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Full Length Research Article

ANALYSIS OF MANGROVE FOREST RESOURCES IN NIGERIA FOR STATE SPECIFIC RESTORATION POLICY

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ABSTRACT
Globally, mangrove forest covers approximately 84,000km^2 in 105 countries. In Nigeria, mangrove forest cover an area of 10,500km^2 making it the largest in Africa and the third largest in the World. Mangrove is important as a source of construction, energy and industrial raw materials as well as ecosystem services. Despite these benefits,, there have been large scale degradation of the mangrove forests across the globe. Mangrove forest resources in Nigeria were analyzed for the dynamics in aerial extent with the aim of providing scientific evidence for the adoption of state specific restoration policies. Spatial datasets of national and sub national mangrove forest were disaggregated from the global mangrove forest datasets using Spatial Analysis module in ArcGIS 10.6. Results of the analysis showed that in 1996; Bayelsa, Delta and Rivers states had the largest mangrove forest resources (40.94%; 25.30 % and 25.12%) while, Lagos, Ondo and Edo had the least (0.46%, 0.37% and 0.28%) respectively. However by the year 2016; Bayelsa, Rivers and Delta had 40.76%; 25.37% and 25.22%. Whereas Lagos, Edo and Ondo had 0.44%, 0.28% and 0.26% respectively. Between 1996 and 2016, Bayelsa, Delta and Rivers states have lost 8,274 ha 4,824 ha and 2,281 ha of their mangrove forests at the rates of 413.7; 241.2 and 114.1 ha/annum respectively. The variation in the annual rate of loss in mangrove per state gave indications for the need of state specific mangrove restoration and protection policies at sub national levels.

Keywords: Ecosystem Services; Mangrove Forest Resources; States – Specific Restoration Policies; Spatial Analysis

INTRODUCTION
Mangroves are diverse group of tree, shrub, and fern species growing on anoxic and saline peaty soils (Ellisson, et. al., 2020). Estimates of the global mangrove forest by Hamilton and Casey, 2016 indicated an area extent of approximately 84,000km^2 in 105 countries. Of the mangroves found in 105 countries (Hamilton and Casey, 2016), the South East Asia Caribbean and Brazil account for over 50% of the global mangrove forests (Hamilton and Friess, 2018) Nigeria with an estimated mangrove area of 10,515km^2(5.8% of global mangrove area) is the African largest and World third largest (Ibianga, 1985; Spalding 1997). Mangrove ecosystem and particularly Nigerian mangrove (Oyieke, 1996) has one of the highest diversities and productivity in the world (Faridah-Hanum and Salleh, 2018) given high litter fall causing high microbial activities (Numbere and Camilo, 2017) which is contributing about 25% of global biological productions (Oyieke, 1996) and primary productivity (24 tons/ha/year) (Udoh, 2016). Carbon sequestration by the mangroves is significant in mitigating against climate change (Donato, *et al.*, 2011; Patil, *et al.,* 2012; Alongi, 2014; Adame *et al.,* 2018). For instance, Atwood *et al.*, 2017; Hamilton and Friess, 2018, found that the global mangrove has the potential to sequester a total of 4.19 × 10^{9}tCof which approximately 0.62 ± 0.13 % are stored at the depth of 1 m in soils and another 0.29 ± 0.01% in the living biomass (Hamilton and Friess, 2018).

Mangrove equally helps in coastline defence and protection against sea-level rise, storm surges, strong winds, wave attenuation, drainage and erosion (Horchard *et al.,* 2019; Kathiresan and Rajendran, 2005; Van Maanen, 2015). Mangrove act as a sink for pollutants, because mangroves have capacities to absorb and retain heavy metals thus preventing them from circulating in the ecosystem (Connolly, *et al.,* 2020). More so, mangrove trees are harmed with tough giant adventitious rooting system which are often coated with algal growth thereby shielding them from exposure to persistent pollutants (Parida and Jha, 2010; Rahmania *et al.,* 2020). Mangrove parts (root, stem, leaf and seed) can be used in attenuating pollutants load in the soil thus helping in pollutants assimilation (Tam and Wong, 1995; Numere, 2021).
Other ecosystem services derivable from the mangroves include water filtration and treatment, natural habitats and breeding grounds for aquatic organisms (Millennium Ecosystem Assessment, 2005). Mangrove forests are also important for provision of logs, fuel wood, charcoal, wood-chips, scaffold poles, construction materials and paper pulp (Chow, 2018), stakes for fish traps, fishing platforms, railway sleepers, wood for making furniture, carvings, materials for roof thatching, medicinal products, sugar, alcohol, acetic and tannin / natural dyes (Ellison, 2008; Chow, 2018); shellfish and finfish (Carrasquilla-Henao *et al.,* 2019). More so, mangroves provide livelihoods through increased fish catches (Das, 2017), medicinal herbs, recreation and spiritual benefits to the residents in the local communities (Spalding and Parrett, 2019).
Mangrove forests are the single most effective forest type supporting climate mitigation, by both sequestering and storing carbon at very high rates. For instance, mangrove restoration has been estimated to remove about 0.069 GT of carbon in aboveground biomass and 0.296 GT of carbon in above soil. Mangroves help to mitigate erosion, storm surges and rising seas through natural wall that do slow or halt the rate of coastal erosion, diminish wave-energy, and storm surges thereby helping to maintain coastal stability. Mangroves protect millions of people from flooding every year, in countries such as Vietnam, India, Mexico, USA, Bangladesh, China, and the Philippines where they reduce the cost of global flood damages at an estimated cost of about US$82 billion each year. Mangroves have been beneficial in enhancing fish stocks. 39 commercially important fish and invertebrate species have been enhanced by mangroves restoration. Available research indicated that the current mangrove cover will add over 1,000 trillion commercially valuable fish and invertebrates to the global coastal waters every year with an

estimated eco - benefits of above US$33,000 -57,000 per hectare (UNEP, 2014).

Mangrove forests globally and in Nigeria have majorly suffered devastation, degradation and loss (Hamilton and Casey, 2016) as a result of natural, anthropogenic, urban encroachment, aquaculture, mining and overexploitation of coastal resources (Alongi, 2014) and climatic change with impacts on the extent, structure and functions of the mangrove and the livelihood of the residents in the coastal areas (UNEP, 2014). Available record indicated that mangrove loss has resulted to the release of 2.0 – 7.5 million tonnes C yr^{-1} / loss of 7.3 – 27.5 million tonnes of CO_2 emissions / 137 – 636 km^2 loss of carbon stocks annually (Atwood *et al.,* 2017; Hamilton and Casey, 2016). Considering the mangrove as a good candidate for inclusion in the Intended Nationally Determined Contributions (INDCs) to the UNFCC for Payments for Ecosystem Services (PES) program, lack of accurate and real time datasets on the area extent of the mangroves particularly at the sub national and regional levels in the developing countries have been affecting the estimation.

Calculations of the emissions from land cover change in national greenhouse gas inventories, ecosystem service loss for PES interventions require robust datasets on the living carbon stocks, and emissions due to land cover change over time. Also, financial transactions under PES requires datasets on variables such as carbon storage and rates of mangrove habitat loss, to allow for the accurate quantification of carbon credits earned through restoration and carbon saved through avoided deforestation (Hamilton and Friess, 2018). Accurate datasets about area extent of mangrove is important to provide information about deforestation and carbon stock and emissions at different scales (local, national and regional levels)and this has been affecting the efforts of the decision-makers to calculate emissions and suitable reduction mechanisms or set adequate baselines of loss, from which to assess the effectiveness of a PESintervention (Harris *et al.,* 2012).The knowledge of the mangrove area extent will provide information on carbon stocks for use in national emissions reporting and PES schemes at high spatiotemporal resolutions.

As the Paris Agreement has provided new opportunities for mangrove conservation through the promotion of novel funding avenues for the financing of forest protection through incentivization of mangrove protection by carbon credit markets under the broad umbrella of payment for ecosystem services (PES). PES is a voluntary transaction between service users and service providers that are conditional on agreed set of rules of natural resource management" (Wunder, 2015). PES schemes in Reducing Emissions from Deforestation and Degradation (REDD+) incentivize conservation through 'avoided deforestation,' with a service buyer paying a service provider to store carbon that would otherwise be emitted due to land cover change or the opportunity costs of alternative uses for mangrove land. Instances where the financial benefits accruable from the sale of blue carbon credits outweighs financial returns from alternative land uses 6, provides incentives for mangrove conservation (Warren-Rhodes *et al.,* 2011).

However, lack of a spatially explicit datasets on the extent of the mangrove forest has been limiting the estimation of carbon prices applicable at different states as carbon prices are usually estimated on site specific basis (Thompson *et al.,* 2017) given the variability in land opportunity costs within and across any region (Yee, 2010). Although datasets relating to mangrove dynamics are available for Nigeria, but the existing dataset are conflicting depending on the author of the datasets. For instance, studies of Spalding *et al.,* 2010 and FAO, 2007 reported 1% per annum loss of mangrove forest in the 20th century and 0.16% yr^{-1} in the twenty-first century (Hamilton and Casey, 2016). Whereas Nwosu and Holzlöhner, 2016 reported a lost at about 5.6% / annum of Nigerian mangrove particularly in Rivers State, Bayelsa, Delta and Lagos States as a result of industrial (crude oil exploration and exploitation) aquacultural activities and urbanization (Duraiappah *et al.*, 2005). While Giri *et al.,* 2011 recently estimated that the total mangroves area in Nigeria could have fell from 10,515 km^2 to a little above 7,000 km^2 (Spalding, 2010) and their loss results to build - up of acid sulfides in the soil, shoreline erosion and sedimentation and collapse of intertidal food webs and inshore fisheries (Ellison and Farnsworth, 2001). Therefore, this study is another attempt at providing datasets on the dynamics of mangrove forest and particularly at the sub national level within Nigeria with the aim of recommending state specific restoration policies for minimizing and or reversing the trends the degradation.

METHODOLOGY

Study Area

Nigeria is located between latitudes 4˚15'N to 13˚55'N and longitudes 2˚45'E to 14˚40'E. Nigeria is bounded in the South by the Atlantic Ocean; in the North by Niger and Chad in the West by Benin Republic and East by Cameroon. Nigeria occupies a total land area of 923,768 sq km and a total human population of 180 million people. Geo-politically, Nigeria comprises 6 regions, 36 states and 774 Local Government Areas (Enuoh and Ogogo, 2018). Whereas, ecologically, Nigeria has mangrove swamps in the coastal region, then the fresh water swamps, followed by the tropical rainforest, the Guinea Savanna, the Sudan Savanna and finally the Sahel Savanna as one moves northward from the coastal areas, and the montane vegetation are found around the Jos and Mambilla plateau of the country. Climatically, the southern part is the equatorial, tropical climate mostly dominates the centre, while the arid region is mostly found in the North. Mean maximum temperatures are 30˚C - 32˚C in the South and 33˚C - 35˚C in the North. Annual rainfall decreases Northward from over 3550 millimeters in the costal and around 2000 millimeters in the coastal Niger Delta region and 500 - 700 millimeters in the North (WWF/ODNRI, 1990).The Southern part of Nigeria is the home to mangrove forest in country (Fig 1).

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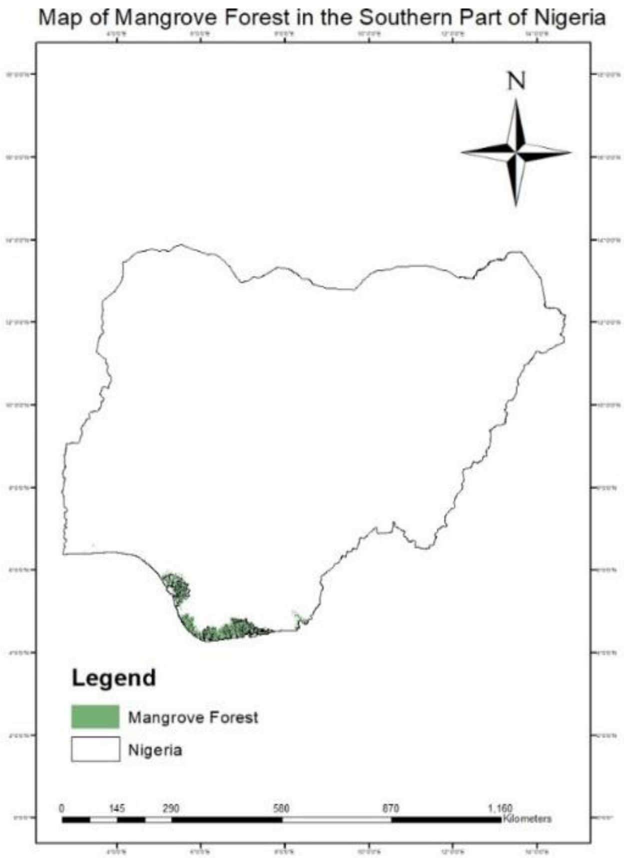

Fig. 1: Map of the Study Area
Source: Author, 2022

The Global Mangrove Watch (GMW) dataset (v2.0) shows the global extent of mangrove forests for series of years were derived using a combination of L-band Synthetic Aperture Radar (SAR) and optical satellite data 1 by the Japanese Aerospace Exploration Agency's (JAXA) Kyoto and Carbon Initiative by Aberystwyth University, Solo Earth Observation and the International Water Management Institute and these datasets are mostly used by UNEP for reporting Sustainable Development Goal 6.6.1. These datasets were derived by classification of a combination of radar (ALOS PALSAR) and optical (Landsat -5, -7) satellite imagery of approximately 15,000 Landsat scenes and 1,500 ALOS PALSAR mosaic tiles. Mangrove sites were derived using geographical parameters such as latitude, elevation and distance from ocean water. 1996 data were derived from ALOS PALSAR and JERS-1 SAR whereas the 2016 data were derived from the ALOS-2 PALSAR-2 data. Global Mangrove Watch maps were derived using consistent data and methods and supplemented with ground-based data for calibration and validation with accuracy being improved by use of satellite data of sizes 25 - 30 metres while the gaps created as a results of Landsat 5 scanline error were filled using maps from 2017 and 2018(Bunting *et al.,* 2017; Simard *et al.,* 2019). The Global Mangrove Watch (GMW) is a reliable global mangrove spatial datasets platform (Simard *et al.,* 2019) and the data was accessed athttps://geowetlands.org/knowledge-base/datasets/global-mangrove-watch/from where the 1996 and 2016 for Nigeria were extracted. Sub national datasets for Nigeria for 1996 and 2016 were derived from the Nigerian Mangrove Watch datasets using spatial analysis toolsets (editing, merging and splitting) in ArcGIS 10.6. The area extent of mangrove forest (resources) for the respective state were thereafter evaluated for the two periods (1996 and 2016) after the spatial datasets have been projected, disaggregated, split, merged and edited using the ArcGIS 10.6.

RESULTS

The results below showed the extent of mangrove forest at the sub – national (States) levels between 1996 and 2006 (Table 1 & Fig. 2); percentage loss of mangrove forest at the sub - national (States) levels between 1996 and 2016 (Table 2 & Fig 3); annual rate of loss of mangrove forest / and percentage contributions of States to the loss of Nigerian mangrove forest (Table 3 & Fig. 4) and rate of change of sub - national mangrove forest between 1996 – 2016 (Table 4).

Table 1: Nigerian Sub - National Mangrove Data

States	1996 (ha)	2016 (ha)
AkwaIbom	20,884	20,796
Bayelsa	324,816	316,542
Cross River	38,892	38,710
Delta	200,727	195,903
Edo	2,233	2,161
Lagos	3,665	3,454
Ondo	2,906	2,042
Rivers	199,347	197,066
Total	793,470	776,674

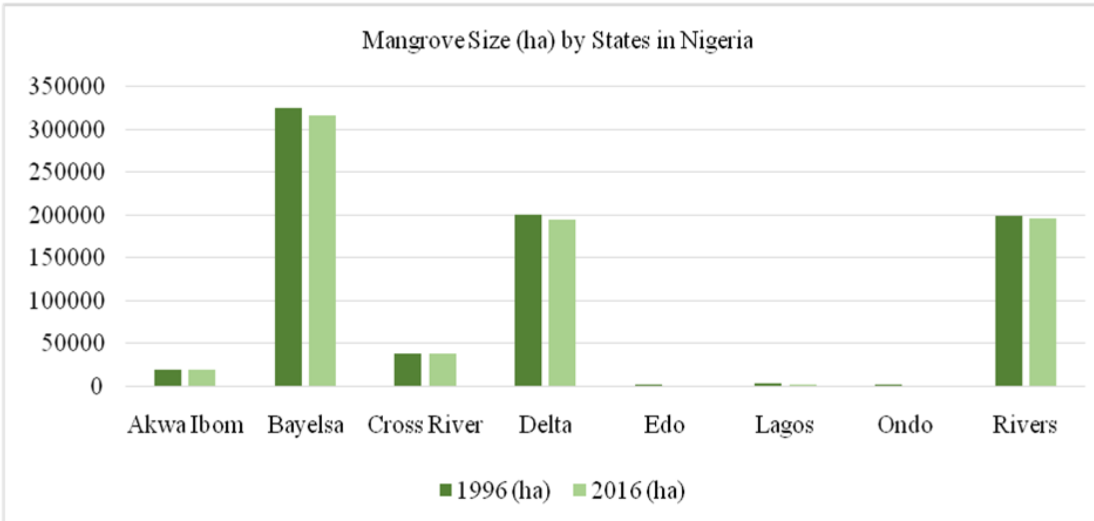

Fig. 2: Size of Nigerian Mangrove by States

Table 2: Loss of Mangrove Forest at States Level between 1996 and 2016

States of Nigeria	Mangrove Size (ha) in 1996	Mangrove Size (ha) in 2016	% State Mangrove of Total in 1996	% State Mangrove of Total in 2016
Akwa Ibom	20,884	20,796	2.63	2.68
Bayelsa	324,816	316,542	40.94	40.76
Cross River	38,892	38,710	4.90	4.98
Delta	200,727	195,903	25.3	25.22
Edo	2,233	2,161	0.28	0.28
Lagos	3,665	3,454	0.46	0.44
Ondo	2,906	2,042	0.37	0.26
Rivers	199,347	197,066	25.12	25.37

Table 3: Rate of Loss of Mangrove Forest / Annual and Percentage Contributions of States to Loss in Nigerian Mangrove

States	Loss of Mangrove (ha)	Loss of Mangrove (ha) /Annum	State's % Contribution to the Total Loss
Akwa Ibom	88	4.4	0.52
Bayelsa	8,274	413.7	49.26
Cross River	182	9.1	1.08
Delta	4,824	241.2	28.72
Edo	72	3.6	0.43
Lagos	211	10.55	1.26
Ondo	864	43.2	5.14
Rivers	2,281	114.05	13.58
Total	16,796	839.8	100

Source : Global Mangrove Watch available at : http:www.gmw.org

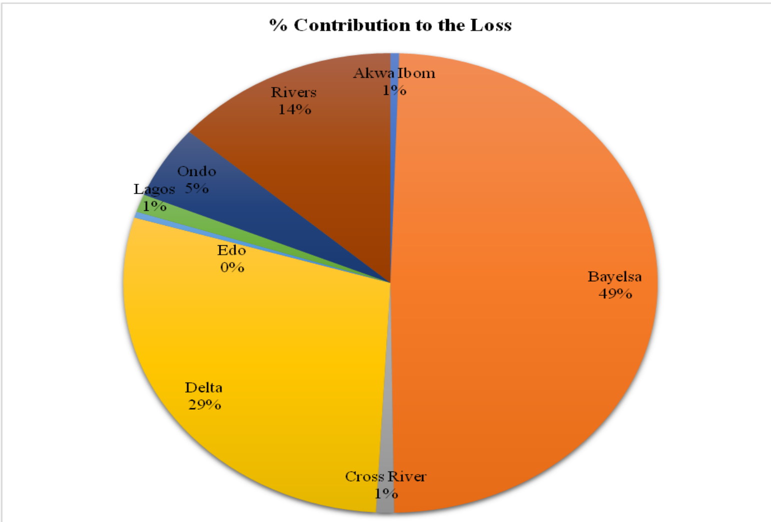

Fig. 3: Percentage Contribution of States to the Loss of Nigerian Mangrove Forest

Table 4: Rate of Change in Sub National Mangrove Forest between 1996 - 2016

States	% of Total Mangrove in 1996	% of Total Mangrove in 2016	% Rate of Change (1996 – 2016)
Akwa Ibom	2.63	2.68	-0.42
Bayelsa	40.94	40.76	-2.61
Cross River	4.90	4.98	-0.47
Delta	25.30	25.22	-2.46
Edo	0.28	0.28	-3.33
Lagos	0.46	0.44	-6.11
Ondo	0.37	0.26	-42.31
Rivers	25.12	25.37	-1.16

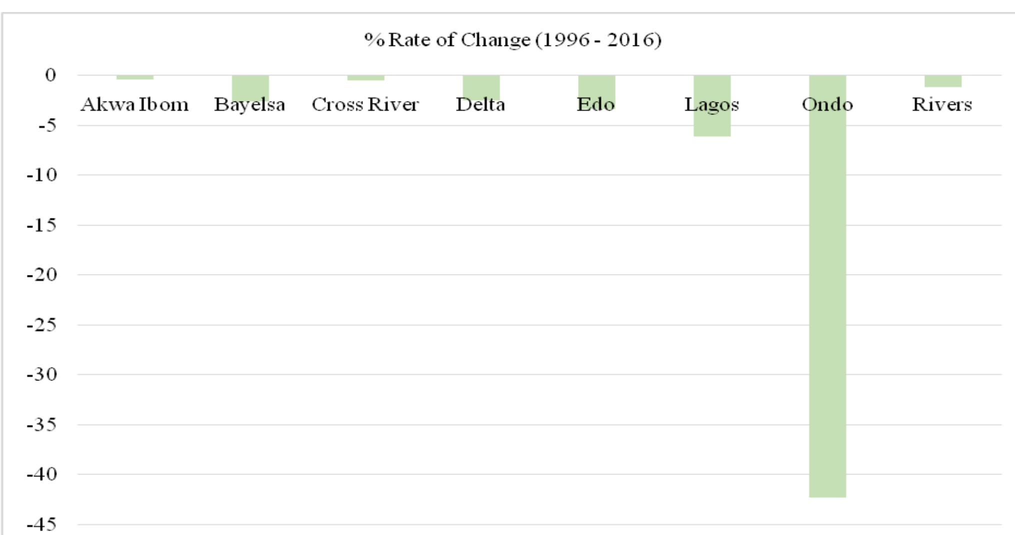

Fig. 4: Contribution to the Loss of Mangrove by States

DISCUSSION

The results of the spatial analysis of the mangrove resources in Nigeria indicated that Bayelsa has the largest (324,816 ha) mangrove size followed by Delta and Rivers states with 200,727 and 199,347 ha respectively and Akwa Ibom with area extent of 20,884 ha in 1996.Indicating that Bayelsa state is the home to 40.94% of Nigerian mangrove, followed by Delta that housed 25.30 % and Rivers with 25.12% had mangrove extent. Cross River, Akwa Ibom, Lagos, Ondo and Edo had 4.90%, 2.63% 0.46%, 0.37% and 0.28% respectively of total mangrove in Nigeria in the year 1996.However, by the year 2016; Bayelsa now has 40.76% of the Nigeria total mangrove extent; followed by Rivers state with 25.37% and then Delta with 25.22%, thereafter Cross River with 4.98% and Akwa Ibom with 2.68%. Other coastal states such as Lagos had 0.44%, then Edo 0.28% and finally Ondo with 0.26%.

For the period (1996 - 2016) under investigation, Bayelsa state has lost 8,274ha of her mangrove forest at the rate of 413.7ha / annum representing 49.26% of the total loss during the period. Again, Delta state lost about 4,824ha at the rate of 241.2ha/annum which represented 28.72% of the total loss (Table 3 & Fig. 3). Then, River state lose 2,281ha over the period under study at the rate of 114.1ha/annum representing a loss of 13.58 % of the total loss. Then followed by Ondo state that lost a total of 864ha over the 20 years period at the rate of 43.2 ha. More so, the loss by Lagos state was 211ha at the rate of 10.55%. So also Cross Rivers loss of 182ha represented a rate of 9.1ha/annum and Akwa Ibom loss of 88ha over the 20 year period under investigation with an annual loss of 4.4ha/annum (Table 4 & Fig. 4).This finding agreed with Giri *et al.,* 2011 who found that Nigerian mangrove forest has been depleted to a little above 7,000 km^2 by the year 2000 from its initial 10,515km^2in the 1960's Ibianga, 1985; Spalding 1997) The variation in the annual rate of loss in mangrove gave an indication for the need of state specific restoration and mangrove protection policies.

Conclusion

Given the importance of the mangrove in filtering the nutrients, stabilizing lagoonal shores, protection of the commercially important fish, helping in soil formation and as a converging point for migratory birds, and as providers of nutrients for marine organisms in food web relationships, as source of firewood/ energy, timber for furniture and construction, medicinal herbs, food for livestock, fish for human consumption and as a store house for blue carbon, therefore, any form of mangrove conversion, degradation and destruction need be wholistically addressed in order to avert its associated climatic change. Results from this study showed that Bayelsa state had the largest mangrove cover (41%) in Nigeria and also accounts for 49% of the total mangrove loss at the rate of -2.61% over 1996 - 2016. However, Ondo state with relatively smaller size (0.3 %) of mangrove has the highest (-42.31%) rate of loss in mangrove followed by Lagos (-6.11%) and Akwa Ibom had the least (-0.42%) rate of conversion of the mangrove. This knowledge of the rate of loss in mangrove is important for identifying the hotspots of the loss, for investigating the drivers, estimating the extent of blue carbon stock depletion and in advocating for aggressive conservation and or restoration efforts at the subnational levels. While this study advocates for the inclusion of blue carbon in the REDD+ arrangement for the protection, restoration and conservation of the mangrove, however, this may be impossible without the availability of accurate datasets on the spatio temporal dynamics mangrove extent. Availability of datasets on mangrove gain and loss is useful for estimating carbon emission avoided owing to mangrove conservation as well as the potential carbon sequestration through mangrove restoration and this is equally useful for estimating the cost of conserving mangrove forests, restoring the mangrove areas previously converted, estimating associated land opportunity costs and carbon stocks. Therefore, this study is useful for making the required datasets available for estimating the opportunity costs of alternative uses of mangrove ecosystems in the estimation of payment for ecosystem services (PES) in carbon market program.

The Federal Government of Nigeria considering the adverse effects of mangrove degradation on climate change, livelihood and humanity survival, enacted Nigeria's mangrove forest reserves, national parks/ protected areas in 1992. However, there is no evidence to believe that the initiative has been efficient in addressing mangrove degradation. In a follow up programme and given the importance of mangrove restoration in carbon credit, the Federal Government of Nigeria in the year 2020 also launched the "Mangrove For Live Project" project aimed at improving coastal sustainability, restoring the degraded mangrove and establishing Marine Protected Areas (MPAs) by increasing mangrove cover by at least 25% to be implemented using community - based approach (CBA) owing to the fact that Nigeria currently does not have national action plans and marine protected areas to adequately ensure sufficient conservation and protection of the mangroves. Thus, this study further recommends educational / awareness campaigns, capacity building, use of energy efficient / alternative sources of energy, application of indigenous knowledge, enforcement of community by – laws and sensitization, mobilization and engagement for climate action, implementation of poverty reduction programme as another sub national measures to strengthen the mangrove protection and conservation at individual states levels within Nigeria to achieve the intended sub national mangrove extent and status.

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