VEGETATION MAPPING IN NIGERIA: CURRENT STATUS, CHALLENGES AND THE WAY FORWARD

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ABSTRACT
Vegetation serves as a critical ecological and socio-economic resource, maintaining biodiversity, regulating water cycles, and providing sustenance, particularly in developing countries. With the increasing threat of global warming due to deforestation, effective vegetation mapping has become essential for biodiversity conservation and forest management. This paper reviews vegetation mapping techniques, types, and their significance in environmental management, focusing on Nigeria. While field-based methods offer high-resolution data, they are time-consuming and costly. Thus, remote sensing has become the preferred alternative. However, despite technological advances, vegetation mapping in Nigeria remains outdated and inconsistent, with notable challenges in accessibility and accuracy. Although groundbreaking, the national mapping projects, including the NIRAD and FORMECU projects, suffer from scale-related errors and inadequate classification schemes. Regional efforts face similar issues, compounded by the lack of a comprehensive, accessible mapping framework. To address these issues, the paper suggests developing a National Mapping Policy, adopting digital interpretation techniques, utilizing hyperspectral imagery, and improving access to vegetation maps through web-based platforms. It also proposes establishing a central geospatial data agency to coordinate and share mapping resources. The recommendations highlight the urgent need for accurate, accessible vegetation data to support sustainable environmental planning and resource management in Nigeria.

Keywords: Vegetation mapping; Biodiversity conservation; Remote sensing; National Mapping Policy; Geospatial data

INTRODUCTION
In the broadest sense, vegetation can be described as the assemblage of plant species and the ground cover they provide. They are valuable resources with vital global ecological and socio-economic attributes designed to maintain the balance of nature and provide unlimited services for all living creatures (Verma et al., 2020). While serving as crucial ecological resources responsible for the preservation of biodiversity, maintenance of soil fertility, regulation of water resources, and support for the geochemical and climatological cycles (Chaturvedi et al., 2021), they also constitute some of the essential natural resources in most countries; serving as the primary revenue earner and source of sustenance to large proportions of the population, especially in the developing world (Vamsi, 2020).

With their distribution influenced mainly by climatic, geologic, ecologic, and anthropogenic factors, vegetation types found on the earth's surface vary from one region to another, ranging from tropical evergreen forests to desert vegetation, with areas of similar factors even on different continents producing vegetation with similar appearances or physiognomy. The prominence of specific vegetation types in particular parts of the world and their absence in others, therefore, while highlighting the comparative advantage of these areas in the provision of particular resources and services, also substantiates the need to protect these unique enclaves against harm or destruction.

This need for protection becomes even more pertinent with the devastating impact of global warming and climate change, which have been attributed in part to the large-scale destruction of forest vegetation which hitherto served as carbon sinks, capturing and sequestering carbon dioxide in trees and soils, thereby controlling the volume of greenhouse gases in the atmosphere (Olorunfemi et al., 2022; Swamy et al., 2023). The 2020 Global Forest Resource Assessment report, a comprehensive study on the state of the world's forests, specifically revealed that the conversion of primary forest to other land cover types due to selective logging and other human interventions has reduced the area of primary forest by 178 million hectares, and an estimated 420 million hectares of forest have been converted to other land uses since 1990. Between 2015-2020, the annual rate of deforestation was estimated at 10 million hectares. This, it was indicated, has decreased the estimated total carbon stock in forests from 668 gigatonnes in 1990 to 662 gigatonnes in 2020 (FAO, 2020). This data underscores the urgency of effective vegetation mapping and conservation efforts in Nigeria.

Vegetation mapping has been recognised as one of the primary components required for the proper management and protection of the ecological diversity of plant species in different parts of the world (Reddy et al., 2021; Maurya et al., 2021) as it presents valuable information for understanding the natural and man-made environments through quantifying vegetation cover from local to global scales at a given time or over a continuous period (Li et al., 2021). It provides the benchmark data for forestry planning, aiding in the sustainable management of forest resources. It also plays a crucial role in different programs on fuel wood energy conservation, helping to identify areas with high biomass potential and guiding efficient energy production (Stolarski et al., 2021). Data from vegetation mapping have also been acknowledged as essential for assessing the temporal and spatial change in vegetation cover (Meng et al., 2020; Panuju et al., 2020), which has divergent applications in global environmental change and sustainability studies (Zhang et al., 2021a&b).

VEGETATION MAPPING: DEFINITION, TYPES AND TECHNIQUES

Explicitly, accurate vegetation maps have been recognised to be of considerable importance in guiding against the range of potential impacts on vegetation communities and providing adequate decision support for management and conservation planning (Bell and Driscoll, 2020). This explains the quantity of vegetation mapping studies in the literature, with most of them reporting the ingenuity of newly developed vegetation mapping techniques (SeeGio et al., 2020; Bamberg et al., 2021). In contrast, others focus on assessing the effectiveness of the existing methods in their application in different parts of the world (See Omojola et al., 2020; Sofiah et al., 2023; Peng et al., 2024).

Although an applied science without a universally acceptable definition, vegetation mapping has been extensively defined. Kuchler (1988), for instance, described it as the application of a given vegetation classification, which assumes that vegetation categories are established in a manner that can be visualised, while Kaneko and Nohara (2014) define it as the illustration of the geographical spread of a plant community, which is a vegetation unit. It delineates the geographic distribution, extent, and landscape patterns of vegetation types and/or their structural characteristics (Brewer et al., 2004). It can also described as an attempt to impose boundaries on the geographical spread of a plant community (a vegetation unit) using its temporal and spatial transition or continuum zone. Simply put, it is the graphical display of the location of different vegetation types in a region, emphasising their spatial relationship.

Usually classified by type into potential and existing vegetation mapping with outputs ranging from maps to associated data like floristic information, structural information and environmental attributes (Mueller-Dombois, 1984; FGDC, 2008), vegetation mapping goes beyond merely enumerating and classifying vegetation types in an area by necessitating the creation of naturally feasible or discernible unique map of assemblages of plant species at different geographic scales ranging from global overviews at tiny scales to individual research plots and one-metre square quadrants at very large scales (Mueller-Dombois, 1984). Specifically, while the potential vegetation mapping typology emphasises the inherent capacity of a land area to support a particular kind of vegetation using the bioclimatic and landscape criteria (Haugo et al., 2015), the existing vegetation mapping typology is interested in extracting mapping criteria solely from the structure of the vegetation using the vegetation architecture and floristics (Mueller-Dombois, 1984).

However, regardless of the vegetation mapping type of interest, conventional ground-based or field-based techniques for vegetation mapping have been acclaimed to provide the most detailed and accurate information about vegetation status in an area (Burchard-Levine et al., 2022; de Castro et al., 2021). These techniques involve direct observation and measurement of vegetation characteristics on the ground, providing high- resolution data crucial for many applications. However, they are also expensive, time-consuming, and limited to smaller regions of interest. Moreover, they are often undertaken at irregular time intervals, making it challenging to capture the dynamic nature of vegetation. This explains the shift to Remote sensing (RS) by utilising satellite – radar – and aerial images in the inventory and mapping of vegetation. This has proven immensely valuable for preparing accurate vegetation maps and monitoring changes at regular intervals.

STATUS AND CHALLENGES OF VEGETATION MAPPING IN NIGERIA

Despite its unique vegetation change pattern, as highlighted by the 2020 forest assessment report wherein the country was reported to have the highest percentage of forest loss among the ten top countries with the most significant net loss of forest area since 1990 (FAO, 2020), much effort has not been exerted in Nigeria to check this phenomenon primarily through the inventory and mapping of land cover change for the entire country (Ademiluyi et al., 2008; Ajibola et al., 2021). The failure and moribund nature of the different mapping projects executed in the country, starting with the 1:125,000 topographic mapping project, which dates as far back as 1910 (Balogun, 2003; Dada, 2012), creates a large gap between the supply and demand of maps (Uluocha, 2012) with the demand further reducing due to the stress users have to go through to gain access to the few available maps since the existence and location of these maps are hardly known.

The most comprehensive of these mapping projects, the 1:50,000 series that was started in 1946, the bulk of which was undertaken through the 1960-63 aerial photographic campaign carried out by the Canadian Aero Services Limited on behalf of the Canadian Government for the Government of Nigeria under the Commonwealth Africa Aid Programme, was never completed. These incomplete 1:50,000 topographic sheets, which have become the country's most available spatial data source, have also never been updated and have recently been digitised.

In the same vein and with specific regards to vegetation mapping in Nigeria, the Federal Government between 1976 to 1978, through the Federal Department of Forestry initiated the Nigerian Radar (NIRAD) project, which employed the use of the Side-looking Airborne Radar (SLAR) to obtain Radar imagery covering the whole of the country to produce the Land Use and Vegetation Map of Nigeria in 69 Sheets at the scale of 1:250,000. This project which generated the first database on vegetation covering the whole landmass of Nigeria, however has several shortcomings, among which are the apparent errors associated with the calculated area of the Country and States and consequent variations among land use, land cover categories; its 1:250,000 scale which makes it useful mainly for small scale mapping; and the use of visual interpretation which has been recognised as inconsistent, time-consuming and expensive (Adeniyi, 1984; FORMECU, 1996; Salami, 2000; Ademiluyi et al., 2008; Adeniyi, 2014).

Apart from the NIRAD mapping project, there is also the World Bank-supported Forestry Resources Management and Coordinating Unit (FORMECU) mapping project of 1994 to 1996, which was part of the Environmental Management Project (EMP) designed to update the NIRAD project database (Ademiluyi et al., 2008). Through the use of a combination of multi-source and multi-date remote sensing data, this project sought to establish a historical statistical record on the status of vegetation and land use (1976/78), which was used as baseline information, establish the current information on vegetation and land use (1993/95) and; analyse the trends (extent and intensity of the changes in vegetation and land use) over 18 years (FORMECU, 1996). The FORMECU mapping project, which can be regarded as the second national and the most current nationwide mapping project in Nigeria coming after the NIRAD project, is also fraught with issues of scaling, inappropriate classification schemes and over- generalisation (Ademiluyi et al., 2008).

Accomplished in addition to these national mapping projects are those of regional and local scales, which, in furtherance of the innovative efforts of the FORMECU project, employed the use of multi-source and multi-date, medium to high-resolution remote sensing data to produce land use/land cover maps for different parts of the country. Using the visual interpretation method, most of these other projects generate more qualitative than quantitative information and exist in disparate forms, making accessibility challenging (Ademiluyi et al., 2008; Adeniyi, 2014).

Evident from the preceding is the poor status of vegetation mapping in Nigeria. The two most comprehensive and accessible nationwide vegetation maps are outdated on a small-scale and fraught with inconsistencies and errors. In contrast, the relatively better regional and local vegetation maps are mostly inaccessible.

THE WAY FORWARD

Several suggestions are offered for improving Nigeria's current unacceptable status regarding mapping in general and vegetation mapping in particular.

1. *Development of a National Mapping Policy*
   A National Mapping Policy (NMP) is urgently needed in Nigeria to address all issues concerning the provision of an adequate geodetic framework, topographic and cadastral mapping, institutional arrangements, and organisational mandates. The Federal Government should be convinced to set up an appropriate committee to work on the policy for its consideration and proper legislation.
2. *Adoption of Digital image interpretation and analysis procedure* Realising the shortcomings of the visual image interpretation procedure, especially the subjective nature of the interpretation, which differs depending on the interpreter, emphasis should be laid on digital image interpretation for mapping in the country.
3. *Use of Hyperspectral imagery and Fused images*
   Rather than multispectral imagery, vegetation extraction from hyperspectral imagery should be adopted. Compared with multispectral imagery, which only has a dozen spectral bands, hyperspectral imagery includes hundreds of spectral bands, which are well suited for vegetation studies as reflectance/absorption spectral signatures from individual species as well as more complex mixed-pixel communities can be better differentiated from the much broader spectral bands of hyperspectral imagery.
   Image fusion of remotely sensed data with multiple spatial resolutions is also an effective technique with good potential for improving vegetation classification. For accurate vegetation mapping, it is essential to efficiently integrate remote sensing information with different temporal, spectral, and spatial resolutions

through image fusion.

4. *Improved Accessibility to Vegetation Mapping products*
   Accessibility to the country's existing and proposed vegetation mapping products must be improved. This should include converting analogue vegetation maps into digital format and uploading them online to make them accessible to all relevant stakeholders. Professionals interested in vegetation mapping must embrace the emerging field of web mapping to portray their product better and even attract investors who would be sure of a return on their investments based on web technologies' exposure.
5. *Establishment of an Autonomous Geospatial Data Production and Sharing Agency*
   Just like the United States Geological Survey (USGS), the British Ordnance Survey, the Japanese Geospatial Information Authority and the National Mapping and Resource Information Authority of the Philippines, there is a need to establish a sustainable platform for the generation and beneficial utilisation of geospatial data in Nigeria by integrating the various professions, disciplines and fields that produce these datasets. Ideally, a more coordinated and sustainable approach for easy integration is the merger of the Office of the Surveyor-General of the Federation (OSGOF), the Nigerian Geological Surveys, Nigeria Metrological Agency (NIMET) and National Space Research and Development Agency (NASRDA) into a single super geospatial data-production and sharing agency.

CONCLUSION AND RECOMMENDATIONS

An attempt was made in this paper to explain the meaning, types, techniques and importance of vegetation mapping. It has also outlined the present status and challenges of vegetation mapping in Nigeria, suggesting the way forward. Specifically, emphases have been laid on the need to realise the importance of vegetation, justifying the necessity for their inventory and mapping. It was suggested that while the existing vegetation maps need to be improved with the micro components and projection issues corrected, there is also the need to improve accessibility to these mapping products, making them available and accessible to all relevant stakeholders in the required format with the use of web mapping technologies and the establishment central agency responsible for sharing the mapping products.

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