

## Review

# An appraisal of landuse and landcover mapping in Nigeria

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Accepted 26 August, 2008

Land use and landcover change have emerged as a global phenomenon and perhaps the most significant regional anthropogenic disturbance to the environment, especially in the 20<sup>th</sup> century. Rapid urbanization/industrialization and large scale agriculture and major changes in human activities have been identified as the major causes of the dramatic changes in land cover and land use patterns globally. Dramatic land cover and land use changes that would have once required centuries now take place within a few decades. Africa is said to have the fastest rate of deforestation in the world as a result of over-dependence on primary resources with direct effect on the bio-diversity. All these call for an urgent need for proper geo-management of land; that is concomitant upon the availability of a detailed, accurate and up-to-date data. Although, there has been a world wide increase in awareness and studies on land use and land cover change analysis in the last four to five decades, there is still an extremely low level of research attention on land use and land cover change studies in Nigeria. Also, some of the few prominent land use and land cover analysis and change detection attempts in the country relied heavily on manual analysis procedure as against the modern recognized digital image interpretation and analysis procedure. It is against this background that this paper attempts the appraisal of some landuse/landcover mapping studies in Nigeria, with a view to ascertaining their usefulness and, more importantly, to suggest the usefulness and application of some of the 'modern' methods to relevant studies in Nigeria.

**Key words:** Landcover, Landuse, Remote Sensing, Biodiversity and Environment.

## INTRODUCTION

Land cover change has been described as the most significant regional anthropogenic disturbance to the environment (Roberts et al, 1998). In essence both land use and cover changes are products of prevailing interacting natural and anthropogenic processes by human activities. Land use and cover change and land degradation are therefore driven by the same set of proximate and underlying factor elements central to environmental processes, change and management through their influence on biodiversity, heat and moisture budgets, trace gas emissions, carbon cycling, livelihoods and a wide range of socio-economic and ecological processes (Desanker et al., 1997; Verburg et al., 2002; Verbug et al., 2000; Fasona and Omojola, 2005).

Studying land use dynamics is essential in order to examine various ecological and developmental consequences of land use change over a space of time. This makes land use mapping and change detection relevant inputs into decision-making for implementing appropriate policy responses (Fasona and Omojola et al., 2005). Land use change detection allows for the identification of major processes of change and, by inference, the characterization of land use dynamics. The reason for such consequence is as a result of over-dependence on primary resources with direct effect on biodiversity; land use and land cover dynamics, terrestrial ecosystem and climate (atmospheric composition, vegetation, temperature changes and occurrence of extreme climatic events). With rapid urbanization and a finite land area, the available land per individual shrinks drastically. The result is an urgent need for proper geo-management of land that is dependent upon the availability of a detailed, accurate and up-to-date data.

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During the 20th century, land use changes have emerged as a “global” phenomenon (Ramankutty et al., 2005). Land cover changes at global, national and local levels have characterized human-environment relationship. Indeed the growing human population has a huge potential for changing the face of the planet earth. Information on land use and land cover is the basis on which the past and present human interactions and the impacts of such interactions with natural resources and the environment can be understood. One major consequence of the globally recognized rapid land cover change is the loss of biodiversity and ecosystem functioning. The rate of biodiversity loss has been accelerating rapidly throughout the industrial era. According to the Global Biodiversity Assessment, species are now becoming extinct at 1.000 – 10.000 times the natural rate. The consequence of biodiversity loss is general ecosystem degradation often measured using the Natural Capital Index (NCI) framework which involves calculating the extent of natural area and the extent of the natural area is determined from land-use maps.

Although, it is now widely accepted that multiple factors in synergetic interactions dominate land-change processes and that these causal clusters vary across regions and time (Geist et al., 2005), agricultural expansion is one of the proximate causes of land use/land cover change (Geist et al., 2005; Reid et al., 2005). Today, roughly a third of the world landscapes are being used for growing crops or grazing cattle (Ramankutty, et al., 2005). Major changes in human activities, particularly through large-scale agriculture have been identified as the major cause of the dramatic changes in land cover and land use patterns globally. These dramatic land cover and land use changes that would have once required centuries now take a few decades to manifest.

The increasing concern for the management of natural resources in recent times has been necessitated by the increasing demographic pressures and its associated man-made activities which have led to serious environmental stress and ecological instability. In the last 300 years, the impacts of land use change have increasingly assumed significant to threatening proportions (Briassoullis, 1999). Expectedly outside a few exceptions it is human and not nature’s agency which brings about these changes and which is responsible for their magnitude and severity. Of course these changes have been found to be more profound in developing countries, due to the high propensity of the population growth rate and the subsequent resource over-exploitation. The impacts of these environmental problems are serious both in the short and in the long term. In the short term food security, human vulnerability, health and safety are at stake: in the longer term the viability of the earth is being threatened (Briassoullis, 1999).

In the face of declining export earnings and debt burdens, many governments tried to boost the exploitation of natural resources and cash crop production. This has led

to widespread environmental damage, as rural communities are forced to cultivate fragile and marginal areas (UNEP, 2002). Also, as a result of poverty, the poor are forced to overexploit resources such as fisheries, forests and water in a desperate struggle to survive, with its attendant environmental degradation. Clearing of vegetation increases the risk of drought and damming of rivers and draining of wetlands reduces the environment’s natural ability to absorb excess water increasing the impacts of floods. If the total size of a habitat is reduced the sizes of the populations of many species particularly large mammals and top predators are forced to decline. Africa’s biodiversity has been subjected to increasing loss (through conversion of natural habitats to urban industrial or agricultural uses), over harvesting (due to increasing population and rising consumption levels), pollution (from urban and industrial sources), and the introduction of alien species (which dominate and alter habitat conditions).

Africa has the fastest rate of deforestation in the world. Competing land uses (agriculture and human settlements mainly) are contributing to the decline of forest and woodland areas and the rising demand for fuel wood and charcoal is also a major cause of deforestation. Over harvesting, agricultural encroachment and unregulated burning are believed to be contributing to the decline of many species in the wild. Depletion and degradation of the natural resource base intensifies competition to less stressed areas. Nonetheless, the point being made is that the environment is so valuable and the inhabitants so precious that the future need not be left to chance or to some curious form of evolution. This paper therefore examines the relevance of some land use/land cover mapping methods in Nigeria and their contributions to the emerging patterns in global land cover/land use studies. In addition, the study examines the need for proper geo-management of land and the importance of the availability of detailed, accurate and up-to-date geo-information in the proper management of land in Nigeria.

### **Sources of data for land use and landcover studies**

Space borne remote sensing has long been an appropriate and effective data source for land cover mapping due to its wide coverage and repetitive observations (Haack and English, 1996; Lee et al., 2002). This explains for why satellite imageries have become very prominent in most land cover and land use studies carried out in Nigeria.

Table 1 shows the various data type scale and their source. Patrono (1996) has observed that small discrepancies may be detected when combining the landsat data with SPOT data. However, he opined that such discrepancies may actually highlight the benefit of the combined use of different sensors in land use and land cover studies especially in terms of resolution.

**Table 1.** Remote Sensing Imageries and their Resolution

Data Type/Sensor	Year	Resolution
Multi-Spectral Scanner (MSS)	1970s	78m
Thematic Mapper (TM)	1980s	30m
SPOT (XS/Panchromatic)	1990s	30m 10m
Landsat	1980s	30m
Radarsat	1990s	12m (variable)
Light Detection and Ranging (LIDAR)	1998	2m (variable)
Compact Airborne Spectrographic Imagery (CASI)	late 1990s	2m (variable)
Interferometric Airborne Synthetic aperture Radar (IFSAR)	1990s	
Polarimetric Synthetic Aperture Radar (PSAR)	1990s	6m
IKONOS	2000	1-4m

Source: Hwang and Ku, 2004; Webster, et al, 2004

The need to combine or merge different sets of imageries is because of the differing advantages that each of the remotely sensed data possess, as the advantages in one tend to complement the disadvantages in another. For instance, it has been found that SPOT data could be used for mapping at 1:50,000 scale with 20 m contours and that if the data were very good and the ground control sufficient, 1:25,000 scale plotting may be possible (Jensen, 1996). Because SPOT sensors collect data over a relatively small 60 x 60 (3600 km<sup>2</sup>) area, it is particularly useful for localized study.

Remote sensing provides information concerning the spatial distribution and the temporal variability of dynamic land cover characteristics. Geospatial technologies are vital for performing analyses to aid decision makers in their difficult task of proving optimal and compromise solutions. GIS and remote sensing have shown active interests in both the operational scale and measurement scale of data. For instance in the field of remote sensing the 78 m resolution Multi-Spectral Scanner (MSS) data of the 1970s has given way to 30 m Thematic Mapper (TM) data in the 1980s SPOT in the 1990s and 1m IKONOS imagery in the 21st Century. As shown in Table 1, such improvements in the spatial resolution/measurement scale allows for a new understanding of geographical phenomena that could not be measured at the previous scales (Hwang and Ku, 2004). The Nigeria SAT-1 data performed relatively well for land use mapping, but the radiometric qualities of the image need to be improved upon as linear features such as roads and rivers in particular can not be discriminated. In the preceding paragraph the many methods employed in the landcover/landuse studies in Nigeria have been described. However, this study is essentially an appraisal study and has then therefore depended on the use of secondary method involving a critical review of some selected studies in Nigeria.

### Study area

Nigeria is made up of 36 States and a Federal Capital

Territory (FCT), which are grouped into six geopolitical regions: North Central, North East, North West, South East, South South, and South West. There are also 774 constitutionally recognized Local Government Areas (LGAs) in the country. Nigeria lies between latitude 4° and 14° North of the Equator and between longitude 3° and 14° East of the Greenwich Meridian. The country is in the West African sub region and borders Niger in the north, Chad in the northeast, Cameroon in the east, and Benin in the west. To the south, Nigeria is bordered by approximately 800 kilometers of the Atlantic Ocean. With a total land area of 923,768 square kilometers, the country is the fourth largest in Africa.

### Relief and climate

Nigeria is diverse climatically and topographically and exhibits a great variety of relief features, encompassing uplands of 600 to 1,300 m on the North Central and the east highlands and lowlands of less than 20 meters in the coastal areas. The lowlands extend from the Sokoto plain to the Borno plains in the North, the coastal lowlands of Western Nigeria, and the Cross River basin in the east. The highland includes the Jos Plateau and the Adamawa highlands in the North, extending to the Obudu Plateau and Oban Hills in the South East. Other topographic features include the Niger-Benue Through and Chad Basin.

Nigeria has a tropical climate with wet and dry seasons associated with the movement of the Inter-Tropical Convergence Zone (ITCZ) north and south of the equator. The dry season occurs from October to March with a spell of coolness and dry, dusty harmattan wind felt mostly in the north in December and January. The wet season occurs from April to September. The temperature oscillates between 25 and 40°C, while rainfall ranges from 2,650 mm in the southeast to less than 600 mm in some parts of the north, mainly on the fringes of the Sahara Desert. The vegetation that results from these climatic differences consists of mangrove swamp forest in

the Niger Delta and Sahel grassland in the north. Within a wide range of climatic, vegetation, and soil conditions, Nigeria possesses potential for a wide range of agricultural production but yearly an increasing amount of the prime agricultural and grazing lands is being lost. However, as a result of rapid land cover and land use change resulting from natural and anthropogenic factors, the country's natural vegetations have gives way in many areas and new species of vegetations are emerging (evident land cover change).

### Land use and land cover studies in Nigeria

There has been a worldwide increasing awareness and studies on land use and land cover change analysis in the last four to five decades. The importance of such studies to sustainable development plan of nations has also been universally recognized. Paradoxically, there is still an extremely low level of recognition and research attention on land use and land cover change studies in Nigeria (Okude, 2006). Some of the few prominent land use and land cover analysis and change detection attempts and which are being reviewed here include NIRAD Project (1976/78), Areola (1977), FORMECU (1996): and Omojola (1997).

The NIRAD Project was commissioned in 1976 and completed in 1978. It was based on imagery acquired through the Side Looking Airborne Radar (SLAR) to produce the first vegetation and land-use maps covering the whole landmass of Nigeria. According to FORMECU (1976), the NIRAD Project constitutes the first and only nation-wide database on the Nigeria environment as at 1976. The primary thematic purpose of the project was the inventory and mapping of vegetation types in Nigeria as well as the demarcation of forest reserves boundaries (Adeniyi, 1984). Thus employing a visual image interpretation method, the NIRAD Project provided the first national land use/land cover information of any appreciable consistency. However, some shortcomings of the study have been identified by Adeniyi (1984) and FORMECU (1996). First, the classification scheme developed in the study is largely related to vegetation (a land cover). Thus the vegetation and land use classes as shown on the 1976/78 produced maps do not discriminate between land use and natural vegetation cover. So it was found that many polygons contain inclusions of other classes to varying degrees.

Secondly, the NIRAD classification scheme did not include human settlements' as a cover category. Hence the interpreters must have treated the interpretation and delineation of settlement boundaries as residual matters. Also, the scheme is also besetted with obvious errors associated with the calculated area of the Country and States and consequent variations among land use, land cover categories. Again, the polygon boundary on the 1976/78 vegetation and land use maps appears to have

been derived in part from observations (that is, Fieldwork) despite what the imagery suggested that the boundary classes should be. And lastly, the NIRAD Project may be regarded as suitable for its ad hoc purpose but not suitable for a national land use classification scheme. However, despite the identified shortcomings, the NIRAD Project provided the first national land use/land cover information of any appreciable consistency (Adeniyi, 1984).

Areola (1977) carried out a study on land types and terrain conditions in Lagos, in which he demonstrated the usefulness of aerial photo interpretation in the identification or mapping of land types. The study which is localized was undertaken in 1977 at about the same time with the NIRAD National Project. The study used Visual interpretation of infrared black and white photography which was flown at about 1970 over the coastal areas of Lagos between the west of Ikorodu and the Yewa River on the boarder with Republic of Benin. In the study, the major land types were morphologically determined, while the sub-divisions within each unit were based on differences in vegetation.

Areola (1977) identified the practical usefulness of such photo-analytical work to include: the understanding of terrain conditions and aspect of the dynamic ecology of the area the analysis of present trends in land use and as an aid in planning future land use and the exploitation of national resources. However, despite the stated usefulness identified by the author some glaring shortcomings were identifiable which support the need for more land use and land cover study in Nigeria. Firstly, because of the rapidity at which changes are taking place in many areas in Nigeria. Secondly, in the study, little quantitative analysis was undertaken. Thirdly, visual interpretation was employed in the analysis. Notwithstanding, the study has the advantages of presenting perhaps the first systematic study of land types and terrain conditions of Lagos.

The second national and the most current nation-wide database on Nigeria land use and vegetation was provided by the study carried out by Forestry Management and Coordinating Unit (FORMECU) in 1996. It was part of the Environmental Management Project (EMP). The objective of the Project was to assess and evaluate the available data; identify data gaps; develop programs for the production of current and reliable information on vegetation changes and degradation over time; develop and implement a GIS database for the country of Nigeria. To achieve the objectives the Project involved three broad tasks: (i) the establishment of historic statistical record on the status of vegetation and land use (1976/78) which was used as baseline information: (ii) the establishment of current information on vegetation and land use (1993/95), and (iii) the analysis of trends (extent and intensity of the changes in vegetation and land use) over an 18 years period. These tasks were undertaken using a combination of multi-source and multi-date remote

sensing data such as Landsat Multispectral (MSS-1976/78), SPOT Multispectral (1993/1995), Landsat Thematic Mapper (TM-1993), ERS-1 Radar-1994/1995), JERS-1 Radar-1995), and National Oceanic Atmospheric Administration (NOAA). Advanced Very High Resolution Radiometer (AVHRR-1978, 1986, 1990, 1995).

Some of the major shortcomings of the FORMECU Project include the fact that the scheme was also more of land cover than land use analysis. Second, the little coverage of the land use aspect was limited to agricultural land use. For instance, urban areas were inputted as point data with associated text. Third, the classification scheme was also limited to the secondary level. Fourth, because of the extent it was more of a generalized study with the intention of correlating the land use in terms of ecological zones in Nigeria. Fifth, the final map products were at a scale of 1:250,000, which were too small for meaningful analysis. Sixth, visual interpretation was utilized. The implication of such is that two individuals may produce different results in addition to being time consuming and expensive. Finally, the impact of human-induced change on water vegetation and soils was on a qualitative basis and so the FORMECU Project recommended for future quantitative land use/land cover change analysis.

However, despite the observed shortcomings, in the FORMECU project, the study actually attempted to update the database provided by the NIRAD project," in order to study environmental degradation trends and propose action programs". So, obviously, it became the second national land use and land cover project in Nigeria. In addition, the FORMECU Project as noted earlier was the first land use/land cover analysis based on a combination of multi-source/multi-scale remotely sensed imagery within a GIS environment in Nigeria.

Omojola (1997) carried out a land use and land cover inventory and change assessment in a semi-arid region of Nigeria using remote sensing and GIS techniques. The major contribution of the study which could be seen as a follow up on FORMECU Project to land use and land cover studies in Nigeria was in the demonstration and evaluation of the integration of remote sensing and GIS techniques for land use and land cover inventory and change assessment. To achieve the objectives set out in the study, aerial photographs for 1962 and 1977 and Landsat MSS and SPOT XS images for 1986 were used. In the study, he used the visual (manual) method of remote sensing analysis in the interpretation and derivation of the land use and land cover attributes.

However, some identifiable shortcomings were found in the Omojola (1997) study. First the visual (manual) method of remote sensing analysis was employed. Of course as has been confirmed by Jensen (1996), the visual method of interpretation is beset by such problems as non-repeatability. Omojola (1997) recommended further research in Nigeria based on an integrated use of baseline data with recent images for an automated image

classification. Again, like earlier land use/land cover studies in Nigeria, only little quantitative data could be provided in the work principally because of the manual interpretation procedure. As Jensen (1996) explained, human interpreter can discriminate only about 8 to 16 shades of gray as against 256 possible shades of gray. Also, the ability of human capacity to keep a great amount of quantitative information is limited. This further justifies the need for further land cover studies using the digital image interpretation and analysis procedure.

From the few studies that have been reviewed above, it is revealed that a lot still need to be done in the area land use and land cover change mapping particularly because of the vast size of the country and the rapidity at which changes are taking place. This calls for an urgent need for the use of some modern methods of digital image interpretation methods for proper management of land in Nigeria. The appropriate digital image interpretation methods to be used would no doubt be influenced by the prevailing problems of funds, technical capacity to interpret data and the availability of relevant instruments etc. among others.

## THE WAY FORWARD

It has become urgent to understand land use and cover changes that have taken place in diverse environments and which have intensified over the past 100 years or so in many tropical countries, particularly those of Sub-Saharan Africa such as Nigeria. These changes occur essentially at the spatial scale of the farm field and the locality. The cumulative effects in terms of biogeochemistry, abundance and composition of terrestrial species, heat and water fluxes, the atmosphere and human living at local, regional and global levels need adequate understanding. Hence the increasing global concerns about land use and cover changes.

Only a small number of studies on land use and cover change/ mapping have been undertaken in Nigeria despite the in increasing worldwide increasing awareness. The diversity is decreasing and the need to balance human well-being and environmental sustainability involves adjusting the way we use ecosystem goods and services produced by the land (Reid et al., 2005). Of course land use is at the centre of these trade-offs. Much of global land-change science has improved our understanding of connections between land use and environment (Reid, et al., 2005).

The Natural Capital Index framework (NCI) measured through the calculation of the extent of natural ecosystems is one of the ways through the impact of the contribution of agricultural practices, heavily deforestation for construction and refineries etc to biodiversity loss can be determined. NCI can assist in the implementation of a nature development policy shaped by a national network of linked ecosystems, including the protection and deve-

lopment of specific habitats and species. It can also serve as a guide to slow down biodiversity loss through efficient spatial environmental and management measures from policy makers. Nonetheless, the point being made is that the environment is so valuable and the inhabitants so precious that the future need not be left to chance or to some curious form of evolution.

As revealed in this paper, very few studies have been carried out on land cover and land studies in Nigeria despite its massive size and its large population associated with diverse anthropogenic activities. This call for urgent action by all stakeholders in Nigeria towards a better understanding of the changing pattern of land use and land cover the country.

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