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Impact of the Construction of Access Roads to OIL Well Locations and Flow stations on the Phytodiversity of Some Niger Delta Floodplains

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Abstract: Impact of the construction of oil well locations and flow stations access roads on the phytodiversity of seasonal swamp forest within some Niger Delta floodplains in Delta, Imo and Rivers States was investigated. Construction of 4-5m wide roads on 2-4m high embankments in this predominantly seasonal swamp high forest was observed to cause changes in the natural hydrological and drainage pattern. The embankment block natural flood channels thereby obstructing the free flow of water. This leads to the compartmentalization of the forest, increased water level (3-6m deep) and permanent water logging. Soil results from impacted areas showed decreased pH (4.10 to 5.30), reduced NO_3^- (7.20 to 12.60mg/kg) and SO_4^{2-}(7.16 to 9.50mg/kg) and reduced exchangeable cation (K, Ca and Mg) values. The impacted freshwater swamps/floodplains are characterized by large-scale death of tree and forest species (manifested by completely defoliated, dead and decaying trees, standing or fallen logs). Six tree species (*Elaeis guineensis, Alstonia boonei, Anthocleista vogelii, Mitragyna ciliata, Cleiostopholis patens* and *Pterocarpus santalinoides*) and a shrub, *Alchornea cordifolia*, were common within the studied areas with *Alchornea cordifolia* most abundant. Short and long term remedial measures are suggested to ameliorate the effect of the construction activities on the soil and forest tree diversity of the affected areas.

Key words: Compartmentalization, Flooding, Floodplains, Niger Delta, Phytodiversity, Road construction, Soil, Swamp forest

INTRODUCTION

The Niger Delta is the largest in Africa. It contains about 20,500 km^2 of wetlands within two meters above sea level[8] and extends over four ecological zones: coastal barrier islands, brackish/saline water mangrove swamps, freshwater swamp forests (permanent and seasonal), and dry upper plain lowland rain forests. The freshwater/seasonal swamp forest, the ecosystems of this study, is sensitive to changes in water quality especially pH[1], and hydrology. During the rainy season (April-October), the major rivers overflow their banks/levees and inundate the adjoining lowlands and floodplains where floodwaters may reach depths of 3-6m. Kinako and Zuofa[10] gave an estimate of vegetation loss (freshwater swamp vegetation) on Kiama and Patani section of the East-West trunk road, which traverses the entire Niger Delta area. With the burgeoning exploration and production (E & P) activities in the area under focus (Figure 1), access road construction of varying kilometers is a *sine qua non*. Thus, concern is increasing about the possible consequences of this construction activity on the ecosystem of the area.

The sensitivity of the seasonal swamp forest ecosystem and their close allies in the Niger Delta to permanent flooding due to road construction and similar ecological disturbances, results from the characteristic nature of the heterogeneous vegetation species, which are adapted to or tolerate brief periods of annual inundation. Most of the areas investigated, which are humid and warm, contain a lot of decaying vegetation formed mainly by forest litters and dead pieces of wood; the soils are imperfectly drained, of low pH (5.4 – 6.1) and are clayey with good nutrient content[13]. Under natural condition, this ecosystem is highly productive, however, changes in soil and habitat history which results from permanent flooding after road construction leaves much to be desired. Consequently, the natural ecosystem may require a long time for recovery.

The onset of each rainy season initiates the seasonal inundation of the forest floor. Naturally, flood from direct rainfall and neighboring water systems is regulated to a large extent by the several folds of leaf litter (most of the forest species are deciduous) and the irregular mounds/ridges on the forest floor (soil) of most areas. The mounds/ridges form numerous intricate

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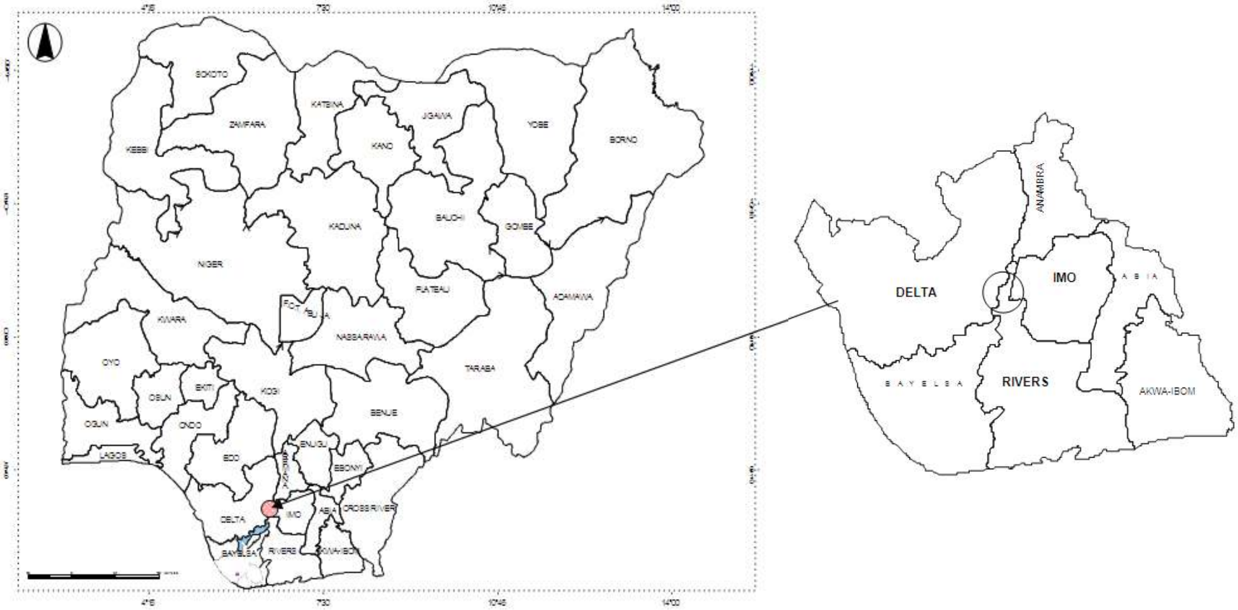

Fig. 1: Map of Nigeria showing the States. Arrow points to the study areas

narrow water channels. Flood in the forest floor circulates through this network of channels all through the rainy season and continuously drains into the surrounding rivers and streams. The absorbing action of the leaf litter and the circulatory pattern of the flood maintain the flood regime of the forest floor to depths less than 1m. This allows normal physiological activities of the forest species and relocation of the wildlife species to the mounds, burrows in fallen or standing trees, and on forest canopies.

Most of the forest trees are established on the mounds that on themselves are held together by the roots and plank-buttresses of the trees. Extensive damage to the forest soil can result from activities, which alter the symbiotic relationship between the trees and the soil. Such activity like flooding for prolonged periods with depths more than 1m will gradually erode the mounds and soil surfaces exposing the roots. Air pores in the soil will be clogged, oxygen will be unavailable in the soil, soil fauna and flora involved in pulverizing soil for plants shall be adversely affected, and nutrient deficiency will set in. Of course, the borrowing fauna of the area will either relocate or be trapped in the flood. Arboreal species remain for a while before final migration. This derangement in the normal functioning of the ecosystem will in no time manifest in yellowing and abnormal defoliation of trees[13], and gradual to colossal forest destruction[10].

The purpose of this study is to summarize the results of investigation on the impact of access road construction activities of E & P companies on the ecosystem of the study areas, and proffer short and long term remedial measures to the affected areas.

Study Area: The investigation was carried out within four Local Government Areas (LGA) in Delta, Imo and Rivers States. These areas are Ndokwa East in Delta State (within latitude 5° 42^2 N and longitude 6° 29^2 E), Oguta and Ohaji/Egbema in Imo State (within latitude 5° 36^2 N and longitude 6° 40^2 E), and Ogba/Egbema/Ndoni in Rivers State (within latitude 5° 40^2 N and longitude 6° 66^2 E). They have common boundaries and ecological similarities (Figure 1). The area is characteristically a flood plain with seasonal swamp high forest (a type of tropical rainforest) as the dominant vegetation. The oil palm bush, an indication of prolonged farming and socio-cultural perturbations on the original forest is prominent in Ohaji/Egbema and Ogba/Egbema/Ndoni LGAs. The major rivers of the area are Rivers Niger, Orashi, Ase and Nkisa. Many lakes including Oguta Lake, seasonal and fast flowing streams, distributaries and rivulets also occur in the area. A common activity in the areas is the construction of access roads leading to oil and gas facilities as shown in Figure 2.

MATERIALS AND METHODS

An evaluation of four impacted and four control sites (one each from each LGA) was made. The impacted sites were chosen to reveal the worst case scenario in each study area based on the conspicuous presence of many dying trees in the forest. Investigation was undertaken to link the problem at

Fig. 2: Access road to a flowstation in the study area. Notice the 2-4m road embankment.

each impacted site with access road construction. The terrain and climatic conditions are the same in each case. Control stations were the closest adjoining healthy forest vegetation.

Existing flow station and oil well location roads within each area were used as transect. In each area, a 100m x 100m sample plot was chosen for both impacted and control stations. Phytodiversity and soil were studied in these 100m x 100m. Forest inventory within the impacted and control sites were designed to encounter all trees above 5m high whether dead or living. Each 100m x 100m area was further demarcated into four random blocks of 20m x 20m each. This was to increase the opportunity of encountering all tree species (living or dead) during inventory. Actual counts of dead or dying trees for impacted areas were undertaken. Forest inventory data collected from each plot in the control areas included:

- Number of trees (total population)
- Tree species present and their families

The abundance of the various tree species in the different plots were expressed in terms of their density, frequency of occurrence and dominance. Results were compared with the impacted areas.

For the control areas, trees were identified to species level using Flora of Tropical West Africa[5,6,7] and Trees of Nigeria[9].

Methods for soil studies followed that of Odu *et al.*,[13]. Two samples each were ramdomly collected from each impacted and control site at 15 to 30cm depth with a hand auger. These were analyzed for pH, NH_3, NO_2, SO_4, K, Ca and Mg in the Plant Physiology Laboratory, Dept of Plant Science & Biotechnology, Faculty of Science, University of port Harcourt.

RESULTS AND DISCUSSION

A total of 627 living and dead trees were encountered during the study viz: 39 forest species belonging to 19 families with a population of 324 trees from the control plots (Table 1) and 303 dead trees from the impacted plots (Table 2). Abundance of each species is expressed in terms of its density, frequency of occurrence and dominance. 7 species, *Elaeis guineensis, Alchornea cordifolia, Alstonia boonei, Anthocleista vogelii, Mitragyna ciliata, Cleiostopholis patens* and *Pterocarpus santalinoides*, were common to the study areas. *Alchornea cordifolia* was the most abundant species with a population of 47 trees, frequency of occurrence of 100% and dominance score of 1175 (Table 2). The 303 dead trees represent 48.32% of the total tree population in the studied areas. This does not represent the actual number of dead trees since the stumps of decayed ones could not be reached during the study. Apart from their roles in maintaining the ecological homeostasis of the area, these trees are of enormous importance in the local economy of the people.

The vegetation of the area is mainly the seasonal swamp high forest type (Figure 3). Apart from different degrees of disturbance, the forest is similar to those described by Richards[14]. The uppermost layer within this forest is made up of tree species within the range of 30 – 45m high. These tree posses conical to wide spreading crown and are well above the forest canopy. They include *Ficus mucoso, Ceiba pentandra, Alstonia boonei, Bombax buonopozense, Milicia excelsa, Terminalia ivorensis, Terminalia superba, Amphimas pterocapioides, Cleiostopholis patens, Symphonia globulifera, Cola* sp. and *Lophira alata*.

The impacted areas have been flooded permanently for upwards of 5 years. Depending on the initial elevation of the area, the water depth range from 3 – 6m. Trees and shrubs in these permanently flooded areas are completely dead (Figure 4). They are seen as submerged logs, standing trunks and defoliated trees. About 70% of the impacted area in Ndokwa East is covered by such species as *Acroceras zizanioides, Nymphaea lotus, Vossia cuspidata* and *Schrankia* sp. The area in Oguta and Ohaji/Egbema L.G.As are covered mainly by *Azolla filiculoides, Centhoteca* sp., *Clappertonia ficifolia* and *Nymphaea lotus*, while the Ogba/Egbema/Ndoni sites are dominated by *Azolla filiculoides, Diplazium sammatii, Cyrtosperma senegalensis, Nymphaea lotus* and *Acroceras zizanioides*. In most cases, these species form continuous mats on the water surface. Except for species of *Bufo* and *Rana*, and few stopover birds (Woodpecker- *Dendropicus fuscescens* and Egret- *Egreta alba*) no wildlife species was identified in these waterlogged areas.

Table 1: Diversity of tree species encountered in the study ares

Species Name	Common Name	Family	Economic Importance
Alchornea cordifolia	Christmas bush	Euphorbiaceae	All plant parts used medicinally
Rauvolfia sp.	-	Apocynaceae	
Harungana madagascariensis	Dragons blood tree	Guttiferae	Building and construction
Elaeis guineensis	Oil palm tree	Palmae	Produces the commercial palm and kernel oil, palm wine and soda ash.
Milicia excelsa	Iroko	Moraceae	Commercial timber wood
Alstonia boonei	Pattern wood/Alstonia	Apocynaceae	Source of timber. Wood also used for carving canoes and household utensils.
Ceiba pentandra	Kapok or Cotton tree	Bombacaceae	Produces kapok. Commercial soft wood used in boat and canoe construction.
Bambax buonopozense	Red silk cotton tree	Bombacaceae	Commercial soft wood; proposed for aircraft construction, source of pulp and paper
Bambussa vulgaris	Bamboo	Poaceae	
Picnanthos angolensis	-	Myristicaceae	Hardwood for building and construction
Albizia adianthifolia	Albizia	Mimosaceae	Used for roof rafters and carving.
Anthocleista vogelii	Gabbage tree	Loganiaceae	Leaves used in rapping. The root and stem bark in decoction is used to cure eczema and rashes.
Spondias mombin	Hog plum	Anacardiaceae	Fruits edible. Plant leaves and twigs edible. Leaves and bark are medicinal mostly in expulsion of placenta after delivery in cattle
Bridelia sp.	-	Euphorbiaceae	Wood used in construction of thatch houses and as fuel wood
Musanga cecropioides	Umbrella tree	Moraceae	Soft wood for household utensils. Root decoction used as anthelmintic while gum exudates is used for fever.
Irvingia gabonensis	Dikanut, bush mango	Irvingiaceae	Fruit and seeds edible, commercial wood, used in boat building
Mitragyna ciliata	Abura timber	Rubiaceae	Wood is commercially used as timber, electric poles carving household utensils.
Symphonia globulifera	Hog gum tree	Guttiferae	Source of timber, electric poles and construction of dug-out canoes
Sterculia tragacantha	-	Sterculiaceae	Produces commercial softwood, adhesives and gums, and ropes.
Ampimas pterocarpoides	Bokanga	Papilionaceae	
Cleistopholis patens	Canoe wood	Annonaceae	Source of timber. Used in the construction of canoes.
Ficus mucoso.	-	Moraceae	
Piptadeniastrum africana	African green heart	Mimosaceae	Wood is used for construction and joinery. Leaves are medicinal.
Funtumia africana	Bush rubber	Apocynaceae	Substitute to *Hevea brasiliensis* for commercial latex. Wood is used for electric poles, manufacture of house hold utensils. Dried leaves used in dressing wounds and boils.
Terminalia superba	Afara	Combretaceae	Soft wood for general furniture needs
Cola gigantea	-	Sterculiaceae	Commercial timber wood
Pterocarpus santalinioides	-	Papilionaceae	Tender leaves are edible vegetable. Produces wood of commerce and resinous exudates used as dye.
Raphia hookeri.	Raphia palm	Palmae	Tree is tapped for its wine. Wine is used in the manufacture of local gin. Fronds used for thatching of mud houses.

Table 1: Continued

Myrianthus arboreus		Moraceae	
Anthonotha macrophylla	-	Caesalpinaceae	
Pentaclethra macrophylla	Oil bean tree	Mimosaceae	Capentary; building and construction; fruit is edible as African salad and of commercial importance
Lophira alata	Iron wood	Ochnaceae	Produces commercial hardwood. Leaves, bark and root is given for the treatment of gastrointestinal disorders, fevers, cough and jaundice.
Uapaca heudelotii	-	Euphorbiaceae	Fruits edible. Wood used in carpentry and general construction. Source of charcoal.
Rothmania whitfieldii	-	Rubiaceae	Produces dyestuff used in tattooing and skin decoration. Fruits are used medicinally as febrifuge, analgesics, emetic etc.
Chrysophyllum albidium	Star apple	Sapotaceae	Tree bears edible fruit and produces timber of commerce
Treculia africana	African breadfruit	Moraceae	Tree bears edible fruit and produces timber of commerce
Ricinodendron heudelotii	-	Euphorbiaceae	Softwood used in the construction of musical instruments, coffins and the root-bark is medicinal
Brachystegia eurycoma	-	Caesalpinaceae	
Baphia nitida	Camwood	Papilionaceae	Source of dye and medicinals
Number of trees/station		19 Families	
Number of dead trees/station			

Table 2: Tree population, density, frequency and dominance value in the study area

SPECIES NAME	Number of tree species/control plot							
	Plot A	Plot B	Plot C	Plot D	Tree Population	Density	Frequency (%)	Dominance (Density x Frequency)
Ceiba pentandra	2	-	-	2	4	1	50	50
Rauvolfia sp.	-	6	2	-	8	2	50	100
Harungana madagascariensis	2	5	6	-	13	3.25	75	243.75
Elaeis guineensis	3	6	9	8	26	6.5	100	650
Milicia excelsa	1	2	-	-	3	0.75	50	37.5
Alstonia boonei	4	2	2	5	13	3.25	100	325
Alchornea cordifolia	7	11	15	14	47	11.75	100	1175
Bambax buonopozense	-	1	-	-	1	0.25	25	6.25
Bambussa vulgaris	-	-	-	2	2	0.5	25	12.50
Picnanthos angolensis	2	-	-	-	2	0.5	25	12.5
Albizia adianthifolia	-	2	3	-	5	1.25	50	62.5
Anthocleista vogelii	5	4	5	6	20	5	100	500
Spondias mombin	3	-	3	-	6	1.5	50	75
Bridelia sp.	-	3	1	-	4	1	50	50
Musanga cecropioides	6	2	-	5	13	3.25	75	243.75
Irvingia gabonensis	-	-	1	-	1	0.25	25	6.25

Table 2: Continued

Mitragyna ciliata	3	2	6	4	15	3.75	100	375
Symphonia globulifera	7	4	2	9	22	5.5	100	550
Sterculia tragacantha	2	-	1	-	3	0.75	50	37.5
Amphimas pterocarpoides	-	-	1	-	1	0.25	25	6.25
Cleistopholis patens	8	4	7	10	29	7.25	100	725
Ficus mucoso.	2	-	-	3	5	1.25	50	62.5
Piptadeniastrum africana	3	-	-	1	4	1	50	50
Funtumia sp.	2	3	1	-	6	1.5	75	112.5
Terminalia superba	3	-	2	1	6	1.5	75	112.5
Cola gigantea	1	-	-	-	1	0.25	25	6.25
Pterocarpus santalinioides	6	2	4	3	15	3.75	100	375
Raphia hookeri.	-	-	-	5	5	1.25	25	31.25
Myrianthus arboreus	4	1	-	-	5	1.25	50	62.5
Anthonotha macrophylla	-	2	1	-	3	0.75	50	37.5
Pentaclethra macrophylla	-	2	3	-	5	1.25	50	62.5
Lophira alata	-	-	-	1	1	0.25	25	6.25
Uapaca heudelotii	-	3	-	2	5	1.25	50	62.5
Rothmannia whitfieldii	1	-	-	2	3	0.75	50	37.5
Chrysophyllum albidium		-	-	1	1	0.25	25	6.25
Treculia africana	-	-	-	4	4	1	25	25
Ricinodendron heudelotii	1	-	-	-	1	0.25	25	6.25
Brachystegia eurycoma	-	1	1	-	2	0.5	50	25
Baphia sp.	-	3	4	2	9	2.25	75	168.75
Number of trees/station	78	72	83	91	324			
Total Number of dead trees/station		94	69	64	76	303		

Letters A, B, C and D in Tables 2, 3a and 3b represents Ndokwa East, Oguta, Ohaji/Egbema and Ogba/Egbema/Ndoni LGAs respectively.

Road construction in Niger Delta region causes one type of embankment or another. The roads act as obstructions and thereby impede the free flow of water within the forest floor of the fresh water swamp[10]. In the study areas, the access roads 4 – 5m wide in each case are constructed on 2 – 4m high embankments (Figure 2). These were observed to cause impediments to water flow through blockage of natural flood channels, creation of permanent water impoundment and compartmentalization of habitats. Subsequently, significant alteration in the water level of the seasonal swamps throughout the year and especially during the rainy season occurred. It is noteworthy that the free flow of water, relatively constant level of dissolved oxygen and seasonal variations in the surface water volume are important characteristics of the flood plain areas investigated. Because of heavy rainfall, predominantly clayey soil texture and high ground water level, these areas have become permanently waterlogged creating anoxia conditions. The impacted seasonal swamp high forest is characterized by large-scale death of tree and forest species (manifested by completely defoliated, dead or decaying trees, standing or fallen logs) as in Figure 4, and drastically reduced terrestrial wildlife species, death of burrowing species and other soil fauna.

Flooding and submergence are major abiotic stresses and rank alongside water shortage, salinity and extreme temperatures as major determinants of species distribution worldwide[18]. The primary effect of

Table 3a: Physico- chemical characteristics of soil samples from impacted areas

Sample code	pH	NH_3 (mg/kg)	NO_2 (mg/kg)	NO_3^- (mg/kg)	SO_4^{2-}	Exchangeable Cations (mg/kg)		
						K	Ca	Mg
A-1	4.10	467.41	8.20	11.40	7.16	23.42	78.80	19.67
A- 2	4.76	462.70	9.22	9.50	7.50	26.50	76.70	18.53
B-1	5.30	560.50	8.50	7.20	9.42	17.50	77.14	23.45
B-2	4.90	490.20	8.40	8.90	9.50	16.92	79.26	23.45
C-1	4.76	575.25	5.00	12.60	8.00	27.86	104.60	26.60
C-2	4.70	540.10	7.10	12.40	8.20	28.15	104.00	17.63
D-1	4.90	470.10	9.27	10.70	8.60	19.46	92.80	15.50
D2	4.86	495.30	7.10	9.42	8.50	21.24	94.62	23.56
Range	4.10 – 5.30	462.70 – 575.25	5.00 – 9.27	7.20 – 12.60	7.16 – 9.50	16.92 – 28.15	76.70 – 104.60	15.50 – 26.60

Table 3b: Physico - chemical characteristics of soil samples from control areas

Sample code	pH	NH_3 (mg/kg)	NO_2 (mg/kg)	NO_3^- (mg/kg)	SO_4^{2-}	Exchangeable Cations (mg/kg)		
						K	Ca	Mg
A-1	6.7	212.43	0.60	14.00	11.42	27.86	128.34	2.00
A-2	6.8	226.16	0.40.	12.80	6.67	28.15	115.60	2.35
B-1	6.0	376.24	0.70	18.24	9.42	29.80	108.50	1.82
B-2	5.2	293.70	0.82	17.80	9.50	29.67	156.00	1.57
C-1	5.8	189.47	0.10	8.90	8.00	19.65	106.86	2.52
C-2	6.1	192.06	0.20	9.90	7.00	24.63	104.68	1.22
D-1	5.6	276.81	0.70	21.01	12.26	31.42	116.54	1.90
D-1	6.4	193.10	0.60	23.84	12.68	29.48	121.34	2.01
Range	5.2 – 6.8	189.47 – 376.24	0.10 – 0.82	8.90 – 23.84	6.67 – 12.68	19.65 – 31.42	104.68 – 156.00	1.22 – 2.52

Fig. 3: Typical forest vegetation in the control areas

permanent water logging is the creation of anaerobic environment from which plants and especially plant roots cannot obtain oxygen[3,11]. Oxygen starvation in these soils arises from an imbalance between the slow diffusion of gases in water compared with air and the rate that oxygen is consumed by microorganisms and plant roots. The outcome is that flooded soil quickly becomes devoid of oxygen at depths below a few millimeters[18]. In the floodwater itself, broad unstirred boundary layers quickly develop around respiring tissues. This can lead to oxygen deficiency within a few hours. Since roots are essentially aerobic organs, the consequences can be fatal because, as aerobic respiration ceases, levels of energy-rich adenylates drop rapidly, causing a dramatic decline in ion uptake and transport[4,17]. At a low pH (4.10-5.30) as recorded in the study areas (Table 3a), the hydrogen ions usually decrease the absorption of cations by plants, while anion absorption is stimulated[2]. All these imply a decline in nutrient uptake by tree species in the impacted areas and an eventual deficiency of basic nutrient requirements after a prolonged period of flooding.

Results in Tables 3 (a & b) show higher values for ammonia (NH_3) and nitrites in the impacted soil when compared with the control. These values are higher

Fig. 4: Showing one of the impacted areas. Notice the several dead trees and aquatic weeds.

than threshold values in soils of the area[13]. Accumulation of NH_3 and nitrites in the soil is as a result of anaerobic conditions. The dominance of ammonia and nitrite, both of which are toxic over nitrate, an essential soil nutrient has deleterious effects on the overall vegetation of the area. The observed low value for nitrate is a consequence of water logging. This also was the trend for sulphates, another soil nutrient, which under such condition are reduced to hydrogen sulphide (H_2S), a potent plant root toxin Russel[15]. Anoxia leads to reduced growth of leaves and overall photosynthetic processes, reduced stem and root growth occurs. Subsequently, the leaves become epinastic, chlorotic and senescent. Changes also occur in all levels of major plant growth hormones[16] as well as reduction in stomata conductance and translocation[11,12].

The construction of these access roads has benefited the adjoining communities in many ways. Communications, accessibility, commerce and transportation problems in most instances have been alleviated. However, apart from the problems observed above, the roads also provide access for un-regulated exploitation of forest trees and other forest resources as seen in Ndokwa East and Ogba/Egbema/Ndoni; thus pristine vegetation does not exist in this area. The roads are used by hunters and local trap setters for wildlife exploitation. The permanently flooded areas are breeding grounds for mosquitoes, amphibians and some weeds like *Pistia stratiotes, Nymphaea lotus*, and *Azolla filiculoides*. Such impacted areas can be rehabilitated by re-establishment of drainage channels via the construction of culverts at intervals of 25 – 50m along affected roads; this mitigation will mimic the natural flood channels, which existed prior to the construction of access roads. Mechanical pulverization/land farming of impacted area after de-flooding is necessary to achieve soil aeration, re-oxygenation and gradual replenishment of depleted soil nutrients. Though natural re-vegetation is foreseen with time, re-vegetation programme using adjoining indigenous species is required to speed up the re-vegetation process. It is important that natural flood/drainage channels are identified by on-going and future Impact Assessment studies by E & P companies in these areas; these studies should recommend appropriate measures to mitigate forest flooding when access roads to oil and gas facilities are being constructed.

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