Mapping and Assessing Above-ground Biomass and Carbon in Omo Biosphere Reserve Using Field and Remote Sensing Data

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Abstract

Forests play an important role in global carbon budget as carbon sinks. The carbon is stored in trees as forest biomass whose assessments would quantify the carbon sink potential of any forest. An accurate field inventory and remote sensing (Landsat 8) data are prime solutions to the carbon balance estimate required for a functional Measurement, Reporting and Verification (MRV) system to support REDD+ programme. This study involved the use of accurate field and remote sensing data to map the spatial explicit of above-ground carbon (AGC) and estimate the Above-ground Biomass (AGB) and AGC (50% of AGB) stock of the Omo Biosphere Reserve. The spatial distribution of carbon density varied among the sample plots and the carbon density drained according to the plot mean biomass/carbon data used for mapping the explicit carbon of the reserve. Omo Biosphere Reserve had mean biomass accumulation of 160.17 t ha^{-1} and mean carbon density of 80.09 t ha^{-1}. The reserve accumulated 1,633,860.72 t of biomass and 816,930.36 t of carbon within the 10,200.57 ha mapped. The biosphere reserve had good pool of indigenous tropical hardwood tree species with high capacity to trap carbon and thus, have high potential to mitigate climate change effects. The carbon distribution pattern produced for this study is a good indicator of biomass/carbon map in the Omo Biosphere Reserve.

Keywords: Biosphere Reserve, Carbon, Remote sensing, Biomass, Climate Change

Introduction

Global climate change had increased the interest of the scientific and political communities in the study of global carbon storage and carbon mitigation capability of forests. Carbon stored in trees is regarded as forest biomass such that its assessments would play major roles in quantifying the carbon sink of any forest. The estimation of forest biomass is an essential aspect of the studies of carbon storage and carbon balance of forests (Xiao and Ceulemans, 2004). Forests play an important role in global carbon budget as carbon sinks (Dixon *et al.*, 1994). Forest biomass constitutes the largest terrestrial carbon sink and accounts for approximately 90% of all living terrestrial biomass (Zhao and Zhou, 2005). Forest biomass constitutes 50% of carbon and as forest biomass increases over the time, so does the forest carbon stock as well as sequestered carbon in standing trees (increase wood volume and density) and forest soils (micro-organisms). Thus, the assessment of forest biomass/carbon in tropical ecosystems is very important for generating the information needed for sustainable forest management as well as its potential climate change in the global carbon balance.

The quantification of carbon sink through forest biomass has received special attention since the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. The countries who signed this treaty are mandated to estimate and report CO_2 emissions and removals by forests through effective Measuring, Reporting and Verification (MRV) systems that comply with the guidelines of the Intergovernmental Panel on Climate Change (IPCC), which is the mandate of Reduce Emissions from Deforestation and Forest Degradation (REDD+) (Mauya *et al*., 2015). The REDD+ programme of the United Nations encompasses results-based finance for incentive on carbon emissions reduction, based on a functional forest carbon MRV system (Gizachew *et al*., 2016).

However, some technical challenges in measurement, reporting and verification exist which contributed to the lack of progress for implementation of REDD+ programme of the agreed countries. A functional MRV system to support REDD+ programme requires estimates of the area of forest loss and gain as well as the corresponding carbon stock and changes (Gizachew *et al*., 2016). These data are needed for the estimation of the actual emissions and the construction of forest reference emissions level as a benchmark against which the actual emissions are compared (Gizachew *et al*., 2016).

Meanwhile, the developing global carbon markets, particularly because of the incorporation of a Clean Development Mechanism (CDM) in the Kyoto Protocol, require accurate and reliable methods to assess the sources and sinks of carbon in forest ecosystems where Certified Emission Reductions (CER) of carbon credits are obtained to offset emission targets of some industrialized countries (Deo, 2008)

Forest biomass/carbon assessment methods can sometimes be difficult, tedious and expensive. Some of these may involve felling of sample trees, excavating their root components, drying and weighing the content to obtain biomass. Therefore, attention has shifted to estimating forest biomass with easily-measured techniques such as the development allometric equation from non-destructive method of forest biomass assessment (Deo, 2008). The combination of accurate field inventory and Remote Sensing (Landsat 8) data are expected to provide solutions to the carbon emission and sink required for a functional measurement, reporting and verification (MRV) system to support REDD+ programme. This study aims at using Remote Sensing (Landsat 8) as auxiliary data for assessment of above-ground biomass (AGB), that is, the sum of the above-ground tree biomass in Omo Biosphere Reserve. The specific objectives are to (i) map the spatial explicit of above-ground carbon (AGC) with the combination of inventory and Landsat 8 data, and (ii) estimate the AGB and AGC stock of the reserve.

Materials and Methods

Study Area

The study was conducted in Omo Biosphere Reserve or Queen's Plot, locally called *Igbo-iyalode* by the rural dwellers in Omo Forest Reserve in Ogun State. Omo Biosphere Reserve lies between 6° 55′ 12.0″-7° 10′ 12.0″N and 4° 13′ 12.0″-4° 24′ 0.0″E within the high forest zone south-western Nigeria. The Biosphere Reserve covers about 14,660 hectares (ha) including its core area and buffer zone, which were constituted as Strict Nature Reserve in 1949 and Biosphere Reserve in 1977 respectively (Onyekwelu *et al*., 2008).

The climate of the study area is humid tropical characterized by two distinct seasons: rainy and dry seasons, as obtained in the southwest geopolitical zone of Nigeria. The wet (rainy) season starts from March and ends in November while dry season lasts from December to February. The mean annual rainfall ranges from 1,700 to 2,200 mm while annual temperature and average daily relative humidity are 26 C and 80% respectively. The rainfall distribution is bi-modal with a marked decline in August and peaks in July and September. The mean elevation is about 123 m in Omo (Onyekwelu *et al*., 2008). The geology of the reserve consists of crystalline rocks of the undifferentiated basement complex but which has been overlain by Eocene deposits of sand, clay and gravel in the southern parts (Augustine, 1995). Thus, the soils are predominantly ferruginous tropical, typical of the variety found in intensively-weathered areas of basement complex formations in the rainforest zone of south-western Nigeria (Nwachokor and Uzu, 2008). The soils are well drained, mature, red, stony and gravely in upper parts of the toposequence (Onyekwelu *et al.*, 2008).

Sampling design

The map of the core area of Omo Biosphere Reserve (undisturbed natural forest) was gridded into plots of 30×30 m as obtained in the Landsat image pixel of the geographically referenced map. Ten (10) sample plots of 0.09 ha were randomly selected from the map and located on the field with the use of Global Positioning System (GPS).

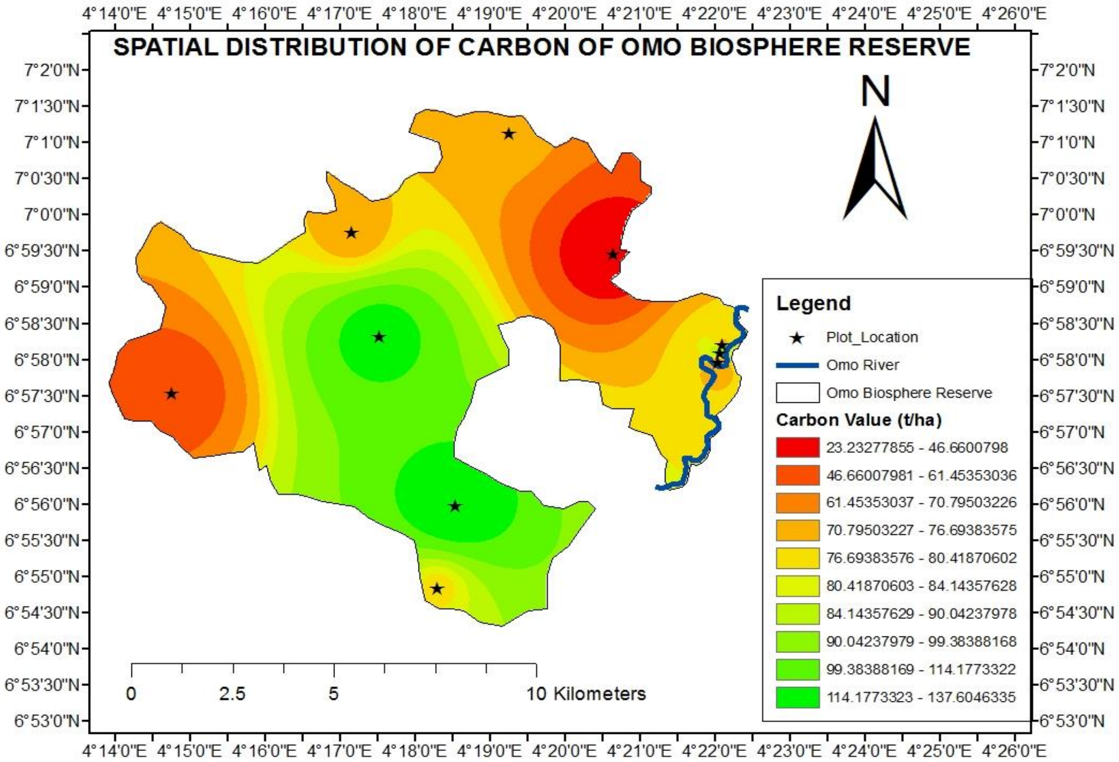

Fig. 1: Spatial distribution of carbon of Omo Biosphere Reserve

Data collection and measurements

All standing trees (with minimum Dbh of 10 cm) within each sample plot were identified by a forest taxonomist and their Dbh measured using a girth tape. The trees in each sample plot were grouped into species and two mean trees per species were selected for further measurements: total height, diameters at the base, middle and top of all the mean trees using Spiegel Relaskop. The linear measurements were used to estimate the volumes. Newton's formula (equation 1) (Subasinghe, 1998) was used to estimate the standing volume of each mean tree:

$$V_{total} = \frac{\pi h}{24}\{D_b^2 + 4D_m^2 + D_t^2\} \quad \text{........... Equation (1)}$$

where:

V_{total} = Volume of the stem
h = Height
D_b = Diameter at the base
D_m = Diameter at the middle
D_t = Diameter at the top.

Estimation of stem core volume

Since the shape of the stem core sample is cylindrical, the volume was estimated with the equation (2):

$$V_s = \frac{\pi d_s^2}{4} l \quad \text{.......................... Equation (2)}$$

where;
d_s = diameter of the core sample, (cm)
l = length of the core sample, (cm)
V_s = volume of the core sample, (m)

Conversion of stem volume and core volume to above-ground biomass

A non-destructive sampling method was used in this study to estimate the above-ground tree biomass from the selected the two mean trees per species group. A core sample of each of the two mean trees of each species was extracted with an increment borer at the breast height point (i.e. 1.3 m). The length of the core extracted using the increment borer was measured (in cm). Core diameter was also measured for the selected sample trees and the average was taken. The core samples were oven-dried at 75ºC to a constant weight and the mass measured using an electronic weighing balance (in g). The above-ground biomass of each stem was calculated by using the equation (3) below (Subasinghe and Harpriya, 2014).

$$AGB = \frac{W_d \times Vol}{V_s} \quad \text{........................... Equation (3)}$$

where:
Vol = total stem volume (m^3)
W_d = oven dry weight of the core sample (kg)
AGB = above ground biomass of the stem (kg)

Carbon stock assessment

The estimated above-ground biomass was used to determine the amount of carbon stock in each of the trees, plots and forest stand based on carbon at 50% of biomass estimates (Losi *et al.,* 2003) as obtained in equation (4).

$\boldsymbol{Carbon = Biomass \times 0.5}$**.....Equation (4)**

Carbon plot-1 was obtained by adding the carbon of all the mean trees within the plot. Carbon ha-1 was computed by first summing the carbon of all the sample plots selected for this study and finding the mean and multiplying by the number of 30×30 m (0.09) sample plots ha-1 which is 11.111. The value ha-1 multiplied by number of ha within the reserve was used to obtain carbon for the entire stand.

Carbon Mapping with Geographic Information System (GIS)

Landsat 8 imagery was obtained through the USGS Earth Explorer (earthexplorer.usgs.gov) with higher accuracy and geometric correction for the study area. The importance of using Landsat 8 data for modelling and mapping purposes can be justified by the fact that it covers large area and is obtained free of charge. Furthermore, Landsat 8 came with considerable improvements in sensor signal-to-noise performance and associated improvements in radiometric resolution (Gizachew *et al.*, (2016). The boundary of Omo Biosphere Reserve was digitized with clear distinction between the buffer and core areas of the reserve as well as showing the present forest cover. The remote sensing data was related with the plot data of above-ground biomass of all the plots with the aim of determining the amount of biomass/carbon sequestered by the trees in the respective plots. The spatial distribution pattern of the biomass/carbon was mapped using the plot above-ground biomass data obtained.

Results and Discussion

The summary of the growth data obtained for trees in the study area is shown in Table 1. The highest number of trees was encountered in plot 4 at 556 stems ha^{-1} followed by plot 5 with 489 stems ha^{-1} while the least number of trees was enumerated in plot 2 with 233 stems ha^{-1}. The highest mean tree biomass was encountered in plot 5 with 276.13 t ha^{-1} followed by plot 3 (253.00 t ha^{-1}) while the least biomass was encountered in plot 2 (46.43 t ha^{-1}). The value of carbon varies in the same pattern as the biomass since it was derived as 50% of the value. The mean height of trees ranged from 16.0 to 26.8 m with the highest value recorded in plot 6 (26.8 m). The plot mean diameter ranged from 17.9 to 26.2 cm with plot 1 having the highest mean Dbh.

Table 1: Tree growth characteristics of the plots in Omo Biosphere Reserve

Plot No.	No of Stems ha^{-1}	Dbh (cm)			Height (m)			Mean Biomass (kg)(10^3)	Biomass kg ha^{-1} (10^3)	Carbon kg ha^{-1} (10^3)
		Mean	Min	Max	Mean	Min	Max			
1	311	26.2	13.0	65.9	20.7	12.0	30.0	14.09	156.51	78.25
2	233	23.1	10.3	55.5	16.0	10.8	23.9	4.18	46.43	23.22
3	467	23.7	10.3	70.0	17.2	11.8	34.5	22.77	253.00	126.50
4	556	19.4	10.0	56.8	18.8	11.5	31.5	13.29	147.60	73.80
5	489	22.1	10.3	80.0	22.3	10.0	33.9	24.85	276.13	138.07
6	311	24.4	10.4	90.0	26.8	21.9	34.5	13.01	144.55	72.27
7	389	17.9	10.5	44.0	23.6	19.8	31.5	9.02	100.24	50.12
8	356	24.3	10.2	59.0	22.4	13.8	29.8	13.29	147.66	73.83
9	367	23.1	10.4	87.8	22.9	16.0	33.9	17.77	197.48	98.74
10	456	19.3	10.4	60.5	21.2	12.5	33.9	11.89	132.14	66.07
						Total		144.17	1601.73	800.87
						Mean		14.42	160.17	80.09

Mapping the spatial distribution of above-ground carbon with GIS

Fig. 1 shows the spatial distribution of carbon based on mean biomass/carbon of each plot extrapolated to ha^{-1} and used to map the study area. The Omo Biosphere Reserve has a pooled mean carbon accumulation of 80.09 t ha^{-1} and accumulated total biomass of 1,633,860.72 t and 816,930.36 t of carbon (Table 2).

Table 2: Biomass and carbon accumulation in trees of Omo Biosphere Reserve

Variables	Kilograms (kg)	Tons (t)
Mean plot Carbon	7,208.53	7.21
Mean plot Biomass	14,417.05	14.42
Carbon ha^{-1}	80,086.74	80.09
Biomass ha^{-1}	160,173.47	160.17
Carbon for the entire Stand	816,930,357.93	816,930.36
Biomass for the entire Stand	1,633,860,715.86	1,633,860.72

Spatial distribution of carbon density

The spatial distribution of carbon density varied among the sample plots and also the carbon density drained according to the plot mean biomass/carbon data for mapping the explicit of carbon of the biosphere reserve. The Biosphere had mean biomass accumulation of 160.17 t ha^{-1} as well as mean carbon density of 80.09 t ha^{-1} (Table 2). The above-ground tree biomass obtained for this study is higher than 80 ±7 t ha^{-1} and 138 t ha^{-1} obtained by Gizachew *et al.*, (2016) and Baccini *et al.* (2012) respectively but lower than 347.17 ± 101.70 t ha^{-1} and 245.09 ± 31.68 t ha^{-1} reported as the above-ground biomass accumulation of Yapo Protected Forest and Natural Voluntary Reserve (NVR) Forest in Côte d'Ivoire respectively (Vroh *et al.*, 2015). This study only estimated biomass/carbon of the main stem as against tree total biomass and did not include the biomass of other above-ground tree components like leaves, branches and twigs.

The Omo Biosphere Reserve has accumulated a total of 1,633,860.72 t of biomass and 816,930.36 tonnes of carbon in the 10,200.57 ha map. This above ground tree biomass/carbon obtained for this study is higher than 140 ± 7 Mt for area of 15,700 km^2 reported by Gizachew *et al.*, (2016) which reported. These values of above-ground tree biomass and carbon content show the potential of the Omo Biosphere Reserve in carbon sequestration and its climate change mitigation capability. This also gives the value of forest as carbon sinks and ultimately their global potential in the UNFCCC (REDD+) campaign (Santilli *et al.*, 2005). Forests sequester and store more carbon than any other terrestrial ecosystem (account for about 90%) and are an important natural mitigation of the effects of climate change (Vroh *et al.*, 2015). The carbon stored in the above-ground living biomass of trees is typically the largest pool and the most directly impacted by deforestation and forest degradation (Vroh *et al.*, 2015). Thus, estimating the above-ground forest biomass is the most important step in quantifying carbon stocks and sink from tropical forests.

Conclusion

Omo Biosphere Reserve is important for *in-situ* biodiversity conservation because of its tree species composition. The Biosphere Reserve has a good pool of indigenous tropical hardwood tree species with high capacity to trap carbon and thus, it is very important for mitigation of climate change effect. Carbon distribution pattern produced in this study is a good indicator of biomass/carbon map in the biosphere reserve. Thus, it will serve as a baseline map for easy mapping of carbon as well as reliable and cost-effective means of estimating biomass non-destructively for carbon assessment in preparedness for REDD+ implementation strategies.

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