Chapter

Mangrove Habitat Loss and the Need for the Establishment of Conservation and Protected Areas in the Niger Delta, Nigeria

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Abstract

Niger Delta mangroves are the largest in Africa, but uncontrolled anthropogenic activities had reduced their population size. The reduction from large to small mangrove stand has some ecological implications on species populations. For instance, stochastic events such as flooding, landslides, sea level rise, high temperature, and humidity affect small populations. Human-mediated actions of random deforestation for firewood production, canalization, and de-silting of waterways, lead to the complete elimination of mangrove stands in specific locations. The cumulative effect of these actions can result in local extinction and loss of genetic variation of mangroves. Destruction of mangroves over the years is detrimental to other species that inhabit the mangroves in the Niger Delta (e.g., fishes, crabs, etc.). This situation can be reversed or stopped if effective protective measures are adopted. Strict protective measures can be done in areas that are highly impacted i.e., regions where oil and gas exploration or massive deforestation activities had occurred. Limited protection can be done in areas with low impact, and is known as a win-win conservation where the peoples welfare is considered. Here, indigenous people are employed to help in the protection of the forest and in return are allowed to exploit its resources.

Keywords: mangrove, Niger Delta, fire wood, dredging, hydrocarbon pollution, urbanization, deforestation, maritime transport

1. Introduction

Mangroves are shrubs or small trees that inhabit the interface between the land and the sea. They are habitat specialists that grow along coastal regions. They grow in swampy soil that is continuously wet from year to year because of the action of tides and heavy rainfall. Mangroves are found in tropical areas with high solar radiation and precipitation [1]. The mangroves of the Niger Delta are the third largest in the world and the largest in Africa [2]. It is a biodiversity hot spot, and is found in the tropics close to the equator where rainfall persists all year round. The climate is hot and facilitates the proliferation of living organisms from microbes to vertebrates through series of speciation and evolutionary events. Biodiversity hot spots are important zones because they contain 25% of all terrestrial species. Hot spots are small areas on the map (i.e., about 2%), but wield so much ecological influence on the surface of the earth. They contain disproportionately large numbers of species on earth. Tropical forest has the largest number of species in the world. It has a lot of taxonomic diversity, which includes plankton, macrophytes, arthropods, fungi, protists, mollusks, crabs, vertebrates including birds and mammals. Mangrove forest is the most dominant amongst the plants found in the coastal region of the Niger Delta area. The reasons for high species diversity in mangrove forests of the Niger Delta are because of high reproduction and productivity [3]. The tropics are areas that have high speciation and less species extinction. Secondly, the stability hypothesis postulates that the tropics have been more stable than present in the last 1000 years and will remain so for a long period of time. It is stable with respect to the abiotic conditions that prevail in the area. Similarly, the equator has been stable with respect to global warming and cooling with lower extinction rate recorded over the years. Furthermore, intense solar radiation had resulted in an increase in overall productivity resulting in high biodiversity turnover. The tilt of the earth also affects how the photon of sun hits the earth. The sun position right overhead the equator serves as a major source of energy. Plants capture solar energy, which they convert to food for other organisms in the ecosystem. The captured energy is converted into biomass, which is transferred to the production of more resources. This is exemplified in the high productivity of mangrove forests recorded in the Niger Delta [3]. Increased litter fall facilitates high decomposition [1] and makes food available for different species of organisms in the food chain. The tropical environment is highly specialized. High specialization and speciation lead to high biodiversity. But the problem of mangroves globally is the gradual loss of their habitat due to anthropogenic activities [4]. This study showed that 35% area of global mangrove forest had been lost as a result of some human activities such as shrimp culture, forest use, fish culture, diversion of freshwater, land reclamation, herbicides, agriculture, salt ponds and coastal developments. In Africa coastal development is a major factor of habitat loss [4]. Although, other studies had revealed that Nigeria has one of the least carbon CO_2 emissions from soil as a result of mangrove losses [5]. Similarly, previous studies have shown that habitat conversion far exceeds habitat protection by a ratio of 8:1 globally [6].

1.1 Mangrove forest resource in Nigeria

A forest is an ecosystem, which is dominated by trees. Forest produces timber and non-timber products. Non-timber forest includes anything other than timber. Forest products are all renewable and can be sustainably managed. More often than not mangrove forest is looked at from the economic resource angle. This is because they are the sources of revenues such as wood, firewood, latex, dyes, thatches, bamboo, reptiles, insects, roots, shoots, stems, flowers, honey resins, gum, silk, fabrics, rope, animal oil, cosmetics, water from streams and lakes. The value of these resources is often difficult to quantify. We also have nature reserves and recreational activities.

Nigeria has a wide and diverse range of habitats from arid zones in the north to the swampy wetlands in the south. Many forest types (tropical rainforest, Sahel savanna, Guinea savanna, Sudan savanna, Montane savanna, etc.) are associated with these zones and have an array of plant and animals species. Some of these biodiversity include:

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1. **Plants**: There are over 4,600 plant species in Nigeria. Out of these figures 205 plants species are endemic. But they are under the threat of extinction through due to overexploitation.

2. **Mammals**: There are about 274 species of mammals, which is the highest number in Africa. Two endemic species are the white coated guenon and the red tailed monkey. They are also endangered.

3. **Birds**: Nigeria has about 839 species of birds with two as endemic. They are Anambra waxbill and Ibadan malimbe. All birds of prey are considered threatened in Nigeria

4. **Reptiles**: They are about 56 species of forest snakes in Nigeria. We also have 56 savanna snake species. Crocodiles, pythons, monitor lizards and turtles, which are under threat.

5. **Amphibians**: There are about 19 recovered species of amphibians in Nigeria, 5 of which are endemic to Nigeria and Cameroun, and 3 are under threat of extinction from habitat destruction.

6. **Invertebrates**: The giant swallow tail and generally other lepidopteran species are under threat in Nigeria due to pollution from oil and gas exploration. Only about 1.7% of Nigeria land is included within protected area as compared with the large landmass. Even the protected areas are being degraded by poaching, illegal logging and infrastructural development.

2. Habitat loss and conversion

There is a gradual but steady loss of mangrove forests in the Niger Delta due to uncontrolled deforestation for the purpose of sand dredging and canalization (**Figure 1**). Mangrove forest is also cut to recover stems, which are used in the production of firewood and wood for the construction of houses. Similarly, numerous oil and gas exploratory activities all over the Niger Delta area open up the forests to further exploitation of resources and invasion by foreign species such as nypa palms (*Nypa fruticans*) [7]. Habitat loss is amongst the three important factors that are responsible for recent species extinction. The other two are overexploitation and the introduction of exotic species [8]. The implication of the loss of mangrove habitat is the loss of ecosystem services it renders to the society [9].

2.1 Habitat loss

Habitat loss leads to extinction because species are adapted to a particular habitat type. For instance, mangroves are habitat specialist that survives in swampy wetland soil, therefore, when they are removed from their native environment and taken to other environment they do not survive. There is also a relationship between the numbers of habitats and the species present. This is because the larger the habitat size the higher the number of species, and the smaller the habitat size the fewer the number of species present. There are many ways humans cause the loss or conversion of mangrove forests, these include tree cutting for production of firewood, agriculture (e.g., fish farming or rice paddies), construction of houses and hydrocarbon pollution from oil and gas exploration activities. Currently, there are numerous

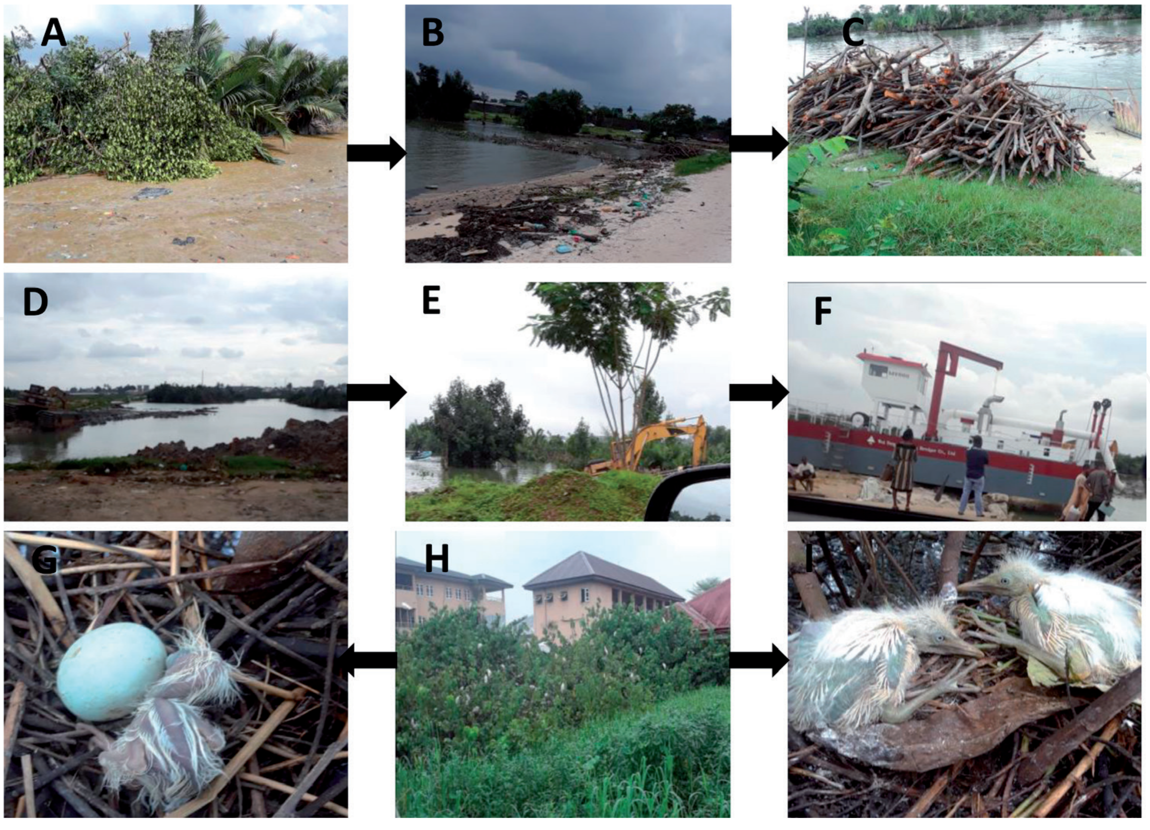

Figure 1.
Consequences of biodiversity loss on species population: (A–C) shows deforestation for fire wood production; (D–F) show canalization of river bottom to create way for sea craft; and (G–I) show the displacement and migration of birds (heron) to urban areas for breeding due to the loss of their natural habitat in the Niger Delta, Nigeria.

locations in the Niger Delta where sand dredging and mining activities are taking place. Usually before the sand dredging the entire mangrove forests in such vicinity are cut down to pave way for the entry of heavy duty machinery (e.g., **Figure 1E, F**).

2.2 Habitat conversion

It is a situation whereby mangrove forests are converted into sand fill or other land use systems that are inimical to the existence and proliferation of coastal species. For instance, in sand filled land only weed grow as the main vegetation cover. This leads to a drastic change in the total number of species. In this context, loss of mangrove forests lead to the loss of forest canopy that houses other species such as birds, tree crabs, monkeys, etc. Increased human activities such as industries, living quarters, and marine transportation result in the increase in waste disposal in aquatic environment. The disposal of liquid and solid wastes into the river contaminates adjoining mangrove forests. Accumulation of organic products promotes the proliferation of algae, which accelerate the process of eutrophication. Fertilization of the aquatic system leads to the increase in biological oxygen demand (BOD) and decrease in dissolved oxygen (DO) in the water. Accumulation of organic waste in mangrove forest leads to anaerobic condition which causes slow death of mangroves. The implication of these activities is that once the habitat type is converted protection becomes extremely difficult [6].

2.3 Mangrove habitat fragmentation

Mangrove fragmentation is the process whereby large contiguous areas of mangrove forests are divided into small habitats as a result of urban development [10].

Figure 2.
*Isolated and fragmented mangrove stands surrounded by invasive nypa palm species (*Nypa fruticans*) and an overlooking urban area at Eagle Island, Niger Delta Nigeria. This mangrove stands are subject to impending stochastic events such as flooding, tidal surge, sediment erosion at the root of the plants which may easily wipe it out in few years time.*

When this happens, fragmented forests become physically isolated from each other, which has a negative effect on the population dynamics of organisms in the forest (**Figure 2**). Fragmentation of mangrove forests has an effect on the connectivity of the forest, which affects the movement of organisms within the forest. The island biogeography theory vividly throws more light on this situation when [11] in his seminal work showed that big island has more species than small islands. In the same way, big mangrove forest will have more biodiversity and less extinction than small mangrove forests. Furthermore, island biogeography theory shows that island close to main land has more species than island far away from mainland. In contrast, the closer the mangrove forest is to urban area the lower the number of species due to human disturbances. Mangroves are only adapted to coastal areas, which prevent them from migrating upland [12]. However, their seeds can migrate to foreign lands through tidal pressure far away from their place of origin. Some individual mangrove seedlings can migrate to oceanic habitat patches. The distance between the patches will affect the rate at which the species get there. This is because human activities that lead to land fragmentation such as urban development and sand filling can lead to the compartmentalization of the mangrove forests. The mangrove in the Niger Delta area has become a sink population, and thus there is a negative population growth due to anthropogenic activities.

2.3.1 Impact of edge effect and fragmentation on mangrove forest

Edge is a location of an abrupt transition between two habitat types. When a large area is fragmented, it increases the amount of edges on a habitat and decreases core habitat, thus exposing the edges to more impacts by humans who gain access to the forest to cause more plundering of its resources. An example is the entry of

Climate/human parameters	Core mangrove habitat	Edge mangrove habitat
Temperature	Lower	Higher
Humidity	Higher	Lower
Light level	Lower	Higher
Wind	Lower	Higher
Human impact	Lower	Higher

Table 1.
The level of environmental impact on fragmented mangrove forests in the Niger Delta, Nigeria.

invasive nypa palm species into mangrove forest due to the direct introduction by humans [7]. Fragmentation of large mangrove forest into small fragments lead to the formation of little mangrove islands that are prone to forces of denudation such as tidal pressure, erosion and flash floods which erodes it banks leading to a gradual loss of the entire mangrove stands (**Figure 2**).

The difference between core and edge mangrove forests in relation to habitat loss is because of the impact of some climatic parameters (**Table 1**).

A major cause of mangrove deforestation in the Niger Delta, Nigeria is its use in the production of firewood, which reduces mangrove forest sizes. The fragmentation of mangrove forest can lead to the formation of numerous edges that subject the forest to further climatic and anthropogenic damages.

2.4 Rarity of species

Rarity of species can be described in three ways [13, 14]:

1. Geographic range: it means how much of landscape is covered by the mangrove forest. It can be wide (i.e., found over a large area), or narrow (i.e., it will exhibit a rare form of the habitat size).

2. Habitat specificity: this involves whether the forest is narrow or restricted to coastal area or broad and found in different habitat type such as riverine and upland locations.

3. Population size: this is important because large population of a given species is better than medium or small populations of species. This is because extinction risk increases as population size declines.

2.5 Danger of small populations of mangrove forests

There are basically six problems associated with small populations of any kind of species [15], they are:

1. **Environmental stochasticity**: there is no constant environment, because of the action of fluctuation. Environmental stochasticity is an unpredictable event such as changes in weather (i.e., climate variability), invasive species, parasites and diseases, soil nutrients, etc. that has to do with environmental variation, and causes variation in survivorship of individuals. If population is large, it is not threatened with the possibility of extinction. But if the population is small it has high probability of extinction. The stochasticity, which

affects survival affects small population size more, which eventually leads to zero. Moderate population size will also go to zero with time. This can occur during major disturbances such as flood, mudslide, deforestation, canalization, sand filling and sand dredging activities. Deforested mangrove will also suffer from reduced population, which will further lead to habitat loss.

2. **Demographic stochasticity**: this is the chance of fluctuation or randomness that is common in small populations. Small populations of mangroves are at a risk of low seedling turnover, which leads to low growth rate. It is easier for small mangrove stands to be wiped out due to environmental and anthropogenic factors than large mangrove stand.

3. **Inbreeding depression**: this can occur in mangroves especially when population size drops resulting in reduced fitness as a result of cross pollination between similar species. This is because individuals in small inbred populations may have small germination rate when compared to large inbred populations. This situation is observed in two mangrove forest communities situated in Buguma and Eagle Island in the Niger Delta. There is a rejuvenated and increased germination rate in red and black mangroves in Buguma as compared to Eagle Island. This is because the mangrove forest in Buguma is isolated from human disturbances resulting in high canopy cover whereas mangroves in Eagle Island are scanty with few populations because of poor growth rate as a result of human intrusion into the mangrove forest. Low population size can also lead to loss of genetic variation.

4. **Genetic variation:** The theory of natural selection states that the rate of evolutionary change in a population is proportional to the amount of genetic variation in the population. Based on this hypothesis all populations can respond quicker to any change in the environment where they have higher genetic variation than lower genetic variation. Populations with high genetic variation can easily adapt to any change. Although, this situation operates at a long term scale. The mangroves are resilient species and take between 20 to 50 years to attain maturity, therefore, any genetic change in mangroves based on environmental perturbations such as pollution from oil spillage will take along time to manifest in the population.

According to [16], there is a relationship between population size and a probability of genetic variation that would be lost from one generation to the next. This is exemplified in Eq. (1):

$$H = 1 - \frac{1}{2N_e} \tag{1}$$

where H is the proportion of heterozygosity remaining in population from one generation to the next and N_e is the effective population size.

Effective population size is the number of adults breeding that contributes to equal genetic material in the population. This implies that small populations tend to lose heterozygosity over time, which is an argument for maintaining large populations and thus larger reserves wherever possible to conserve these species. Years of population abundance can be interrupted by stochastic events leading to population bottlenecks, a situation, which occurs when a population experiences a severe temporary reduction in size. Thus population bottleneck reduces effective population size, thus, when population size is small genetic variation declines. Small population size creates extinction vortex, where abundant population continuously gets smaller and finally goes extinct.

3. Estimation of population viability

To understand the population dynamics of mangrove forest in the face of anthropogenic action, the minimum viable population size (MVP) needs to be estimated. It is defined as the smallest isolated population size that has 99% survival probability for 100 years period [17]. It is a crucial tool of conservation for the prevention of extinction of species. For perennial plant such as mangroves, it should have a minimum population size of 500–5000 individuals in a given location from year to year. This means any isolated forest below 500 tree stands is not a viable population and has the risk of going into extinction within a short time would be high. Two methods can be employed in determining the MVP. They are:

1. Study of viability of population at different sizes: this method is like a trial and error where different isolated populations are observed for some time to see if there will be survival. If the tree stands survive they are viable, but if they do not survive they are not viable.

2. Population viability analysis (PVA): this method is a mathematical model that can be applied to studying mangrove population. Here assumptions are made to simplify factors that cause population decline. This method can be used for any species to determine the viability of population. Two types of PVA approaches include: (i) count-based PVA: this involves the collection of information from a number of individuals in a population for a period of time. The steps include: (a) counting the population size for some time (b) calculating population growth rate each year, and (c) constructing a model that predicts future population size based on the growth obtained. (ii) Demographic PVA: it uses demographic information explicitly in the PVA. It incorporates life history data into the PVA.

4. Establishing protected areas around mangrove forest in the Niger Delta

The mangrove forest in the Niger Delta needs urgent protection due to the adverse impact of human activities, which had resulted in the decimation of their populations in many locations. Unabated destruction of the mangrove forest will result in local extinction of these species. Therefore, to reduce human impact on mangroves, protected areas need to be urgently established to restrict human entry into forest. This can be achieved in three ways:

1. By law (public lands) for state or federal level

2. By purchase of private lands

3. By conservation easement, which would restricts developmental rights within mangrove forest. Deeds of property to land owners within and around mangrove forests should be revoked or restricted to prevent the destruction of mangrove forest for purpose of building or establishing of any kind of developmental project (e.g., resort). Furthermore, persons who own land within this area can be compensated and asked to relinquish ownership for the sake of conserving the forests.

Restricted areas can be declared by both state and federal government as national park to prevent the exploitation of its resources by land speculators. Inspiration can

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be drawn from the first national park i.e. the Yellowstone National Park, that was established in the United States, in 1872 by President Grant [18]. It measures 300 square miles and had geological features, which is of national interest. As for mangrove forests in the Niger Delta there are no major natural features therein that makes them to attract the attention of government for protection. Nevertheless, the interest in the mangrove forest in the Niger Delta lies in the extraction of their resources such as oil and gas exploitation and exploration, tree felling for firewood production and sand dredging activity. Although the mangroves have no geological significance it has ecological significance because of the numerous ecosystem services they render to the environment (e.g., coastal protection from tidal flushing, biodiversity hotspot).

The Niger Delta mangrove forest is a global biodiversity hotspot. Global biodiversity hotspots are often determined based on species richness and endemism, which are all found in the mangroves of the Niger Delta. These areas include: tropical rainforest, coral reef, alpine forest and Mediterranean areas. Four notable global biodiversity hotspots based on the assessment of the author are:

1. Niger Delta mangrove forest zones: these are areas in Nigeria that have the highest concentration of aquatic organisms in Africa (**Figure 3**). The problem is that the area has not been formally recognized as a global biodiversity hotspot by international agencies such as the the International Union for the Conservation of Nature (IUCN). The species range from plankton (phytoplankton and zooplankton), aquatic invertebrates (bivalves, crabs, mussel, periwinkles, hermit crabs, etc.), land insects (beetles, butterflies, mosquitoes, ants and termites), and vertebrates (monkeys, manatee, hippopotamus etc). It has five major species of mangroves amongst others. These include: red mangroves (*Rhizophora* spp.), black mangroves (*Avicennia* spp.), white mangroves (*Laguncularia germinans* spp.), buttonwood (*Conocarpus* spp.) and mangrove fern (Acrostichum aureum).

2. Cape floristic province: it has the greatest non-tropical concentration of higher plants species in the world. Five of South Africa's 12 endemic plant families are found in the Fynbos. One hundred and sixty species are endemic.

Figure 3.
Some species found within the Niger Delta mangrove forest: (A) Senilia senilis, *Anadara; (B)* Crassostrea gasar, *oyster; (C)* Tympanotonus fuscatus, *periwinkle; and (D)* Uca tangeri, *male crab.*

3. California Floristic Province: has the largest avian breeding ground in the US. It has large number of endemic species with many threatened. It is the source of all agricultural production in the US.

4. Mountains of Southwestern China: it is the most endemic rich temperate flora in the world. Golden monkey, giant panda, red panda and snub nose monkeys are found in this area.

Biodiversity hotspots in Africa are more often grouped together without the recognition of the rich biodiversity across different locations. For instance, the entire forest biodiversity in West Africa was grouped as "West African forests" by [19]. Whereas, each country in this region possess rich supply of biodiversity. Niger Delta area in Nigeria has the third largest mangrove forest in the world, and the largest in Africa, i.e., 1 million hectare out of 3.2 hectare in the whole of Africa.

Based on the importance of the biodiversity hotspots to the environment, it is pertinent to protect them for future generation. This is because only 6% of the earth's surface is protected. Half of these are scientific reserves and national parks (1.3%). They vary greatly from country to country. There are already six major parks in Nigeria [7]. But there is a need for mangrove forest parks in critical areas of the region aimed at forestalling the degradation of the forest. Two kinds of protection to be considered (**Figure 4**) are

1. **Strict protection**: in this type of protection, no resource extraction is allowed. Here trees will not be felled for firewood production and aquatic organisms will not be harvested for commercial or subsistence purposes. The sole aim of this kind of protection is biodiversity conservation. However, there might be some allowances for scientific and educational uses to increase knowledge in mangrove research.

2. **Limited protection**: Here some resource extraction can be allowed such as hunting, fishing, logging, use of stem for firewood production, tourism and recreation, etc. In this type of protection there is much more human impact, but the primary goal is the management of the natural resources for multiple goals.

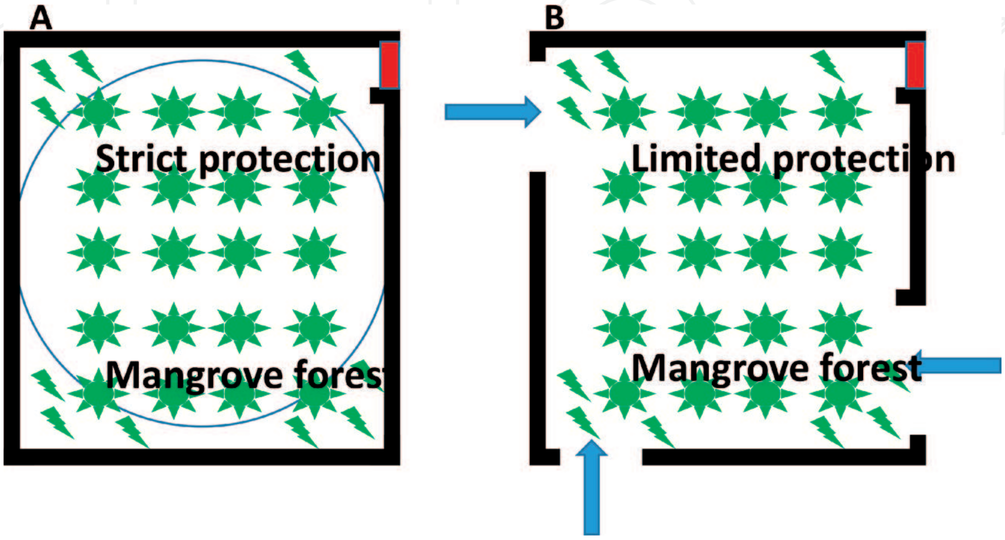


Figure 4.
A design of (A) strict and (B) limited protection of mangrove forest in the Niger Delta, Nigeria. Limited protection has more accessibility and resource exploitation than the strict protection.

In the past, conservation of biodiversity hotspot was mainly focused on species richness, but now it considers ecosystem integrity, water quality, climate impacts, unique adaptations, ecosystem services, intact fauna and flora, specialized/unique habitat and ecological processes.

In other to establish priority for protecting mangrove zones, the following need to be considered:

3. The goal of a particular protected area:

   a. what to preserve in terms of species, community and ecosystem? Here the mangrove species (red, black and white) are to be protected along with other flora and fauna communities and the entire ecosystem in identified locations. In this type of protection, firstly, species approach and historical records can be used to determine endangered species, taxonomic uniqueness and endemic species. Secondly, the community and ecosystem approach (modern tactics) can be used, which focuses on protecting the ecosystem to preserve the communities and species within. In this approach, the species and ecosystem are not mutually exclusive. This is because if the ecosystem is healthy and intact, the species will equally be healthy and intact.

   b. where to preserve? (a) Gap analysis can be used: It is the use of various remote sensing data to build overlaid sets of maps of various parameters (e.g., vegetation, soils, protected areas, species distribution) to identify spatial gaps in species protection and management programs (**Figure 5**). This can be performed at local, regional and global levels. It is done for both threatened and common species. It is typically done using GIS via map overlays. However, the use of gap analysis is becoming old-fashioned because currently small drones called unmanned aerial vehicles (UAV) are now deployed to study forest including protected and unprotected areas (**Figure 6**). It can also be used to study the impact of invasion on mangrove forest [20].

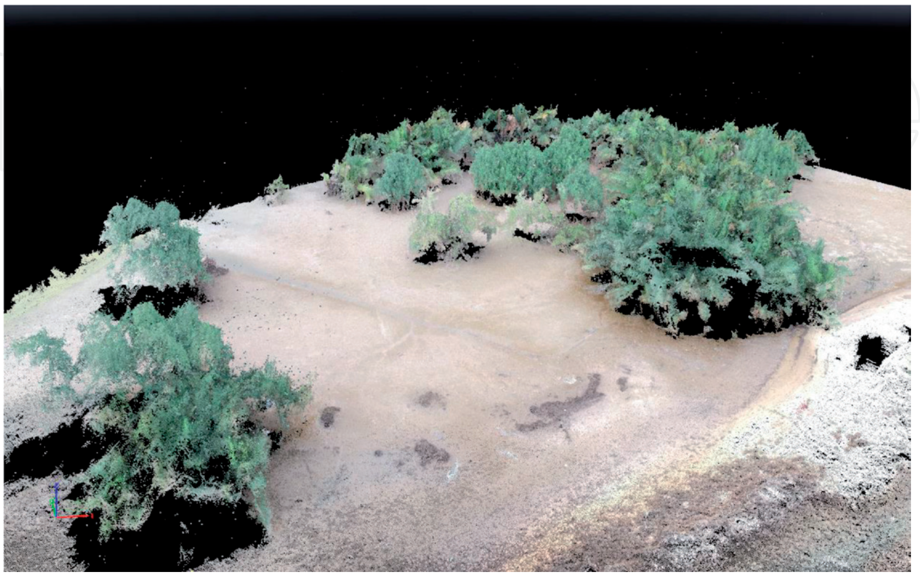
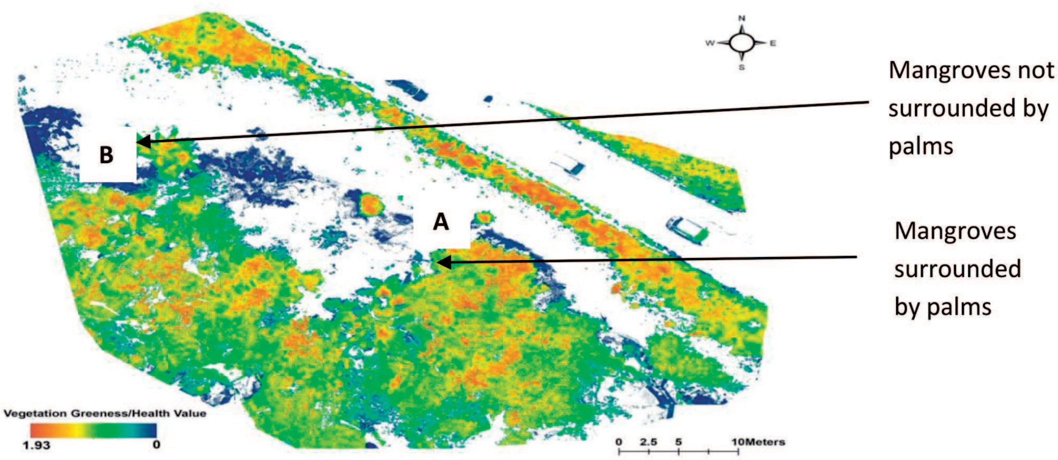


Figure 5.
A three-dimensional reconstruction of tree canopy and gaps within some mangrove forests captured with a DJI drone at Eagle Island, Niger Delta, Nigeria.

(a)



(b)

Figure 6.
(a) RGB imagery of mosaicked mangrove forest at Eagle Island, Niger Delta Nigeria (Source: [20]). (b) Mosaicked image of mangrove forest that has been processed with visible atmospherically resistance index (VARI) to show areas of stress caused by Nypa palms and depicted by red and yellow color (Source: [20]).

The protection of mangrove forest should follow the principles of reserve design such as:

1. Protection of entire habitats because the more the protected habitat the better it is.

2. Avoidance of reserve fragmentation by anthropogenic activities such as construction of high ways through mangrove forest.

3. Clumped reserve is far better than linear for easy migration of species within the mangrove forests

4. Circular reserve is ideal to minimize edge effects.

In terms of size, the bigger the terrain the better for the proliferation of species. According to the species-area relationship, bigger reserve has more resource, greater population with greater biodiversity leading to lower probability of extinction [21]. This is because small populations are prone to more extinction of species than large populations. Similarly, rather than have one large reserve it is good to have several small reserves (SLOSS problem), which will protect more species. This is because isolation can stop the spread of diseases.

5. Conclusion

Habitat loss and conversion are two major problems that can lead to the extinction of mangrove forest in the Niger Delta if not checked. This is because one or two stands of mangrove forest, which is made up of at least 5–10 trees are lost daily from this region as a result of deforestation for firewood (i.e., logging), sand dredging, urban development (e.g., roads, building of houses), etc. As the mangroves are brought down, their positions are quickly taken over by human structures such as roads, houses, industrial complexes and crude oil platforms. Areas that have not undergone infrastructural development, but have been disturbed by human actions contain scanty forests that become vulnerable to environmental pressures from invasive species, which had already completely taken over 60% of mangrove forest in the Niger Delta. Urgently, it is important to embark on deliberate protective measures, which can prevent the exploitation and plundering of the remaining mangroves resources in the zone.

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