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Species Diversity and Modification in Freshwater Swamp Forest Ecosystem: Implications for Conservation and Climate Change

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Abstract

Freshwater swamp forests are wetland ecosystems found across the tropics in seasonally or permanently waterlogged soils. Although they provide valuable ecosystem services, they are poorly known when compared to other tropical forest ecosystems. Beyond its description and few inventories, not much is known with regards to its richness, structure and modifications across the Niger Delta, where it is the most extensive across West Africa. This study assessed the species richness, diversity and modification across 8 one hectare forest plots. Total number of species across the disturbed sites was higher than the ones in the intact sites. In terms of species richness and diversity, the ecosystem was found to be poor when compared with other tropical forest ecosystems. The disturbed forest sites were found to be more modified in its floristic composition, as most pioneer species were replaced with more-light tolerant flora. Such replacements were mostly made up of palms which are less carbon dense when compared with the other native species. Ensuring that forest modification is reduced across the ecosystem are steps towards ensuring that the biodiversity of the ecosystem are conserved and that it remains resilient and capable of coping with future climatic changes in the region.

Keywords: carbon storage, climate change, disturbance, floristic modification,

Introduction

Swamp forests belong to a broad category of forest wetlands that are found in different climatic regions of the world. Across the tropics, they cover about 60% of its entire tropical wetlands (1.5 km^2) (Lugo et al. 1990; Migeot and Imbert, 2011) and are mostly categorized as mangrove, peat and freshwater swamp forests. Freshwater swamp forests are found in the tropics on fertile alluvial and predominantly waterlogged soils. They normally occur in the lower reaches of rivers and freshwater lakes, where they are normally inundated or flooded on seasonal or permanent basis. This category of forest ecosystem are known to provide valuable ecosystem services such as the regulation of flood and maintenance of water quality (Asthana and Asthana, 2003), genepool protection and nursery for fishes especially during the floods. Freshwater swamp forests are found between the lowland rainforest and mangrove swamp forest in Nigeria, where it covers an extensive area of about 12,000 sq km (NDES, 1997) and where it provides a suitable corridor for the migration of flora and fauna between the ecosystems. It is found inland beyond the reach of tidal waters on generally low lying areas across the Niger Delta region, being where it is mostly concentrated.

Even though the freshwater swamp forest does not seem to be as popular and scientifically inquired as the mangrove swamp forest across the Niger Delta, notable biologically important biodiversity has been documented across its ecosystem (Igu, 2016). Notable among these is the Niger Delta red colobus (*Procolobus badius epieni*) which was new to science (Blench and Dendo, 2007), as well other threatened species such as: the almost extinct abura (*Hallea ledermannii*) and the near threatened raptor-fish eagle (*Heliaetus vocifer*). This ecosystem forms part of the biogeographic unit that is classified as a biodiversity hotspot (Myers et al. 2010) and has remained a host to some endemic and rare flora and fauna across the region. Initial inventories have been able to able shed some light on the taxonomic features of the ecosystem as well as its biogeographic characteristics. Notable among such surveys is the groundbreaking work of Keay (1959; 1989), which gave some insights to its ecology and highlighted its floristic composition as well. However, while these works gives a general overview of what is obtainable in the ecosystem, it has not been able to account for its diversity and ecosystem function and most importantly its composition and dynamics following recent modifications and changes across the ecosystem.

Initially, the freshwater swamp ecosystem across the Niger Delta escaped deforestation due to its relative inaccessibility (Omokhua and Koyejo, 2008); however, this has changed over the years mainly due to a host of underlying and contextual issues surrounding forest use and loss across the ecosystem (Igu, 2017). Such activities have not only turned the ecosystem into mosaics and vegetation islands in most of the forest areas, but have contributed to modifying the composition and functional traits of the ecosystem at landscape and regional scales. Understanding the extent to which such changes could influence and shape the composition of the ecosystem are necessary steps towards achieving biodiversity conservation of the ecosystem. To elucidate these issues, this work aims to show the richness or diversity of the ecosystem across different disturbance gradients, elucidate the extent to which forest modifications across the ecosystem could affect or shape its composition and highlight the climate change implications of such changes on the ecosystem.

Materials and methods

Study area

This study was carried out in freshwater swamp forests in the Niger Delta. The region is generally a low lying vast sedimentary basin. The locality is characterized by a short dry season (normally between December and February) and a long rainy season which mainly lasts from March to October. The flooding regime in the locality starts in August and tapers off in December. It is a generally swampy region with mainly medium to coarse unconsolidated sands, silt, clay, shale and peat. It is made up of hydromorphic soils that are either permanently or seasonally waterlogged (Areola, 1982). The soils across the landscape are fertile and support luxuriant vegetation growth and crops (agricultural activities). Average monthly maximum and minimum temperatures vary between 28ºC to 33ºC and 21ºC to 23ºC, respectively. The sites are located in Akarai-Obodo and Otuwe (Fig 1) in Ndokwa East L.G.A, Delta state. The settlements are owned and occupied by the Ukwani people group and few Isoko migrants.

Vegetation data collection

The survey employed standard plot methods that were 1 hectare each; which was used to enumerate trees that were ≥ 10 cm DBH. Each of the 100 x 100 m plots were arranged in transects that were 1km apart between each transect and 500 m between each of the plots. To ensure that none of the stems to be enumerated were omitted each of the 100 x 100 m plots were further divided into 20 x 20 m plots. All the trees that were ≥ 10 cm diameter at breast height (130 cm) were identified to species levels in the field.

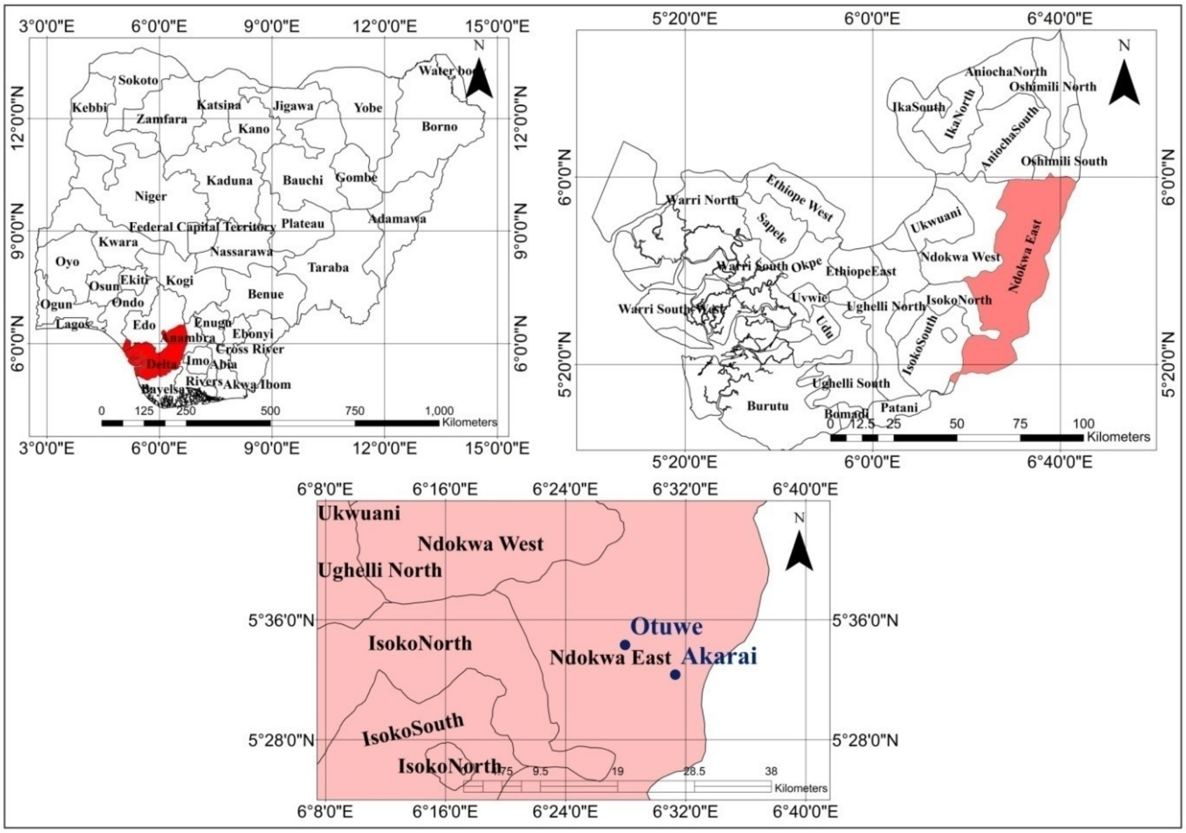

Fig 1 Map of the study sites with the map of Delta and Nigeria inset

Data analysis

The diversity was calculated with Shannon-Weiner index as follows:

Shannon-Wiener index:

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

Where H[l] is the Shannon-Weiner index, s is the total number of species, pi is the proportion of individuals in the ith species, and ln is the natural logarithm.

Margalef's species richness index:

$$M = \frac{(S-1)}{lnN}$$

Where S is the total number of species in a community, N is the number of individuals and ln is the natural logarithm.

The presence of palms in the ecosystem was used as a proxy for assessing the extent of modification for each of the sites.

Results

Overview

The composition of the forest locations differed across across each of the plot/site. Abundant species that characterized the first site (Akarai-Obodo) were mainly *Elaeis guineensis, Cleistopholis patens, Sterculia oblonga and Hallea ciliata*, while *Diospyros mespiliformis*, *Erythrophleum ivorense*, *Sterculia oblonga* and *Sterculia rhinopetala* were the abundant ones for the second site (Otuwe).

Species richness and diversity

The sites were varied in their richness, with the plots in Akarai-Obodo having more species than those in Otuwe. The total number of species across the first site was 80, while the second site had 15 species. Their richness index ranged from 5.4 to 8.65 and 0.52 to 3.26 (Fig 2) in Akarai-Obodo and Otuwe, respectively. Diversity equally ranged from 3.56 to 4.38 and 1.98 to 3.13 (Fig 3) in the first and second sites, respectively.

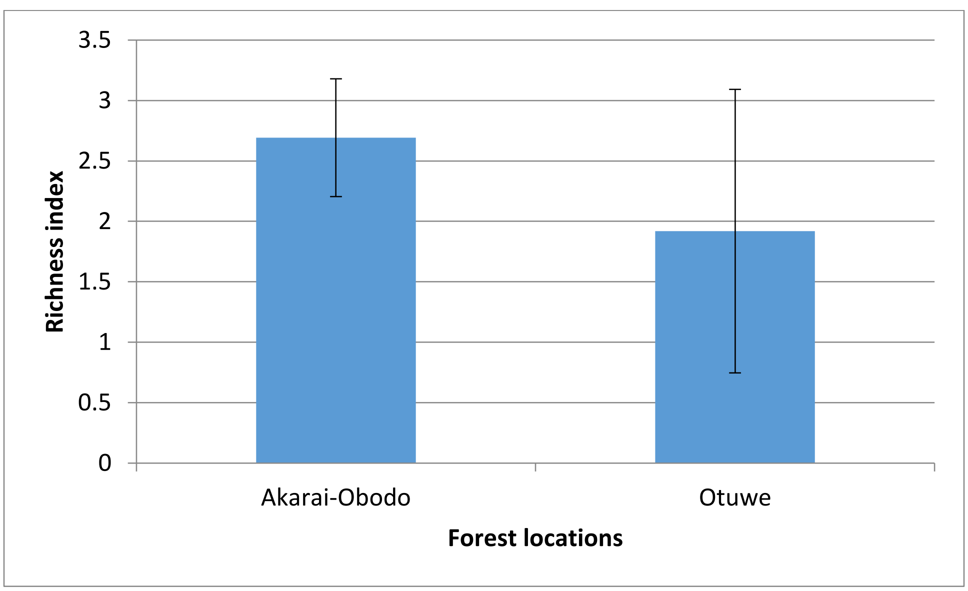

Fig 2 Species richness index of the different sites

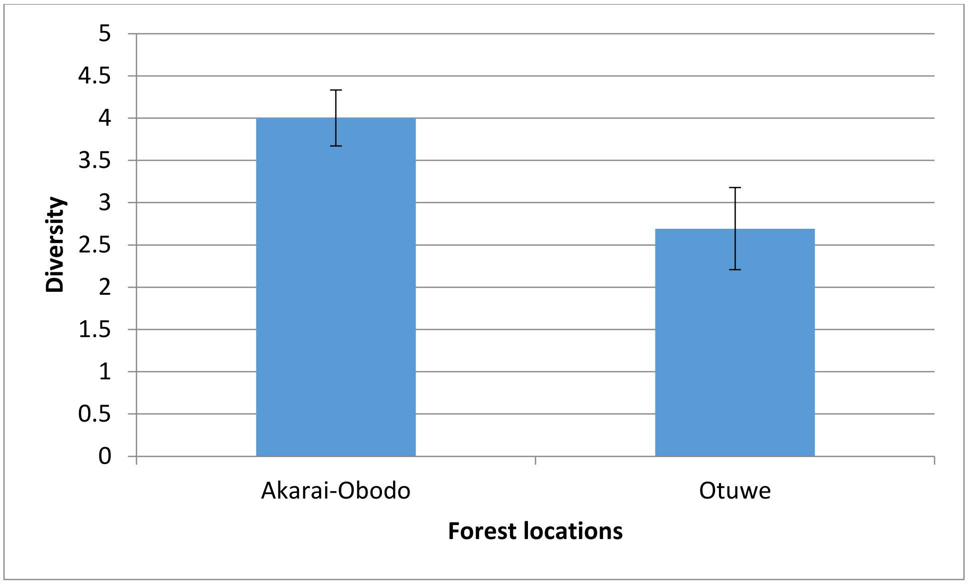

Fig 3 Species diversity of the different forest sites

Stem abundance and modification

Each of the sites had a sizeable number of stems, their disturbed or intact state notwithstanding. This ranged from 167-283 stems ha^{-1} in Akarai-Obodo to 128-304 stems ha^{-1} in Otuwe. The first site, being a disturbed forest landscape was more modified than the second site. Total number of palms across its site ranged from 20 to 43 as against the second site that only had a single occurrence of palm (Table 1).

Table 1 Number of species, stems and palms across the forest locations

Location	Number of species	Number of stems	Number of Palms
Akarai-Obodo 1	38	283	43
Akarai-Obodo 2	35	209	34
Akarai-Obodo 3	46	181	32
Akarai-Obodo 4	26	167	20

Otuwe 1	13	128	0
Otuwe 2	9	264	0
Otuwe 3	4	304	0
Otuwe 4	19	250	1

Discussion

Forest ecosystems across the tropics are generally perceived to be diverse ecosystems with high species richness. While this assertion is true for some tropical forests such as the lowland rainforests, some other ecosystems such as the freshwater swamp forests may not be so. Evidence from the study showed that the species richness and diversity of the ecosystem was generally low across the forest locations. Such low species richness has been reported in other freshwater swamp forests in the Niger Delta (Igu, 2016) and across other tropical landscapes such as in South America (Teixeira et al. 2011; Kurtz et al. 2013). Species richness was lower in Otuwe forest location than in Akarai-Obodo since the former and later sites were intact and disturbed forest landscapes, respectively. Lower botanical diversity and a concentration of the total species just on few forest trees was characteristic of the intact site, since there were no sufficient disturbance and gap dynamics that would have supported the growth of newer (light-tolerant) species across the forest location. Conversely, since the disturbed landscapes of the first site permitted higher species coexistence, its species pool was more easily enriched with species from its ecosystem and other surrounding landscapes. Ensuring that some of the disturbed sites are included in the locations gazetted as reserves or set aside for conservation at community levels, will help to ensure that the biodiversity found in such landscapes are preserved. On the other hand, since the ecosystem is characterized by low species richness and diversity, efforts to ensure that the pioneer and native species of the ecosystem (which are few in number) are effectively preserved, is advocated.

Forest modification was higher and much more pronounced in the first site than across the second site. This was quite visible through the dominance and abundance of palms across all the plots in the first site (Table 1). Even though palms are known to grow across forest landscapes in the Niger Delta and across its swamps, they tend to grow more in places where disturbances have made plenty moisture and unimpeded forest canopy to be much available (Sowunmi, 1999). As the forest canopies of most of the forest landscapes across the first site and in many other locations across the freshwater swamp forest are degraded, more suitable climate that would promote the growth and spread of palms are created and the forest composition of the ecosystem become more altered and modified. These modifications have continually become more pronounced across the region due to the intensification of agricultural activities across most of the forest landscapes in the zone. With such trends continuing at very high scales across the ecosystem and in many other tropical forest landscapes, the issue of long-term conservation, biodiversity preservation and ecosystem service provisions would continually be a challenge (Chazdon et al. 2009; van Breugel, 2013). Such modifications would particularly affect the ability of the freshwater swamp forest to sequester carbon across the region since palms generally have lower carbon storage potentials compared to the pioneer species that were originally found in the ecosystem. This lower carbon potential (of the palms) are as a result of its possession of exceptionally dynamic structures (with large radial gradients in tissue density) which reduces its carbon storage capacity (Rich, 1987; Igu and Marchant, 2016); hence are not good replacements for the native species found in the ecosystem. Since the floristic composition of the ecosystem continues to experience modifications due to the anthropogenic disturbance across most of the forest landscapes in the region, their ability to cope with climate change scenarios for the region through carbon sequestration seems minimal.

Conclusion

Freshwater swamp forests are found across the tropics, yet, they are not as species rich and diverse as other tropical forest ecosystems. They are equally composed of notable tropical forest species which should act as good carbon sinks in the face of climate change, but are however, being replaced and modified due to the escalating disturbance events across the region. Such occurrences have not only modified its composition and replaced its native species with other less carbon dense taxa, but also affected its role in regional climatic regulation and carbon sequestration. Efforts that will ensure that species extinction and modification are reduced to its minimum are advocated.

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