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Estimation of Forest Carbon Stock in Southwestern Nigeria Using Moderate Resolution Imaging Spectroradiometer Enhanced Vegetation Index (MODIS EVI) Time Series

BY

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DEDICATION

This work is dedicated to: Almighty God, the creator of heaven and earth

My beloved Parents (Mr George and Mrs Cecilia)

My admirable siblings (Patricia, Gloria, Frederick, Mary and Alfred)

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To the most High God be glory great things He has done. I acknowledge Your great provisions, protections and support throughout the duration of this course.

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LIST OF ACRONYMS

Acronyms	Description
APAR	Absorbed photosynthetically active radiation
ARVI	Atmosphere resistant index
AVHRR	Advanced very high resolution radiometer
Ba.SV	Barren/sparsely vegetated
CNVM	cropland/natural vegetation mosaic
Cr	Cropland
CS	closed shrubland
DBF	Deciduous broadleaf forest
DBH	Diameter at breast height
EBF	Evergreen broadleaf forest
EVI	Enhanced vegetation index
FAO	Food and Agriculture Organization
FDP	Forestry development programme
FMC	Forest management committee
FOSA	Forest outlook study for Africa

GESAVI	Generalized soil-adjusted vegetation index
GHG	Green house gases
GIS	Geographic information system
GLC	Global land cover
GPS	Global positioning system
Gr	Grassland
HDF	Hierarchical data format
IPCC	Intergovernmental panel on climate change
LAI	Leaf area index
LULC	Landuse/Landcover
MF	Mixed forest
MODI	Moderate resolution imaging spectroradiometer
MQUAL	Modland quick airborne look
MRT	MODIS reprojection tool
MRV	Monitoring, reporting and verification
NAMA	National appropriate mitigation action
NAPA	National adaptation programme of action
NDVI	Normalized difference vegetation index

NESREA	National environmental standards and regulation enforcement agency
NFAP	Nigerian forestry action programme
NOAA	National oceanic and atmospheric administration
NPP	Net primary productivity
NTDP	National tree nursery development
OS	Open shrubland
PCA	Principle component analysis
RADAR	Radio detection and ranging
REDD	Reduction of green houses gases from deforestation and forest degradation
RS	Remote sensing
Sa	Savannas
SAVI	Soil adjusted vegetation index
SIN	Sinusoidal
SMA	Spectral mixture analysis

TM	Thematic mapper
UNFCCC	United nations framework convention on climate change
VI	Vegetation indices
WS	Woody savannas

ABSTRACT

The study estimated vegetation biomass using moderate resolution spectroradiometer enhanced vegetation index (MODIS EVI) product. It also accessed the changes in the forest areas, identified hot and cold spot areas and investigated the correlation between EVI and the forest types. This was with a view to providing information on the efficacy and reliability of the use of MODIS EVI to monitor report and verify reducing emission from deforestation and degradation (REDD) project.

The study took place in the tropical rainforest of the Southwestern Nigeria. Both satellite images and forest inventory data were used for the study. An average of sixteen days at 500 m resolution data, labelled as MODIS/Terra Vegetation Indices 16-Day L3 Global 500 m SIN Grid V005 spanning from 2010 to 2014 in raw format (HDF format), was downloaded. MODIS EVI data was extracted from the MODIS VI product (MOD13A1). Layer stacking was performed on the geo-reference EVI images, which measured the "greenness" signal as a proxy for the amount of vegetation at a location and afterwards masked for the study area. The scene covering the study area was subjected to the supervised classification procedure in order to determine the various vegetation types for carrying out cell statistics to determine the EVI signal which was used to estimate the vegetation biomass. A trend analysis and image differencing was carried out on the EVI time series to determine the changes in forest areas and used to detect hot (negative hot spot) and cold spots (positive hot spot) area. Pearson correlation analysis was also used to determine the correlation between the forest types and EVI.

The results of the cell statistics showed that the broadleaf (deciduous and evergreen) forest had the highest green biomass (4256.44 and 4239.15) compared to other landuse/landcover (LULC) types while barren/sparsely vegetated surface had the lowest value (207.72). The trend analysis showed that there was a general decline in vegetation greenness for most of the landuse/landcover (LULC) types during the study period, with 2012 having the lowest greenness. Idanre and Ogbesse Forest reserves were showed more of positive hot spot areas, while Oluwa and Oni Forest Reserves had more of negative hot spot areas. The correlation between EVI and the different forest types indicated that there was a strong relationship meaning the EVI image was able to distinguish between the different types. The strongest relationship occurred between the woody savanna and the savanna EVI values (0.984) which was significant at the 0.01 level. However, mixed forest, open and close shrubland showed very high coefficient of variation indicating that the MODIS EVI was not efficient in detecting vegetation signal from these areas.

The study concluded that using MODIS EVI in monitoring, reporting and verification (MRV) of the REDD project was efficient and reliable.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Forests are important plant communities that consist of trees and other woody vegetation that performs life supporting functions on earth. The contributions of forests to the well-being of humankind are extraordinarily vast and far-reaching. Forests play a fundamental role in combating rural poverty, ensuring food security and providing decent livelihoods; they offer promising mid-term green growth opportunities, conservation of biodiversity and mitigation of climate change (FAO, 2015).

Forests, particularly humid tropical forests, provide a number of benefits to society. They are extremely rich in biodiversity and provide important ecosystem services, such as food, fibre, and water regulation. Forests contain about 80% of global terrestrial above-ground carbon stocks biomass), and play an important role in the global carbon cycle (Houghton, 2005). Tropical forests have also been reported to be a strong carbon sink (Stephens *et al*., 2007) and contributed about one fifth of total anthropogenic carbondioxide (CO_2) emissions to the atmosphere through tropical deforestation (Houghton *et al*., 2007). Despite the above mentioned importance of forest, the forest is being continuously destroyed at a very fast and alarming rate (Pimm *et al.*, 1995). More than 50% of the tree cover has disappeared due to human activities mainly through forest vegetation removal (Kaewkrom *et al*., 2011).

Estimating the carbon stocked in forests is important to assess the mitigation effect of forests on global change and to predict the potential impact of mechanisms to reduce emission.

Mapping and monitoring carbon stocks in forested regions of the world, particularly the tropics, has attracted a great deal of attention in recent years as deforestation and forest degradation account for up to 30% of anthropogenic carbon emissions, and are now included in climate change negotiations.

Forests sequester can store more carbon than any other terrestrial ecosystem and are an important natural 'brake' on climate change. When forests are cleared or degraded, their stored carbon is released into the atmosphere as carbon dioxide (CO_2). Tropical deforestation is estimated to have released of the order of 1–2 billion tonnes of carbon per year during the 1990s, roughly 15–25% of annual global greenhouse gas emissions (Malhi and Grace, 2000; Fearnside and Laurance, 2003, 2004; Houghton 2005). The largest source of greenhouse gas emissions in most tropical countries is from deforestation and forest degradation. In Africa, for example, deforestation accounts for nearly 70% of total emissions of carbon (FAO 2005). Moreover, clearing tropical forests also destroys globally important carbon sinks that are currently sequestering CO_2 from the atmosphere and are critical to future climate stabilization (Stephens et al*.,* 2007).

In Nigeria, the total value of forest product, as well as their environmental functions, is enormous though not completely quantifiable (Moormann *et al*., 1975). Nigerian forest and woody vegetation resources include the high forest, woodland, bush lands, plantations and trees on farms. Each of these various resources contributes to production, protection and conservation functions. Studies have shown that forest reserves occupy about 10 million hectares (ha) in Nigeria, which accounts for about 10% of a land area of approximately 96.2 million ha (FAO, 2005). Over the years, however, the land area identified as forest lands have been decreasing steadily due to industrial and social development which competes for the same pieces of land upon which the forest stands. The scenario expressed above was a source of reawakening for conservators to try, under stringent conditions, and establish forest plantations as well as conserve existing forest estates, especially estates of natural forests (Hall, 1977).

Political acceptance and implementation of climate policies aimed at reducing carbon emissions from deforestation will require resolution of scientific challenges. Foremost among these challenges is identifying feasible approaches to assess national-level carbon emissions from deforestation and degradation in developing countries. To estimate emissions, we need to know the area of cleared forest and the amount of carbon that was stored in those forests.

Despite the importance of avoiding deforestation and associated emissions, developing countries have had few economic or policy incentives to reduce emissions from land use change (Santilli *et al.,* 2005). More recently, the importance of including emissions reductions from tropical deforestation in future climate change policy has grown (Santilli *et al*., 2005). The United Nations Framework Convention on Climate Change (UNFCCC) recently agreed to study and consider a new initiative, led by forest-rich developing countries, that calls for economic incentives to help facilitate reductions in emissions from deforestation and forest degradation (REDD) in developing countries. The REDD concept is at its core a proposal to provide financial incentives to help developing countries voluntarily reduce national deforestation rates and associated carbon emissions below a baseline (based either on a historical reference case or future projection). Countries that demonstrate emissions reductions may be able to sell those carbon credits on the international carbon market or elsewhere. These emissions reductions could simultaneously combat climate change, conserve biodiversity and protect other ecosystem goods and services.

Management of forests as carbon reservoirs have become an important component of broader environmental practices aimed at the protection of biological, soil, water, and air resources. It has been pointed out by many studies that reduction in forest harvesting, skilful management of forest and agro forestry systems, as well as restoration and management of degraded forest lands has potential for the conservation and sequestration of carbon (Dixon *et al.*, 1993).

Currently, there is a tremendous amount and diversity being carried out that is related to forest and carbon accounting with a variety methods used for measurement. Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Wilkie and Finn, 1996). Remote sensing provides local/global estimates of carbon fluxes in forests. Remote sensing can fill in gaps where inventory information is unavailable. Remote sensing is most valuable applications in carrying out assessments of how climate change might be having an impact on forests by tracking major disturbances, changes in the growing season, and Net Primary Productivity (NPP).

The use of remote sensing technology has become the most effective approach to biomass estimation (Gaitan *et al.*, 2013; Gao *et al.*, 2013). Vegetation indices (VIs) calculated from the reflectances measured by remote sensing can reflect the photosynthetic activity of the vegetation and are therefore increasingly used to monitor forest biomass (Piao *et al.*, 2007).

Based on this, the study attempted to estimate forest carbon stock using MODIS EVI for South West Nigeria.