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Full Length Research Paper

Carbon flow pattern in the forest zones of Nigeria as influenced by land use change

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Forest in Nigeria plays a much wider role in the overall balance of issues affecting the country than those of climate change alone. Nigeria's tropical forest is depleting fast, due largely to uncontrolled human activities. Poverty, urbanization, population growth and insecurity are the major causes of this trend. Tracking carbon flow in these forest life zones will help account for the effect of these activities on the environment. COPATH, an acronym for Total Carbon Flow from Conversion to Agriculture, Pasture, Harvest and OTHER land-uses including construction of dams, roads, forest fires and human settlement, etc., was used for tracking carbon flow in the forest zones. From the five forest life zones, total carbon stored was estimated to be 2.55 TgC. The four activities of agriculture, harvest, pasture and bush burning were pronounced in contributions to land use changes, particularly to forest depletion. In this paper it is shown that carbon emission was highest from harvesting activity in year 2000, principally from clear-cutting activity in the lowland rainforest as against that of 1990 study, which showed agricultural activity as the major anthropogenic activity leading to carbon release into the atmosphere. Further, it is shown that the value of carbon emission is on the increase as compared to the earlier study with 1990 as the base year. During the two periods of study, it was however, observed that the relative contribution of each of the activities that are responsible for deforestation and affects carbon flow pattern in the forest zones and invariably causes carbon emission had not changed. Though a look at the fractional contribution of each of these activities in 2000 as against that of 1990 estimates shows a marked change. The study also concludes that if there is no change in the estimated deforestation rate of 2.23% per annum of the forest formations, lowland rainforest and riparian forests are likely to disappear by 2040.

Key words: Carbon flow pattern, forest life zone, land use, human activities, deforestation.

INTRODUCTION

Nigeria's forest ecosystems could act as either net sink or source for carbon depending on the degree of efficiency of its management regime. Further, they could serve as cheap, effective and significant means to achieve reduced greenhouse gas (GHG) emissions as well as carbon sequestration, if their carbon stocks could be increased considerably by decrease in the rates of deforestation. According to Okali and Eyo-Matig, (2004) and Banyara et al. (2010), trends in forest cover in the country shows changes from 1953 when compared to the forest cover in 1995, which indicates that the country had being witnessing land use change, especially over the last 20 years (reference here). Thus improving land use management could easily lead to reduced changes observed in land use.

Presently, carbon dioxide (CO_2) forms the bulk of the greenhouse gases emitted from forestry sector in Nigeria. The emissions of CO_2 may be traced to a number of activities, including biomass burning, forest clearing, soil disturbance and anaerobic processes among others. Other GHG and precursor gases are also emitted. The objective of this study is to present the carbon flow pathways based on activities in Nigeria's forest eco-systems with the aim of identifying opportunities available for reducing future emissions from the sub-sector.

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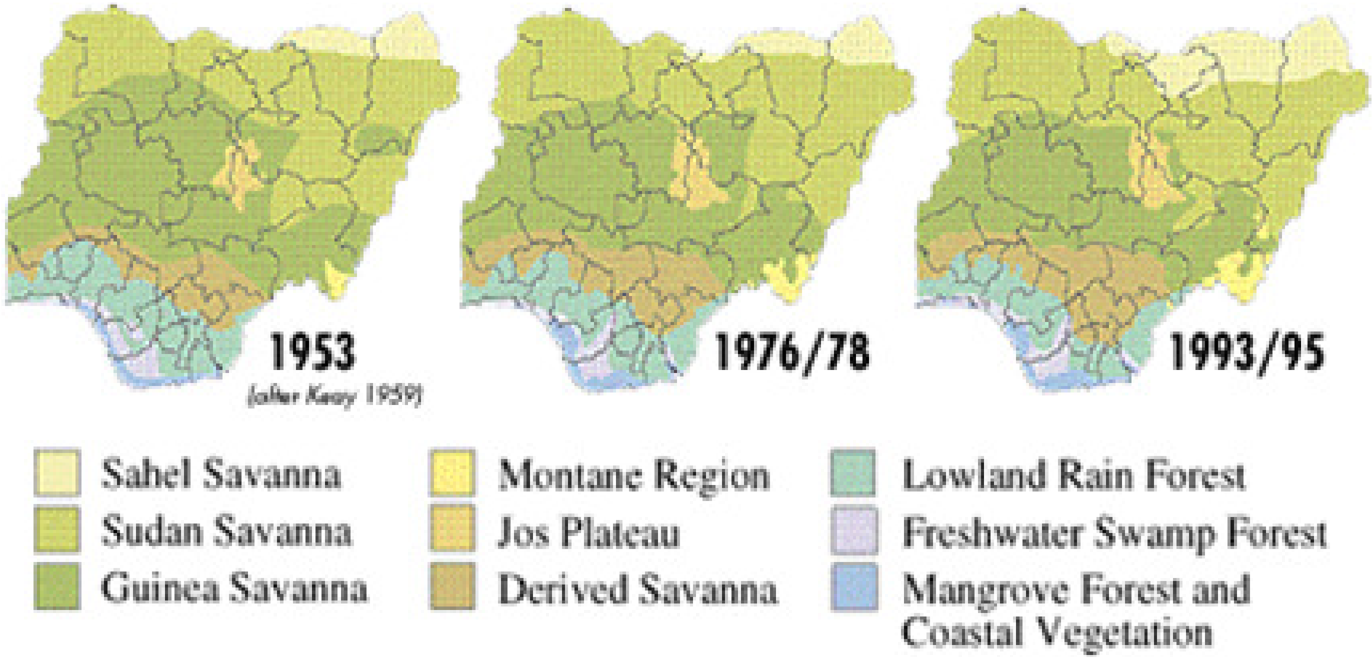

Figure 1. The Evolution of the Different Vegetation Classes in Nigeria from 1953 to 1995 (FORMECU, 1997) adapted from Keay (1959).

Forests in Nigeria play significant role in the overall balance of issues affecting the country including climate change. Agriculture contributed about 35.7% to the GDP in 2000 with the forestry contributing about 1.4% (CBN, 2000). However, the real contribution from forestry may not have been totally captured due to data paucity within the country. In addition, considering the high level of forest degradation, forestry's contribution to the national income is likely to be greater than officially reported (FMANR, 1996). Another area not factored into national accounting about the forest is its contribution in relation to the domestic energy, food and medicinal supply especially to the rural people (FDF, 1998). As indicated in the results of earlier studies, land use change occasioned principally by forest depletion, had contributed significantly to GHG emissions from Nigeria to the atmosphere and less uptake resulting in total net emissions (Siyanbola et al.,1996; Obioh et al., 1996). Despite this economic contribution, it is observed presently that the depletion rate of Nigeria's tropical forest, occasioned, largely by uncontrolled human activities demands quick intervention to sustain it. Thus it becomes germane to draw attention of policy makers to the need to develop sustainable management system in this sub-sector.

The scope of this work is limited to anthropogenic activities carried out in Nigeria's five forest zones from between 1976/1978 and 1994/1995, representing a 17 year period from which extrapolation of land use changes is made for up to 2000. The values obtained thereof were then used to assessed and determine their influence on carbon flow from the forest ecosystem to the atmosphere.

Objective of the study

It is imperative that the major causes of land use change leading to increased GHG emissions be examined. One means of achieving this is be to track carbon flow in the forest life zones to help account for the effect of identified land use activities that contributes to deforestation, which in turn impacts the environment. This forms the objective of the study.

Natural factors affecting vegetation distribution

In terms of vegetation structure, Nigeria can be divided into nine vegetation zones (Siynabola et al., 2003). Out of these, five are forest formations and four are savanna formations (Figure 1). The forest types are mangrove, freshwater swamp, lowland rain forest, riparian, and montane forests respectively.

The vegetation over any geographical area of Nigeria appears to be influenced by natural and anthropogenic factors. The climate and soil of geographical areas are the dominant natural factors identified as affecting vegetation (ARIAL, 2003). Since the climate of West Africa is highly influenced by the movement of the inter-tropical discontinuity (ITD), which spells the duration of rainfall and dry season at any location, it is also observed to have a direct influence on the vegetation patterns across the country (INADEV, 2000; ACMAD, 2008). In this regard, areas, which lie south of the ITD for most of the year, have predominantly higher rainfall than those areas which lie north of it for most of the year. The

Table 1. Forest cover annual change in kha: 1978, 1995 and 2000.

Forest type	Area occupied kha						
	1978	1995	Annual average change	% of area occupied	2000	Annual change	% of area occupied
Mangrove forests	999.4	997.7	-0.04	-0.004	996.40	0.18	-0.01
Freshwater swamp forest	1,831.6	1,649.9	-10.09	-0.61	1519.30	9.68	-1.42
Lowland rainforest	22,738.5	16,407.2	-351.74	-2.14	14,545.09	277.18	-2.46
Riparian forest	740.2	525.4	-11.93	-2.27	371.90	9.28	-6.88
Montane forest	676.2	675.9	-0.017	-0.003	675.69	0.037	-0.01
Total	26,985.9	20,256.1	-373.82	-1.85	18,656.55	296.36	-2.23

Source: Figures for 1978 and 1995 from FORMECU: Forest Resource Study by BEAK International Incorporated/GEOMATICS Nigeria Limited 1999. Figures for 2000 were projection made using GIS.

Table 2. Projected forest cover for 2000.

Forest formation	Land area cover 2000		Area deforested		% Deforested in forest formation
	(kha)	% of total	(kha)	% of total	
Mangrove forest	996.4	6	0.18	<0.01	0.01
Freshwater swamp forest	1,519.3	9	9.68	0.12	1.42
Lowland rainforest	14,545.1	80	277.18	1.97	2.46
Riparian forest	371.9	2	9.28	0.14	6.88
Hill and Montane	675.7	4	0.037	<0.01	0.01
Total	18,656.6	100	296.36	2.23	2.23

southward migration of the Sahara desert is also an important natural factor affecting vegetation cover. Of recent, the impact of desertification appears to be compounded by anthropogenic factors affecting desertification itself, making it difficult to resolve the natural influence from the anthropogenic influence. Hence rainfall associated with the north-south movement of the ITD is about the most dominant natural factors affecting vegetation distribution. Because rainfall is the predominant climatic factor affecting vegetation cover in Nigeria, the two key aspects of its variation usually used to quantify its impact are the gross annual rainfall amount and its seasonal distribution (Siyanbola et al., 2003).

Thus the progressive decline in total rainfall from the south to the north and the variation in the length of the wet season, vegetation belts are demarcated on west to east pattern characterized by transitional zones from one belt to another. Apart from desertification induced vegetation change, none of the natural factors is known to be able to induce significant changes in the vegetation patterns in a locality within periods of less than a few hundred years. In most cases, such changes may only be observed over many thousand years, except in cases of persistent extreme weather and climate events. Carbon flow patterns from biosphere into the atmosphere are therefore not usually significantly influenced by natural factors.

Anthropogenic activities affecting land use change and carbon flow pattern in Nigerian forests

Nigeria's tropical forests are known to be depleting fast, due, largely to uncontrolled human activities (Tables 1 to 3) driven by high population growth rates, poverty, accelerated food production and urbanization (ARIAL, 2003; Babanyara et al., 2010). The anthropogenic factors which drive land use change are primarily population pressure on land (that is, mean population per unit area), intensity of agricultural activities, rate of forest logging and other wood products extraction activities, urbanization and other major developmental activities. The percentage of relative contribution of these anthropogenic activities to deforestation in Nigeria is shown in Table 4 (Porter and Brown, 1996). It is a combination of these activities, which contribute to the gradual depletion of biomass affecting carbon flow pattern between the biosphere and the atmosphere in the forest estates. The actual activities leading to loss of forest include conversion of forests for subsistence and commercial agriculture, logging, fuel wood and other bio-fuels extraction, and the extractions of non-timber forest products for various uses. It is believed that the contribution of fuel-wood (including charcoal) consumption to tree stock decline in Nigeria forests is significant (Babanyara and Saleh, 2010). Fuel-wood

Table 3. Real forest cover from 1978 to 1995 and projection to 2040 in Km^2.

Year	1978	1995	2000	2010	2020	2030	2040
Total forest area	269859.4	202587	186565.5	158700.4	135593.6	116419.7	100497.2
Average total deforestation	-	-3389.06	-296.36	-2557.36	-2121.3	-1760.84	-1462.8
Lowland rainforest	22738.5.4	16407.24	14545.09	10820.8	7096.50	3372.21	-352.09
Rel annual change	-	-3178.49	-2887.79	-2383.72	-1967.64	-1624.19	-1340.68
Mangrove forest	9994	9964	9955.18	9937.53	9919.88	9902.24	9884.59
Rel annual change	-	-1.80	-1.79	-1.79	-1.79	-1.78	-1.78
Freshwater swamp	18316	16499	15964.59	14895.76	13826.94	12758.12	11689.29
Rel annual change	-	-101.50	-98.40	-92.55	-87.04	-81.87	-77.00
Riparian forest	7402	5254	4622.24	3358.71	2095.18	831.65	-431.88
Rel annual change	-	-107.15	-96.86	-79.14	-64.66	-52.83	-43.17
Montane forest	6762	6759	6758.12	6756.35	6754.59	6752.82	6751.06
Rel annual change	-	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17

Source: Siyanbola et al. (2003) Land use Change and Forestry Sector Report (2003) (NEST/CIDA). The negative figures indicate annual amount by which that particular forest type has been depleted.

Table 4. Relative activity contribution to deforestation.

S/N	Activity	Contribution (%)
1.	Commercial logging (selective and destructive)	20
2.	Clearing for subsistence agriculture	50
3.	Cattle ranching (Rangeland + pastoralism)	15
4.	Others (construction of dams, roads, mining, plantations, etc)	5
5.	Bush burning (forest fires)	10

Source: Porter and Brown (1996).

induced deforestation occurs as a result of overpopulation and the demand for wood as an energy source for cooking and space heating. Fuel-wood contributed 66% to the overall total energy consumption in Nigeria in 2000 (Akinbami and Ibitoye, 2003). This high demand makes extraction of wood as a fuel to outstrip the regeneration of forest cover.

METHODOLOGY

The first step to evaluating the carbon flow pattern in Nigeria's forests involves the determination of the changes in land area occupied by forests between 1976/1978 and 1993/1995. For this reason the study had to rely mainly on available secondary data relating to land use changes over the period of 1953 to 1976/1978 and 1993/1995. These two comparative periods were chosen in this study because the 1976/1978 Landsat MSS and 1993/95 SPOT XS, Landsat TM, ERS-1 radar, and JERS-1 radar are the latest land use pattern available presently in the country till date. The earlier version of land use pattern is that developed by ERGO (1994) which was based only on the Side-looking Airborne Radar data for 1981. Comparing these two documents was with the view to ascertain deforestation trend in the country's forest formations over the 17-year period for which satellite imageries were acquired. Land use change trend observed from these imageries enabled extrapolation of the deforestation rate to be done to year 2000, the base year for this study (Tables 1 to 3) using statistical technique, namely, forecasting approach. The study limits itself to year 2000 for two reasons. First, statistical extrapolation beyond 5 years of available may not lend itself to realities due to the assumptions that land use activities would remain at the same level for beyond five years. Secondly, the latest satellite imageries for Nigeria forest ecosystems available for this study is only for 1993/1995, and thus limited the scope of extracting land use change information for the country. Based on FORMECU (1999), the methodology simply looked at Nigeria forests as having witnessed three phases in the evolution of its management. These phases are: the reservation phase (1899 to 1930); the exploitation phase (1930 to 1960); and the development phase (1960 to the present). The next step was to evaluate the percentage contribution of each activity that had been identified to influence land use change in the country's forest formations, thus causing deforestation as shown in Table 4 (Porter and Brown, 1996).

This is then followed with the determination of emissions and uptake from each of the activities contributing to deforestation in each forest zones of the country using COPATH, a spreadsheet model developed by Makundi et al. (1991). COPATH is an acronym for Carbon Path Agriculture, Pasture, Harvest, and OTHER land uses. The emissions and uptake of each forest zone were then summed up to get the total national emission from forest zones as influenced by land use; projections of emissions and uptake of carbon were then projected based on the observed current land use trend. The impact of emissions from the land use and forestry on the atmosphere was the last evaluation done in this analysis. The impact was measured by looking at the difference between what was emitted due to forest depletion or removal and uptake by the forest due land use management which could be from natural

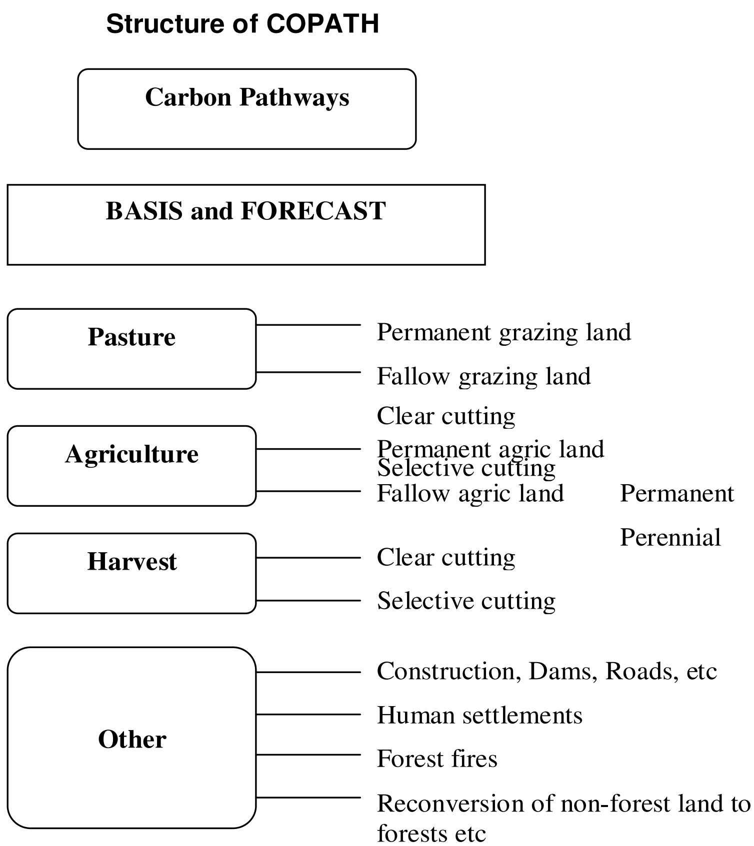

Figure 2. Structure of COPATH (Source: Makundi et al., 1991).

re-growth, reforestation or planting.

Detail description of COPATH

The description here is based on the work of Makundi et al. (1991). COPATH, as presented in Figure 2, is designed to calculate carbon flow pattern in any given forest type (life zone); the flow pattern being carbon emissions and sequestration based on connected spreadsheets. There are two modules in COPATH, namely, BASIS and FORECAST. In BASIS estimates of base year carbon stock, emissions and uptake can be made while in FORECAST, projection is made into the future. The summarized equation describing the model is given thus:

$$\sum_{i=1}^{n} N_{it} = \sum_{i=1}^{n} [R_{it} + d_{it} - U_{it}]$$

Where i = forest type, n = number of forest types in the country, and t = year of estimation.

BASIS takes specific information about a given forest and computes stored carbon (in the vegetation and soil), carbon emissions (released carbon) and sequestration (carbon uptake) for the base year which is 2000 in this case. Stored carbon is determined by computing destructive and inventory sampling data. (Destructive sampling data is computed from the product of the dry biomass density and the carbon content of the dominant species, or a weighted average of the most common species in the basal area. Destructive sampling is very scanty and tends to be concentrated in few medium moist life zones (Brown and Lugo, 1992). Inventory sampling data are the most common based on estimate of stem wood volume and provide a basis for estimating the total aboveground stem biomass. It is computed by estimating carbon stored in the vegetation and in soil (Makundi et al., 1991). The total amount of stored carbon represents the maximum carbon which can be released into the atmosphere from the vegetation during deforestation. This is in addition to a large amount of stored carbon in the soil that will also be released during the conversion. Determination of the ‘released carbon’ in BASIS is based on the fact that all four main land use conversion (agriculture, pasture, harvest and other land uses) have prompt and residual carbon releases into the atmosphere. Prompt carbon release which is the first stage, takes place during deforestation through biomass combustion and/or soil disturbance. The residual carbon release (second stage) occurs over a period of time through decomposition when the remainder of the biomass-based carbon is released. The amount of carbon released in each stage depends on the mode of forest conversion as well as the type of the biomass e.g. structural wood which may take more than 50 years to oxidize or newsprint which take less than 2 years to decay. The release from each land use conversion activity is computed separately, which are then summed up if more than one method is active for a given area. The amount of ‘carbon uptake’ depends on the type of vegetation which replaces the primary tropical forest after clearing and conversion to another land use type.

FORECAST takes information from the base year estimates and by applying various assumptions on the future states of the forest resources and consumption of forest products, it predicts the future

Table 5. Trend in deforestation rates as estimated for Nigeria's forests from various studies.

Source	Rate (%)	Annual amount (kha)	Total forested area (Mha)	Year of study
World resources institute	2.3	311	13.517 (as at 2000)	2003
FAO	2.55	400	13.517 (as at 2000)	2001
FORMECU	3.5	480	10.1 (as at 1990)	1996
GEOMATICS/BEAKS	1.85	129	20.26 (as at 1995)	1998
This study	2.23	296.4	18.65 (as at 2000)	2003

carbon emissions and uptake from the forestry sector. The 'net carbon release' is the sum of prompt release and emissions from annual decomposition, less the amount of sequestered carbon in the year under consideration. The prompt release mainly comes from combustion and soil disturbance while it is assumed that the soil carbon released in the year of deforestation. The residual biomass which is not carbonized is assumed to decompose over a known period of time with equal release every year. Therefore, the annual decomposition is a cumulative amount from all past years due for release in year t, while the decomposition is assumed to begin in year t+1. The 'carbon uptake' is derived from an assumed linear growth curve and assumed to begin in the base year. The estimate of future net release is based on the following factors, namely, knowledge of deforestation in the base year, the change of deforestation rate, growth rate of secondary vegetation, rotation age and decomposition period (Table 13).

RESULTS AND DISCUSSION

The results of carbon stock, emissions and uptake representing the carbon flow pattern for the various forest formations in the country as influenced by land use changes are presented.

Estimated deforestation rates in Nigeria

Figures vary as to the actual deforestation rate in the country as indicated in Table 5. FORMECU (1999) reported an average deforestation rate of 480 $khayr^{-1}$ or about 3.5%, but the methodology behind this estimate is not known. FAO estimated that an average rate of 2.55% of the forest cover in 1990 with an estimated area of almost 16 million hectares has been removed. In 1995, the forest cover was estimated by FAO to be 13.52 million hectares (FAO, 2001 FAO website). In the FORMECU report (1999), between 1978 and 1995 land designated as forests in Nigeria had declined significantly. Specifically, 2.2 million ha of the forest were converted, primarily to agriculture, during the period, representing an average yearly decrease of about 129 kha, which translates to an annual deforestation rate of about 1.85% over the 17-year period. World Resources Institute (2003) reported a loss of approximately 31,089 km^2 between 1990 and 2000, which translates to an average annual deforestation rate of 2.3% or approximately 311 kha per annum between 1990 and 2000. These values are for only those areas lost due to shifting cultivation, permanent agriculture, ranching, settlements, and infrastructure development; notably, it does not particularly state the areas of land loss due to fuel-wood gathering.

However, by the analysis in this study, it was estimated that the average annual deforestation rate between 1978 and 1995 projected to 2000, was 2.23% of the total forested areas estimated at 18.65 million hectares (Mha). The estimated deforested area for 2000 was 296.36 kha. The trend of deforestation in the forest formations shows that areas designated as mangrove have remained relatively constant. Similarly, areas of forested freshwater swamp remained relatively constant until 1990. However, since 1990, significant areas of forested freshwater swamp have been drained for agricultural purposes. As a result, areas of forested freshwater swamp have decreased from 2.1 million hectares (Mha) in 1990 to 1.8 million hectares (Mha) in 1994. Areas exposed to erosion/bare soil started to become more prevalent in 1986. From 1986 to 1995, there was a noticeable progression from areas dominated by trees and shrubs to bare soil. In the areas dominated by trees and shrubs, the trees and shrubs were removed, probably for fuel-wood, leaving behind the grasses. The remaining grasses were not able to stabilize the soils, which resulted in erosion. Consequently, grassland areas were converted to areas of bare soil. A summary of studies from some sources on deforestation trends is presented in Table 5.

In this paper it is shown that carbon emission was highest from harvesting activity in year 2000, principally from clear-cutting activity in the lowland rainforest as against that of 1990 study that showed agricultural activity as the major anthropogenic activity leading to carbon release into the atmosphere. Further, it is shown that the value of carbon emission is on the increase as compared to the earlier study with 1990 as the base year (Siyanbola et al., 1996). During the two periods of study, it was however observed that the relative contribution of each of the activities that are responsible for deforestation and affects carbon flow pattern in the forest zones and invariably causes carbon emission had not changed. Though a look at the fractional contribution of each of these activities in 2000 as against that of 1990 estimates shows a marked change. For instance, in 1990 it was estimated that agriculture contributed about 6.25 Tg or 63% of carbon emitted from the activity, but in 2000

Table 6. Area of forest type and stored carbon in different forest types for year 2000.

Forest formation	Area		Carbon stored	
	kha	%	GtC	%
Mangrove	9,964.0	5.34	0.1	3.86
Freshwater swamp	15,193.0	8.58	0.197	7.72
Lowland rainforest	14,545.09	79.92	2.14	83.77
Riparian	3,719.0	2.54	0.068	2.66
Montane	6,756.9	3.62	0.051	1.99
Total	186,565.50	100	2.55	100

Table 7. Percent contribution by land use activities for the different forests.

Variables	Mangrove	Freshwater	Lowland	Riparian	Montane	Total
Used area (kha)	0.18	9.68	277.18	9.28	0.037	296.28
Agriculture (%)	0.01	0.13	0.87	0.30	0.00	1.31
Pasture (%)	0.00	0.02	0.26	0.40	0.00	0.68
Harvesting (%)	0.01	0.44	0.61	1.20	0.00	2.25
Forest burning (%)	0.00	0.01	0.17	0.10	0.00	0.29
Dominant species	*Rhizophora*	*Nauclea vanderguchtii*	*Milicia excelsa*	*Uapaca spp.*	*Terminalia brownii*	
Carbon content	0.5	0.5	0.5	0.5	0.5	

contribution from agriculture was 3.96 Tg or 15% of carbon emitted. The trend of land use change and deforestation also shows that the potential of Nigeria becoming a net emitter of GHG in the future is high if the present land use trend particularly as affected by deforestation is not controlled. In 1990, study by Siyanbola et al. (1996) shows that total carbon emission from the land use and deforestation was 9.94 Tg and in 2000, it was estimated at about 26.77 Tg. The changes in values could be understood against the backdrop of the deforestation values of 205 kha for 1990 as against the value of 296 kha in 2000, a difference of about 44.6%. This difference in the estimates for the two studies could also be attributed to the fact that the present study draw from available local sources of information.

The trend observed with current human activities contributing to land use change, notably deforestation, in the country shows that it could be impacting seriously upon the climate especially through the release of carbon to the atmosphere. However, there is a need for further studies principally in the area data gathering and data validation, which will help to fine tune existing information as related to the studies of interactions between land use and climate change in the country. Also, raising public awareness and promoting understanding of the essential linkages between the communities living around forest locations and policy makers involved in environmental issues will help to sensitize the stake-holders to the importance of forests to its influence on the climate. This will enhance information dissemination amongst stakeholders, which will allow for better country-wide interfacing of issues that connects land use, forestry and climate change.

Carbon stored in the Nigeria forest life zones

Of the five categories of forest life zones, Lowland Rainforest occupies about 80% of the land area and contributing about 84% to the total carbon stock in the forest zones of Nigeria in year 2000. Total carbon stored was estimated to be 2.55 Tg[1]C as against the estimated value of 2.84 TgC in 1990. Table 6 presents detail of contributions from each forest life zone. Lowland Rainforest stored 83% of the total carbon sequestered for year 2000; Montane Forest formation stored the least with 1.99% contribution. Total carbon stored of 2.55 TgC was found to be about half of the carbon stored in the forests of Zaire (Makundi, 1998).

Uptake and release of carbon in Nigeria forest life zones

Percentage contribution to the overall land use activities leading to carbon uptake and emission is presented in Table 7. Agriculture, harvest, pasture and bush burning (referred to as forest fires in the COPATH) were very pronounced in their various contributions. In Mangrove forests, it is noticed that anthropogenic activities has not affected the formation significantly, even by the trend of

[1] 1 Tg of Carbon is equal to 10^{12}g of Carbon which is the same as 1 Gigatonne of Carbon

Table 8. Carbon uptake by land use activities in Nigeria: 2000.

Forest type	Gg of C				
	Agriculture	Pasture	Harvesting	Forest burning	Total Forest
Mangrove	0.04	0.01	0.34	0.00	0.38
Freshwater	0.82	0.07	10.11	0.00	11.01
Lowland	42.95	6.18	943.20	0.21	992.54
Riparian	15.14	0.15	15.46	0.00	30.75
Montane	0.00	0.00	0.03	0.00	0.03
Total activity	58.94	6.42	969.15	0.21	1,034.72

Table 9. Carbon release by land use activities in Nigeria: 2000.

Forest type	Gg of C				
	Agriculture	Pasture	Harvesting	Forest burning	Total forest
Mangrove	1.77	1.16	4.71	0.01	7.66
Freshwater	591.87	49.64	529.19	0.66	1171.36
Lowland	3330.49	1806.99	19369.21	98.23	24604.93
Riparian	36.55	88.14	857.75	1.80	984.24
Montane	0.20	0.28	0.42	0.00	0.89
Total	3,960.88	1,946.21	20,761.28	100.70	26,769.07

Table 10. Carbon flow pattern in nigeria forest life zones for year 2000.

Forest type	Land deforested (kha)	Gg of C		
		Carbon uptake	Carbon released	Net release
Mangrove	0.18	0.38	7.66	7.28
Freshwater	9.68	11.01	1,171.36	1,160.35
Lowland	277.18	992.54	24,604.93	23,612.38
Riparian	9.28	30.75	984.24	953.48
Montane	0.037	0.03	0.89	0.86
Total	296.36	1,034.72	26,769.07	25,734.35

deforestation observed for this forest type. Freshwater, Lowland Rainforest and Riparian forests show copious level of activities leading to land use change. In all, agriculture and harvest seems to have contributed the largest percentage of activities leading to forest removals. The increase in land area harvested for wood products is indicative of the new trend of increase in the tree species earmarked for selective cutting as against the former practice of only a few species in the past. Lowland Rainforest contributed the largest in absolute value of 277.18 kha of the total land deforested in 2000 as seen from Table 2. The effect of land use activities on the uptake and release of carbon as estimated in GgC for the base year 2000 are shown in Tables 8 and 9. Summary of these results are shown in Table 10 showing a net release of 25.7 TgC for the year 2000 from the forest life zones. Harvesting of wood leading to deforestation contributed the major portion to each of the resultant effect noticed from land use pattern, which is a major source of anthropogenic release of carbon flow pattern in the forests. It was also observed that need for agricultural land was a major cause for deforestation in these forests. In Tables 11 and 12 respectively are given the projected uptake and release of carbon in Nigeria's forest life zones from 2001 to 2040. As is the trend, activities transpiring in the Lowland Rainforest are expected to have the highest contribution to both the uptake (sink) and release (emission) of carbon from the forests due primarily to anthropogenic activities. In projecting emissions and uptake, the analysis assumed that land use change affecting the forests would follow the pattern of population growth rate of 2.9% average over the period of study. This is because, as earlier highlighted, population growth exerts pressure on land and thus affects land use change and forestry significantly, particularly for the purpose of supplying new areas for subsistence agriculture. Also, urbanization was observed to be on the increase, with an annual average growth rate of 3.7%. However, specific

Table 11. Cumulative carbon uptake from forest formations from 2000 to 2040.

Year	In MtC					Total cumulative
	Forest types					
	Montane	Freshwater	Mangrove	Riparian	Lowland	
2000	<0.010	0.01	<0.001	0.031	0.993	1.03
2005	<0.010	0.065	0.0023	0.176	5.680	5.92
2010	<0.010	0.117	0.0042	0.306	9.940	10.40
2015	<0.010	0.168	0.0061	0.425	13.80	14.40
2020	<0.010	0.218	0.0081	0.532	17.30	18.10
2025	<0.010	+0.265	0.0100	0.628	20.50	21.40
2030	0.0001	0.312	0.0119	0.716	23.40	24.50
2035	0.0001	0.357	0.0138	0.795	26.10	27.20
2040	0.0001	0.400	0.0157	0.866	28.40	29.60

Table 12. Cumulative carbon release from forest formations from 2000 to 2040.

Year	In MtC					Total cumulative
	Forest types					
	Montane	Freshwater	Mangrove	Riparian	Lowland	
2000	<0.001	0.06	<0.001	24.50	0.984	26.20
2005	4.09	1.22	0.013	51.80	106	164
2010	10.10	1.26	0.010	54.50	2.51	327
2015	16.40	1.29	<0.001	57.30	409	491
2020	23.50	1.33	<0.001	62.70	573	655
2025	30.00	1.37	<0.001	65.50	764	873
2030	40.90	1.41	<0.001	68.20	982	1090
2035	49.10	1.45	<0.001	70.90	1200	1340
2040	60.00	1.49	<0.001	76.40	1450	1610

Table 13. Net carbon release (MtC) from forest formations: 2000 – 2040.

Year	Total cumulative uptake	Total cumulative release	Net release
2000	1.03	26.2	25.17
2005	5.92	164	158.08
2010	10.4	327	316.6
2015	14.4	491	476.6
2020	18.1	655	636.9
2025	21.4	873	851.6
2030	24.5	1090	1065.5
2035	27.2	1340	1312.8
2040	29.6	1610	1580.4

contribution of household fuel-wood burning was not captured in this analysis.

CONCLUSION AND RECOMMENDATIONS

Despite significant contributions of Nigeria forests ecosystem to the well being of the country in terms of the economy and the environment, it is sad to note that our forests are rapidly "dying" without any visible remedial actions being taken. With an aerial cover of about 18 million hectares in 2000, the Nigerian forests have been an important source of wood for various industrial and construction purposes, and domestic fuel especially in form of firewood. This has happened from increasing population pressure, economic activities for development and primarily inadequate/neglected management practices necessary for sustainable maintenance of the forests.

These factors had led to rapid depletion of the forest resources and also degradation of the land. Data available from literature shows that as much as 250 kha of forests are being removed from Nigeria's forest annually. Other sources put this value at between 2.1 and 2.8% of the total forest cover of the country; whereas reforestation/afforestation is only being done at a rate of 20 kha per annum. Recent interactions with the experts on the field show that the situation is even worse now as indeed, deforestation from human induced activities is considered one of the most important current environmental issues in Nigeria.

The forestry sector is also a major contributor to both greenhouse gas emissions and carbon sequestration. The consequence of inadequate management of the country's forestry dual role is partly felt by the level of associated environmental problems particularly deforestation, which is responsible for desertification and savannaisation. It has also led to severe land degradation and soil erosion. This study estimates an annual deforestation rate of 2.23% or an aerial cover of 296.4 $khayr^{-1}$. With no let up of this rate, it is estimated that by 2040, lowland rainforest and riparian forests would have disappeared.

So that from analysis, the study concludes that carbon flow pattern in Nigeria forests is impacting negatively on climate change. To stem this trend, it is important that improved land use management be vigorously pursued, particularly for the forests. In order to achieve sustainable land use management regime to stem observed human activities which contributes to carbon emission to the atmosphere, the study recommends the need to increase research into the country's forestry ecosystems. Secondly, research output from these efforts should be disseminated to studied communities. This could be done through increased gown-town[2] interactions, particularly with the communities living around forest locations and policy makers involved in environmental issues to sensitize stakeholders to the importance of forests to its influence on the climate. With this synergy, it is expected that researchers arrive at more dependable values of estimated carbon emissions into the atmosphere from the forestry ecosystem. Thirdly, this will enhance information dissemination amongst stakeholders, which will allow for better interfacing of land use, forestry and climate change issues.

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[2] That is,fostering increased interactions between university/research institution involved in environmental studies and management on the one hand, and communities hosting forests – either natural or plantations on the other hand