determine the leached and retained diesel concentration in the soil by imputing the parameters in the equation, we have the

$$LC = -12458-432.07000* Cv +64936* RI +26287* Cv ^2+60880* RI ^2+1136* Cv * RI$$

$$LC = -12458-432.07000* (50,000) +64936* (10) +26287* (50,000) ^2+60880* (10) ^2 +1136* (50,000)* (10)$$

$$LC = 6.57181E+13 \text{ ppm of TPH}$$

$$RC = 138.41111+92.24833* Cv -0.88167* RI +89.00833* Cv ^2-172.19167* RI ^2-1.61000* Cv * RI$$

$$RC = 138.41111+92.24833* (50,000) -0.88167* (10) +89.00833* (50,000) ^2-172.19167* (10)^2-1.61000* (50,000) * (10)$$

$$RC = 2.22525E+11$$

Hence the Leached and retained concentrations are 6.57181E+13 ppm of TPH and 2.22525E+1113 ppm of TPH respectively. After reclamation of the soil, the leached and retained concentration of diesel in the soil is reduced to a range of 2.8ppm to 59 ppm. The remaining portion of the diesel will be leached gradually with the passage of time.

Secondly, cost of reclamation of the contaminated land. This research emphasizes on the influence of rainfall intensity in reclamation of diesel contaminated spill soil (Akpan et al., 2022) and (Akpan, Ugwoha, Nwikina, Stephen and Letam, 2021). The contaminated soil was borrowed to a vacant site where the base and all ends have been properly channeled to a reservoir where disposal would be done after proper treatment of the fluid have being done Akpan et al., (202). Rainfall intensity of 10mm/hr was allowed to continuously fall on the soil to washout the diesel contaminant from the soil (Akpan , Ugwoha, Nwikina, Philip-Kpae, and Letam, 2021). This was done repeatedly until the soil contaminant was entirely leached out (Akpan et al.,2022). Table 3.1 showed the cost of reclaimation of contaminated land. The total cost of ₦875, 600, 000 is required to construct the facility used to reclaim the soil. It is the cheapest method of soil reclamation and has the ability of achieving 95% reclamations within a short time. Cost minimization can be easily achieved (Mahmud, Gbinu, Amie-Ogan, Ndam, Letam., and Akpan, 2022). This will enable the famers maximize profit also (Gbinu, Mahmud, Akpan, Badom,Nwiyor, and Letam, 2022). .

Thirdly, Determination of the cost of production of cassava, maize, yam Palm fruit crops and fish farming. Bori has a land mass of 103600 hectares (UNEP report,2011). The entire contaminated land in Bori is approximately 5 hectares. Five community's farm land was affected with varying proportions of contaminants, since the causes of the spill are same. Each community has about a hectare of land affected by the diesel spill (Petaba, Badom, Pepple, Amie-Ogan, Nwikina, and Akpan, 2022) and (Amie-Ogan et al. 2022). The costs of production of the farm produce for five hectares of land are presented in the table 1.

Table 1: Productivity of farm produce per plot/year

Farm Type	Crop Yield/Fish Produced (Kg/Hectare/ Year)	Cost of Farm produce Per KG(₦)	Productivity of farm produce plot/ Year(₦)	Productivity of farm produce plot/Year(₦)
Maze	600	1800	1080000	16200000
Cassava	900	1300	1170000	17550000
Yam	3530	400	1412000	21180000
Oil Palm	2500	750	1875000	28125000
Fishery	15000	550	8250000	123750000
Net productivity of farm produce in plot /per year				**206805000**

The productivity of farm produce per plot/ hectares/ year is presented in table 1
Productivity of farm produce/per plot = Farm yield * Cost of farm produce per Kilogram
Productivity of Maze/plot = 600* ₦18001800 = ₦1080000
Productivity of Cassava/plot =900* ₦ 1300 = ₦ 1170000
Productivity of Yam/plot =3530 * ₦ 400 =₦ 1412000
Productivity of Oil Palm/plot =2500*₦750 = ₦ 1875000
Productivity of Fishery/plot =15000*₦550 = ₦ 8250000
Productivity of farm produce per hectare = Farm yield * Cost of farm produce per Kg
A hectare of land is equivalent to 15 plots of land, therefore productivity per hectare is
Productivity of Maze/ hectare = 600* ₦18001800*15 =₦16200000
Productivity of Cassava/ hectare =900* ₦ 1300*15 = ₦ 17550000
Productivity of Yam/ hectare =3530 * ₦ 400 *15 = ₦ 21180000
Productivity of Oil Palm/ hectare =2500*₦750 *15 =₦28125000
Productivity of Fishery/ hectare =15000*₦550*15 =₦123750000

Table 2: Benefit of farm produce per plot/per year

Farm Type	Production Cost Hectare/Year(₦)	Productivity of farm produce Hectare/Year(₦)	Benefit Hectare/Year (₦)
Maze	930450	16200000	149550
Cassava	940450	17550000	229550
Yam	885450	21180000	526550
Oil Palm	1345900	28125000	529100
Fishery	3,849,000.00	123750000	4401000
Net benefit of cultivating the entire hectare per year			5835750

Benefit per plot of farm cultivated = Productivity of farm produce(Plot/Year) -Cost of production (Plot/Year)
Benefit per plot of maize cultivated =₦16200000 - ₦ 930450 = 149550
Benefit per plot of cassava cultivated =₦17550000 - ₦ 940450 = 229550

Benefit per plot of yam cultivated =₦21180000 - ₦ 885450 = 526550
Benefit per plot of oil palm cultivated =₦28125000 - ₦ 526550 = ₦529100
Benefit per plot of fish farming =₦123750000 - ₦ 930450 = ₦4401000
Net benefit of farming the entire plot per year= ₦5835750
Benefit of soil reclaiming a hectare of land. = ₦5835750*15 = **₦81097500**
Calculating for the net benefit of cultivating on the reclaimed soil
Cost of reclaiming the entire land = cost of reclaiming a land * 15
Cost of reclaiming the entire land (Hectares) = ₦ **5406500*** 15 =₦ **81097500**
Net productivity of farm produce in Hectares /per year = ₦ 206805000

Net benefit of farming in the reclaimed
Hectares of land in Bori = Cost of reclaiming the – Net productivity entire land (Hectares)

= ₦206805000 - ₦ **81097500=** ₦125,707,500

It is highly profitable to invest in reclamations of contaminated land in Bori using the developed model and recommendations in this work (Akpan et al.,2022). A hectare of land is equivalent to 15 plots of land. More benefit will accrue with the passage of time

III. 2.1 COST MINIMIZATION AND PROFIT MAXIMIZATION MODEL

Game theory was used to develop an optimization model.

2.2 Model Assumption

i. The game has mixed strategies. (Player A and Player B)

ii. Player A is a minimizer with an objective function of minimizing the cost of cultivating and rearing maize, yam, cassava, palm fruit and fish.

iii. Player B is a maximizer with an objective function of maximizing profit from the five plots of reclaimed diesel spilled land in Bori.

iv. The payoff matrix is obtained from the accrued benefit of cultivating maize, cassava, yam oil palm and rearing fishes on five plots of reclaimed diesel spilled land in Bori.

v. Diesel spill occurred on 10%, 32%, 10%, 23% and 25% of land in plot A,B,C,D,E and F at Bori respectively.

Table 3. Payoff matrix of accrued benefit of farm produce on five plots of reclaimed diesel spill land at Bori

Player A

Player B		Maize	Cassava	Yam	Oil Palm	Fishery
	Plot A	149550	229550	526550	529100	4401000
	Plot B	149550	229550	526550	529100	4401000
	Plot C	149550	229550	526550	529100	4401000
	Plot D	149550	229550	526550	529100	4401000
	Plot E	149550	229550	526550	529100	4401000

Table 4.

Table 4. Payoff matrix of accrued benefit of farm produce on five Plot of reclaimed diesel spill land in Bori per million naira.

Player A

Player B		Maize	Cassava	Yam	Oil Palm	Fishery
	Plot A	0.1	0.2	0.5	0.5	4.4
	Plot B	0.1	0.2	0.5	0.5	4.4
	Plot C	0.1	0.2	0.5	0.5	4.4
	Plot D	0.1	0.2	0.5	0.5	4.4
	Plot E	0.1	0.2	0.5	0.5	4.4

Since diesel spill occurred on 10%, 32%, 10%, 23% and 25% of land in Plot A,B,C,D,E and F at Bori respectively. The new payoff matrix becomes.

Table 5. Payoff matrix of diesel spill on 10%, 32%, 10%, 23% and 25% of land in Plot A,B,C,D,E and F at Bori respectively.

			Player A				
			Maize	Cassava	Yam	Oil Palm	Fishery
Player B	10%	Plot A	0.01	0.02	0.05	0.05	0.44
	32%	Plot B	0.04	0.07	0.16	0.16	1.32
	10%	Plot C	0.01	0.02	0.05	0.05	0.44
	23%	Plot D	0.03	0.05	0.11	0.11	0.88
	25%	Plot E	0.01	0.02	0.05	0.05	0.44

From the new payoff matrix, using game theory, firstly, determining the saddle point. In determining the saddle point we have,

Table 6. Determining the saddle point

		Player A					
		Maize	Cassava	Yam	Oil Palm	Fishery	
Player B	Plot A	0.01	0.02	0.05	0.05	0.44	0.01
	Plot B	0.04	0.07	0.16	0.16	1.32	(0.04)
	Plot C	0.01	0.02	0.05	0.05	0.44	0.01
	Plot D	0.03	0.05	0.11	0.11	0.88	0.03
	Plot E	0.01	0.02	0.05	0.05	0.44	0.01
		(0.04)	0.07	0.16	0.16	1.32	

Therefore, since saddle points exist. The players have pure strategies at Saddle point :(2,1).
Player A can best minimize his cost at $Z_{min}= 0.01x_1+0.04x_2+0.01x_3+0.03x_4+0.01x_5$ while player B can maximize profit at $Z_{max}=0.01y_1+0.02y_2+0.05y_3+0.05y_4+0.44y_5$ and the game value is 0.04 where the saddle point exist

IV. RESULTS AND DISCUSSIONS

Table 7: Benefit of farm produce per Hectare/per year

Farm Type	Production Cost Plot/Year(₦)	Productivity of farm produce Plot/Year(₦)	Benefit Plot/Year(₦)
Maze	930450	16200000	149550
Cassava	940450	17550000	229550

Yam	885450	21180000	526550
Oil Palm	1345900	28125000	529100
Fishery	3,849,000	123750000	4401000
Net benefit of cultivating the entire Plot per year			5835750

Discussion of the result in table 7

i. Table 7 showed that the farm produce to be cultivated and reared on the reclaimed diesel spilled land are maize, cassava, yam, oil palm, and fishery.

ii. The production cost of maize, cassava, yam oil palm, and fishery per plot are ₦930,450, ₦ 940,450, ₦ 885,450,₦28,125,000, and ₦ 3,849,000 respectively.

iii. The productivity of maize, cassava, yam , oil palm and fishery per Plot are ₦16,200,000, ₦17,550,000, ₦21,180,000,₦ 1,345,900, and ₦1,23,750,000respectively.

iv. The accrued benefit per Plot of land per year are ₦ 149,550, ₦ 229,550, ₦ 526,550,₦ 529,100, and ₦ 4,401,000

v. The net benefit of the entire Plots of land per year is ₦5835750

Table 8. Payoff matrix of accrued benefit of farm produce on five plots of reclaimed diesel spilled lands at Bori per million naira

			Player A				
			Maize	Cassava	Yam	Oil Palm	Fishery
Player B	10%	Plot A	0.01	0.02	0.05	0.05	0.44
	32%	Plot B	0.04	0.07	0.16	0.16	1.32
	10%	Plot C	0.01	0.02	0.05	0.05	0.44
	23%	Plot D	0.03	0.05	0.11	0.11	0.88
	25%	Plot E	0.01	0.02	0.05	0.05	0.44

Discussion of the result in table 8

i. Figure 8 showed the payoff matrix of diesel spill that affected 10%, 32%, 10%, 23% and 25% of land in Plot A,B,C,D,E and F at Bori respectively.

ii. Player A plays his strategy to minimize cost of cultivating maize, cassava, yam, oil palm, and fishery while player B plays his strategy to maximize profit on Plot A,B,C,D and E

iii. The value in the payoff matrix is the accrued benefit per million of a multipurpose multi objective project.

Table 9. Determination of the game

		Player A					
		Maize	Cassava	Yam	Oil Palm	Fishery	
Player B	Plot A	0.01	0.02	0.05	0.05	0.44	0.01
	Plot B	0.04	0.07	0.16	0.16	1.32	(0.04)
	Plot C	0.01	0.02	0.05	0.05	0.44	0.01
	Plot D	0.03	0.05	0.11	0.11	0.88	0.03
	Plot E	0.01	0.02	0.05	0.05	0.44	0.01
		(0.04)	0.07	0.16	0.16	1.32	

Discussion of the result in table 9

i. Saddle points exist.
ii. The players have pure strategies at Saddle point :(2,1).
iii. Player A can best minimize his cost at $Z_{min}= 0.01x_1+0.04x_2+0.01x_3+0.03x_4+0.01x_5$. at a minimal score of ₦5,540,746 per plot of land
i. Player B can maximize profit at $Z_{max}= 0.04y_1+0.07y_2+0.16y_3+0.16y_4+1.32y_5$. at a maximum score ₦75,826 per plot. The game value is 0.04 where the saddle point exist. This agrees with the thoughts of Gupta and Hira (2014) and Gbinu et al., (2022)

Table 10. Cost of production and Benefit per plot of land

FARM TYPE	PRODUCTION COST(₦)	PROFIT(₦)
Maze	930450	149550
Cassava	940450	229550
Yam	885450	526550
Oil Palm	1345900	529100
Fishery	3,849,000	4401000
Total	**7951250**	**5835750**

Discussion of the result in table 10

ii. Maize and fishery had the lowest and highest cost of production.
iii. The total cost of production for maize, cassava, yam, oil palm and fishery per plot of land is ₦7,951,250
iv. The total profit (benefit) of cultivating maize, cassava, yam, oil palm and fishery on per plot of land is ₦5,835,750

V. CONCLUSION

Maize and fishery had the lowest and highest cost of production. Hence it is more profitable to invest more on fishery sis the profit is enormous compared to fishery.

The accrued benefits per plot of land per year are ₦ 149,550, ₦ 229,550, ₦ 526,550, ₦ 529,100, and ₦ 4,401,000. The net benefit of the entire plots of land per year is ₦5835750 and per hectare per year is ₦ 87,536,250. Therefore, cultivation on 1000 hectares of land, the accrued benefit is ₦ 87,536,250,000

Player A can best minimize his cost with strategy Zmin = 0.01x1+0.04x2+0.01x3+0.03x4+0.01x5 at a minimal score of N75,826 per plot of land and N1,137,390 per hectare of land. Cultivation on 1000 hectares of land player A can best minimize the cost of cultivation at N1, 137,390,000 (Gupta and Hira, 2014) and (Mahmud et al., 2022).

Player B can maximize profit in cultivating on the entire plots of land using strategy $Z_{max}=0.01x_1+0.04x_2+0.01x_3+0.03x_4+0.01x_5$ to score ₦5,540,746 per plot and ₦83,111,190 per hectare of land. The accrued benefit of cultivation on 1000 hectares of land is ₦83, 111,190,000. The game value is 0.04 for Z_{min} and Z_{max} .This agrees with the thoughts of Gupta and Hira (2014) and Gbinu et al., (2022)

The profit obtained in cultivation 1000 hectares of land using cost/benefit analysis and game theory gave ₦ 87,536,250,000 and ₦ 83, 111,190,000 respectively. The correlation coefficient between the two methods is 0.95. This implies that the developed model should be adopted and is useful in multi-purpose / multi-objective projects like this.

VI. RECOMMENDATION

The following are recommended.

i. Ministry of environment and Khana Local government in alliance with national oil spill detection regulation agency(NOSDRA) should sponsor a bill for adoption and implement the developed diesel infinite optimization models as it will help to optimally maximize profit at minimized cost and fulfill the requirements of ISO 14001:2015

CONTRIBUTION TO KNOWLEDGE

i. This research work agrees with the implementation of environmental management system as per clause 5, 6, 7, 8, 9 and 10 of ISO 14001:2015.
ii. The developed model and concept will help to achieve optimal benefit when diesel contaminated soil is reclaimed.

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