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Carbon Sequestration Potential of Kpashimi Forest Reserve, Niger State, Nigeria

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Abstract

The neglect of renewable natural resource sector such as forest resources is one of the major factors fuelling the continuous economic stagnation in Nigeria. This study provides an analysis of carbon storage and the potential to increase carbon stocks in the Kpashimi Forest Reserve, Niger state, Nigeria. Carbon density values for vegetation communities were estimated based on data collected in forty-eight randomly selected400 square metre plots covering the Kpashimi Forest Reserve. Tree biomass was estimated from diameter at breast height (dbh) measurements and allometric equations, while deadwood, litter and herbaceous vegetation biomass were quantified using destructive sampling. Soils were sampled using core rings and organic carbon were analysed using dry combustion technique. Four satellite imageries TM, SPOT, ETM+, and NIGERIASAT-1 of 1987, 1994, 2001 and 2007 respectively were used to estimate vegetation cover dynamics and the influence of vegetation cover change over 20 years period on forest carbon stocks. The average carbon stock density (Mg C/ha) of the vegetation communities was in the decreasing order; Riparian forest (123.58 ± 9.1), Savanna woodland (97.71 ± 8.2), Degraded forest (62.92 ± 6.1), Scrubland (36.28 ± 4.1), Grassland (18.22 ± 5.1), and bare surface (9.31 ± 3.1). Deforestation and forest degradation between 1987 and 2007 with limited reforestation have resulted in a net loss of about 240 mega tons of carbon (881.5 Mg tons of CO_2emission). This loss occurred at the rate of 12.01 mega tons of carbon (44 Mg tons of CO_2emission) per annum. The distribution of carbon densities within the forest reserve and variation between vegetation coverclasses suggests that restoration management practices could increase Kpashimi Forest Reserve carbon stock back to speculated 1987 levels and even higher.

Keywords: Carbon stock, Sequestration, forest reserve, deforestation, degradation

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1.1 Introduction

Recent recognition of the importance of land use change in the carbon cycle, and the commitment to include reduced emissions from deforestation and degradation (REDD) in the post-2012 agreements of the UNFCCC, has raised the policy relevance of carbon storage in terrestrial ecosystems(Brown, 1997; Houghton, 1997; Watson *et al*., 2000). Research has traditionally focused on the role of ecosystems as carbon sinks, rather than as potential sources(Houghton *et al.*, 1995), but the importance in climate change mitigation of protecting the existingcarbon stocks is becoming increasingly recognised(Brown and Gaston, 1995; Cao *et al*. 2001).

Forest clearance results in emission of about 20% of total global emissions of carbon dioxide (CO_2) tothe atmosphere (IPCC 2007). Consequently, reducing forest loss is of crucial importance for climate change mitigation. Recognizing that protected areas are one potential tool for achieving these emissions reductions, it is pertinent to understand the extent and capacity to which protected areas are subjected to land use change, and whether enhancing the effectiveness of their management could contribute to reducing emissions from deforestation and forest degradation.

Protected areas, which are by definition designated with the primary aim of conserving biodiversity, generally constitute legal restrictions on land use change, and potentially play an important role in maintaining terrestrial carbon stocks. It has been estimated that globally, ecosystems within protected areas store over 312 Gt carbon or 15% of the terrestrial carbon stock (Campbell *et al.* 2008a). Despite their legal status, designation of protected areas does not ultimately guarantee protection of the ecosystems they contain. Recent research indicates that whilst protected areas generally reduce deforestation relative to unprotected areas, they arenot entirely free from land use change within them (Clark *et al*. 2008). Therefore, it is important to understand the extent and rate at which protected areas are affected by land use change, and the degree to which improving the effectiveness of existing protected areas could make an effective contribution to reducing emissions from deforestation and forest degradation.

Forestry based carbon offset projects have the potential to act as both a climate change mitigation tool and a means of fostering sustainable forest preservation.

While modelling has provided positive assessments of the potential for African tropical forests to sequester large amounts of carbon, the lack of localized field studies has limited the feasibility of initiating biotic carbon emissions offset projects in many of the continents threatened forests.

This study aims to assess carbon sequestration potential in the Kpashimi Forest Reserve. The objectives of the study includes to:

1. determine vegetation cover dynamics associated with various plant communities in the forest reserve over 20 years period.
2. determine the carbon stock density of the forest reserve.
3. determine carbon stock changes in the forest reserve between 1987 and 2007.
4. determine the capacity for the forest reserve to sequester carbon.

Good Practice Guidance for LULUCF activities requires carbonstock changes to be estimated in an unbiased, transparent,and consistent manner, where uncertainties are determined andrecorded over time (IPCC, 2003). Nigeria ratified the Kyoto Protocol and the United NationsFramework Convention on Climate Change (UNFCCC). Consequently, net carbon stocks in each foresttype in Nigeria need to be assessed for reporting under KyotoProtocol.This study provides a preliminary assessment of the biophysical potential for carbon sequestration. Such an assessment is required by Nigeria under the United Nations Framework Convention on Climate Change and as a baseline for participation in the Clean Development Mechanism of the Kyoto Protocol to the convention.

The conceptual framework of the study is based on stock difference approach (IPCC, 2003) in which the amount of carbon sequestration is estimated as the net change in carbon stocks over time.

$$\Delta C = (C_{t2} - C_{t1}) / (t_2 - t_1)$$

Where:

ΔC = Annual carbon stock change in pool (tC/yr)

ΔC_{t1} = Carbon stock in pool at time t_1 (tC)

ΔC_{t2} = Carbon stock in pool at time t_2 (tC)

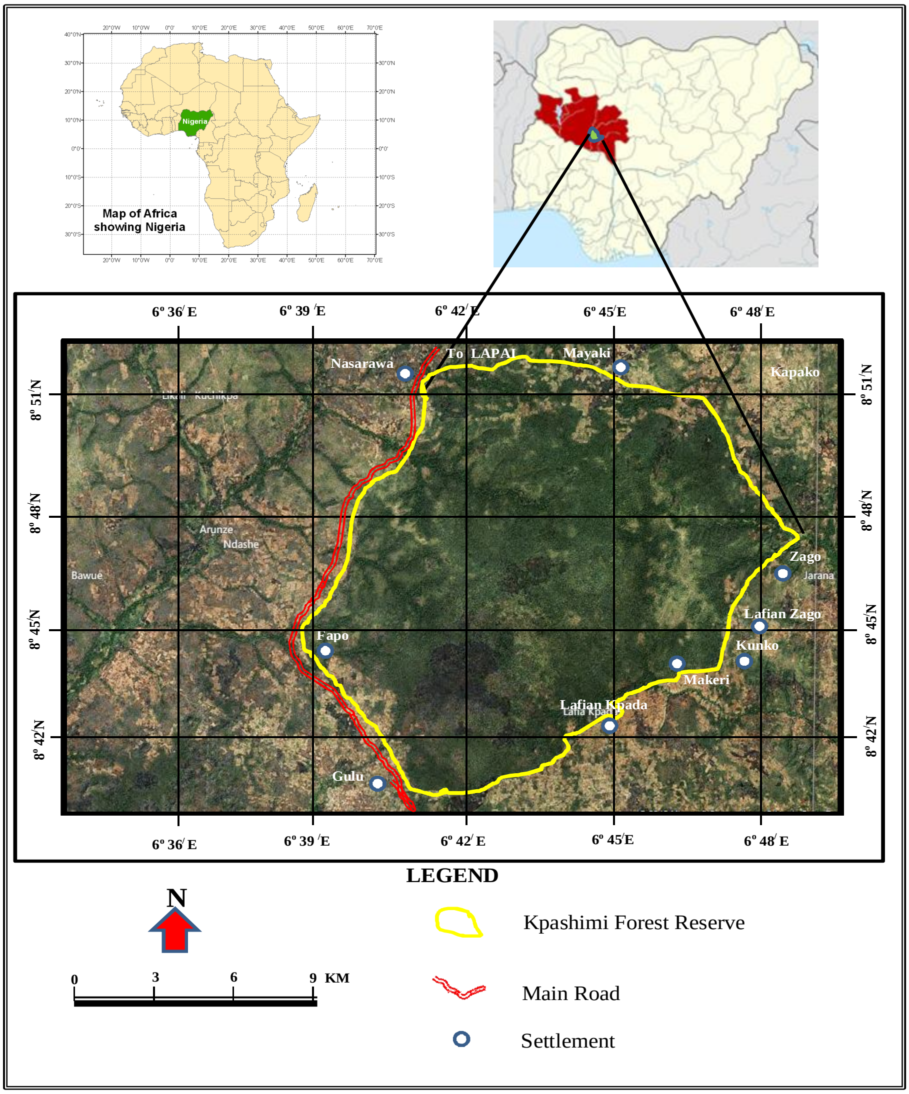
The stock difference approach implies that the total amount of carbon stored in a region is increased by increasing the area covered by a carbon dense cover type, that is, the amount of carbon sequestered is estimated as the net change in carbon stocks over time (Iverson *et al*. 1993). Thus this study is based on the carbon stock change approach.

2. Materials and Methods

2.1 Study Site

Kpashimi Forest Reserve is located on latitude 8° 38**'** to 8° 52**'** North and 6° 34**'** to 6° 48**'** East covering approximately 213.101 kilometres square (Figure 1). The study area lies within the tropical hinterland (tropical rainy climate with dry season) climatic belt of Nigeria; characterised by alternating wet and dry season coded as 'Aw' by Koppen's classification. The mean annual rainfall is about 1,300 mm with mean annual temperature of about 28°C (Ojo, 1977). The geology of the study area is made up of cretaceous sedimentary rocks underlain by the Precambrian basement complex rocks (FORMECU, 1994). The topography is gently undulating, sloping generally towards different directions in different locations. Soils in the study area based on the CCTA (Commission de Cooperation Technique en Afrique) classification system belong to *ferruginous tropical soils.* In some depressional areas, and valley bottom positions *hydromorphic* soils are found; while those around the inselbergs and other residual hills, and at the bed of rivers, are *weakly developed* (Areola, 1978; Jaiyeoba&Essoka, 2006). The study area lies within the southern Guinea savannah zone classified as woodland savannah vegetation with the understory dominated by annual grasses (Keay, 1953; Jaiyeoba&Essoka, 2006).

Figure 1. Map Showing the Location of Study Area



Source: Niger State Forest Management Unit.

2.2 Sampling Design

In line with recommended practice in carbon stock inventory, the sample size for the study was determined by the estimation of variation of tree stocking; as the variance of the dominant carbon pool captures most of the variance (Brown, 1997; MacDicken, 1997; IPCC, 2003; and FAO, 2008). During the reconnaissance/pilot survey conducted prior to detailed field data collection, 15 randomly laid out samples plots (250 m^2 with 8.92 m radius) were distributed to cover all possible variation in the study area (IPCC, 2003). The mean and the standard deviation of the plot tree basal areas were calculated and the number of sampling units (n) was calculated using the formula:

$$n = \frac{CV^2 t^2}{E^2}$$

Where:

CV = is the coefficient of variation of tree basal area at breast height
t = is the t value for the 95% confidence interval.
E = is the allowable sample error of estimation.

The number of sampling units (n) required to attain a desired precision at sampling error (E) of 10% at 95% confidence level was calculated to be 48 plots for the study area.

2.3 Vegetation Cover Classification and Change Detection

The study made use of satellite imageries TM, SPOT, ETM+, and NIGERIASAT-1 of 1987, 1994, 2001 and 2007 respectively. The images were rectified, transformed, enhanced and classified using Maximum Likelihood Classification algorithm by the extraction of Normalised Difference Vegetation Index (NDVI) based on supervised classification. Sampling was performed in the six cover types identified on the maps: savanna woodland, riparian forest, degraded forest, grassland scrubland and bare surface. In the Arc GIS environment, the vegetation cover classes were identified. Eight pixels were randomly selected from each of the vegetation classes on the imagery; and their coordinates recorded. Selected points were determined to the nearest minuit.

All plot positions were recorded using a GPS unit and later geo-referenced to the land cover maps. Plots were generally assigned to a cover class by their geo-referenced location. A post classification change detection was carried out based on the four imageries pixels per area coverage.

2.4 Field Data Collection

Carbon density was estimated based on data taken in fourty-eight 20x20m sample plots for six carbon storage pools: live tree aboveground biomass, tree belowground biomass, coarse deadwood (≥ 10 cm diameter), litter, herbaceous vegetation, and soil (Brown, 1997; MacDicken 1997). All samples were taken between 2nd September and 15th October, 2013.

Aboveground biomass of the individual trees was estimated from stem diameter at breast height, of 1.3 m by employing published generic allometric equation for dry topics by Brown *et al,* (1989).

$$AGB = \exp\{-1.996 + 2.32 * \mathrm{Ln}(D)\}$$

Where:

Ln means “natural log of (…)”
AGB = above-ground biomass in kg
DBH = diameter at breast height (1.3 m)

Belowground biomass was calculated as a proportion of aboveground biomassusing anallometric equation derived for tropical trees by Cairns *et al.* (1997).

$$RBD(t/ha) = \exp\{-1.0587 + 0.8836 \times \ln(AGB\ t/ha)\}$$

Where:

RBD = Root biomass density in tons/hectare (t/ha)
AGB = above-ground biomass density in tons per hectare (t/ha)

Dead wood biomass was estimated using the line-intersect method (IPCC 2003). The diameters of all pieces of wood > 10cm that intersect the line were measured, and debris is organised into three density classes: rotten (fully decomposed), intermediate (partially decomposed), and sound Thebiomass density of this deadwood was calculated. The volume per hectare was estimated for each density class as follows (Brown 1974; Harmon and Sexton, 1996; IPCC 2003):

$$Volume\ (m^3/ha) = \pi^2 * \left(\frac{d_1^2 + d_2^2 + \dots d_n^2}{8 * L} \right)$$

Where: $d1$, $d2$, ...,dn= Diameters of intersecting pieces of dead wood (cm);
L = Length of the line; meters

Finally, the biomass of dead wood was calculated by the formula:
$AGB_{WD} = \varrho V*_{WD}$

AGB_{WD}: aboveground biomass of woody debris (Mg/ha)
ϱ : wood density of downed woody debris (g/cm3)
V_{WD} : volume of woody debris per unit area (m^3/ha)

Clip plots were used to measure understory vegetation and litter biomass (MacDicken, 1997). At each corner of the 20m x 20m inventory plot a 1 x 1 m subplot was established and all understory vegetation in the four subplots was cut and placed in a weigh bag. The wet weight was recorded, the sample was well mixed, and a 200g sub-sample was taken, oven dried and reweighed. The wet to dry weight conversion of the subsample was used to estimate total dry weight for herbaceous vegetation. This same procedure was followed for litter which was collected in each clip plot after herbaceous vegetation was removed.

To analyse moisture content, all sub samples (undergrowth, dead wood and litter) collected from the field were transported to the laboratory, and each sample was oven dried at 85 °C constant-temperature. Oven-drying takes 2 days for leaves and wood under 10 cm in diameter, while 4 days wood over 10 cm in diameter. After drying, conversion ratios between the oven-dry and fresh weights were calculated using the formula below:

$$DW_W = \frac{DW_S}{FW_S} \times FW_W$$

where,

DW_W : whole dry weight
DW_S : dry weight of sample
FW_W : whole fresh weight
FW_S : fresh weight of sample

Soils were sampled in the same subplots as herbaceous vegetation and litter. After the vegetation and litter was removed, soil samples were subsequently collected from the soil depth of 0 to 15 cm and 16 to 30 cm within the quadrats, air dried and sieved through 2.0 mm mesh, and then texture and organic C content determined. Accompanying bulk density samples were collected from the same soil depths. The undisturbed soil samples were used for the bulk density determination. Soil organic C was analysed in the laboratory by Walkley and Black (1934) method. The bulk density was determined from oven-dried core samples at 105°C for 24 h. Soil C per hectare was calculated from the organic C content and the bulk density.

Average carbon density estimates for the sampled land cover classes were calculated by aggregating contributions from all measured carbon pools. It was assumed that 50% of vegetative biomass was carbon (MacDickon 1997; IPCC, 2003) allowing carbon densities (Mg C /ha) to be calculated from biomass densities found in each plot. The mean plot carbon density was found for a land cover class in each carbon pool and the sum of the pool means was taken to be the average carbon density for the class. Calculated cover class averages were applied to the entire area of that land-cover class to calculate total carbon storage in the forest reserve at specific times.

3. Results and Discussion

3.1 Vegetation Cover Dynamics

Table 1 indicates that in 1987, Savanna woodland constitutes 34% of the vegetation cover but eventually decreased persistently to 18% in 2007.

On the other hand, Degraded forest increased persistently from 21.8% in 1987 to 32.4% in 2007. It is also evident that while the area coverage of Bare surface, Degraded forest and Scrubland are on the increase, that of the Savanna woodland and Riparian Forest were on the decline. Exceptionally, Grassland coverage experienced an increase between 1987 and 2001 but eventually declined between 2001 and 2007. It is also observable that in the last seven years of the study period (between 2001 and 2007), Riparian forest and Savanna woodland coverage increased marginally; implying that the rate of forest degradation slowed between 2001 and 2007 and this may be attributed to intensified monitoring and conservation efforts of the management unit.

Table 1 : Area Coverage of the Vegetation Communities Over the Examined Period

Vegetation Communities	**1987**		**1994**		**2001**		**2007**	
	Area(ha)		Area(ha)	%	Area(ha)		Area(ha)	%
Bare surface	2311.78	**10**	2441.36	**10.6**	2888.80	**12.5**	3237.84	**14**
Grassland	2247.18	**9.7**	3787.73	**16.4**	4753.58	**20.6**	2623.48	**11.3**
Scrubland	2467.03	**10.7**	2115.23	**9.1**	2075.35	**9**	2971.76	**12.8**
Degraded Forest	5032.32	**21.8**	6007.11	**26**	7356.85	**31.8**	7480.38	**32.4**
SavannahWoodla	7930.30	**34.3**	6266.58	**27.1**	3845.02	**16.6**	4148.28	**18**
RiparianForest	3132.44	**13.5**	2503.04	**10.8**	2201.45	**9.5**	2659.31	**11.5**
TOTAL	23121.05	**100**	23121.05	**100**	23121.05	**100**	23121.05	**100**

It is obvious that in spatial context, as illustrated in Figure 2 that while Degraded forest, Bare surface and Scrubland had more expansion between 1987 and 2001, Savanna woodland and Riparian forest experienced more shrinking. Savanna woodland recorded the highest change by 47.7%, followed by Riparian forest 15.1%. Consequently, deforestation and forest degradation in the study area would have resulted in much carbon emission over the period under study.

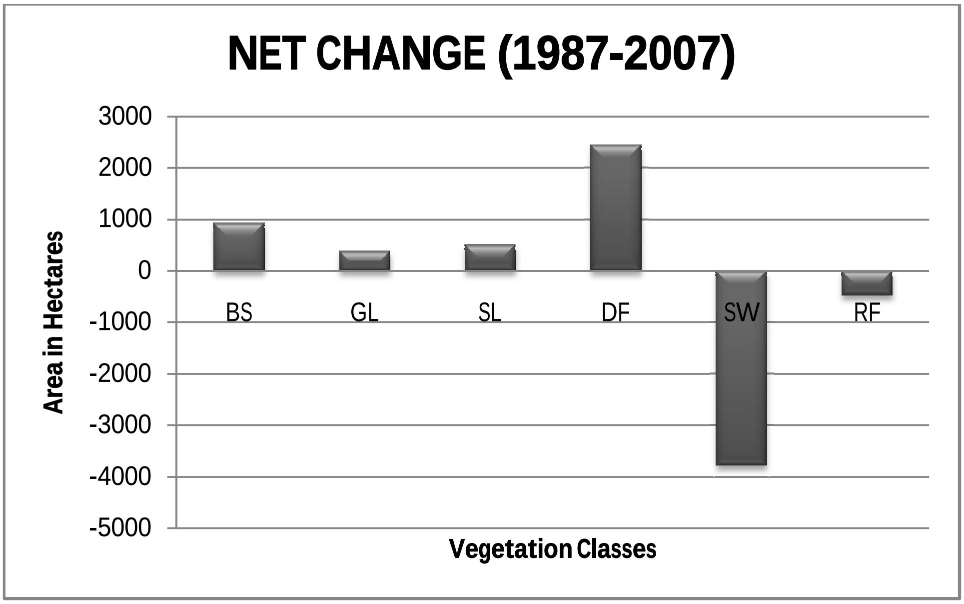


Figure 2: Net Change between 1987 and 2007

3.2 Carbon Stock Densities of Vegetation Communities

Analysis of Carbon stock in the respective pools shows that the soil carbon pool dominates with highest stock values across the vegetation communities; while the least stock values were recorded for the litter pool. Carbon stock density of the vegetation communities was in the decreasing order; (see Table 2) Riparian forest (123.58 ± 9.1), Savanna woodland (97.71 ± 8.2),Degraded forest (62.92 ± 6.1), Scrubland (36.28 ± 4.1), Grassland (18.22 ± 5.1), and bare surface (9.31 ± 3.1).

Table 2: The Carbon Stored in Each Carbon Pool Sampled Andthe Total Carbon Storage for Each Vegetation Community (Mg C Ha^{-1})

Carbon pools	Savanna Woodla	Riparian Forest	Degraded Forest	Scrubland	Grassland	Bare Surface
Tree	19.83	25.08	12.77 ± 6.5	7.36	3.70 ± 2.3	1.89
Root	8.01	10.13	5.16	2.97	1.49	0.76
Under Growth	2.62	3.31	1.69	0.97 ± 0.8	0.49	0.25
Dead Wood	3.27	4.14	2.11	1.21	0.61 ± 0.4	0.31
Litter	2.55	3.23	1.64	0.95	0.48	0.24
Soil	61.43	77.70	39.56	22.81	11.45	5.85
Total	**97.71**	**123.58**	**62.92**	**36.28 ± 4.1**	**18.22**	**9.31 ± 3.1**

3.3 Changes in Carbon Stock and Sequestration Potential

Extrapolating the mean carbon density of each cover class to the entire area of that cover class in the year 2007 yielded an approximate total carbon storage of 1390.4 Mega tons of carbon; which is comparatively lower than the baseline of 1630.6 Mega tons of carbon (see Table 3). This suggests incidence of carbon loss due principally to emission from deforestation and forest degradation. A total loss of 240.2 Mega tons of carbon was incurred at an annual rate of 12.01 Mega tons of carbon.

Table 3: Total Carbon Stock (Mg C ha^{-1}) Under the Various Land Cover

Vegetation Communities	Mean Carbon Stock (Mg ha^{-1})	Area (Hectare)		Carbon Stock (Million tons ha^{-1})		
		1987	2007	1987	2007	Change
Savanna Woodland	97.71	7930.3	4148.28	774.9	405.3	-369.5
Riparian Forest	123.58	3132.44	2659.31	387.1	328.6	-58.5
Degraded Forest	62.92	5032.32	7480.38	316.6	470.7	+154.0
Scrubland	36.28	2467.03	2971.76	89.5	107.8	+18.3
Grassland	18.22	2247.18	2623.48	40.9	47.8	+6.9
Bare Surface	9.31	2311.78	3237.84	21.5	30.1	+8.6
TOTAL				1630.6	1390.4	-240.2

Vegetation cover changes between 1987 and 2007 may have resulted to decrease of 240.2 Mega tons of carbonstock in the forest reserve; which is equivalent to emission of 881.5 Mg tons of CO_2 at an annual rate of 44 Mg tons of CO_2. Based on the theory of "the stock-difference approach," in which the total amount of carbon stored in a region is increased by increasing the area covered by a carbon dense cover type,the regeneration of proportionate hectaresof forest reserve would result in sequestration of same 240.2 Mega tons of carbon; which indicates the carbon sequestration capacity of the reserve.

This study illustrates that forestry based carbon offset projects can be effective in mitigating global carbon emissions from land use change and wood consumption if they collectively cover large areas. However, every individual project is implemented on a local scale and local factors would inevitably determine its success or failure (Brown, 1997; Houghton, 1997; Watson *et al*., 2000). For instance, Jibrin*et al* (2013) posited that sustainable carbon offset projects depends not only the biophysical potential of an area to sequester more carbon, but also on the project's ability to account for the needs of the area's inhabitants and other stakeholders.

Findings from this study also confirm previous research (e.g. Campbell 2008a; Campbell 2008b Clark *et al*. 2008) which indicate that whilst protected areas generally reduce deforestation relative to unprotected areas, they do not entirely eliminate carbon stock change within them. Furthermore, considering Clark *et al.* 2008 findings that protected areas designated under categories I-IIseem to be more effective at reducing deforestation than those which include a focuson sustainable use (V-VI), carbon emission would be not be ruled out from Kpashimi Forest Reserve which falls in to IUCN management category VI. Thus, conservation effectiveness in the study area needs to be strengthened.

4. Summary and Conclusion

This work demonstrates the potential role of protected areas in climate change mitigation and will be a useful input to current discussions on a mechanism for reducing emissions from deforestation (REDD) under the UN Framework Convention on Climate Change (UNFCCC), or any other mechanism for protecting carbon stored within ecosystems.The study shows that the carbon sequestration potential Kpashimi forest reserve could be achieved through restoration of degraded parts of the forest reserve.

The results of this study revealed potential for further carbonsequestration in the Kpashimi forest reserve as a “carbon sink,” as illustrated by the considerable differences in carbon densities both between land cover classes and over the time period.Carbon storage can be altered by transitions between land cover types of different carbon densityand this was seen in the land cover transitions between 1987 and 2007 which resulted in a net loss of about240 mega tons of carbon. In theory, carbon storage in theforest could be increased from current levels by at least this amount by restoring the historical vegetation cover pattern. There is therefore, a great need to analyse carbon offset feasibility in the study area and to make itenough flexible to adapt to the regional, national and local constraints.

References

Areola, O. (1978).Soil and vegetation resources of Nigeria. In Oguntoyinbo et al. (Eds.), A geography of Nigerian development. Heinemann Education Books Nigeria Limited.

Brown, S & Gaston, G., 1995.Use of forest inventories and geographic information systems toestimate biomass density of tropical forests: application to tropical Africa. Environmental Monitoring and Assessment, 38, pp. 157-168

Brown, S., Gillespie A. and Lugo A.E. (1989). 'Biomass estimation methods for tropical forests with applications to forest inventory data' In: Forest Science. 35 881–902

Brown S., 1997. Estimating Biomass and Biomass Change of Tropical Forest: a Primer. Rome: Food and Agriculture Association of the United Nations (FAO)

Cairns, M.A., Brown, S., Helmer, E.H., Baumgardner, G.A. (1997). 'Root biomass allocation in the world's upland forests' In: Oecologia 111: 1-11.

Campbell, A., Miles. L., Lysenko, I., Hughes, A., Gibbs, H. (2008a). Carbon storage in protected areas: Technical report. UNEP World Conservation Monitoring Centre.

Campbell A., Kapos V., Lysenko I., Scharlemann J.P.W., Dickson B.,Gibbs H.K., Hansen M., Miles L. (2008b).Carbon emissions from forest lossin protected areas. UNEP World Conservation Monitoring Centre.

Cao MK, Zhang QF, ShugartHH., 2001. Dynamic responses of African ecosystem carbon cycling to climate change. Climate Research 17 (2, Special Issue), pp.183-193

Clark, S., Bolt, K., Campbell, A. (2008) Protected areas: an effective tool to reduce emissions from deforestation and forest degradation in developing countries? Working Paper, UNEP World Conservation Monitoring Centre, Cambridge, U.K

Clark DB, Clark DA, Brown S, Oberbauer SF, Veldkamp E., 2002. Stocks and flows of coarse woody debris across a tropical rain forest nutrient and topography gradient.Forest Ecology and Management.164 (1-3), pp.237-248

Food and Agricultural Organization, 1999.State of the World's Forests.Rome: United Nations Food and Agricultural Organization.

FORMECU (1994). Forest Management Evaluation and Co-ordinating Unit (1994) World Bank/Government of Nigeria Forestry III project Vol. VI Environmental Assessment, Forest Management Component, kpashimi Forest Reserve, Final Draft.

Harmon, M. E. and J. Sexton. 1996. Guidelines for Measurements of Woody Detritus in Forest Ecosystems. US LTER Publication No. 20.US LTER Network Office, University of Washington, Seattle, WA, USA.

Houghton, J. et al. 1995,.Climate Change 1995: The Science of Climate Change: Contribution of Working Group 1 to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press

Houghton, J., 1997. Global Warming: the Complete Briefing. 2ed. Cambridge: Cambridge University Press.

Houghton, R. A., Lawrence, K. T., Hackler, J. L., and Brown, S. 2001. The spatial distribution of forest biomass in the brazilian amazon: a comparison of estimates. Global Change Biology, 7(7):731-746

Houghton, R. A. 2005. Tropical deforestation as a source of greenhouse gas emissions. In: Tropical Deforestation and Climate Change (eds. Moutinho, P.,Schwartzman, S.). IPAM, Belem

IPCC (2000).Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Penman J., Kruger D., Galbally I., Hiraishi T., Nyenzi B., Emmanuel S., Buendia L., Hoppaus R., Martinsen T., Meijer J., Miwa K., Tanabe K. (Eds). Intergovernmental Panel on Climate Change (IPCC), IPCC/OECD/IEA/IGES, Hayama, Japan.

IPCC, 2007. Climate change 2007. The Physical Science Basis. Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

IPCC, (2003).Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF).Intergovernmental Panel on Climate Change. Institute for Global Environmental Strategies, Kanagawa, Japan.

Iverson, L.R., Brown, S., Grainger, A., Prasad, A, Liu, D. 1993. Carbon sequestration in tropical Asia: an assessment of technically suitable forest lands using geographic information systems analysis. Climate Research, 3, pp.23-38.

Jaiyeoba, I. A., &Essoka, P. E. (2006). 'Soils and Vegetation' in The Middle Niger River Basin: A field course hand book. Department of Geography, Ahmadu Bello University, Zaria.

Jibrin, A., Musa, I.J., Abdulkadir, A.,Yisa, C.L., and Kaura, S.J., (2013) 'Towards harnessing forestry-based carbon sequestration potentials in Nigeria: Costs and Benefits' In: Nigerian Geographical Journal, Volume 9 No. 1 Pp 40-54, Abuja.

Keay, R.W. J. (1953). An outline of Nigerian Vegetation (2nd ed.). Lagos: Government Printed.

MacDicken, KG., 1997. A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects.Winrock Institute for Agricultural Development.

Ojo, O. (1977).The climates of West Africa. London: Heinemann.

Watson, R. et al., 2000. IPCC Special Report on Land Use, Land-Use Change and Forestry.Cambridge: Cambridge University Press