Finima Nature Park

Carbon Stock and Ecosystem Service Assessment of Finima Nature Park

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NCF
NIGERIAN CONSERVATION FOUNDATION
For nature...for people...for Nigeria

Nigeria LNG Limited
30 YEARS

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Global Knowledge and Framework Partners

Content

List of Acronyms and Abbreviations

AGB	Above Fround Biomass
BGB	Below Ground Biomass
DBH	Diameter at Breat Height
FNP	Finima Nature Park
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
Mg t	Megatons
Mt CO2e ha-1 yr-1	megatons of carbon dioxide equivalent hectares per year
NCF	Nigeria Conservation Foundation
NLNG,	Nigeria Liguified Natural Gas
PSP	Permanent Sample Plots
REDD+	Reduction of Emissions from Deforestation and forest Degradation
t C ha-1 yr-1	tons of carbon per hectare per year
t ha^{-1}	tons per hectare
UNFCCC	United Nations Framework Convention on Climate change.

EXECUTIVE SUMMARY

Forest ecosystem of different types including lowland rainforest, mangrove and swamp provides services that are critical to human welfare. Providing clean water; protecting watersheds and reducing or slowing the amount of erosion and chemicals that reach waterways; Serving as a buffer in natural disasters like flood and rainfalls and providing habitat and spawning ground to many other species as well as moderation of climate and a major carbon pool. The current global drive for climate change adaptation and mitigation depends entirely on sustainable forest management. This is hoped to curtail the rate of deforestation and forest degradation as forest play critical role in climate mitigation. Forest also contain one of the largest carbon pools and have a significant function in the global carbon cycle.

The study was carried out in Finima Nature Park within the confines of the Nigeria Liquefied Natural Gas (NLNG) company in Bonny Island Rivers State. The Park was estimated to cover an area of about 1000ha. With three Reserve patches that makes up the core conservation area viz; Eastern block, Hippo Creek and the Western block were estimated to cover an area of 375.68ha, 30.76ha and 228.08h respectively. The Park is ecologically diverse with three land cover types including the Lowland rainforest, Mangrove forest and the Swamp forest.

A nested plot method was used in the sampling design for because of its easiness for data collection. A nested square plot measuring 35m by 35m was used for lowland rainforest and swamp forest because of its easiness for data collection, each plot was composed of four nested sub-plots of 35m x 35m (**Nest 1**), 25m x 25m (**Nest 2**), 7m x 7m (**Nest 3**), and 2m x 2m plot (**Nest 4**). While 10m x 20 m rectangular plots laid along a 100m transect at intervals of 10m; with 1 m x 1 m sub-plots nested within them, and in an alternate manner was used for the mangrove. The Dbh at 1.3m from the ground and merchantable and total height were taken. The plots were distributed to cover the three land cover categories and also across the three parcels of land within the park. This will enable the assessment of carbon contribution in each of the land cover categories. The old plot established in 2016 were proposed to be used as the permanent plots, however, few could be assessed. However, new plots were established. A **stratified random sampling design** was used in order to capture spatial variability of land-use types and forest carbon stocks. A total of 11 plots were used, four permanent plots, five new plots and 2 plots within the buffer zone. The distribution by land cover indicates that 5 plots were laid in the swamp, 3 in the tropical lowland forest and 2 in the mangrove. The in

situ data (Field data) were analyzed adopting allometric equation for Rhizophora and tropical species, according to Chave et al. (2014), Komiyama et al, (2005), IPCC (2007) and Winrock International (2011).

A total of 165 trees species (≤ 5m dbh) were measured which yielded AGB of 1593.49 ± 0.23 tons within the sampled plots and a mean AGB of 177.05 ± 0.23 t ha^{-1}. The highest proportion of biomass (83277.70 tons) is stored in freshwater swamp. The mean increment in total biomass was 75.04 t ha^{-1} translating to 255.01 t $ha^{-1}yr^{-1}$.

In terms of carbon stocks, 106.23 t C/ha was estimated, showing that 67406.94 tons of carbon is sequestered in the FNP in 2019. The average carbon sequestration rates in the three land cover of lowland forest, mangrove and fresh water swamp were 125.67 tC ha^{-1}, 47.08 tC ha^{-1} and 129.88 t C ha^{-1}, respectively.

The carbon stocks translates to carbondioxide equivalent. Consequently indicating CO_2 equivalent absorbed in the forest (not emitted) is between 2.05 Mg tCO_2ha^{-1} and 826.96Mg/t_CO_2ha^{-1}. A total of 247,158.78 mg t $CO_{2\,e}$ is locked up in the FNP.

In Parcel A alone, a total of 146206.33 Mgt_CO_{2e} is locked up, while swamp forest has the highest amount of CO_2 not emitted (152672.52 ± 0.23Mgt_CO_2e ha-^{1}.

An estimated 3.53ha of the FNP (634.52) have been deforested this means that 0.56% of the FNP has been converted other uses. This translates to 1.18ha yr^{-1} (0.19%/year).

In terms of diversity, the swamp forest contained the highest number of trees species (16 species) and the highest diversity index of 2.591, Mangrove forest contained only two species with the lowest diversity index of 0.69 among others. The average diversity recorded in the FNP was 1.844'

It is concluded that sustainable forest management has a significant positive impact on ecosystem functioning such as climate moderation. Hence, recommended that a more robust assessment be carried, reforestation of degraded areas of the park and monitoring should be intensified.

1. BACKGROUND

Forest ecosystems provide a number of provisioning, regulatory, supporting, and cultural services that are important to the lives and livelihoods of humans, and they also play an important role in maintaining habitats that support important global biodiversity (Raich et al. 2014; Escobedo et al. 2011). Besides providing habitats for animals and livelihoods for humans, forests also offer watershed protection, prevent soil erosion and mitigate climate change. Forest also contain one of the largest carbon pools and have a significant function in the global carbon cycle. Forests store carbon and contain approximately 80% of the total above-ground organic carbon and 40% of the total below-ground organic carbon worldwide (Pan et al. 2011; Vicharnakorn, et.al, 2014).
The concern of global climate change problems has become a widespread and growing issue that has prompted many extensive international discussions and negotiations. Responses to this concern have focused on reducing emissions of greenhouse gases, especially carbon dioxide, and on measuring carbon absorbed by and stored in forests, soils, and oceans. One option for slowing the rise of greenhouse gas concentrations in the atmosphere as a result of several activities related to oil and gas exploration, and thus possible climate change, is to increase the amount of carbon removed by and stored in forests that necessitate a momentous opportunity for field survey for identifying the variation in carbon stocks across the diversity of land cover. Deforestation, particularly in tropical regions, is the second largest source of anthropogenic CO2 emissions after fossil fuels, contributing 12–20% of the total (IPCC 2007). Scientists have also determined that tropical deforestation releases 1.5 Gt of carbon into the atmosphere each year [Gullison et.al. 2007]. This occurs as a result of changes in land use and land cover which takes place either through conversion from one land-cover type to another or modification of a condition within the forest ecosystem. Nigeria being the rate of deforestation is put at 3.3% annually (FAO, 2006).

The upsurge of atmospheric greenhouse gases (GHG) and the potential consequences of future climate change have engendered understanding of the dynamics of the forest ecosystem as the "Lungs" for GHG particularly in the industrial areas such as Niger Delta of Nigeria where oil and gas exploration and exploitation is predominant. It is important in quantifying the biomass, carbon stocks and carbon dioxide equivalent stored or emitted from the forest. The extent of land cover and species diversity influence the amounts of biomass and vis-à-vis carbon stocks (Nkor, 2017). The rate of biomass accumulation and carbon sequestrations become important indicators in understanding forest ecosystem dynamics for climate change mitigation. Therefore, the, preservation of biodiversity and maintenance of other ecosystem values would help to minimize the atmospheric concentration of carbon dioxide. Viable options such as Nature Park have adopted to fast-track ecosystem protection in supporting the role of forest ecosystems in moderation of climate. Hence, tracking the rate, magnitude and trends of forest/tree cover, biomass, carbon stock and management of forests and its structure is important.

This was the highpoint of the rapid biodiversity studies of Finima Nature Park (FNP), Bonny Island, Rivers State; a freshwater swamp forest lying along Nigeria's southern coastal area of Bonny Island, Rivers State. The park currently provide environmental services for conservation, recreation, ecotourism and research in flora, fauna as well as serving as cultural heritage of Bonny Island with its rich collection of wildlife some of which are endangered.

Importantly, land use sectors such as forest, Nature Park and grasslands are significant to mitigating climate change by enhancing the stock of carbon in biomass and in soil or by reducing CO2 emissions. Most land based developmental eco-destinations have the potential to deliver carbon benefits (carbon stock enhancement or CO2 emission reduction) as a co-benefit of eco-destinations that have socio-economic development or improve management of natural resources as the main goal.

The main carbon pool in tropical forest ecosystems consists of the living biomass of trees, understory vegetation, dead mass of litter, woody debris and soil organic matter. The carbon stored in the AGB of trees is the largest pool and is directly impacted by deforestation and degradation. The estimation of AGB carbon is therefore the most critical step in quantifying carbon stocks and fluxes from tropical forests. To estimate GHG emissions, the area of cleared forest and the amount of carbon stored in those forests need to be known

The report of IPCC (2006) highlighted the methods of estimating greenhouse gas emissions and removals in the Agriculture, Forestry and Other Land Use (AFOLU) sector which it presented into two broad categories: 1) methods that can be applied in a similar way for any of the types of land use (i.e., generic methods for forest land, cropland, grassland, wetland, settlement and other land); and 2) methods that only apply to a single land use or that are applied to aggregate data on an area-level, without specifying land use.

Quantitative estimation of the carbon stock on an area can be achieved by taking a representative sample rather than measuring the carbon in all components over the whole area. A small, but carefully chosen sample can be used to represent the population. The sample reflects the characteristics of the population from which it is drawn. For carbon sampling, measurements should be accurate (close to reality for the entire population) and precise. Allometric carbon estimation technique using appropriate guideline to undertake non-destructive biomass (Above-Ground Biomass) is among the new methods that are now being used both nationally and at global level for carbon stock and ecosystem assessment. This also agrees with the recommendation by the United Nations Framework Convention on Climate Change (UNFCCC).

The Kyoto Protocol recognized the importance of forest in mitigating the greenhouse gas emission (i.e. carbon dioxide, methane and other compounds) and has included forest and soil C sequestration in the list of acceptable offsets (UNFCCC, 1997). Understanding spatial variation in carbon storage in natural habitats is critical for climate change mitigation efforts.

This report provided a meaningful highlight of allometric field survey conducted to identifying the variation in carbon stocks across the diversity of land cover within FNP to further articulate the sustainable impact of the Nature Park in ameliorating the effects of oil and gas activities around Bonny estuary.

Objectives

Generally, objective of this research was to monitor forest carbon stock and assess carbon sequestration rates in the Finima Nature Park (FNP).

The specific objectives were to:

A. Assess Above and Below Ground Biomass in the Finima Nature Park (FNP)
B. Assess forest carbon stock in the FNP
C. Monitor and update changes in forest carbon stock and carbon sequestration rates in the forests for better management of forest ecosystems of the FNP
D. Assess tree species diversity within the FNP
E. Provide understanding of the role that forests play in mitigating climate change

2. STUDY AREA:

2.1 Location:

The study was carried out in Finima Nature Park within the confines of the Nigeria Liquefied Natural Gas (NLNG) company in Bonny Island Rivers State. Finima Nature Park (FNP) established in 1999, is approximately 35 km southeast from the capital. It is located in the south of Bonny and south east of Finima community. It lies within latitude 4°22'49" and 4°23'53" and longitude7°8'40" and 7°12'17". The Finima Nature Park evolved from a consensus between the Nigerian Liquefied Natural Gas Company (NLNG) Limited and the Finima communities, Bonny Island in Rivers State in Nigeria, to protect the forests for its integrity and its biodiversity, under the sole sponsorship of NLNG. The Park was estimated to cover an area of about 1000ha. However, following a ground-truth survey, using GPS and 2016 remote sensing imagery the three Reserve patches that makes up the core conservation area viz; Eastern bloc, Hippo Creek and the Western block were estimated to cover an area of 375.68ha, 30.76ha and 228.08h respectively. The total core area is now estimated to cover 634.43ha.

2.2 Climate:

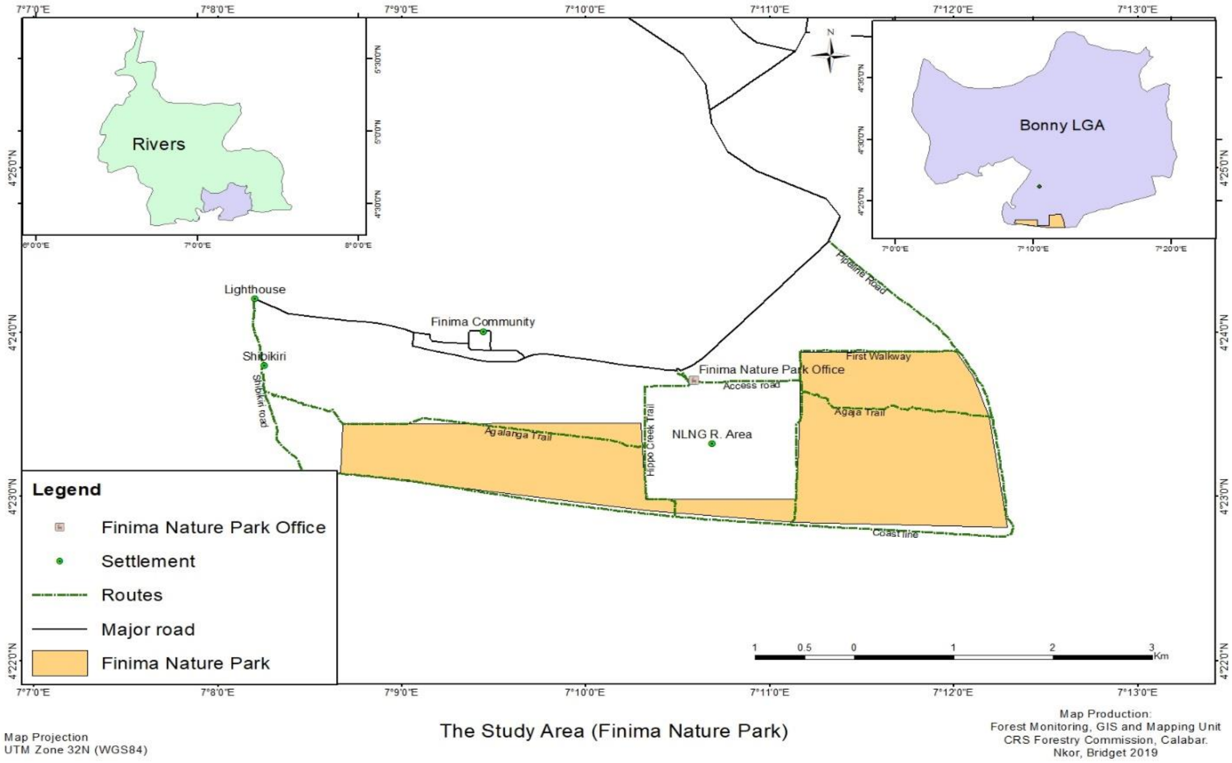
The park area has a climate typical for much of Nigerians' coastal states, in terms of annual rainfall, dry season, mean annual temperatures, which are consistent with other coastal locations throughout the year.

2.3 Vegetation:

The reserve area covers the rain forest and mangrove swamps, as well as an ecologically important area of sandy soil with freshwater ponds and tall timber between the swamps and the beach. The reserve is home to some wildlife species of high conservation value, a variety of mammals, bird species and reptiles, such as the Mona monkeys, crocodiles, snakes and monitor lizards. FNP is home to a number of species classified by International Union for Conservation of Nature (IUCN) as vulnerable or critically endangered such as the African Grey Parrot – *Psittacus erithacus*, Hooded Vulture – *Necrosyrtes monachus*, Ekki – *Lophira alata* and *Mitragyna stipulosa*. The diversity in FNP is a good representation of the Niger Delta ecology, which affords a unique opportunity for research and educational activities. There have been series of physical and ecological changes in FNP over the years and it is considered appropriate to carry out a carbon stock assessment for the Park as a way of generating scientific information on the current status of the reserve vis-a-vis the ecosystem functions and services provided by the Park for the past 16 years.

2.4 Biomass and Carbon stock

Previous study recorded the biomass in t/ha of the 3 sample areas which makes up the FNP core conservation area (Eastern Block, Hippo Creek and Western Block) to be 149.29, 43.17 and 79.90 respectively. The total biomass in the sampled plots (Core conservation areas of the Park) was estimated as 1,327.91 tons, in average of 120.72 (t/Ha) in approximately 634.52Ha. The total biomass was 76,598.77tons, carbon stock was 38,299.39 and carbon dioxide CO_2 e tons was 140,558.75 t.



The Study Area (Finima Nature Park)

3. METHODS

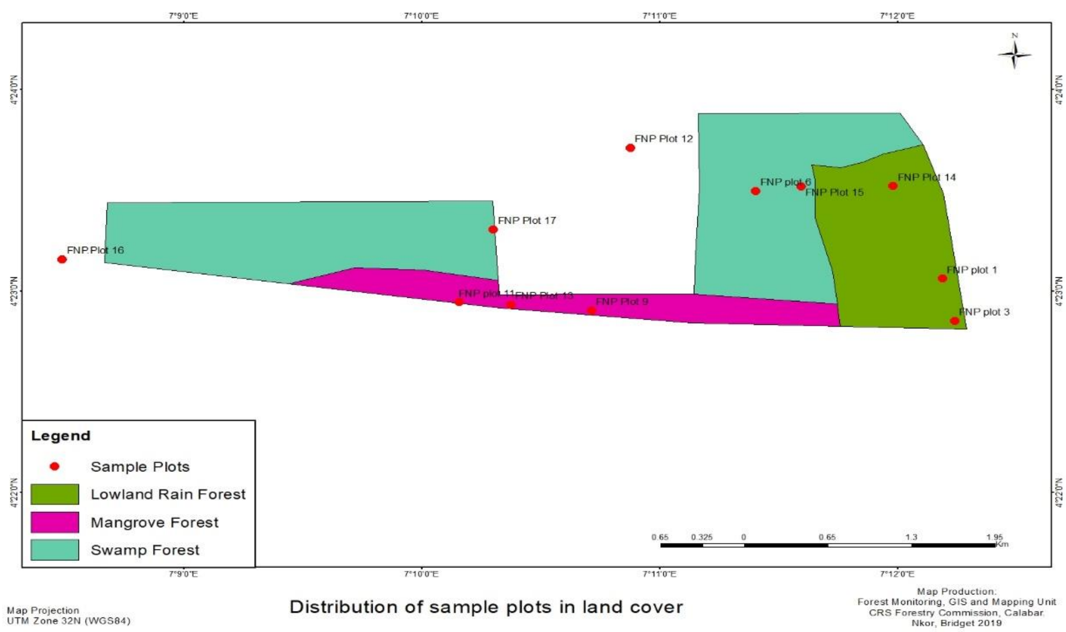
3.1 Sampling plots design and intensity

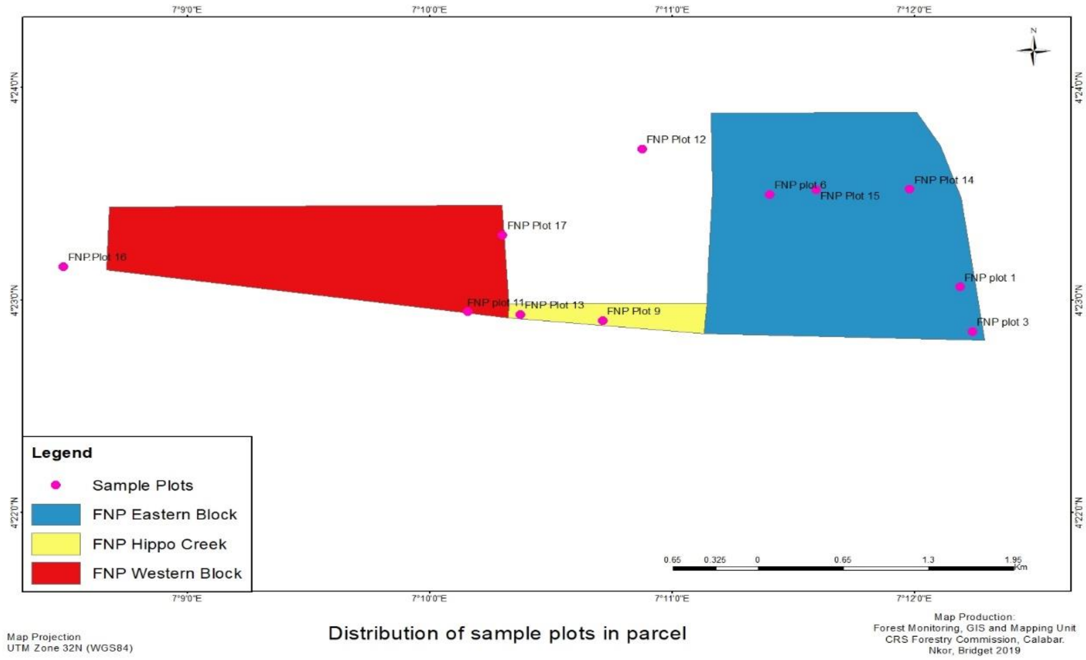
Sampling design

The study was conducted in three major forest types of the Finima Nature Park in NLNG, Bonny Island. The sampling design consisted of nested sample plots that were randomly distributed across 3 land cover categories of Bonny island (Figure 1). The nested plot method was used in the sampling design because of its easiness for data collection.

The plots were distributed to cover the three land cover categories (Figure 2); and also across the three parcels of land within the park. This will enable the assessment of carbon contribution in each of the land cover categories. The former plots established in 2016 were proposed to be used as permanent sampling plots. However, due to inundation of the park area as a result of rain few pots were accessible. New plots were however established considering the land cover categories and the parcels. A total of 11 plots were used, four permanent plots, five new plots and 2 plots within the buffer zone. The distribution by land cover indicates that 5 plots were laid in the swamp, 3 in the tropical lowland forest and 2 in the mangrove. Out of the 11 plots, nine (9) plots within the core conservation area were actually used for the carbon assessment. **Therefore, a stratified random sampling design was used in order to capture spatial variability of la**nd-use types and forest carbon stocks.

A square plot sampling design was adopted for the study. Though there are six carbon pools {above ground (live tree) biomass, belowground (live tree) biomass, deadwood (standing and lying/down), litter, non-woody plants and soil organic carbon}, however, the estimation of carbon stocks was limited to two carbon pools. i.e.; AGB and BGB. The size of the FNP was determined using remote sensing and GIS. The location of former plots of the study carried out in 2016 was used to determine if there will be changes. GPS was used to track the location where the plots were laid. Each plot was composed of four **nested sub-plots of 35m x 35m (Nest 1), 25m x 25m (Nest 2), 7m x 7m (Nest 3), and 2m x 2m plot (Nest 4) (Figure 3)**





3.2 Data collection

The study site is located in a tropical forest containing various forest types.

To minimize biases, an MS- excel simulation was used to allocate sample plots in the core conservation area. The plot locations were traced in the field using their coordinates stored in the GPS. AGB survey was carried out using two types of design base on three major land cover in the study area. In the lowland forest swamp forest, a 35m x 35m 3 nested sample plot, sub-divided into 2mx 2m (all saplings below 5cm in diameter); 7mx 7m (for trees between 5cm-19.9cm Dbh); 25mx25m (for trees 20cm – 49.9cm Dbh) and 35m x 35m (trees of 50cm >) will be used (Figure 3). In the mangrove habitat, a national design used for Nigeria REDD+ was adopted. The design uses three-10m x 20 m rectangular plots laid along a 100m transect at intervals of 10m; with 5m x 5m sub-plots nested within them, and in an alternate manner (Figure 4). Also, 10m was allowed for edge effect. All trees with diameter > 10 cm were measured in the entire plot (for trees with stilt/roots, measure diameter at 0.3 m (30 cm) above stilt Stilts was sampled in a 1 m x 1 m randomly located quadrat. Diameter at breast height (1.3m from the ground level) was measured with diameter tape and tree height was measured with the Haglof Clinometer.

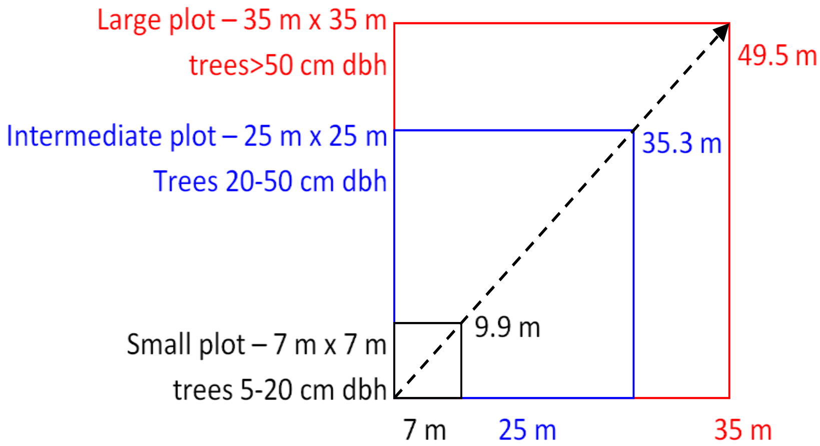


Figure 3: Nested sample plot design for the mangrove forest

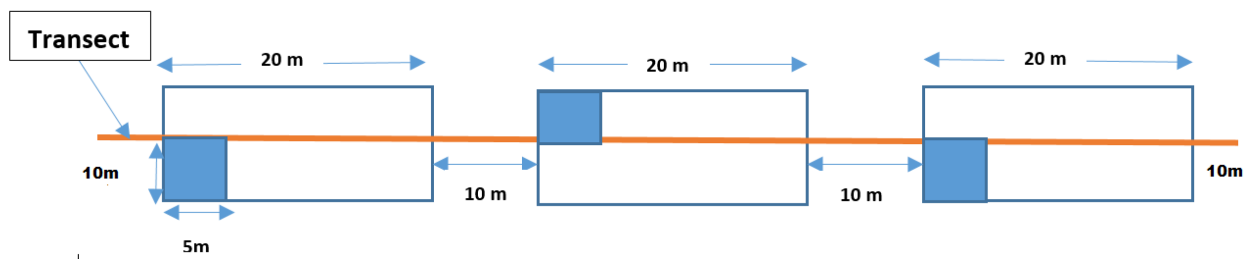


Figure 4: Straight line sample plot design for the Mangrove

Undergrowth and Regeneration

The undergrowth layer (trees with a Height value < 1.30 m and less than 5cm in Dbh) including seedlings were measured in a nested sub-plot of 2 × 2 m quadrats.

Field Instruments/Measurements

The following instrument were used

S/N	EQUIPMENT	ACTIVITY
1	GPS	For the spatial location of the plots
2	Compass	To traverse and lay the plots;
3	Measuring tape	To measure horizontal distances to lay the plots
4	Diameter tape	To measure DBH of trees
5	Digital Haglof EC-II-D electronic Clinometer	For measuring height of trees;
6	Ribbon /flagging	To flag the plots
7	Marking tape/marker	To mark the trees that have been enumerated to avoid double counting;
8	Cutlass	For clearing the path
9	Field form/template	For recording data collected with name of Community(ies); Plot No.; GPS points; Land cover

		type; Tree No.; height; DBH; etc.
10	Criterion RD1000 laser dendrometer	diameter at tree base (Dbase), at mid-stem (Dm) and top (Dt op)

3.3 Method of data analysis

The carbon stored in the AGB of trees is the largest pool and is directly impacted by deforestation and degradation. The estimation of AGB carbon is therefore the most critical step in quantifying carbon stocks and fluxes from tropical forests (Kumar and Shama, 2015).

The in-situ data (Field data) were analyzed adopting allometric equation for Rhizophora and tropical species, according to Chave et al. (2014), Komiyama et al, (2005), IPCC (2007) and Winrock International (2011)

Allometric equation for Rhizophora AGB - $0.225pD^{2.46}$

Where:

AGB_{est} - Above Ground Biomass (kg)

P = species specific wood density (g/cm^3)

D = diameter at breast height (cm)

Allometric equation for Rhizophora BGB – $0.199p^{0.899}$ X $D^{2.22}$ (Komiyama et al 2005)

Where:

BGB_{est} - Below Ground Biomass (kg)

P = species specific wood density (g/cm^3)

D = diameter at breast height (cm)

This equation was updated by Chave et al. (2014):

$$\mathbf{AGB_{est} = 0.0673 \times (P \times D^2 \times H^{0.976})}$$

Where:

AGB_{est}= Above Ground Biomass (kg)

P = species specific wood density (g/cm^3)

D = diameter at breast height (cm)

H = height (m)

Species composition and diversity

Shannon-Weiner index will be used in analyzing the diversity of species in the area. The index is given as: H1= $\sum_{i=1}^{S} p_1 \text{ loge } P(i)$

Where:

H^1	=	Value of Shannon Wiener diversity
S	=	No. of species in the community (taken as sample plot)
Pi	=	The properties of species
loge	=	Natural logarithm of P(i)

3.4 Tree identification and classification

Trees were identified by taxonomist based on unique morphological characters to distinguish them as separate species, each of which was assigned unique field codes of 6, 4 and 2 digits respectively, stating the genus and species. Voucher specimens were collected for all the morphospecies and matched at the end of fieldwork to harmonize the taxonomy in different transects. Information concerning the tree species, including the scientific names of the trees, was collected. Local names were used for those that could not be identified directly and identified using herbarium.

3.5 Data entry

During the process of data collection, field measurements were recorded on field data sheets designed for the purpose. At the completion of data collection, data entry into spreadsheet in the system was done immediately after the completion of the field measurements on daily basis. Spot checks cross matching the already entered data with the field data sheets was carried out to avoid errors.

3.6 Study design and set-up

The study design and set-up were carried out in preparation for the field data collection. A tripartite meeting between Safety unit of NLNG, NCF and the consultant was held to draw up the plan for data collection and safety.

4. RESULT

4.1 Accumulation of Biomass

Distribution of Above Ground Biomass (AGB) by plots

AGB represents all biomass in living vegetation, both woody and herbaceous which is above the soil. Plot method was used to estimate the volume or weight of tree and non-tree biomass in a set of sample plots using the measured values of parameters such as diameter at breast height (DBH) and height of tree and applying generic algometric equations which relate DBH and height to volume.

A total of nine (9) plots out of 11 established during the study were used in the analysis. The nine were in the core conservation area. Out of this, five were the permanent plots that were accessible while 4 were newly established plots. Three parameters were used to estimate the biomass and carbon content of the forest (dbh, height and wood density). DBH and height were data collected through direct field measurement, while wood density was gotten from wood density of the tropical tree species (Reyes 1992). Table 1 shows the distribution of the Biomass by sampled plot. The range of AGB was between 0.93 t ha^{-1} and 375. 89 t ha^{-1} in the sample plots (Figure 5). A total of 165 trees species ($\leq$ 5m dbh) were measured which yielded a total AGB of 1593.49 ± 0.23 tons within the sampled plots and a mean AGB of 177.05 ± 0.23 t ha^{-1}. The AGB per hectare in each parcel of Eastern bloc, Hippos creek and Western bloc were 229.04 t ha^{-1}; 116.88 t ha^{-1} and 107.26 t ha^{-1} respectively. While 220.57 t ha^{-1}; 82.64 t ha^{-1} and 227.96 t ha^{-1} were the average AGB per hectares in Lowland rain forest, Mangrove forest and Freshwater swamp forest respectively.

The accumulated AGB based on the total area of FNP (634.52 ha) was 112,344.90 ± 0.23 tons.

Below Ground Biomass

From table 1, the estimated BGB ranges between 0.19 and 75.18 t ha^{-1} within the sampled plots. A total of 318.70 tons of BGB estimated in the plots, yielding 22,468.98 ton in the FNP. This translates to average BGB of 35.42 t ha^{-1}. The total BGB of 1912.19 tons ranging between 1.12 and 451.07 t ha^{-1} per plot were recorded, with the mean of 212.47 t ha^{-1}.

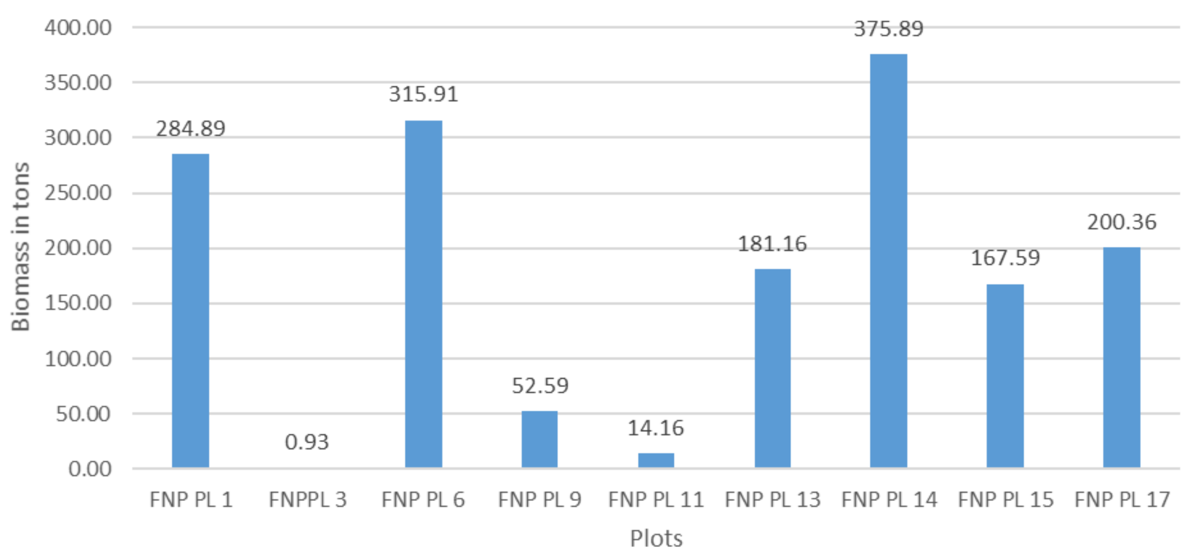


Fig. 5: Distribution of AGB (t/ha) by plots

Table 1: Distribution of Biomass by sample plots

Plot ID	AGB (t/ha)	BGB (t/ha)	Total AGB + BGB
FNP PL 1	284.89	56.98	341.87
FNPPL 3	0.93	0.19	1.12
FNP PL 6	315.91	63.18	379.10
FNP PL 9	52.59	10.52	63.11
FNP PL 11	14.16	2.83	17.00
FNP PL 13	181.16	36.23	217.40
FNP PL 14	375.89	75.18	451.07
FNP PL 15	167.59	33.52	201.11
FNP PL 17	200.36	40.07	240.44
Total	1593.49	318.70	1912.19
Average	177.05	35.41	212.47
Grand Total in FNP	112,344.90	22,468.98	134,813.88
Area of FNP	634.52	634.52	634.52

Total Biomass

By Land Parcel, the eastern bloc (Parcel A) contained the highest proportion of Biomass (50.15%) which translates to 79750.61 tons (relatively 274.85 t ha^{-1}) (Table 2). Hippos Creek contained the least biomass of 4.85% (6533.45 tons). By Land cover, the highest proportion of biomass (83277.70 tons) is stored in freshwater swamp. Lowland rainforest and mangrove accumulated 32443.66 tons and 19095.10 tons respectively.

Table 2: Distribution of biomass by land parcel and land cover

PARCEL	Area	% Area	AGB (t/ha)	TOTAL AGB (tons)	BGB (t/ha)	Total (AGB + BGB) t ha^{-1}	Total Biomass in (tons)	%Total
A (Eastern Bloc)	375.35	59.15	229.04	66455.72	45.81	274.85	79750.61	59.15
B (Hippos Creek)	30.75	4.85	116.88	5444.29	23.38	140.25	6533.45	4.85
C (Western Bloc)	228.42	36.00	107.26	40441.76	21.45	128.72	48532.40	36.00
Total	**634.52**	**100.00**		**112344.90**			**134816.46**	**100.00**
LAND COVER		**% Area**	**AGB (t/ha)**	**TOTAL AGB (tons)**	**BGB (t/ha)**	**Total AGB + BGB**	**Total Biomass in (tons)**	% Total
Lowland rain forest	152.70	24.07	220.57	27035.11	44.11	264.69	32443.66	24.07
Mangrove forest	89.87	14.16	82.64	15911.84	16.53	99.17	19095.10	14.16
Freshwater swamp forest	391.95	61.77	227.96	69394.82	45.59	273.55	83277.70	61.77
Total	634.52	100.00		112344.90			134816.46	100.00

4.2 Distribution of Carbon Stocks

Carbon stock estimates for the study area was calculated from the living and dead wood standing biomass from two pools viz. AGB and BGB. The different parameters used to calculate total forest carbon stocks are presented in Annex.

Distribution of Carbon Stocks by Plot

The distribution of carbon stocks by plots laid across the different land cover ranged between 0.56 t C/ha and 225.53 t C/ha. Plot 14 holds the highest proportion of 225.53 tons among other the sampled plots. Plot 3 with the least stocks of 0.56 tons (Fig. 6). On average, 106.23 t C/ha was estimated, showing that 67406.94 tons of carbon is sequestered in the FNP in 2019.

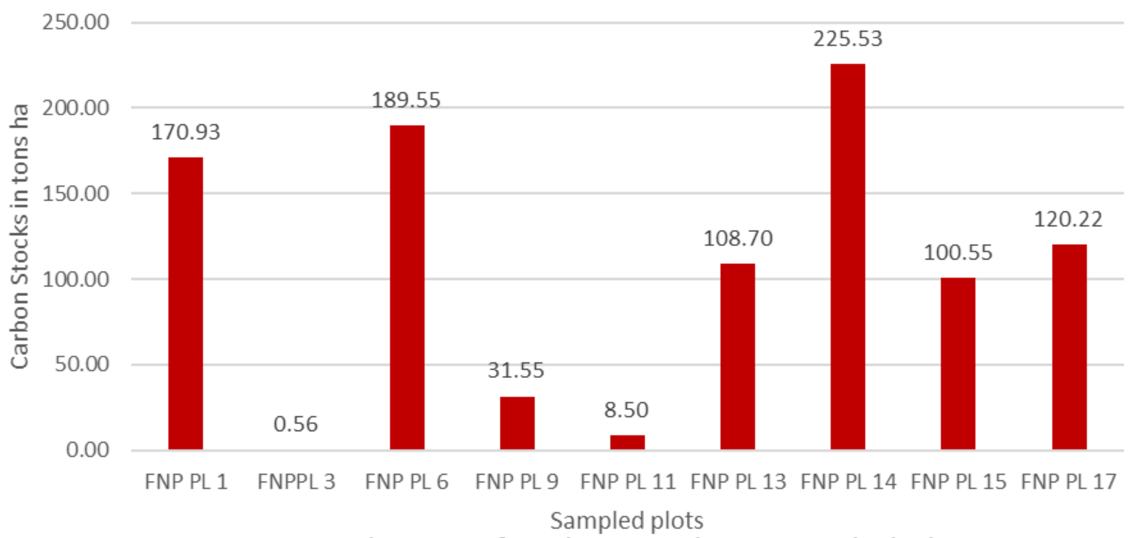


Fig. 6: Distribution of Carbon stocks in sampled plots (ton_C/Ha)

Distribution of Carbon Stocks by Land Parcel

The carbon sequestered in the three bloc were 39873.43 tons; 3266.57 tons and 24265.06 tons respectively. The Eastern bloc which cover 375.35 ha sequestered 50.54% of the carbon stock, i.e an average of 130.50 ton/ha^{-1} (Table 3).

Distribution of Carbon Stocks by Land cover categories

The carbon stocks in Lowland rainforest, Mangrove and swamp forest were found to be 16221.07 tons; 9547.10 tons and 9547.10 tons respectively. The swamp forest sequestered 61.77% of the total carbon stocks in the FNP (Table 4). Also, the average carbon sequestration rates in the three land cover were 125.67 tC ha^{-1}, 47.08 tC ha^{-1} and 129.88 t C ha^{-1}, respectively.

Table 3: Carbon Stocks in different Land Parcel

PARCEL ID	Area	% Area	ton_C/Ha	% ton_C/Ha	Total Carbon in (tons)	% Carbon Stock
A (Eastern Bloc)	375.35	59.15	130.50	50.54	39873.43	59.15
B (Hippos Creek)	30.75	4.85	66.59	25.79	3266.57	4.85
C (Western Bloc)	228.42	36.00	61.11	23.67	24265.06	36.00
Total	634.52	100.00	258.21	100.00	67405.06	100.00
Total			**956.10**			
Average			**106.23**			
Grand Total in FNP			**67406.94**			
Area of FNP			**634.52**			

Table 4: Carbon Stocks in different Land cover

LAND COVER	Area	% Area	ton_C/Ha	% ton_C/Ha	Total Carbon in (tons)	% Carbon Stock
Lowland rain forest	152.70	24.07	125.67	41.53	16221.07	24.07
Mangrove forest	89.87	14.16	47.08	15.56	9547.10	14.16
Freshwater swamp forest	391.95	61.77	129.88	42.92	41636.89	61.77
Total	634.52	100.00	302.64	100.00	67405.06	100.00

4.3 Trends of Biomass and Carbon Stocks

The biomass and carbon stocks were compared with the previous study in 2016. The stock-difference and gain-loss approaches are the two fundamentally different, but equally valid approaches for the measurement of carbon stock change (Brown and Braatz 2008).

The stock-difference approach was used, in this approach carbon stocks are physically measured using sampling for each forest carbon pool over a certain time interval (2016 and 2019).

Comparison of biomass in the previous study indicates that there has been significant increase in biomass within all the accessible plots in the area except plot 11 (Fig. 7). For instance, no biomass was recorded in Plots three in 2016, however, 1.12 t ha^{-1} was obtained in 2019. Between the two periods, a mean increase of 62.53 t ha^{-1} of AGB was recorded with annual change of 20.84 t $ha^{-1}yr^{-1}$ (6.21% per year). The mean increment in total biomass was 75.04 t ha^{-1} translating to 255.01 t $ha^{-1}yr^{-1}$ (Table 5).

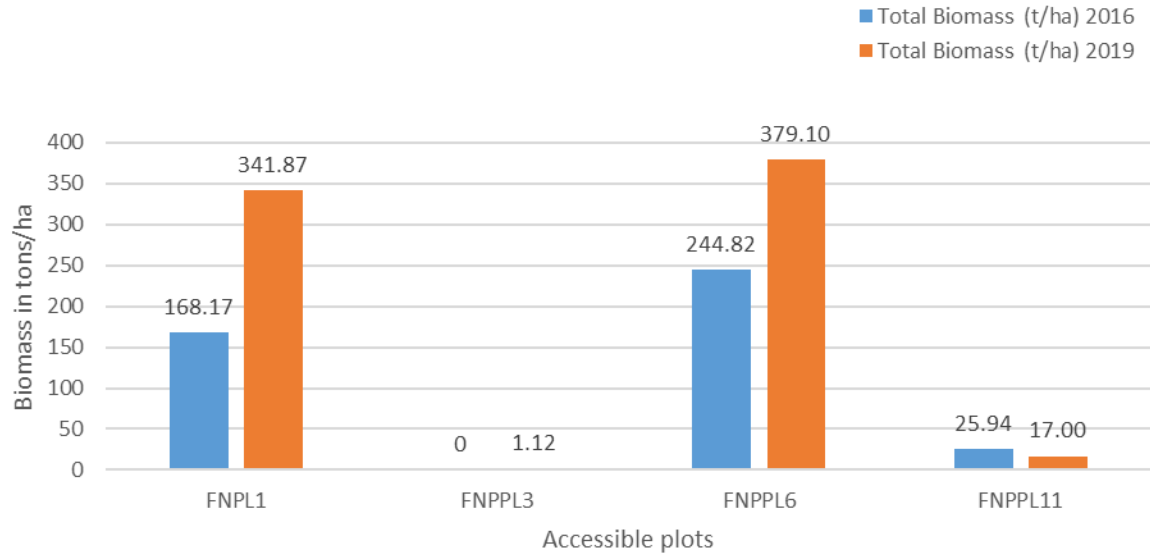


Fig.7: Biomass accummulation in sampled plots between 2016 and 2019

Table 5: Biomass accumulation in sampled plots between 2016 and 2019

Plot ID	AGB (t/ha) 2016	AGB (t/ha) 2019	Change in Biomass	Annual change	% Change	Annual % change

FNPL1	140.14	284.89	144.75	48.25	34.43	11.48
FNPPL3	0	0.93	0.93	0.31	33.33	11.11
FNPPL6	204.02	315.91	111.89	37.30	18.28	6.09
FNPPL11	21.62	14.16	-7.46	-2.49	-11.50	-3.83
Mean	**91.45**	**153.97**	**62.53**	**20.84**	**18.64**	**6.21**

BGB						
Plot ID	**BGB 2016**	**BGB (t/ha) 2019**	**Change**	**Annual change**	**% Change**	**Annual % change**
FNPL1	28.03	56.98	28.95	9.65	34.42	11.47
FNPPL3	0	0.19	0.19	0.06	33.33	11.11
FNPPL6	40.8	63.18	22.38	7.46	18.29	6.10
FNPPL11	4.32	2.83	-1.49	-0.50	-11.47	-3.82
Mean	**18.29**	**30.79**	**12.51**	**4.17**	**18.64**	**6.21**

Plot ID	**Total Biomass (t/ha) 2016**	**Total Biomass (t/ha) 2019**	**Change**	**Annual change**	**% Change**	**Annual % change**
FNPL1	168.17	341.87	173.70	57.90	34.43	11.48
FNPPL3	0	1.12	1.12	0.37	33.33	11.11
FNPPL6	244.82	379.10	134.28	44.76	18.28	6.09
FNPPL11	25.94	17.00	-8.94	-2.98	-11.49	-3.83
Mean	**109.73**	**184.77**	**75.04**	**25.01**	**18.64**	**6.21**

In the land parcels of the FNP, the eastern bloc has the highest average accumulation rate of AGB which increased from 149.29 ton/ha^{-1} in 2016 to 274.85 ton/ha^{-1} in 2019. This represents a mean increase of 90.49 ton/ha^{-1} in 3 years. Thus, indicating an annual increment rate of 30.16 ton/ha^{-1}yr^{-1} (Table 6).

Table 6: Biomass accumulation in land parcels between 2016 and 2019

Parcel	**Average Biomass (t/ha) 2016**	**Average Biomass (t/ha) 2019**	**Change**	**% Change**	**Annual Change**	**Annual % Change**
Eastern block	149.29	274.85	125.56	84.11	41.85	28.0
Hippo	43.17	140.25	97.08	224.88	32.36	75.0

creek						
Western block	79.9	128.72	48.82	61.10	16.27	20.4
Mean	**90.79**	**181.27**	**90.49**	**123.36**	**30.16**	**41.12**

4.4 Carbon sequestration between 2016 and 2019

The carbon sequestration rate in the accessible plot shows that in plot 1 +86.85 t C ha-^{1} have been sequestered in three years translating to +28.95 t C ha-^{1} yr^{-1}. An average of 37.52 t C ha-^{1} between 2016 and 2019, indicating 12.51 t C ha-^{1} yr^{-1} (Table 7).

The weighted annual carbon sequestration rates in these three blocks from 2016 to 2019 were 18.62 tC ha^{-1}, 15.00 tC ha^{-1}, and 7.06 tC ha^{-1}respectively (Table 8).

Table 7: Carbon sequestration rates in Accessible plots between 2016 and 2019

Plot ID	ton_C/Ha 2016	ton_C/Ha 2019	Change	Annual change	% Change	Annual % change
FNPL1	84.09	170.93	+86.85	+28.95	103.29	34.43
FNPPL3	0.00	0.56	+0.56	+0.19	100.00	33.33
FNPPL6	122.41	189.55	+67.14	+22.38	54.85	18.28
FNPPL11	12.97	8.50	-4.47	-1.49	-34.48	-11.49
Mean	**54.87**	**92.38**	**37.52**	**12.51**	**68.38**	**22.79**

Table 8: Carbon sequestration rates in land parcels between 2016 and 2019

Parcel	ton_C/Ha 2016	ton_C/Ha 2019	Change	Annual change	% Change	Annual % change
Eastern block	74.65	130.50	55.85	18.62	74.82	24.94
Hippo creek	21.58	66.59	45.01	15.00	208.51	69.50
Western block	39.95	61.11	21.17	7.06	52.98	17.66
Mean	**45.39**	**86.07**	**40.68**	**13.56**	**89.61**	**29.87**

4.5 Carbon dioxide Equivalent (CO_{2e}) stored or emitted in FNP

Using Stoichiometric conversion ratio to translate the Carbon stocks per hectare to accounts for CO_2 equivalent that is stored in the forest (not emitted). The IPCC Carbon Fraction default value of 0.47 t C t-1 dry matter was used (IPCC 2006). Emissions of CO_2 are estimated from the carbon content of or emission factors for all biomass removed.

The range of CO_2 equivalent absorbed in the forest (not emitted) is between 2.05 Mg tCO_2ha^{-1} and 826.96Mg/t_CO_2ha^{-1}. Figure 8 shows the distribution of the CO_2 equivalent (CO_2e) stored across the different sample plots. A total of 247,158.78 mg t $CO_{2\,e}$ is locked up in the FNP.

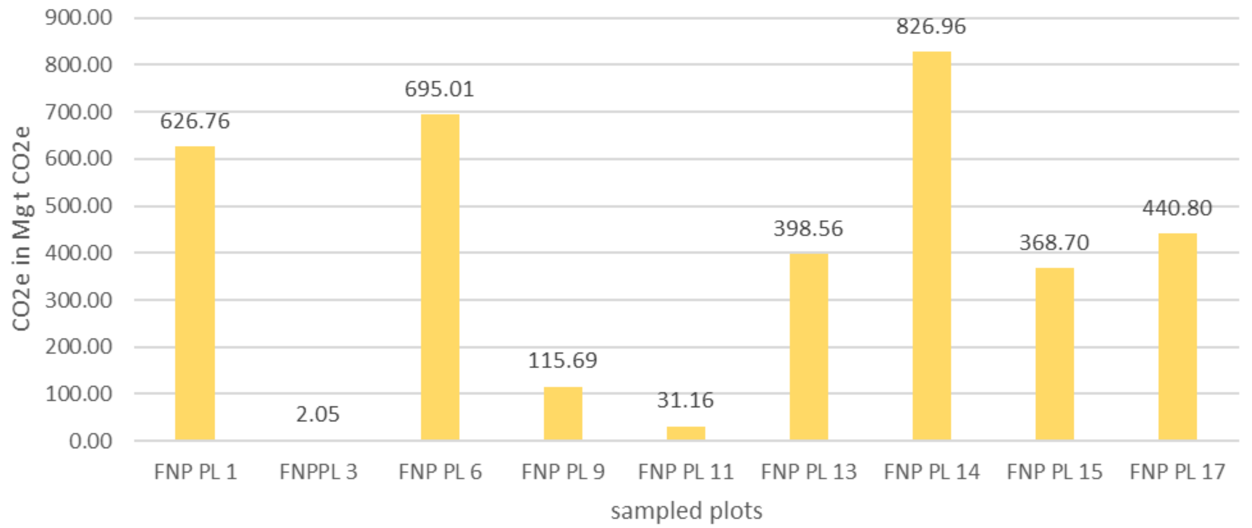


Fig. 8: Carbon diooxide equivalent in sample plots Mg ton_CO2eq/Ha

The analysis by Parcel in Table 9 indicates that in the eastern bock (Parcel A), the highest CO_2 equivalent was recorded (478.50 ± 0. 46 Mgt_CO_{2e} ha^{-1}). Thus the total of 146206.33 Mgt_CO_{2e} is locked up in parcel A .

The CO_2 locked up in each of the land cover categories indicates that the swamp forest has the highest amount of CO_2 not emitted (152672.52 ± 0.23Mgt_CO_2e ha^{-1} (Table 9).

Table 9: Carbon dioxide Equivalent (CO_{2e}) stored in land parcels and land cover

PARCEL ID	Area	% Area	Mg ton_CO2eq/Ha	% mg t CO2/Ha	Mg ton_CO2e	% sink
A (Eastern Bloc)	375.35	59.15	478.50	50.54	146206.33	59.15
B (Hippos Creek)	30.75	4.85	244.17	25.79	11977.74	4.85
C (Western Bloc)	228.42	36.00	224.09	23.67	88974.16	36.00
Total	**634.52**	**100.00**	**946.75**	**100.00**	**247158.23**	**100.00**
				0.00		
LAND COVER	**Area**	**% Area**	**Mg ton_CO2eq/Ha**	**% mg t CO2/Ha**	**Mg ton_CO2e**	**% sink**
Lowland rain forest	152.70	24.07	460.80	48.67	59478.77	24.07
Mangrove forest	89.87	14.16	172.64	18.24	35006.94	14.16
Freshwater swamp forest	391.95	61.77	476.23	50.30	152672.52	61.77
Total	**634.52**	**100.00**	**1109.67**	**117.21**	**247158.23**	**100.00**

4.6 CO_2 removals (absorption) and emission in FNP

The analysis of the Carbon dioxide (CO_2) stored or emitted from the forest is one of the indicators of effectiveness of the conservation measures. All the accessible plots compared shows significant removal (absorption) of CO_2 except plots 11. From the table 10, the range of CO_2 sink was between 2.05 and 318.45 Mg t CO_2 ha^{-1} in three years (i.e. between 0.68 and 106.15 Mg t CO_2 ha^{-1} yr^{-1}) (Table 10). The CO_2 flux shows that on average between 45.86 and 49.71 Mg t CO_2 ha^{-1} yr^{-1} is absorbed in FNP. On the other hand a low emission of -5.47 Mg t CO_2 ha^{-1} yr^{-1} was recorded in plot 11 thus leaving the balance 45.86 t CO_2 ha^{-1} yr^{-1}. Parcel A has the highest removals (Table 11).

Table 10: Trends of CO_2 removals and emission in sampled plots

Plot ID	Mg ton_CO2eq/Ha 2016	Mg ton_CO2eq/Ha in 2019	Change in tCO2eq/ha	Annual change in tCO2eq/ha	% Change	Annual % change
FNPL1	308.31	626.76	318.45	106.15	34.43	11.48
FNPPL3	0.00	2.05	2.05	0.68	33.33	11.11
FNPPL6	448.84	695.01	246.17	82.06	18.28	6.09
FNPPL11	47.56	31.16	-16.40	-5.47	-11.49	-3.83
Mean	**201.18**	**338.74**	**137.57**	**45.86**	**22.79**	**7.60**

Table 11: Trends of CO_2 removals and emission in Land parcel

Parcel	Mg ton_CO2eq/Ha 2016	Mg ton_CO2eq/Ha in 2019	Change	Annual change	% Change	Annual % change
Parcel A: Eastern block	273.70	478.50	204.80	68.27	74.82	24.94
Parcel B: Hippo creek	79.14	244.17	165.02	55.01	208.51	69.50
Parcel C: Western block	146.48	224.09	77.61	25.87	52.98	17.66
Mean	**166.44**	**315.58**	**149.14**	**49.71**	**89.61**	**29.87**

4.6 Summary

The total accumulated biomass in the Core conservation areas of the Park was 134, 813.88 tons, in average of 212.47 (t/Ha). The annual accumulation rate of 19405.04 ton/yr^{-1} was obtained for biomass. The total carbon stock was 67406.94 and carbon dioxide equivalent of 249405.68 tCO_2e were obtained. However, A total forest area of 3.53ha (0.56%) have been cleared, thus leading to slight destruction of 754.95 tons of biomass and emission of 1396.67 Mgt_CO_{2e} (Table 12).

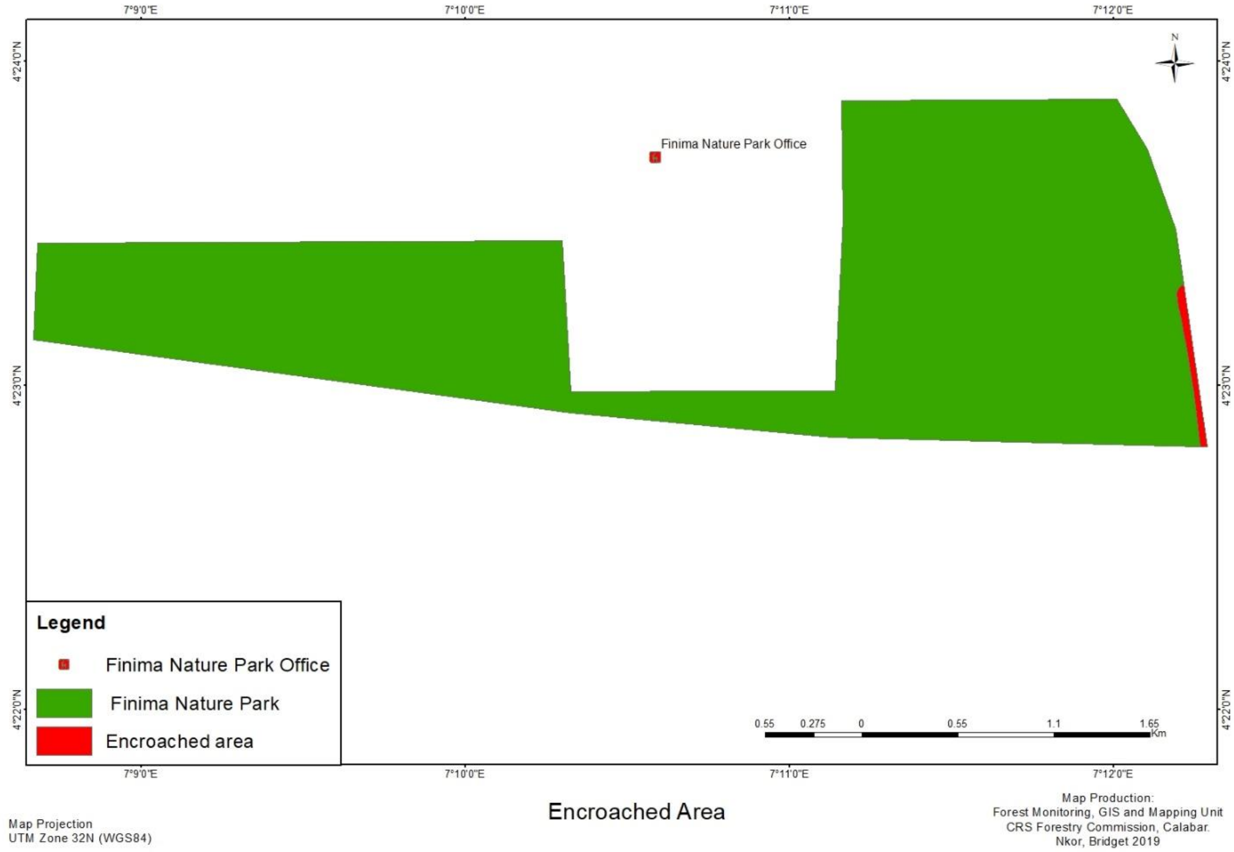
Table 12: Summary of Biomass, Carbon stocks and CO_2e

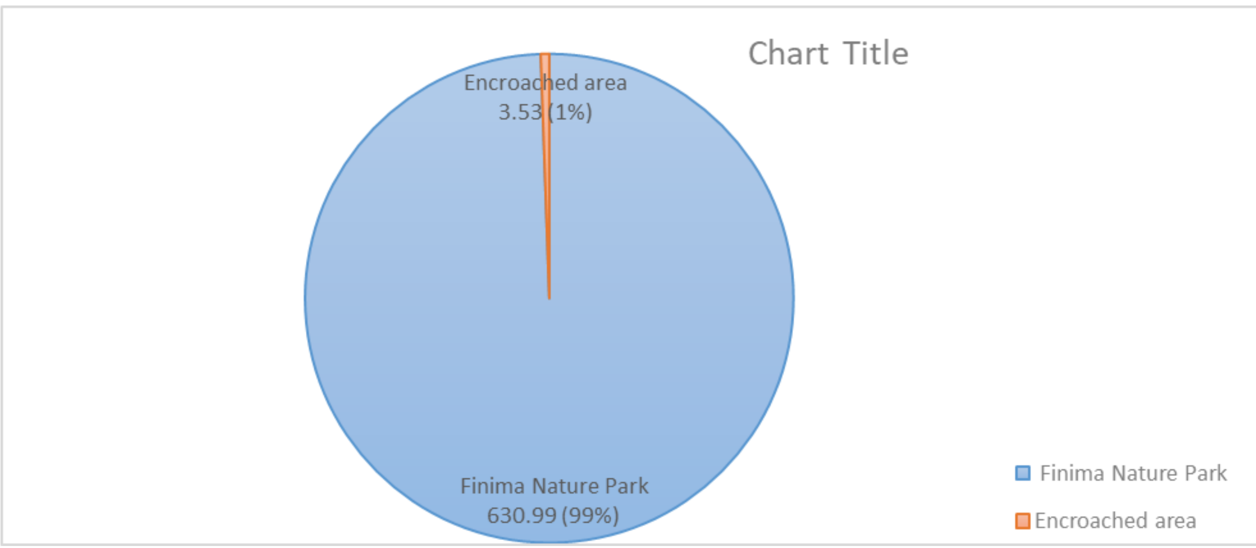
Summary	2016 Assessment	2019 Assessment	Change (Sequestration)	% Change	Annual Change	Annual % Change	Net Emission
Approximate	634.52	630.99	-3.53	-0.56	-1.18	-0.19	

area of FNP (Ha)							
Total biomass in the sample plot (ton)	1327.91	1912.19	584.28	44.00	194.76	14.67	
Average biomass (t/Ha)	120.72	212.47	91.75	76.00	30.58	25.33	
Total biomass in FNP (ton)	76598.77	134813.88	58215.11	76.00	19405.04	25.33	754.95
Carbon stocks in FNP	38299.39	67406.94	29107.55	76.00	9702.52	25.33	377.48
Carbon dioxide CO2 e to	140558.75	249405.68	108846.93	77.44	36282.31	25.81	1396.67

4.7 Rate of change of land cover

Forest cover change was monitored using inputs from various sources such as historical records and recent analysis. The uses of Landsat images to monitor forest cover changes over time is used widely because of its free availability at fine resolution and high temporal resolution (Bhattarai *et.al, 2015*). Figure 11 shows the encroached area. Figure 12 indicated up to 0.56% change, this means that 0.56% of the FNP has been converted to other uses. An estimated 3.53 ha has been converted to bare land. This translates to 1.18ha yr^{-1} (0.19%/year).



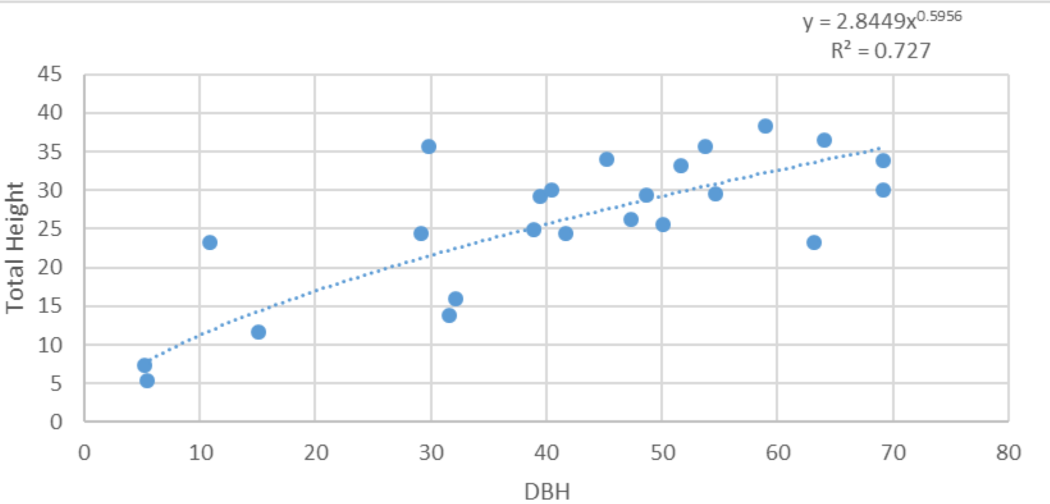


4.8 Tree Species Diversity

Species diversity measures richness and evenness of species in an area. Shannon wiener index captures richness and evenness that depict distributional pattern of species. Species diversity was measured using Shannon wiener index to ascertain the diversity of the across the different land cover and land parcel**.** The swamp forest contained the highest number of trees species (16 species) and the highest diversity index of 2.591, Mangrove forest contained only two species with the lowest diversity index of 0.69 among others. The average diversity recorded in the FNP was 1.844 (Table 13).

Table 13: Tree Species Diversity in FNP

LAND COVER TYPE	SPECIES COMPOSITION	SPECIES DIVERSITY
LOWLAND RAINFOREST	13	2.248
MANGROVE	2	0.693
SWAMP FOREST	16	2.591
MEAN		**1.844**
LAND PARCEL	**Species Composition**	**Species diversity**
PARCEL A	18	2.581
PARCEL B	2	0.643
PARCEL C	7	1.613
MEAN		**1.612**



Scattergram for correelation between DBH and Height

4.9 Conservation status of tree species in sample plots

A total of 27 species of trees from 12 families were identified and documented within the sample plots. 11 (40.7%) out of the 27 are vulnerable (VU), 8 (29.6%) are of least concern (LC) and 8 (29.6%) are not evaluated (NE) according to the IUCN Red list 2015 (Table 14).

Table 14: List of tree species and their conservation status (IUCN Red list 2015)

S/N	Scientific Name	Frequency	Family	[1]Species Status (IUCN Red List 2015)
1	*Albizia spp*	3	Fabaceae	
2	*Alstonia boonei*	25	Apocynaceae	LC
3	*Anthocleista djalonensis*	3	Loganiaceae	VU
4	*Anthostema aubryanum*	6	Euphorbiaceae	NE
5	*Avicennia africana*	2	Avicenniaceae	LC
6	*Baphia spp*	1	Papilionaceae	LC
7	*Cleistopholis patens*	3	Annonaceae	VU
8	*Elaeis guineensis*	12	Palmae	NE
9	*Erythrophleum ivorense*	1	Leguminosae	NE
10	*Klainedoxa gabonensis*	5	Irvingiaceae	NE
11	*Lophira alata*	1	Ochnaceae	VU
12	*Macaranga*	2	Euphorbiaceae	VU
13	*Mitragyna stipulosa*	1	Rubiaceae	VU
14	*Parkia bicolor*	5	Leguminosae	LC
15	*Pierreodendron africanum*	3	Simaroubaceae	NE
16	*Rhizophora recemosa*	10	Rhizophoraceae	LC
17	*Spondiathus preussii*	8	Euphorbiaceae	NE
18	*Vitex spp***	1	Verbenaceae	VU
19	*Xylopia aethiopica*	1	Annonaceae	NE

Species need to be verified.

[1]*Vulnerable (VU) – High risk of endangerment in the wild.*
Least concern (LC) – Lowest risk. Does not qualify for a more at-risk category. Widespread and abundant taxa are included in this category.
Not evaluated (NE) – Has not yet been evaluated against the criteria.

5. Discussion

The data obtained from the FNP indicates variation in Biomass, carbon stocks and CO_2e. A total of 165 trees species (≤ 5m dbh) were measured which yielded AGB of 1593.49 ± 0.23 tons within the sampled plots and a mean AGB of 177.05 ± 0.23 t ha^{-1}. The range of AGB was between 0.93 t ha^{-1} and 375. 89 t ha^{-1} in the sample plots. The highest proportion of biomass (83277.70 tons) is stored in freshwater swamp. This agrees with the range obtained by Chave et al. (2004) and Keller et al. (2001) in moist tropical forests found to be 109.29t/ha – 228.84 t/ha) of AGB. Also, Nkor (2018) surveyed biomass in the lowland rainforest of Cross River and found out that on average, forest land contained the highest total AGB of 247.43t/ha. The total amount of accumulated biomass in forest ecosystems may vary with variation The FNP stores a high volume of biomass which is an indicates its potential to sequester carbon.

Estimating the amount of forest biomass is very crucial for monitoring and estimating the amount of carbon that is emitted during deforestation, or the volume sequestered and stored as carbon. (Vashum and Jayakumar, 2012). Forest plays an important role in the global carbon cycle as carbon sinks. The diversity of the woody plants in the FNP influenced the level of carbon stocks. From the study, an average of 106.23 t C/ha was estimated, showing that 67406.94 tons of carbon is sequestered in the FNP in 2019. The carbon stocks vary based on locations and land cover. The average carbon sequestration rates in the three land cover of lowland forest, mangrove and fresh water swamp were 125.67 tC ha^{-1}, 47.08 tC ha^{-1} and 129.88 t C ha^{-1}, respectively. Also, the weighted annual carbon sequestration rates in these three blocks from 2016 to 2019 were 18.62 tC ha^{-1}, 15.00 tC ha^{-1}, and 7.06 tC ha^{-1}respectively. This conforms with the assertion by Pan et al. 2011 and Scott et al. 2004 that compared to other terrestrial ecosystems, forests store the most carbon with the majority of sequestered carbon held in woody biomass. The FNP stores huge amount of carbon and serve as the lungs for the absorption of carbon.

Forest's ecosystem takes up the carbon dioxide in the atmosphere in the process of photosynthesis. In this natural process, it removes the carbon dioxide from the atmosphere and stores the carbon in the plant tissues, forest litter and soils. The range of CO_2 equivalent absorbed in the FNP (not emitted) is between 2.05 Mg tCO_2ha^{-1} and 826.96Mg/t_CO_2ha^{-1}. shows the distribution of the CO_2 equivalent (CO_2e) stored across the different sample plots. A total of 247,158.78 mg t $CO_{2\,e}$ is locked up in the FNP. The CO_2 locked up in each of the land cover categories indicates that the swamp forest has the highest amount of CO_2 not emitted (152672.52 ± 0.23Mgt_CO_2e ha-^{1}. The CO_2 flux shows that on average between 45.86 and 49.71 Mg t CO_2 ha^{-1} yr^{-1} is absorped in FNP. On the other hand a low emission of -5.47 Mg t CO_2 ha^{-1} yr^{-1} was recorded in one sampled plot, leaving the CO_2 balance 45.86 t CO_2 ha^{-1} yr^{-1}. Parcel A has the highest removals. Conservation of forest has the potential to increase carbon storage and decrease greenhouse gas (GHG) emissions, and moderating in the composition of global atmospheric GHGs (Srinivas, and Sundarapandian, 2019; Lung and Espira, 2015 and Miller et.al. (2007))

However, the Pressures on forest especially in the tropical regions as reported by Akingbogun et al. (2012), Egbe et.al (2015) and Yaro (2015) to provide economic resources have been increasing rapidly, thereby increasing the reduction in forest. An estimated 3.53ha of the of the FNP (634.52 have been deforested this means that 0.56% of the FNP has been converted other uses. This translates to 1.18ha yr^{-1} (0.19%/year). Deforestation and forest degradation influence the amount of carbon in the atmosphere, with deforestation and forest degradation contributing an estimated 18% of total global anthropogenic greenhouse gas emissions (Karki et.al, 2016). Leplay and Thoyer (2011) also noted that deforestation is the second leading cause of greenhouse gas emissions including CO2, after industrial activities. Major ecosystem disturbances are one of the primary mechanisms that have the potential to reset carbon-sequestration pathways and change ecosystems from carbon sinks to sources (Running, 2008).

In the FNP, there were evidence of cuttings around the buffer zone and collection of rattan inside the FNP. Already approximately 0.56% of the total area has been encroached. This is along the pipeline axis of the FNP and also around the mangrove (Hippo Creek) where the mangrove is predominantly used for drying fish.

6. Conclusion, Recommendations, Proposed Management/ Mitigation plan

This study provides current estimation of forest biomass, carbon stock, and annual carbon sequestration in the FNP, which are important biophysical outcomes of the forest landscape.

There was considerable variation in the species, biomass, carbon stock and rate of carbon sequestration. These parameters differ according to the forest types and its geographical location.

The results show that “Swamp forest” had higher level of above-ground biomass, carbon stock than “lowland rainforest and mangrove. This is influenced by tree species diversity. The CO_2 locked up in each of the land cover categories indicates that the swamp forest has the highest amount of CO_2 stored in the forest (not emitted). Trees lock atmospheric carbon dioxide in the form of carbon, and hence reduce atmospheric greenhouse gas (GHG) accumulation. Conservation of forest has the potential to increase carbon storage and decrease greenhouse gas (GHG) emissions and moderating the composition of global atmospheric GHGs.

However, Deforestation and forest degradation influence the amount of carbon in the atmosphere, with deforestation and forest degradation contributing an estimated 18% of total global a. anthropogenic greenhouse gas emission. The storage capacity for a given landscape or region can be determined by the extent of specific factors or processes, including changes in LULC and changes in land management within the defined area. Major ecosystem disturbances are one of the primary mechanisms that have the potential to reset carbon-sequestration pathways and change ecosystems from carbon sinks to sources. The current global drive for climate change adaptation and mitigation depends entirely on sustainable forest management. This is hoped to curtail the rate of deforestation and forest degradation.

Recommendations

- Reforestation of degraded areas of the reserve with endemic species for ecological restoration and possibly, increasing the carbon stock of the Reserve
- A more robust assessment be carried out to assess all carbon pools i.e. Above Ground Biomass (AGB), Below Ground Biomass (BGB), dead wood, litter and soil carbon within the core park area for a better representative data of the carbon stock in the Park.
- Building on this preliminary survey and the results, a monitoring system should be put in place with a plan of a bi-annual carbon assessment for the reserve to assess and monitor the carbon stock of the reserve.
- Detailed mapping of the park to delineate and document the actual land area, including the buffer zones for proper planning and management.
- Monitoring should be intensified along the pipeline area
- Capacity building for staff of the FNP should be given priority

- Future reassessment of the carbon stock and ecosystem of FNP be done in the dry season of the year; preferably between November and April where the area is less inundated for easy accessibility and hitch-free assessment.

Proposed Management/ Mitigation plan

- Pro-active, engagement of local communities in participatory monitoring and protection of the park should be considered.
- Investments should be provided to secure alternative or substitute sources of fuel wood to fishing communities like fish drying kilns, to reduce pressure on flora and the fragile ecosystem.
- Encourage taking examples of world best practices in ecosystem management through environmental education of immediate stakeholders on the dangers and benefits of High Conservation Values (HCV) areas such as the park.
- Support off site conservation efforts of communities to inculcate conservation attitudes.
- Intensify regular patrol of park guards to check poaching and deforestation activities.
- Carry out regeneration of the degraded areas in the mangrove.

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Annex- Picture