Carbon stock of the Extension 2 concession of the Owan Forest Reserve, Edo State, Nigeria

By

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Summary

A 1% sampling effort was used to estimate above-ground carbon stock in the Extension 2 concession in the former Owan North Forest Reserve, Edo State, Nigeria. All trees with diameter at breast height (dbh) ≥10 cm were measured, identified and their height estimated within 68 1-ha belt transects. The vegetation cover in the extension is extremely degraded, with a mixture of plantations, fallows, herbaceous formations and few pockets of secondary forest. Tree density in the area was very low, averaging only 24.33 ±19.7 individuals per hectare. Above-ground carbon stocks were also very low, averaging 1.8±2.1 Mg C ha^{-1}. Total carbon stock for all 6,812 ha of extension 2 is estimated to 829,292.88 metric tons.

Location and description of the Okomu Extension 2 concession

Location of the concession

The Okomu Extension 2 concession is located in BC 12 of the de-reserved areas of Owan North Forest Reserve (ONFR) in the Edo State of Nigeria (Figure 1 and 2). Edo State is located in South-central Nigeria. It is bordered on the west by Ondo State, southeast by Delta State and northeast by Kogi State. The concession lies between Latitudes 6° 38' - 6° 48' N and Longitudes 5° 48' and 5° 55' E. The climate of the area is tropical with a low annual range in temperature, usually less than 5 ˚C. The area has a tropical climate characterized by two distinct conditions of wet and dry seasons while April-October is wet with a brief a lull in August. The dry season occurs during November-March. Annual rainfall in the landscape is high towards the coast, averaging 2500 mm near the coastal areas and 1500 mm in the northernmost part of the state. Temperatures across the state is relatively high (22-36º C) with a narrow variation in seasonal and diurnal ranges.

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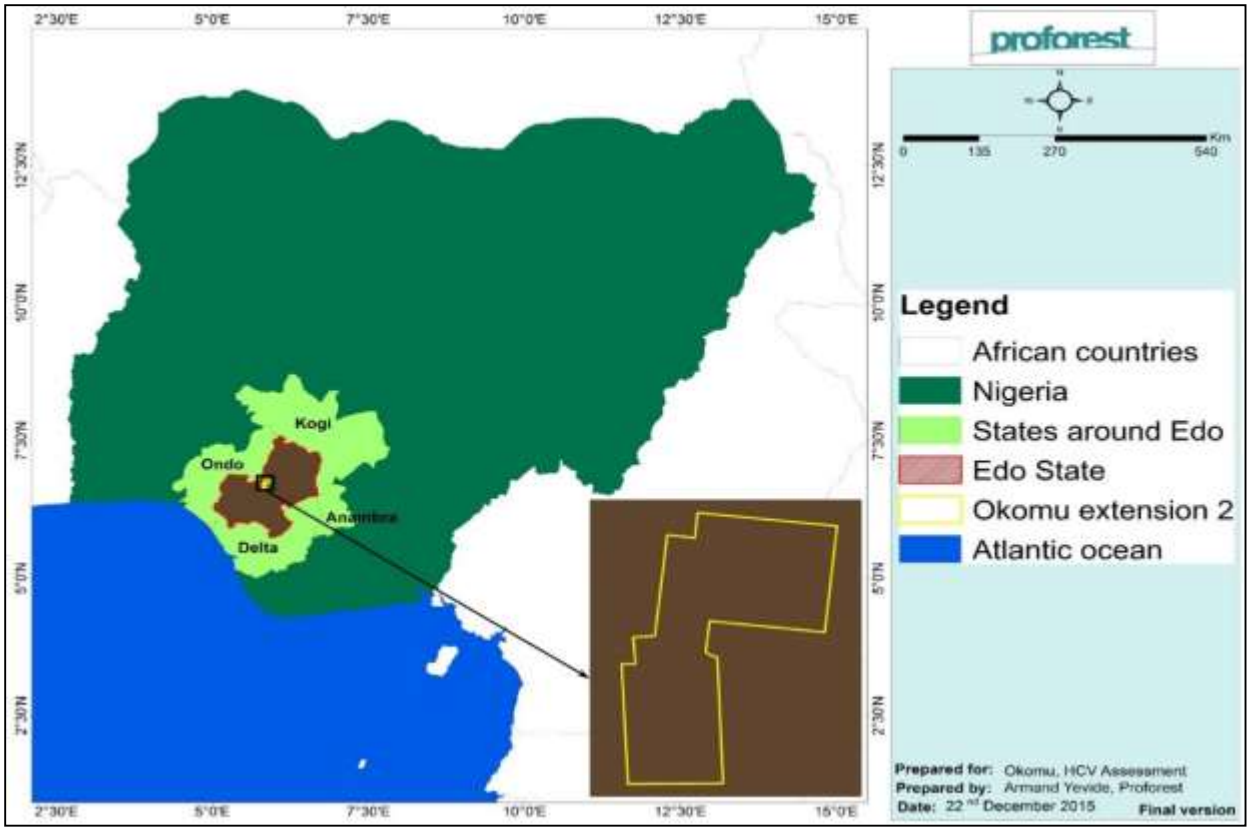

Figure 1: Map of Nigeria showing location of Okomu Extension 2 concession in Edo State, Nigeria.

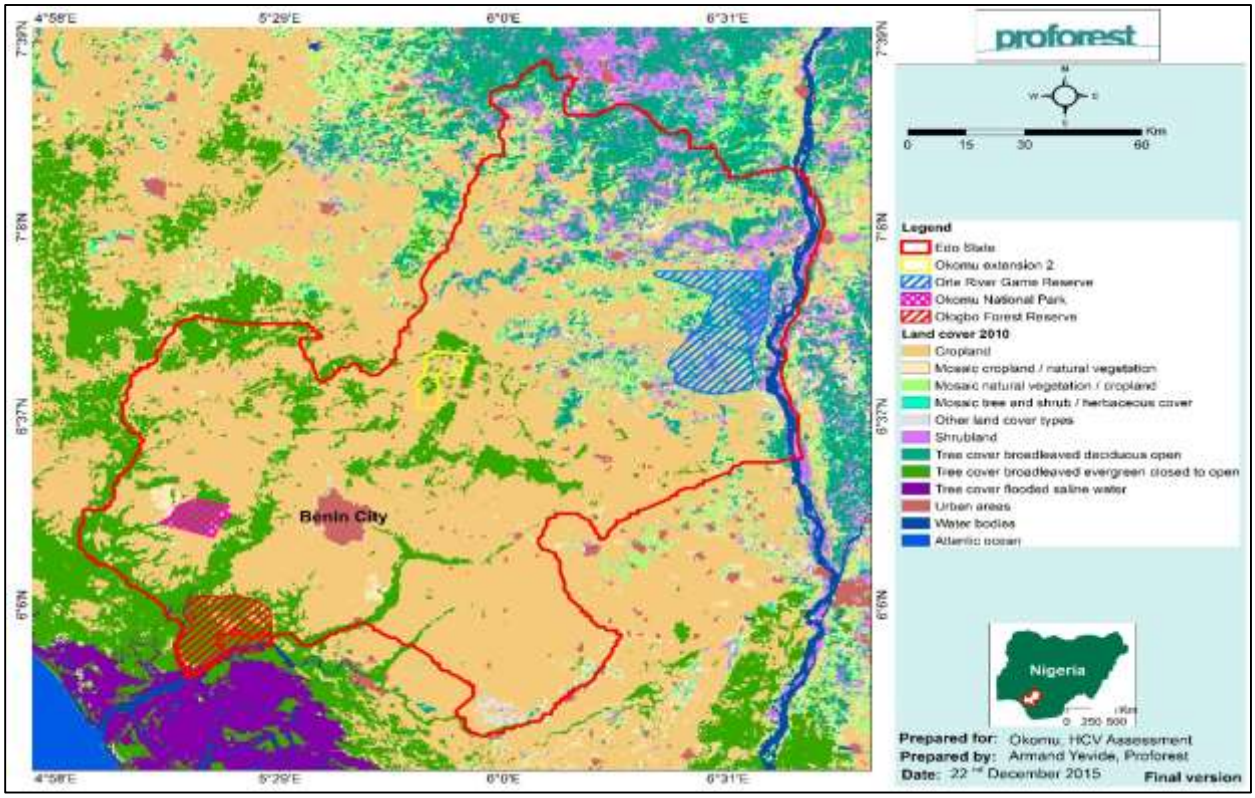

Figure 2: Map showing the location of the concession in Edo State of Nigeria

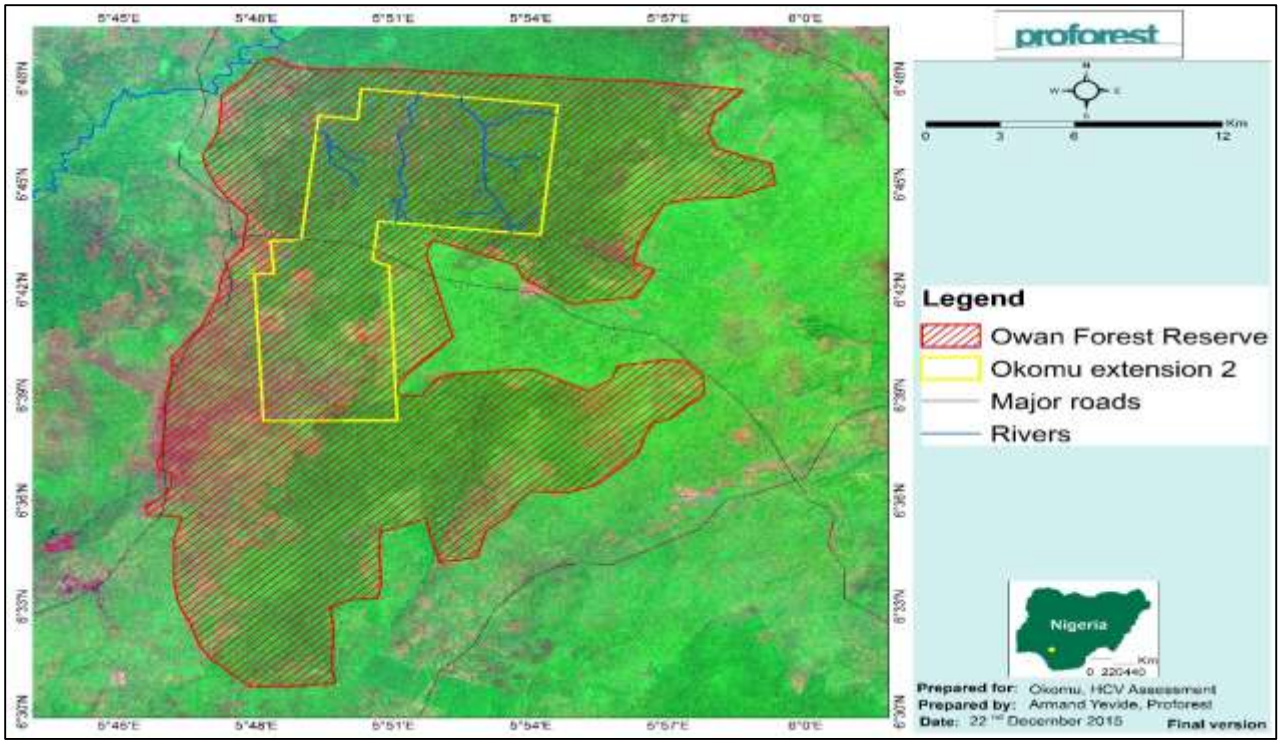

Figure 3: Location of the concession within the former Owan North Forest Reserve

Description of the concession area

The total areas of the concession which was originally allocated to Iyaye Brothers by the State Governor for a period of 99 years for agriculture development is 11,416 ha. The Iyayi Brothers later reassigned the concession to A & Hatman Company who in turn re-assigned to Okomu in November 2013. Of the total area of 11, 416 ha, the previous lease holders converted 760 ha in three different locations (Figure 4 below) of the concession into oil palm plantation between 1997 and 2006 before the land was re-assigned to Okomu Oil Palm Company. Although located within a former forest reserve, the entire concession area has been used for both subsistence and commercial farming to the extent that the original vegetation cover has been signified modified. Major food crops being cultivated on the land include yam, cassava, rice, and maize in addition to the existing oil palm plantations. What remained at the time of this assessment consisted of:

- A mosaic of abandoned farms and farmlands, mainly grasslands, plantain and cassava, in both the southern and northern sections of the concession
- Pockets of active farms in the northern section of the concession whose owners were compensated by the previous lease holder
- Pockets of forests in swampy areas, along rivers and on steep slopes; and
- Approximately 3,856 ha of recently cleared area of abandoned farm and grasslands in the southern section of the concession (Figure 4 below)

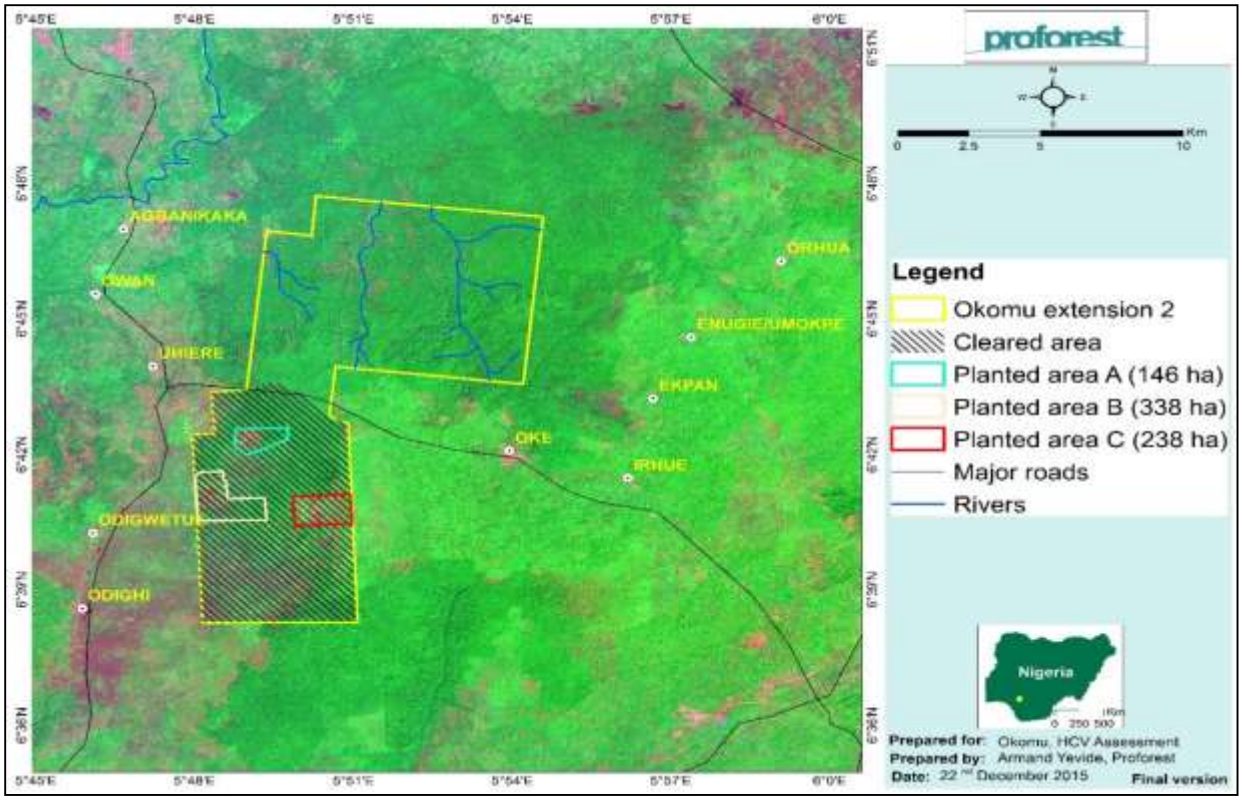

Figure 4: Landscape map showing locations of the Extension 2, existing oil palm plantations within newly cleared areas (hatch yellow) and neigbouring communities

Method

Experimental design

Given that about 3,856 ha (most part of the southern section as seen in Figure 4) of the concession was cleared by Okomu during the first half of 2015 and just before the carbon stock assessment, those areas were excluded from the assessment since there were no trees. Additionally, the existing 760 ha old oil palm plantation was also excluded from the carbon stock assessment. The carbon stock assessment was therefore limited to the remaining 6,800 ha of the concession mainly in the northern section (Figure 5).

We estimated above-ground carbon stocks of the Extension 2 concession using 68 1-ha (500m x 20 m) belt transects (~1% sampling effort). Each transect was subdivided into 25 quadrats of 20x20 m (400 m^2). Only leaving trees with trunk diameter at breast height (dbh) ≥ 10 cm were measured using a diameter tape. These big trees account for the major part of the biomass in tropical lowland forests (Slik et al., 2013). In addition to the dbh measurement, the height of each individual tree was estimated visually. Each quadrat within each transect was assigned to a

vegetation type. The total number of quadrats in each vegetation type was used to estimate its area within the entire extension.

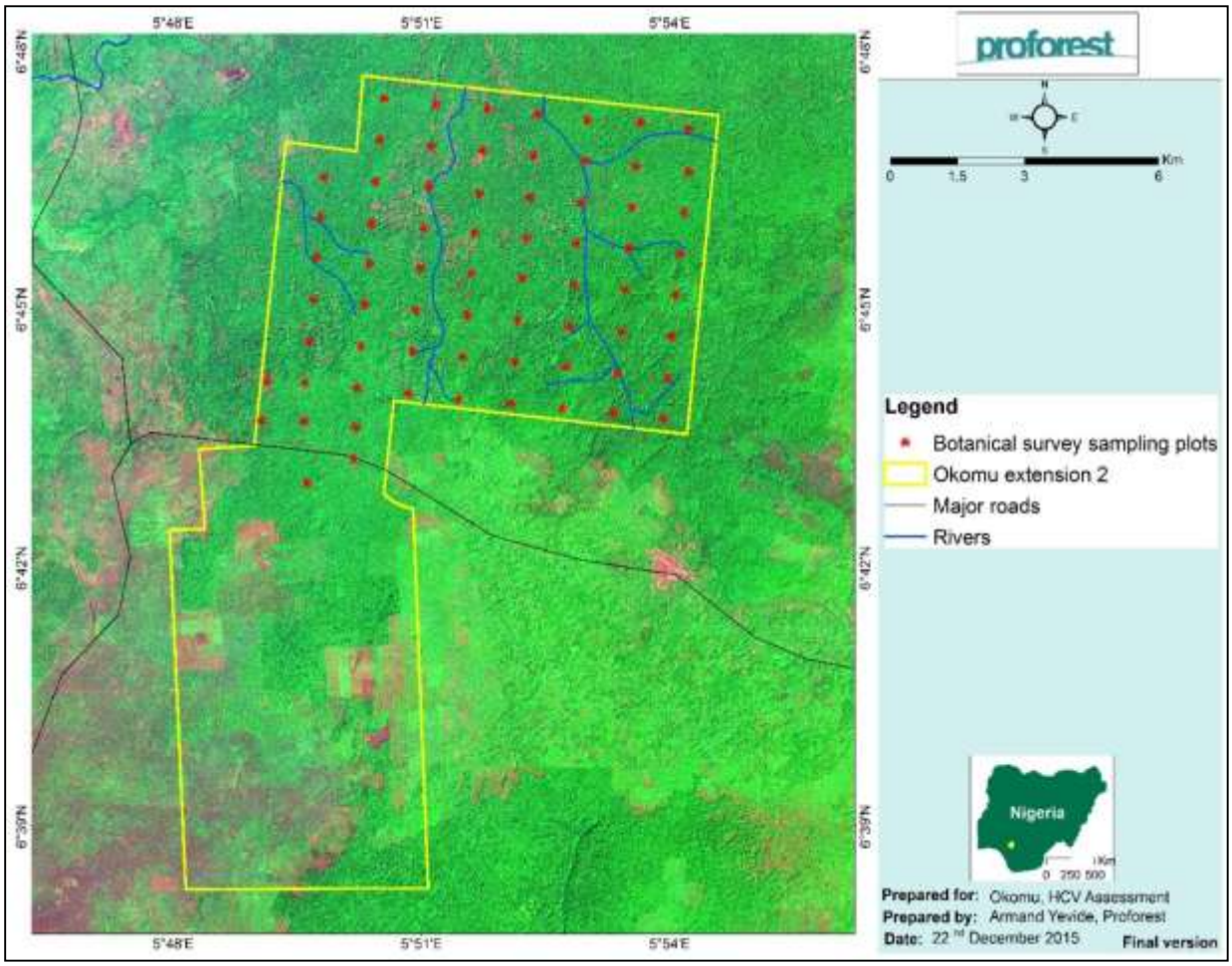

Figure 5: Map of the concession showing the area surveyed and the locations of the 68 belt transects

Data Analysis

Above-ground biomass was estimated using the latest improved allometric model of Chave et al. (2014). The equation uses tree height, trunk diameter and wood density as covariates of above-ground biomass. To deduce carbon content from the biomass, we used the assumption that carbon concentration is about half (47.5%) of the biomass (Whittaker & Likens, 1973; Brown, 1997; Losi et al., 2003; Nasi et al., 2009). The biomass was estimated for each individual tree (including all stems for multi-stemmed trees) using the equation:

$$AGB = 0.0673 \times (\rho D^2 H)^{0.976}$$

*Where **AGB** is aboveground dry biomass (in kg); **ρ** is wood density (in g/cm^3) and **D** is dbh (in cm).*

Wood density was compiled from (Chave et al., 2009), the African Wood Density Database (Carsan et al., 2012) as well as the World Agroforestry Centre wood density database (http://worldagroforestry.org/regions/southeast_asia/resources/db/wd). Of the 92 species recorded in the inventory of this extension, wood density was available for 56 (60.87%) species. For the remaining species not reported in these databases, we used the mean wood density of the matching genus (31 species) or matching family (5 species).

Results

The vegetation cover of extension 2 was highly degraded, consisting of current plantations, fallows, herbaceous formations with no or small trees and small pockets of disturbed forests. Fallows represented 31% of the total area while herbaceous formation represented only 69% (Table 1).

A total of 1,654 living trees with dbh ≥ 10 cm were recorded within the 68 hectares surveyed. These trees belong to 92 species in 75 genera and 34 families. *Musanga cecropioides* and *Ricinodendron heudelotii* were the most abundant species. *Ricinodendron heudelotii* also was the most important species in terms of above-ground carbon stock, followed by *Pterygota macrocarpa* and *Musanga cecropioides* (Table 2).

Table 1: Total carbon stock in trees with dbh≥10 cm in different vegetation types of the sampled area and the Extension 2 concession area 3.

	Sampled area				Total extension	
Vegetation type	**Area (ha)**	**Proportion**	**Total carbon (Mg)**	**Carbon (Mg ha^{-1})**	**Total area (ha)**	**Total carbon (t)**
Fallows	12.2	0.18	76.69	6.29	1226.16	94034.22
Herbaceous formations	51	0.75	0	0	5109	0
Plantations	4.2	0.07	26.29	6.26	476.84	12536.13
Secondary forest	0.6	0.01	18.77	31.29	68.12	1278.62
Total	68	1	121.74	1.8	6812	829292.88

Tree density was low in extension 2, with only 24.33 ±19.7 individuals per hectare, which translated into low above-ground stock of Carbon. Above-ground carbon stock estimated within the 68 hectares surveyed was 121.74 Mg and averaged only 1.8 Mg C ha^{-1} (Appendix 1). The

fallows represented only 18% of the area surveyed, but accounted for 63% of the total carbon stock (Table 1). Above-ground Carbon stock was highest in secondary forest (31.29 Mg C ha^{-1}) compared to other vegetation types. Herbaceous formations with no or small trees represented 75% of the area surveyed and stocked no carbon.

Table 2: Ten most important tree species in terms of above-ground carbon stock with their abundance in 68 hectares of in extension 3.

Species	Carbon (Mg)	N
Ricinodendron heudelotii	12.45	283
Pterygota macrocarpa	9.61	16
Musanga cecropioides	8.71	292
Pterocarpus osun	6.26	10
Albizia zygia	5.31	67
Blighia sapida	4.71	9
Albizia lebbeck	4.62	65
Cola gigantea	3.98	23
Irvingia gabonensis	3.53	7
Pterocarpus santalinioides	3.29	4

Discussion and conclusions

The vegetation of the extension 2 concession of the Owan North forest was highly degraded, dominated by herbaceous formations with no trees or only small trees with dbh <10 cm. There were small pockets of secondary forest but that represented only a tiny fraction of the area in the extension. The degraded status of the extension is confirmed by the abundance of several species indicators of secondary growth such as *Musanga cecropioides*, *Margaritaria discoidea*, *Alchornea cordifolia*, *Harungana madagascariensis*, *Alstonia congensis*, *Cleistopholis patens* that were recorded in many transects.

Above-ground carbon stock in extension 2 was very low (1.8 Mg C ha-1) compared to the average of 202 Mg C ha^{-1} in tropical Africa (Lewis et al., 2009). The low carbon stock of the former Owan North Forest Reserve can be attributed to the low tree density, only 25 individuals/ha compared to 426 individuals/ha in African lowland forest (Lewis et al., 2013). Based on the proportion of each vegetation type in the extension, we estimated the total carbon stock in trees with dbh≥10 cm to 829292.88 Mg (Table 1).

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Appendix 1: Abundance and carbon stock of trees with dbh≥10 cm in 68 1-ha plots in Extension 2 of the Owan Forest Reserve. N = total number or Individuals.

Transect	Carbon (Mg ha^{-1})	N
01	0.13	20
02	3.45	37
03	7.79	40
04	6.88	49
05	3.86	60
06	1.48	23
07	3.99	47
08	2.38	42
09	2.29	52
10	1.04	15
11	0.12	12
12	3.17	44
13	0.47	19
14	0.91	31
15	2.07	36
16	0.25	12
17	10.45	47
18	4.15	20
19	3.5	22
20	3.13	20
21	1.94	52
22	0.36	11
23	2.43	90
24	0.63	29

25	1.56	19
26	2.17	39
27	2.34	37
28	4.16	35
29	1.68	23
30	1.04	30
31	0.81	21
32	1.54	22
33	6.46	67
34	2.23	60
35	0.68	17
36	1.06	40
37	1.87	22
38	0.18	26
39	0.02	1
40	6.49	58
41	3.47	43
42	0.02	5
43	1.02	17
44	0.59	22
45	0.12	4
46	0.87	7
47	4.15	38
48	1.75	52
49	2.56	15
50	0.17	2
51	0.16	1
52	0.33	6
53	0.47	12
54	0.21	3
55	0.5	7
56	0.26	6
57	0.01	2
58	0	0
59	0.77	1
60	1.09	14
61	0.53	12
62	0.58	9
63	0.1	3
64	0.15	6
65	0	0
66	0.12	4
67	0.74	5

68	0.18	11
Total	121.74	1,654
Average	1.8	24.33
Stdev	2.11	19.7