12 The Impact of Oil and Gas Exploration: Invasive Nypa Palm Species and Urbanization on Mangroves in the Niger River Delta, Nigeria

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Abstract

The Niger River Delta is a world-acclaimed biodiversity hot spot according to the World Bank. Its mangrove forest is the largest in Africa and the Atlantic. This ecosystem provides firewood, building materials, medicinal herbs and food for the local population. But oil and gas exploration, deforestation, dredging, urbanization and invasive species over the years had converted it from a pristine to a disturbed state. The greatest damage to mangroves in the Niger Delta comes from oil and gas exploration activities, which began in 1956 in Oloibiri. Millions of crude oil spillages had occurred, since the striking of the first oil well from ruptured well heads, pipelines, and jetties, constructed on both onshore and offshore locations. This degraded condition had reduced the mangrove forest from highly dense to lowly dense and also to mixed forest. Exploratory activities had also resulted to additional problems, such as invasion by alien species and urbanization of mangrove areas. Urbanization is beneficial to man's development, but costly for the mangroves. The establishment of industrial and residential quarters to accommodate oil workers and their families had increased the urban sprawl around mangrove forest areas. These activities had reduced the resilience of mangroves against the invasion of nypa palm (*Nypa fruticans*). The palms were intentionally introduced into the Niger Delta in 1906, but for close to a century the mangroves had kept them in check. However, in the last 20 years, the palms had overwhelmed and completely colonized most mangrove forests.

Keywords

Niger Delta · Urbanization · Invasive species · Hydrocarbon pollution · Mangrove · Exploration · Seismic activities · Oil spillages · Pipelines

12.1 Introduction

Global loss of wetland is put at 30% with 10–15% decline of mangroves predicted by the year 2100 (Alongi 2008). The major causes of biodiversity loss include habitat loss, invasive species, pollution, over population and over exploitation (James et al. 2007). In the Niger Delta, mangroves are being lost as a result of the "evil quartet" of pollution, deforestation, invasion, and urbanization. Although, natural disturbances such as tsunami, hurricane, climate change and sea level rise significantly reduce global mangrove population (Ellison 2005; Webb et al. 2014), human-mediated effect far exceeds the natural effect in the Niger Delta. The delta serves as a habitat for numerous organisms ranging from microorganisms to invertebrates and vertebrates. The region has a rich supply of animals such as monkeys, hippopotami and crocodiles that have all existed in pristine form for centuries before the advent of man. The area is regarded as a global biodiversity hotspot because of its rich natural resources (NDES 1997). It has two national parks, namely, the Cross River National Park (Latitudes 8° 15′ and 9° 30′ E; and longitudes 5° 05′ and 6° 29′ N) and the Okomu National Park (Latitudes 6°.15′ and 6°.25′; and longitudes 5° 9′ and 5° 23′). The World Wide Fund for Nature classified it among 200 global eco-regions that are critically endangered (WWF 2001) while the World Bank regarded it as the second most sensitive environment in Africa (World Bank 1995). The resources of mangrove forest had been the source of livelihood for the local people who depend on them for wine, food, roofing sheets, baskets, hats, mats and fire wood, which are all locally produced from mangrove by-products (NDES 1997; Polidoro et al. 2010). In addition,

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farmers derive manure from the swamps, which they use to fertilize their crops while fishermen get high catch from the numerous fisheries resources present within the surrounding waters. Out of all the causes of environmental degradation in the Niger Delta, oil and gas exploration has the most significant effect on the environment.

The first oil well in Nigeria was struck in a riverine community called Oloibiri in the Niger Delta in 1956 (UNEP 2011). The discovery of crude oil placed Nigeria on the global map of oil producing nations of the world. Nigeria is the largest producer of crude oil in Africa, and the sixth largest in the world (UNEP 2011). However, this enviable position has not come without a price. This is because the discovery had changed the undisturbed ecological state of the mangroves to a disturbed state. Many mangrove forests in the Niger Delta had been converted to waste land, which has defied all forms of restoration attempts because of the constant presence of oil spills. Oil and gas exploration activities had resulted to spillages, which severely damage mangrove ecosystem (Mastaller 1996; Ohimain et al. 2008), and contribute to their global decline (Duke et al. 1997). Similarly, the creation of a right of way (ROW) passage for crude oil pipelines that transport refined products to and from the refineries also leads to massive deforestation. Increase in industrial activities in rural areas leads to the migration of people from urban to rural areas, thus facilitating urbanization, which in turn decreases mangrove forest in the Niger Delta. For example projects such as construction of residential quarters, roads, hospitals, recreational sites and schools are done to cater for the expanding population of people migrating from the countryside to the rural areas in search of industry-based jobs. Urban settlements are often centers of occupational and production specializations, which lead to commercial activities. Influx of workers leads to increase in social vices (e.g. artisanal refineries, pipeline vandalism, militancy etc), reduction in traditional occupations (e.g. farming, fishing and hunting), and increase in third party agitations (e.g. loss of assets and properties, employments etc). These situations have negative effect on mangroves (Wang et al. 2016) by encouraging the entry of invasive nypa palms (*Nypa fruticans*) (CEDA 1997) and other alien species into mangrove forests.

Pollution is another major threat to mangroves, and it leads to the impairment of soil, water and air quality. It also leads to the reduction in biodiversity and increased morbidity for upper respiratory tract infection such as asthma and emphysema. These diseases are particularly prominent amongst children and adults as a result of constant inhalation of soot from gas flared from oil industries (Aquilera et al. 2010). Poor environmental conditions contribute to the decline in the average life span of the people to 50 years (UNEP 2011). Oil pollution on rivers had destroyed the fish industry that was once the hub of commercial activities in the area (Ohimain et al. 2008), and the few aquatic resources that survive pollution are contaminated with heavy metals.

The Niger Delta Environmental Survey (NDES 1997) revealed that within a period of 20 years over a million barrel of crude oil was discharged into the environment through numerous cases of oil spills. The demand for increased petroleum products locally and internationally is complicating the already existing environmental problems by making the oil industries to increase their production quota leading to more oil fields with more pipelines and more spillages. Clean-up operations are usually costly and difficult to embark on (IUCN 1993). The oil spills, which represent contaminants to the mangroves alter succession, productivity and nutrient cycling (Twilley 2008). Hydrocarbon pollution cause differential mortality of trees leading to long-term changes in mangrove community structure (Lugo 1980; Snedaker et al. 1996; Twilley 1988). There is a positive correlation between pollution and chlorophyll-deficient mutations in red mangroves (*Rhizophora mangle*) (Klekowski et al. 1994). Similarly, prolonged exposure to toxic substances in mangroves causes deformities that take a long time to recover (Levings and Garrity 1994; Odum and Johannes 1975). For instance, during a field work in Buguma a deformed red mangrove propagule (*Rhizophora mangle*) was found that has two rather than one growing tip, which is typical of this species. Red mangrove trees make up 65% of the mangrove forest in the Niger Delta (Numbere 2014). They are the species mostly subjected to long term contamination from hydrocarbon pollution. Hydrocarbon pollution could remain inert inside the swamps for decades, but when exposed becomes activated and poison newly growing plants. It takes a minimum of 20 years for the toxicity of crude oil to completely disappear (Burns et al. 1994), and another 30–40 years for mangroves to regenerate after a complete clearance (Adegbehin & Nwaigbo 1990). The loss of mangrove community leads to a decrease in area, which could result to extinction (Alongi 2008).

12.2 Description of the Niger Delta Geology

The Niger Delta is located in the southernmost part of Nigeria, and covers an area of 211,000 km^2 (UNEP 2011). It is made up of 853 km long coastlines surrounded by mangroves (UNEP 2011). The Niger Delta consist of fluvial and marine sediments built up during the cretaceous period over 60 million years ago. Its land structure is a coarsening upward regressive sequence of tertiary clastics that is developed around south of Anambra and Benue troughs (Ifeadi and Awa 1987), leading

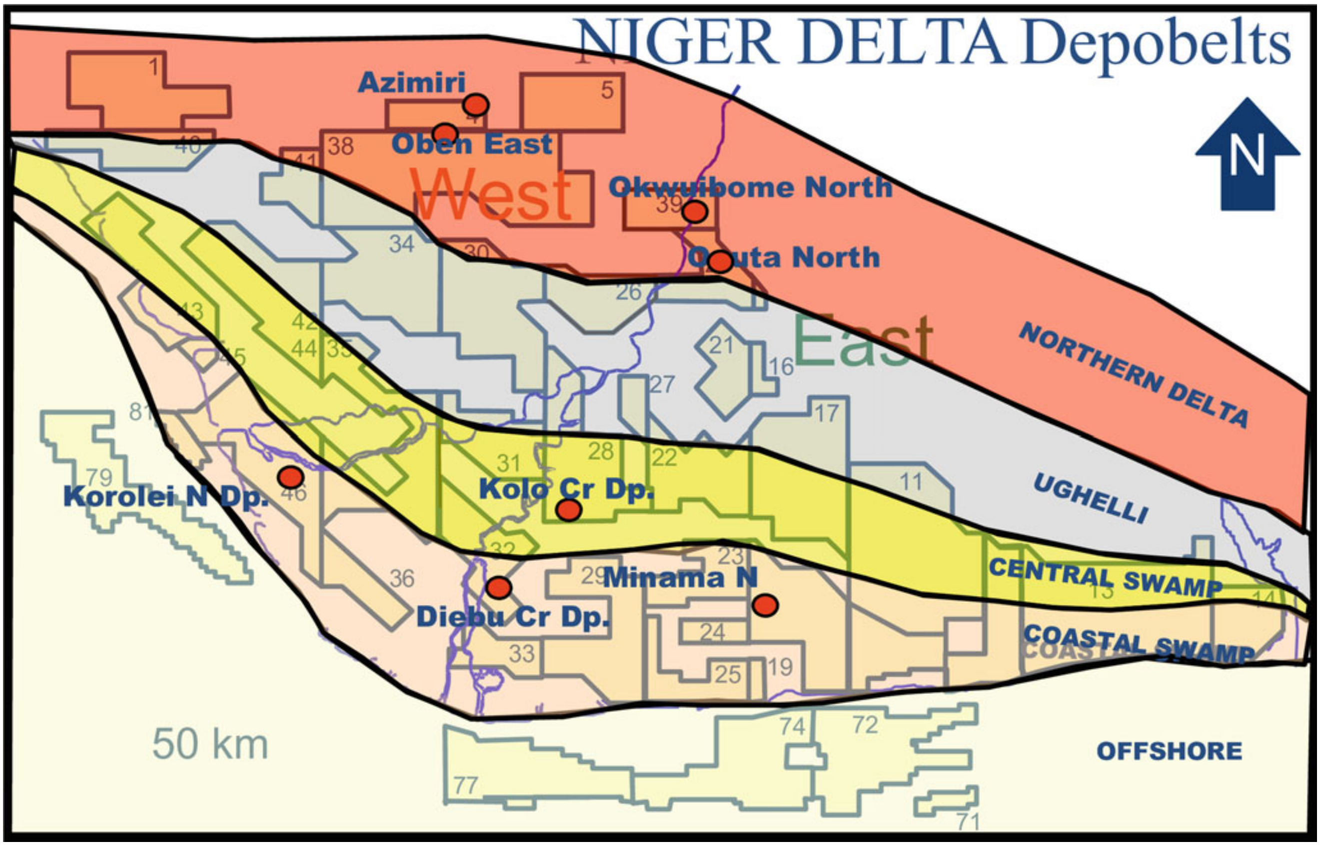

Fig. 12.1 Niger Delta depobelts (Dp) shows areas of crude oil deposits, where exploratory activities are carried out (Credit: A.O. Numbere)

to the formation of depobelts that represent the most active part of the delta at each stage of development (Fig. 12.1). Its age is estimated to be Eocene-Recent (i.e. 0–45 million years ago). The Niger Delta is divided into three lithostratigraphic units namely: Benin, Agbada and Akata formations. The primary source of rock is the geologically active Akata Formation, with contribution from overlying marine sand-shale sequence. It is a sedimentary rock formed through sedimentation process (SPDC 1999). Beneath the earth crust are large storages of crude oil resource, which is formed by decomposed plant and animal matter. The bulk of the plant material comes from dead mangrove vegetation trapped within sediments to form peat. The peat is weathered to form crude oil after being subjected to high temperature and pressure for millions of years.

The Niger Delta area is environmentally sensitive (Gundlach et al. 1981), and supports large amount of biodiversity, but exploratory activities had destabilized the growth and development of the mangrove forest. The delta region acts as a trap and a filter to pollutants that are carried by river into the estuarine mangrove forest. The continuous exploration, production and processing of crude oil and its transportation and marketing expose the mangrove environment to constant threat of oil pollution (Ohimain 2003). Oil and gas exploration activity is the major problem of mangrove in the Niger Delta (Fig. 12.2). Exploration activities cause domino effect by leading to hydrocarbon pollution, invasion and urbanization (James et al. 2007). These activities are mainly man-made hazards that cause accidents, risk or dangers in the environment, and could subject living things to a material risk of death, injury or impairment of health. These hazards can be physical, chemical, and toxic, and also corrosive, flammable and explosive (Withgott and Brennan 2011).

To fully account for the impact of exploratory activities on mangrove forest, the topics below are considered in this chapter.

12.3 Oil and Gas Exploration

Exploratory activity has adverse impact on plants and animals in the environment (Nellemann and Cameron 1998). It involves chain of events that adversely impact the mangrove ecosystem. These events are grouped into three

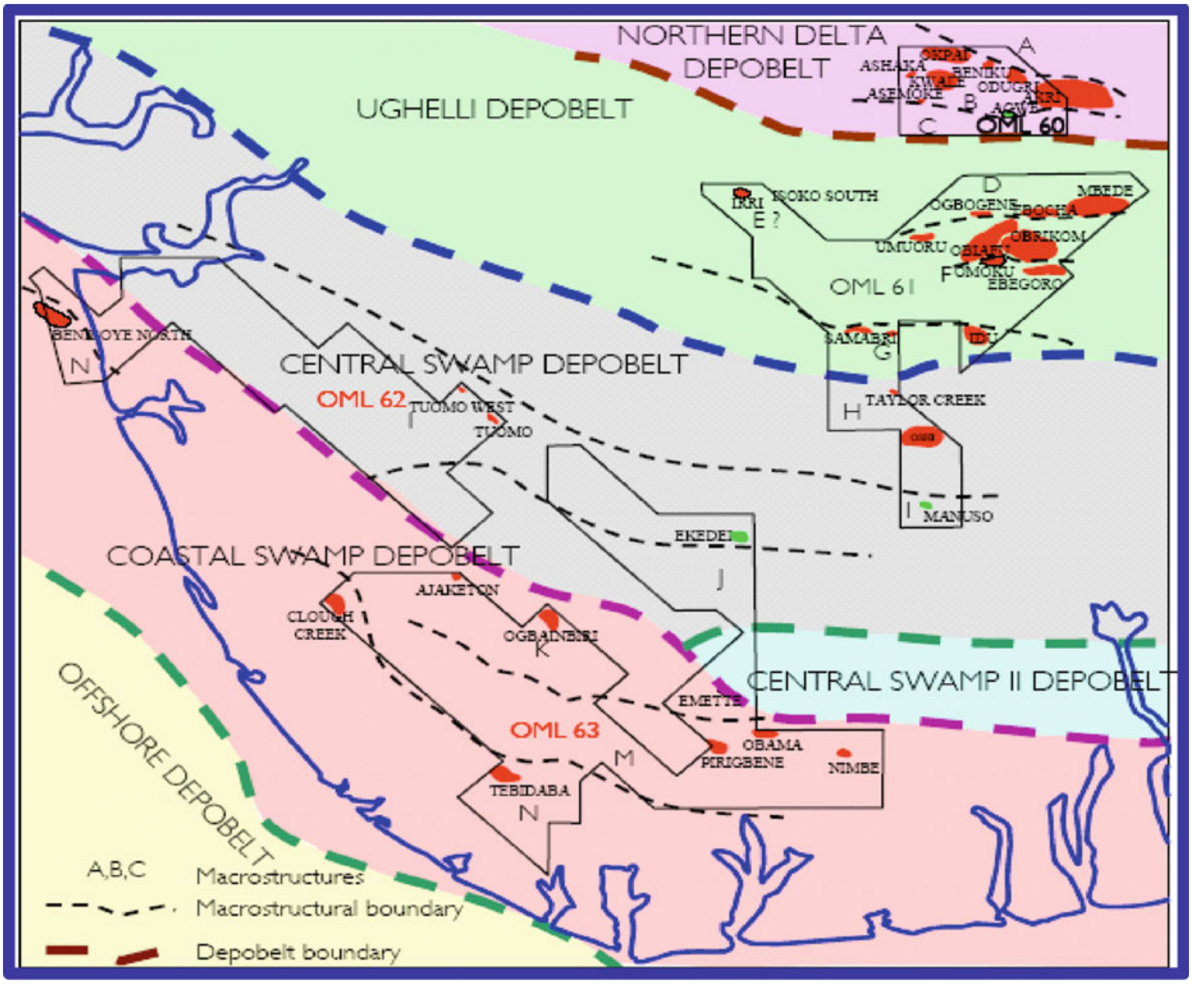

Fig. 12.2 Exploratory activities in the Niger Delta, Nigeria. A depobelt boundary shows areas of active oil and gas exploration. Different oil mining licenses (OML) are owned by both private and government firms. The OML give the companies the right to explore for crude oil at the depobelts (Credit: A.O. Numbere)

stages namely : (1) pre-exploratory; (2) exploratory; and (3) post-exploratory.

12.3.1 Pre-exploratory

Reconnaissance work is carried out within the mangrove forest before the commencement of a full blown exploration. This preliminary work is aimed at detecting the presence of crude oil within seismic layers of the earth crust. Mangrove trees are cut along the seismic route to create unrestricted access into the forest for the survey department of the exploratory team to go in and carry out their job (Ohimain et al. 2008). The survey department follows after the permit unit. The permit unit is involved in land acquisition, and initiates the exploratory process by securing the rights to explore from local and regional authorities. The function of the survey department is to transfer what is on the map to the ground, by determining the actual positions of the seismic lines. Once the seismic locations are identified, workers are assembled to clear the forest and lay the lines. The surveyors determine the actual width of seismic lines that will accommodate the workers and their materials. The environmental effect of this activity is that mangrove trees along seismic lines are cut down leading to massive deforestation (Fig. 12.3). The more the number of workers in the exploratory team, the wider the seismic lines, and the larger the amount of vegetation to be removed. This makes the interior of the mangrove forest to get exposed to further exploitation (Ohimain et al. 2008), and destruction of the mangrove community (Fagbami et al. 1988). This action is devastating as it takes the mangroves about 15 years or more to re-vegetate as compared to the rain forest that takes up to 5 years to grow to maturity. However, field observations had indicated that

Fig. 12.3 Massive deforestation to create right of way (ROW) passage for crude oil pipelines within the Niger Delta mangrove forest. This location is close to a jetty head, and the mangrove trees were cut to create room for the installation of oil and gas pipelines. The area is mangrove dominated but had been invaded by the palms as shown in the background (Credit: A.O. Numbere)

paths created within mangrove forest during exploratory work hardly or don't grow even after several years.

The Drill Department is the next, and comes in after the seismic lines had been successfully established by the surveyors. The duty of the drill department is to mark off and drill the holes where the geophones will be placed to take seismic responses or the dynamites will be placed and blasted. Two ways by which the drill department carry out their duty include: (i) drilling of a deep hole that measures 20–30 m in length with one single charge of 1 kg dynamite placed within the earth, and (ii) drilling of multiple (4–5) shallow holes that measures 3–5 m each in length. The dynamites are placed in the holes after the drilling, covered with soil and blasted. The hazardous effect of this action is that the blow-up destroys nearby mangrove trees and creates craters in the soil, leading to soil degradation. The holes created, if allowed to remain will be washed away by erosion. Iron cuttings from drilling activity also increase the heavy metal concentration of the soil (Lacerda et al. 1993; Mackey et al. 1992). Bentonite, a chemical, used for drilling, is often left on the soil surface to be washed away by rain deep down the soil profile or into nearby water body. Because of the small particle size of mangrove soil they accumulate heavy metals quickly (Clark et al. 1997), and transmit them to the root and stem of the mangroves (Yim and Tam 1999). The acoustic effect of the exploding dynamites scares away animals in the mangrove forests. The sound of the blasting dynamites triggers minor tremors and shock waves that could lead to artificial earthquakes, which destabilize the soil sub-structure. Furthermore, unexploded dynamites called "sleeping dynamites" are potent forces of destruction when activated by animals and humans that traverse the mangrove forest.

The laying of crude oil pipelines is an adventurous activity, but has hazardous effect on the mangrove forest. Seismic drilling and production operations had converted an estimated area of mangrove swamps totaling over 1000 km^2 into areas crisscrossed with oil and gas flow lines (Fig. 12.4).

A large tract of mangrove forest is often made bare of vegetation in other to create a right- of-way (ROW) passage

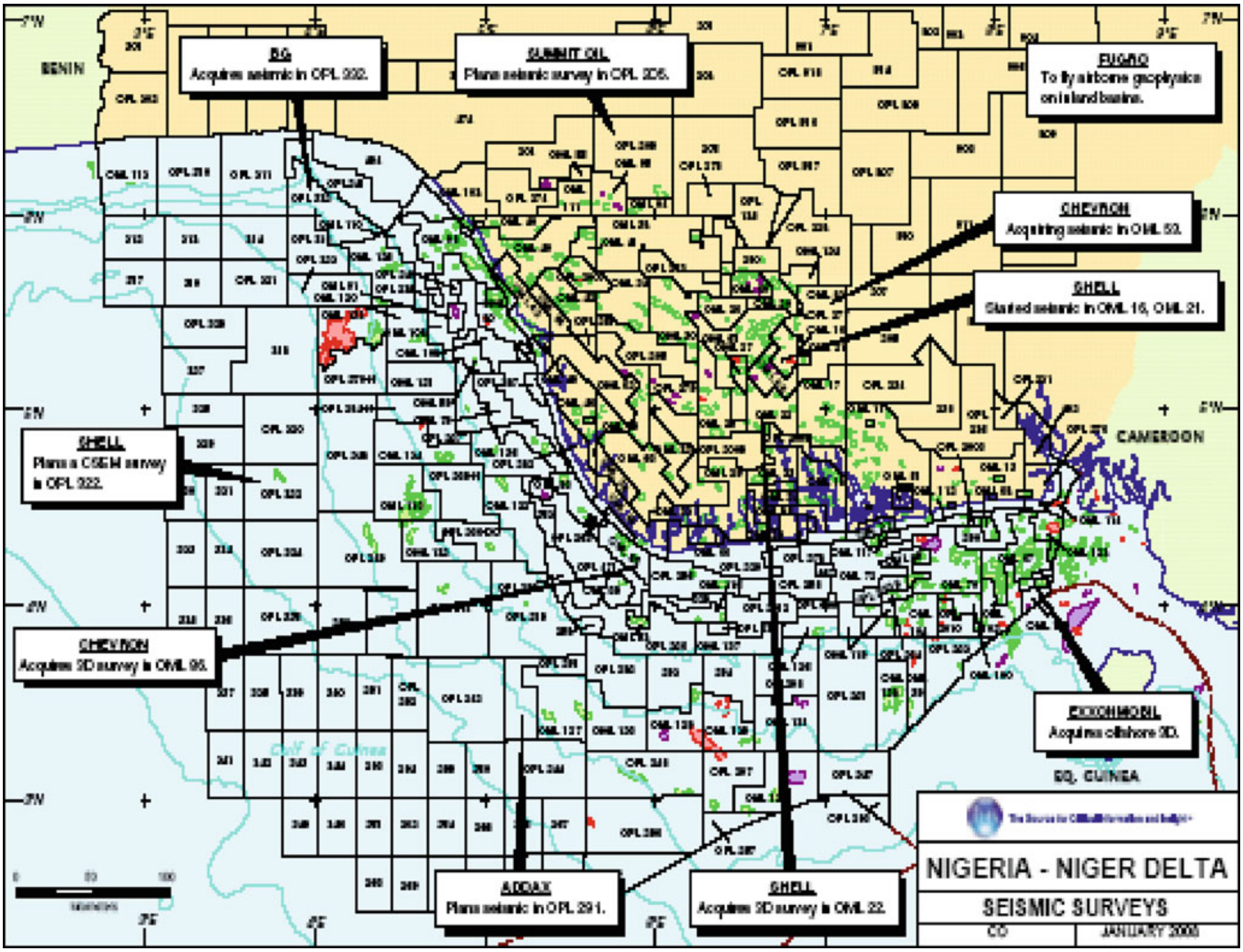

Fig. 12.4 On-shore and off-shore seismic survey points established by some local and international oil companies (e.g. Shell, Chevron, BG, Fugro etc.) running across or beneath land and water surfaces in the Niger Delta. This indicates the amount of perturbation experienced by the area since the first oil well was struck in 1956 (Credit: Niger Delta Seismic Surveys, 2008)

for pipelines (Fig. 12.5), well locations and contractor camps. The surface of the nickel/steel alloy pipes corrodes after several years' under the elements of the weather to contaminate the underlying soil. During welding of pipelines, metal scraps are released into the swamp or water body. The scraps corrode and change the chemistry of the mangrove soils. Destruction of the mangroves forest along the ROW creates opportunity for foreign species to invade and proliferate (UNEP 2011) and become host to diseases that cross over to the mangroves. Examples of other plant species that proliferate in the area include corn vine (*Dalbergia ecastophylum*), coco plum (*Chysobalamus icaco*) carpet grass (*Axonopus compressus*), elephant grass (*Pennisetum purpureum*), guinea grass (*Panicmum maximum*), goose grass (*Eleusine indica*) and goat weed (*Ageratum conyzoides*).

A typical pipeline ROW is about 20 m wide and runs for about 16 km and traverses flat land, stream and swamp locations. The numbers and dimensions of the pipes are two 14″, one 8″ and one 2″ pipes for natural gas liquid (NGL), vapor, and gas respectively. The pipes running through the swamp sit on concrete culvert in the land/residential area while pipe racks are used across the swamp area (EIA 2001). The concrete pipe racks are often constructed by first laying deep foundations, which contribute to the solidification and destabilization of the swamp.

Construction of jetty facilities also contributes to the removal of large sections of mangroves. The jetty contains the following parts: a concrete flare, a fiscal metering system, a vapor return compressor, 12″ NGL loading arm, an NGL analyser and 8″/10″ vapor unloading arm (EIA 2001).

Oil companies undertake dredging of canals at the jetty, which is a detrimental activity on the mangroves (Ohimain 2003). It is the process of soil excavation in swampy terrain for the purpose of widening existing water courses, creation

Fig. 12.5 Nickel/steel alloy pipelines (measuring between 8 and 10″) starting from the refinery to the loading jetty at Okrika in the Niger Delta area of Nigeria. It has an approximate length of 16 km. Mangrove forest is found on the left and right sides while the middle area, which formerly had mangrove trees is now made bare to create a right of way passage (ROW) for pipelines. The ROW contains about 10 pipelines in a row. These pipelines are over 30 years old and the process of corrosion has already begun as shown (Credit: A.O. Numbere)

of new canals, and a re-use of excavated materials for reclamation. The canal is dredged parallel to the new causeway to allow for the entry of barges for piling works and materials transportation. The dredging allows tankers to berth at the port without interference. The total dredging depth is ~12.10 m. The hazardous effect here is that the dredged materials called "dredged spoils" are dumped on existing fringing mangrove forest leading to stifling and poisoning, which cause the death of young mangroves trees (Ohimain 2004). The "dredged spoils" affect surface topography and hydrology, and cause acidification and accumulation of heavy metals in surface and ground water (UNEP 2011). Transportation of dredging equipment such as swamp boogies and barges disfigures the swamp terrain, destroys trees, and destabilizes surface and benthic organisms (Olgard and Gray 1995).

12.3.2 Exploration Stage

This is the stage where the actual drilling occurs, where raw crude oil and gas are pumped out from the earth crust and channeled through pipes via oil well heads (Fig. 12.6) to the refineries for further processing into petro-chemical products. Frequent crude oil spillages usually occur from failed pipes during this stage (Fig. 12.7). The crude oil contaminates and destroys the mangroves (Fagbami et al. 1988). The Niger Delta mangroves constantly sit on thick layers of crude oil as a result of several years of frequent oil spillages (UNEP 2011). Areas where crude oil spilled in the 1970s are still in a polluted state. For instance, a town called Ejama-Ebubu in the Niger Delta that experienced oil spillage 40 years ago is still in a contaminated state despite series of clean up attempts (UNEP 2011).

Fig. 12.6 Crude oil well-head located in a mangrove swamp in Buguma, Niger Delta Nigeria. It shows some sections of the mangrove forest already cleared to install rigs and pipes. Pipeline corrosion occurs several years after submergence under water (Credit: A.O. Numbere)

Crude oil is discharged into the river and mangrove forest during transfer into ocean liners. The discharged crude oil cuts off oxygen supply to the lenticels and pneumatophores of mangroves (Teas et al. 1993). Other sources of pollution include: noise from detonation of dynamites, movement of heavy and light vehicles in and out of the forests, rattling of drilling rigs 24 h daily, disposal of spent lubrications, diesel and domestic wastes, spent drilling mud and chemical and well blow-outs (Okoye et al. 1987). Part of the crude oil pipes that runs under the soil surface displaces soil organisms and truncates biotic processes. This also affects ground and soil water quality, which could be impaired by leachates from generated dredged spoil. The pipelines that pass under water also damage aquatic life such as zooplankton, phytoplankton, benthic organisms and fisheries. The disturbance of the river excites bottom sediments and increases the turbidity of the sea, which affects light penetration and photosynthesis. This could lead to the reduction in species composition and diversity of aquatic resources. The corrosion of pipes placed in aquatic environment triggers explosion leading to oil spillages, which contaminates the entire mangrove community (Snowden and Ekweozor 1987).

Crude oil well heads are pipeline connections that frequently experience engineering failures, sabotages by third party, accidents and natural causes leading to massive oil spillages (Fig. 12.7). These processes destroy large expanse of mangrove forest (Fig. 12.8).

Drilling activity has direct effect on mangrove through the generation of waste. For instance, some drill cuttings have no hazardous effect on the environment. But shale that

Fig. 12.7 The multi-colored oil film on the swamp floor indicates a fresh crude oil spillage that just occurred close to a ruptured oil pipeline at Okrika crude oil jetty location. Crude oil contaminates the swamps, asphyxiates mangrove roots and cause leaf yellowing and death. (Credit: Numbere A.O)

comes from beneath the earth crust most times contains heavy metals and radioactive elements that harm the mangrove forest (Goyer 2001). Similarly, radioactive fallouts occur during logging to assess for deep oil wells. Other waste generating activity in the field includes abandoned drilling pipes, stationeries and kitchen items etc. Splashed concrete used to reinforce enhanced recovery well hardens and prevents the growth of vegetation. The action of making bare the wetlands surface is what enables opportunistic species such as the nypa palms and other alien species to invade and colonize the area (UNEP 2011). Furthermore, construction and drilling activities lead to disturbance of soil dwelling organisms and affects the soil quality.

12.3.3 Post-Exploratory Stage

Oil wells after years of crude oil exploration get dried up, and are abandoned for other oil wells. These abandoned wells are later converted to enhanced recovery (ER) or fluid injection wells. The ER wells are used to recover some crude oil still remaining in the earth crust (Withgott and Brennan 2011). The recovery process involves the bombardment of the well with water to push out the remaining oil from the earth crust. This forceful ejection creates pressure and increases the stress regime of the rocks, which fractures the earth crust and creates seismic fault lines that affect the entire landscape. During this process artificial earthquakes, shocks and tremors do occur. An example is the earthquake in Denver, USA in 1967 caused by Chevron, which occurred when water was pumped into the ground to increase oil supply. In Nigeria no known earthquake had been witnessed, rather there had been some recorded cases of earth tremors. The first earth tremor was recorded in a town called Warri situated in the Niger Delta in 1933. The most recent earth tremor occurred in 2016 in Mbiama, a town in the Niger Delta. The News Agency of Nigeria (NAN) reported that the earth tremor occurred around some oilfields operated by Shell Petroleum Development Company (SPDC) located in two states in the Niger Delta (http://dailypost.ng/2016/09/25/earth-tremor-rivers-bayelsa-communities-cry-out/). These areas are oil producing communities and host several oil companies. There is a general belief that if artificial earthquake should ever occur in Nigeria it will be in the Niger Delta region

Fig. 12.8 Defoliated mangrove forest caused by an oil spill at an oil well head located in Buguma, Niger Delta, Nigeria. There was complete death of mangrove trees along the path of spillage while trees on the left side, outside the path of the spilled crude, were still alive (Credit: A.O. Numbere)

because of several years of oil and gas exploration activities that had created seismic faults within the earth crust in the area. Any earthquake incidence would be a disaster for both the mangroves and human communities along the coasts.

Other sources of pollution at the post-exploratory stage are refining and petrochemical processes. These activities lead to effluent discharges, gas flaring and emissions, tank leakages, valve malfunctioning and human errors, explosions and fire out-brakes. The pipeline and product marketing operation (PPMO) is also a major post exploratory activity embarked upon by the refinery to distribute refined products to marketers and end users (Nwankwo and Irrechukwu 1981). This activity impact the mangrove forest by acting as a source of pollution via pipeline leakages and ruptures, tank leakages and overflows, road tanker and sea tanker collisions, valve and pump malfunctions and hose ruptures at jetties or depots (Table 12.1).

12.3.4 Impact of Oil Pollution on Vegetation and Fisheries

Impact on vegetation (flora): Sheltered mangrove swamps and salt marshes at beach ridges are very sensitive shorelines. Thus floating oil transported by wave energy impairs the growth of mangrove vegetation by oiling them. This results to the yellowing and defoliation of the trees (Anderson and Lee 1995; Snowden and Ekweozor 1987). In some cases, the juvenile vegetation are killed outright as a result of the smothering action on the pneumatophores of the red (*Rhizophora racemosa*), black (*Laguncularia racemosa*) and white (*Avicennia germinans*) mangroves leading to oxygen starvation (Mastaller 1996).

Table 12.1 The potential impact of oil and gas exploration on the mangrove and human environment create numerous problems for the mangrove ecosystem

S/No.	Oil operations	Potential impact
A	Exploration	Destruction of vegetation, farm lands and human settlements, introduction of foreign and invasive species (E.g. *Nypa fruticans*)
1	Geo-physical investigation	Noise and seismic shooting, effects on animals and fisheries, pigging waste
2	Drilling	Noise and seismic shooting, drill cuttings, drill mud, craters and destruction of vegetation
B	Production/processing	Facility and pipeline installation, facility operation
1	Gas flaring	Air pollution from gas and oil processing, evaporation and flaring, heat production affects and destroys the mangroves
2	Tanker loading	Water pollution from ship ballast, destruction of seabed by dredging
3	Storage depots	Land clearance, Land pollution from effluents
4	Transportation	Destruction of seabed, sedimentation, air pollution, erosion and flooding
5	Refinery	Air, water and soil pollution
6	Health effects	Respiratory disease e.g. emphysema, asthma and bronchitis

Impact on fisheries (fauna): The categories of organisms mostly affected by oil pollution include different species of mollusks, crustaceans, echinoderms, polychaetes, cnidarians, oysters, scallops and periwinkles. The immotility of many benthic organisms as well as the free swimming larvae confined to the bottom of the river makes them especially vulnerable to oil pollution (Olsgard and Gray 1995). These organisms are very susceptible to oil pollution because many of them inhabit the intertidal zones where they easily become coated with oil, and smothered when spilled oil drifts ashore (Hayes and Gundlach 1979). Edible crabs that are found in these areas such as *Callinectes palidus*, *Uca tangeri, Ostrea tulipa* and the inedible crab, *Goniopsis pelii* are killed by oil pollution. These organisms will not exist without the mangrove serving as a sanctuary.

12.4 Invasive Nypa Palms (*Nypa fruticans*)

Four main drivers of global environmental change are nitrogen, climate change, land use change and invasive species (Aber et al. 2001). Invasive species compete for resources and modify the habitat in which they are found (Wootton 1994). They are ecosystem engineers as they change some fundamental aspect of the physical and chemical environment (Jones et al. 1997). They are the next major threat to mangroves after oil and gas exploration in the Niger Delta. The palms are monotypic genus that are widely distributed in Asia and the western world including India, Sri Lanka and northern Australia (Jones 1995). They are regarded as mangroves in some areas, but are not true mangroves (Kathiresan and Bingham 2001). They have inimical and domineering relationships to the true mangroves (e.g. *Rhizophora*). They were intentionally introduced into the Niger Delta in 1906 for the purpose of flood and erosion control (Keay et al. 1964). It was believed that they will act as a barrier against surging flood eating deep into the coastal regions. But this would not be achieved as they began expanding their range and started encroaching into the mangrove forest. They have presently occupied large parts of the mangrove dominated areas in the Niger Delta (Wang et al. 2016) as well as parts of West Africa (Sunderland and Morakinyo 2002) such as Cameroun. In some areas they had completely taken over the mangrove stands as the dominant species (Isebor 2003) (Figs. 12.9 and 12.10). For instance, within the Niger Delta region the following areas are highly infested with nypa palms: Bonny, Andoni, and Okrika estuaries, Marine base and Eagle Island creeks along Port Harcourt, Ogoni axis, New Calabar, Imo, Saint Barbara, Saint Bartholomew and Orashi Rivers along the Atlantic Coast. Large percentages of previously exclusive mangrove zones had been completely taken over by the palms in the last 20 years. In some areas there are mixed forest of mangroves and nypa palms (Wang et al. 2016), yet in some areas the mangroves had been encircled by the palms while in other areas no mangrove exist at both the upper and lower stream sections of the river. What is found in some areas are little “mangrove islands” that are left in the middle of the river waiting to go into complete extinction. The rapid growth of the palms is facilitated by anthropogenic perturbations of the mangrove soil whose organic content had risen drastically as a result of constant deposition of human waste and other

Fig. 12.9 A restoration site at Asarama in the Niger Delta, Nigeria where red mangrove species (*R. racemosa*) were existing before overtaken by the palms (*Nypa fruticans*). The red mangrove propagules are now planted within the nypa palm stands to recover the mangrove population. This area was mangrove dominated before the invasion of the palms. At the background are palms, which indicate that the mangroves still have a long way to go to recover their territory from the palms (Credit: A.O. Numbere)

pollutants (Okoye et al. 1991). In areas where both nypa palms and mangrove grow, the latter are out-competed (Numbere 2014; Numbere and Camilo 2016) and their positions taken over by the palms (CEDA 1997).

It was observed during field work that the nypa palms grow outwardly from the center of the mangrove forest in groups of multiple stands in a sort of center-spread fashion. The reason for this growth pattern is still being investigated, but it is believed that the growth of the nypa palms within the mangrove stands is for protection from surging ocean currents. This is because the nypa palms are poorly equipped to ward off tidal currents. In addition, the palms grow amongst the mangroves to absorb soil nutrients embedded within mangrove soils. The seeds of the nypa palms develop fibrous roots and absorb nutrients at a faster rate than the mangroves. This deprives the mangroves of nutrients leading to deficiency, outright migration or death. A recent study (unpublished) comparing the morphology of mangrove and nypa palm roots and their nutrient utilization capability shows that nypa palm roots are "straw-like" and more porous as compared to the mangrove roots that have thick and tightly packed cells (Fig. 12.11). The structure of the palms predisposes them to absorbing more nutrients when placed in the same environment as the mangroves.

In this study, it was found that there were more bacterial content (4.85 ± 0.6 cfu/g $\times$ 10^6) than fungi (0.35 ± 0.01 cfu/g $\times$ 10^6) in nypa palm and mangrove roots. Mangrove roots had more microbial content (2.85 cfu/g $\times$ 10^6) than nypa palm roots (2.35 cfu/g $\times$ 10^6). In the same vein, nypa palm roots (7.7 ± 3.2 mg/kg) had higher heavy metals than mangrove roots (2.7 ± 1.2 mg/kg) while average nutrient content (i.e. nitrogen, phosphorous and nitrates) was more in mangrove roots (123.9 ± 121.1 mg/kg) than in nypa palm roots (44.9 ± 40.7 mg/kg). This shows that mangrove roots had more un-transported nutrients than nypa palm roots, which implies that nutrient transportation was

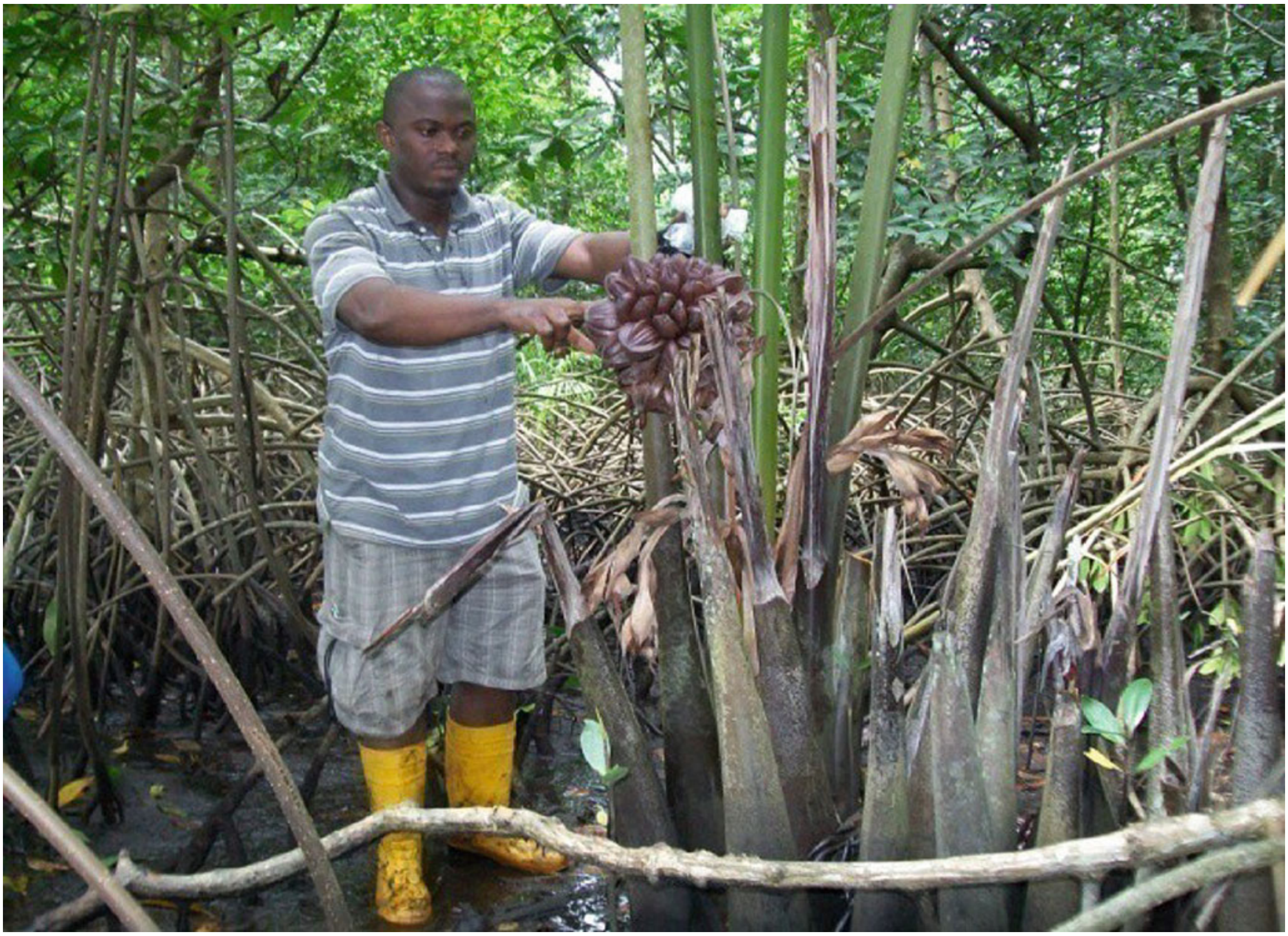

Fig. 12.10 Nypa palm (*Nypa fruticans)* stands embedded within a previously exclusive mangrove forest. The soil chemistry and texture change in areas where the palms dominate, and this affects mangrove growth. There is also high subsidence in nypa palm dominated areas because of the inability of the nypa roots to compact the soil and prevent soil erosion as do the mangroves (Credit: A.O. Numbere)

slower in mangroves than in nypa palms. Therefore, mangrove trees will stand little or no chance of survival if placed in the same environment with the palms.

In another study, it was found that nypa palm seedlings had better growth and higher survival rate in mangrove soil than in nypa soil (Numbere 2014). In yet another experiment carried out to test the effect of propagule pressure in mangrove forest, it was found out that Nypa palm seedlings out-numbered mangrove propagules in a mangrove forest in a ratio of 27:1 (in press). These studies indicate that nypa palms are a major threat to mangroves in the Niger Delta. And if nothing is done to curb the aggressive colonization of mangrove forest by the palms in the next 50 years the mangrove population would have reduced to an endangered level, and might go into extinction in a century. The reason behind this prediction is that in 2002, I sampled a small mangrove forest measuring about 400 m^2 for my Masters work at the foot of a bridge near a small creek at Marine Base, after 15 years, in 2017, when I re-visited the area, I observed that no single mangrove was found in that location. This is because the area had been completely taken over by nypa palms as a result of deforestation and waste disposal in the forest. This same pattern of mangrove disappearances had been observed in other locations. Every year a mangrove territory falls to the rampaging palms. In other to stop this trend it will take a deliberate effort of the government or non-governmental agencies (NGO's) to come to the rescue of the mangroves or else we may be seeing the end of the mangroves in this region.

12.5 Urbanization

Urbanization is also a key product of deforestation that had decimated large amount of mangrove forest stands in the Niger Delta. One of the major causes of deforestation is

Fig. 12.11 (**a**) Mangrove and (**b**) Nypa palm roots. The roots of nypa palm are more fibrous, lighter and completely buried in the soil whereas the mangrove roots are adventitious, harder and protrude from the soil surface. The nypa roots are hollow and "straw-like" while the mangrove roots are non-hollow and have tightly packed cells. The roots of palms have the advantage of faster nutrient absorption than the mangrove roots (Credit: A.O. Numbere)

population explosion in Nigeria with about 182 million persons (NPC 2017). Nigeria is the most populous country in Africa, and the most populous black nation in the world. The Atlantic coastal areas are the highest centers of human habitation. For instance between Senegal and Nigeria an estimated 60 million people representing 25% of the population live within 60 km of the coastal areas (NOAA/NOS 2002). In Nigeria 20 million people live along the coastal zone (IPCC 2000) in areas locally called "water side". Increase in poverty and the need for shelter had pushed the people deeper into the mangrove forests to seek for shelter. These shelters are locally constructed with palm fronds and wood from the mangrove trees. But most times after clearing the mangrove forest on site, the swamp is solidified with thick mangrove soil locally called "chikoko" (Numbere 2014). This chikoko soil has the tendency of becoming hardened after reinforcement with wood and mud. It is on this hardened platform that the foundations for wooden or concrete buildings are erected. Human alterations of the ecosystem such as the clearing of large sections of the forest to build houses have rendered the mangrove susceptible to invasion by foreign species. Land reclamation in the form of sand dredging is often done around the mangrove swamp (Ohimain 2003). The area that is dredged and sand filled is left to lie fallow for several years. This activity alone had led to the loss of significant amount of mangrove forest communities in the Niger Delta (Fig. 12.12). In a questionnaire survey conducted in three local settlements built on cleared mangrove forest in the Niger Delta, it was found that 70% of the respondents said they like mangroves because of the benefits they derived from it. But when probed further on how much they will pay to preserve it, their response indicated that they cared less about its preservation (in press).

Increase in urban areas result to the conversion of high density to low density mangrove forest (Wang et al. 2016). Urban regions, which include construction site, road, urban vegetation, buildings and other infrastructural facilities, had taken over an area of mangrove swamp estimated at 185.7 km^2 out of 3459 km^2 of the total mangrove forest sampled. This makes 5.4% of the mangrove vegetation in the Niger Delta (Wang et al. 2016). This study indicates that urban areas increased rapidly from 1984 to 2007, and had negative relationship with mangrove forest and a positive relationship with mixed forest. Mixed forest includes a combination of mangrove and nypa palm trees. This study further indicates that there is a linkage between exploration and urbanization. Apart from the destruction of mangrove forest by pollution (Snowden and Ekweozor 1987), exploratory activities had resulted to an increase in urban areas and a decrease in mangrove swamps. Areas where mangroves are removed were quickly flooded with developmental projects

Fig. 12.12 Dredged and sand filled mangrove forest in Buguma, Niger Delta, Nigeria. There are still some mangroves that can be seen at the background. On the left of the picture is the fence of a secondary school. No mangrove tree has ever grown on this area since the sand filling in 1984. The area is now occupied by weeds and other alien plant species (Credit: A.O. Numbere)

such as industrial complexes, residential quarters and social amenities (Fig. 12.13). James et al. (2007) revealed that 210 km^2 of mangrove forest had been lost as a result of urbanization, dredging and oiling activities in the Niger Delta. Similarly, Wang et al. (2016) revealed that 5% of mangrove forests had been lost from 1984 to 2007 in the Niger Delta (Fig. 12.14). Exploration activities increased urban areas and reduced wet mud, leading to land fragmentation. Wet mud is the swampy areas, which serves as the natural habitat for mangroves and other wetland species. The disappearance of wet mud is an indication of mangrove loss and replacement with urban areas and nypa palms (Wang et al. 2016).

An example of dredging and sand filling activity occurred in a town called Buguma in the Niger Delta in 1984. This action removed a total of about 4.2 million m^2 of mangrove forests from the landscape (Fig. 12.15). The dredging was embarked upon as a program by the local authority to reclaim land for human habitation. The decision to reclaim more land was reached following increase in population in the small island town. Since this dredging activity took place over 30 years ago the area had remained bare of vegetation without any trace of mangrove re-growth.

12.6 Interaction Effect

At present, a far greater threat to mangrove forest in the Niger Delta that is not often mentioned in the literature is the interaction effect of hydrocarbon pollution, urbanization and invasion. The mangroves are naturally resilient and resistant to environmental perturbations (Boesch 1974; Gunderson et al. 2002; Horn 1974). But the interaction of these three threats have further denigrated their power of resilience, and had reduced their survival ability in the face of multiple threats. Continuous deforestation and replacement of the mangrove

Fig. 12.13 Urbanization in progress. The conversion of mangrove forest to urbanized area. At the far end are some mangrove trees still standing, while at the middle are residential buildings with one under construction in Buguma, Niger Delta, Nigeria (Credit: A.O. Numbere)

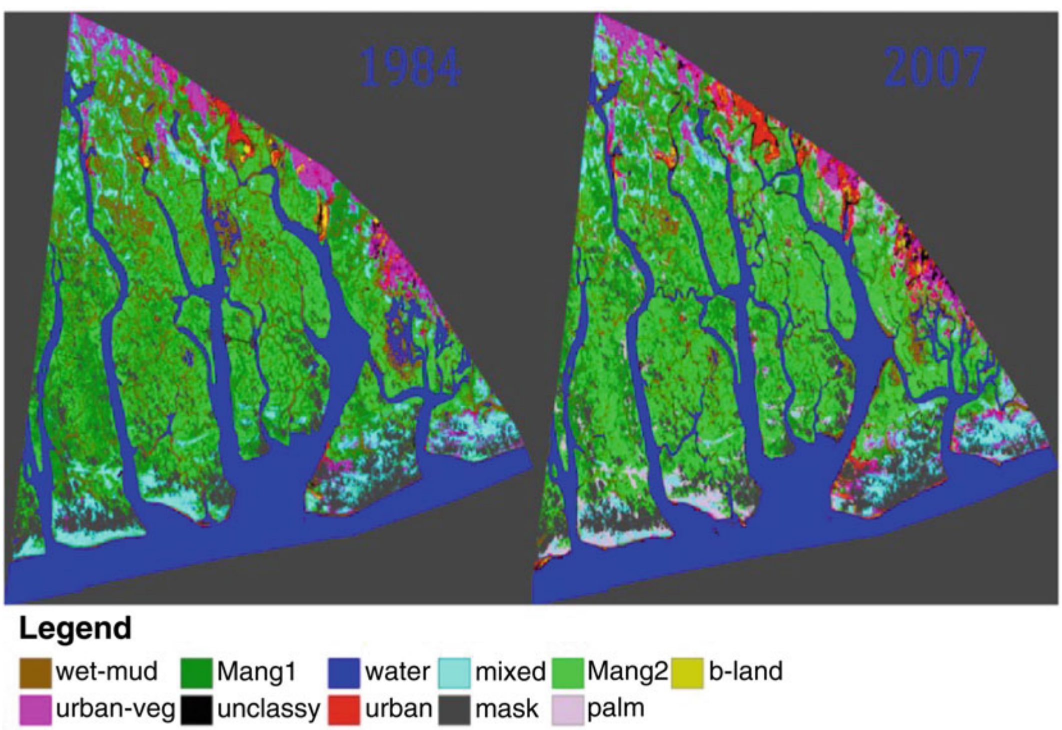

Fig. 12.14 Mangrove landscape change between 1984 and 2007 in the Niger Delta, Nigeria. Wet mud refers to swampy areas, Mang 1 refers to high density mangroves, Mang 2 refers to low density mangroves and urban refers to urbanized areas, and include industrial, residential complexes, and construction sites. (Source: Wang et al. 2016).

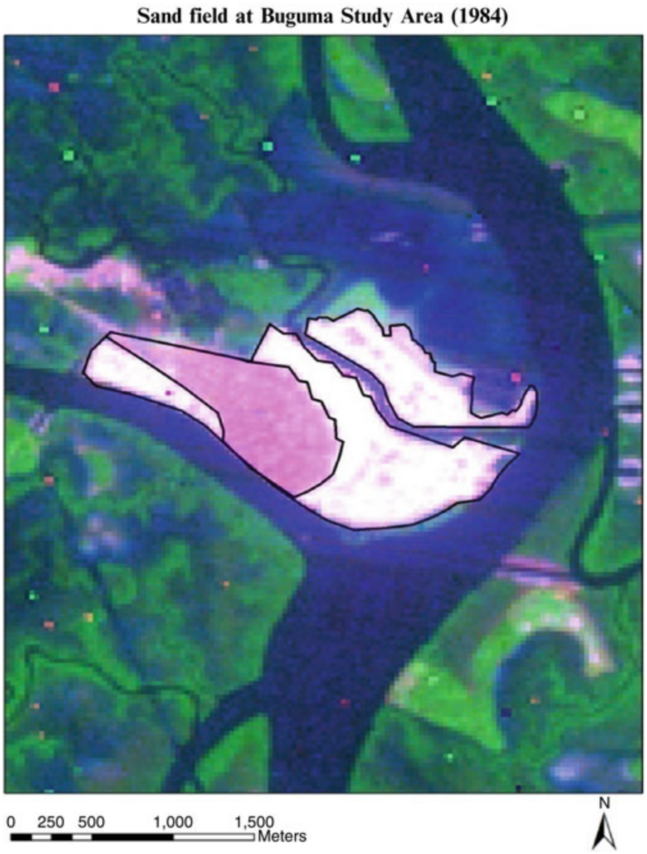

Fig. 12.15 Dredged and sand filled area in Buguma, Niger Delta, Nigeria. The white patches indicate the sand filled area while the green patches indicates mangrove forests that are still standing. The white patches sum up to give a total of 4.2 million m^2 of mangroves removed in 1984. This estimates was made using Arc GIS (ESRI 2006)

forest with urban infrastructure had given the mangroves no chance to exist in their natural habitat. And mangroves cannot co-exist with urban areas because they are habitat specialist that only thrives in wetland environment. Studies had shown that mangroves can survive limited hydrocarbon pollution (Numbere 2014), and recuperate if tidal flushing reduces the level of hydrocarbon pollution. Litter decomposition also take place on the forest floor in highly polluted mangrove forest (Numbere and Camilo 2017). Mangroves can also have limited growth in the presence of nypa palms, and can survive dredging to relaim land for urban development, as experienced in Buguma. But will have difficulty surviving when the three components are acting at the same time (Fig. 12.16).

12.7 Concluding Remarks and Conservation Measures

The key problem of conservation of mangroves in Africa is poverty. This is because indigenous people rely more on the numerous by-products of mangroves such as fire wood, medicinal herbs, and food, but have little or no benefit from the palms (UNEP 2007). The reason might be that they have not found any use of the palms yet. Therefore, for any mangrove conservation effort to succeed in the Niger Delta there need to be the inclusion of human management. The creation of zones of use, buffer and transition is advantageous to plants, animals and humans. At the core area no resource extraction is to be allowed, rather scientific activity can be permitted to monitor population dynamics of the mangrove ecosystem. If this design were adopted, it means at the buffer zone some level of resource use by people can be allowed. Tourist potentials can also be tapped to generate funds to run the reserve. The transition zone will have higher level of resource use such as commercial activities, building of residential quarters and ecotourism. Human habitation can be allowed to enable the people to protect and also act as custodians of the forest. The model recommended for the Niger Delta is similar to that of the Great Buffer Reef Marine Park Authority (GBRMP) in the east coast of Australia (Day 2002). Here use and preservation zones were established. The preservation zone is used for scientific study, but prevents tourism and commercial activities. The park allows the establishment of breeding sites for threatened and endangered species. In the GBRMP ten percent of the coral reef was designated as protection zone.

Another key restoration measure against hydrocarbon pollution that can be implemented in the Niger Delta is the planting of fresh mangrove propagules from nursery bed to the field. This is because studies had shown that high density mangrove can withstand hydrocarbon pollution better than low density mangrove (Wang et al. 2016). This same study indicates that oil and gas exploration significantly decreased the areas occupied by mangroves. In other to restore mangrove vegetation more mangrove propagules should be planted in dedicated areas that will be strictly protected to prevent human intrusion. The planting of more mangrove seedling is important to prevent propagule pressure from the palms, which had already overwhelmed the mangroves in many locations. In another context, a win-win conservation measure or limited protection can be adopted in areas that have large human population to ensure a balance between forest restoration and human utilization. In the same vein, the proliferation of urban areas and the reduction of swampy areas mean that mangroves are losing their natural habitat through land modification (Ellison 1994), which is not good for the survival of the mangroves. As a remedial measure against invasion, the palms should be destroyed with swamp boogies and the seeds removed to prevent re-growth and re-colonization (see Fig. 12.16). The disturbed soils should also be removed and replaced with mangrove soils to facilitate the growth of the mangroves after the removal of the palms. This is because mangrove seedlings have poor growth performance when planted in

Fig. 12.16 Eagle Island estuary, Niger Delta, Nigeria. A combination of pollution, urbanization and invasive nypa palms had led to a complete disappearance of a once thriving mangrove forest in this location. Twenty years ago this area was a mangrove dominated forest (*R. racemosa*). The nypa palms were uprooted by swamp boogies because they were blocking an adjoining canal. At the background are buildings (urban areas) constructed several years ago after the swamps were dredged and made bare (Credit: A.O. Numbere)

the same environment with the Nypa palms (Numbere and Camilo 2016).

Despite the threats of oil and gas exploration, urbanization and invasion all hope is not lost. This is because the situation can be reversed if the oil companies performed their social and environmental duties responsibly by ensuring that old oil facilities are maintained to avoid oil spillages. In addition, local land owners and communities from whom the exploratory lands were acquired should be adequately compensated to prevent acts of agitation and sabotage of the pipelines. Personnel from the oil companies should respond quickly to incidences of spillages and be pro active in detecting the cause of oil spillage. The oil companies can save the mangrove environment by embarking on less intrusive seismic refraction method rather than the use of a more intrusive method of using explosives like dynamite to explore for crude oil. The refraction method can be used for oil and gas exploration and exploitation, and applies the principle of refraction and reflection to locates oil deposits in the earth crust without adverse effect on the environment.

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