Geospatial Analysis of Deforestation and Land Use Dynamics in a Region of Southwestern Nigeria

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1. Introduction

Deforestation is a complex phenomenon as there is little agreement about the components and the processes involved in it. FAO, (2001a) defined deforestation as 'the conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10 percent threshold'. The world's original forest area, estimated at about 6 billion hectares, has declined steadily and about one-third of the forests have been lost during the past few hundred years (Sharma et al., 1992). The forests and woodlands of North Africa and the Middle East, for example, declined by 60 percent; those of South Asia by 43 percent; of tropical Africa by 20 percent; and of Latin America by 19 percent (Houghton et al. in WRI, 1987).
Although the world's forest area has been declining for centuries, it is in the last half of 20th century that the process was accelerated to an alarming rate (Osemeobo, 1991; Federal Environmental Protection Agency, 1992; Jaiyeoba, 2002). Since the 1960s, there has been a major change in the rate at which the forests are cleared. FAO, (1997) reported annual rates of deforestation in developing countries at 15.5 million hectares for the period 1980-1990 and 13.7 million hectares for the period 1990 - 1995. The total forest area lost during the 15-year period was more than 220 million hectares, much larger than the total land area of Mexico. Between 1950 and 1983, the area of Africa's woodlands and forests declines by 23% from 901 to 690 million hectares. Between 1981 and 1985 tropical African countries such as Nigeria, Cote d'lvoire, Sudan and Zaire were losing their forest at annual rates of 4.0%, 2.5%, 5.0% and 3.7%, respectively (IBRD/World Bank, 1992). In absolute terms, tropical forests in Africa are being lost at the rate of 3.7 million hectare a year with over half of the deforestation in West Africa alone (UNEP, 2002). The rate of deforestation in Nigeria in the 1980s was of the order of 400,000 ha yearly, while afforestation was a mere 3,200 ha. At such rates, Nigeria's remaining forest area would disappear by 2020 (Jaiyeoba, 2002).
Deforestation and forest degradations are now widely recognized as one of the most critical environmental problems facing the human society today with serious long term economic, social and ecological consequences. This issue has received much attention from policy makers to general public in recent years with vivid images of cleared forests and burning trees around

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the world. One of the consequences of deforestation is that the carbon originally held in forests is released to the atmosphere, either immediately if the trees are burned, or more slowly as unburned organic matter decays (Moutinho and Schwartzman, 2005). As reported by Diaz, et al., (2002), tropical deforestation in the Amazon alone is responsible for 2/3 of the Brazilian greenhouse gas emissions and it is estimated that 200 million tons of carbon, not including emissions from forest fires, are released annually into the atmosphere.

The effect of deforestation on biodiversity and climate change has been the subject of scientific studies and many documentaries of media. Achard et al., 2002; Houghton, 2003; Fearnside and Laurance, 2004, revealed in their studies that Global deforestation and forest degradation rates have a significant impact on the accumulation of greenhouse gases (GHGs) in the atmosphere. The Food and Agriculture Organization (FAO, 2001) estimated that during the 1990s 16.1 million hectares per year were affected by deforestation, most of them in the tropics. The Intergovernmental Panel on Climate Change (IPCC) calculated that, for the same period, the contribution of land-use changes to GHG accumulation into the atmosphere was 1.6±0.8 Giga (1 G = 109) tonnes of carbon per year (Prentice et al., 2001), a quantity that corresponds to 25% of the total annual global emissions of GHGs. The United Nations Framework Convention on Climate Change (UNFCCC), in recognizing climate change as a serious threat, urged counties to take up measures to enhance and conserve ecosystems such as forests that act as reservoirs and sinks of GHGs. The Kyoto Protocol (KP), adopted in 1997, complements the UNFCCC by providing an enforceable agreement with quantitative targets for reducing GHG emissions. Besides, Aina and Salau, (1992) and Adesina, (1997) reported that forest loss leads to loss of wildlife habitats and extinction of plant and animal species that play important roles in maintaining a balance in the environment.

From the foregoing, it becomes obvious that the world tropical forest including Nigeria is depleting fast because of human influence. This is a problem at the macro and micro-level; such depletion is the result of government activities such as road development, arable farming, and land clearing for pasture (Osemeobo, 1991; Taylor et al., 1994; and Olofin, 2000). Statistical estimates have also shown that there is a negative correlation between exploitation of the forest and conservation in Nigeria that is, the annual rate of forest los is greater than the rate of conservation (Osemeobo, 1990).

The state of forests in general and tropical forests in particular, has been drawing the increasing disturbing attention of the world community. For instance, in the tropics, where about 2.5 billion people depend on natural forest resources for many economic and environmental goods and services, the depletion of forests has been posing threat to their means of livelihood.

Recently, the United Nations initiated a global awareness through its Global Environmental Outlook 2000 (GEO, 2000). In the developed countries of Europe and America, this awareness is high and it is the cause of several policies and strategies aimed at environmental preservation and conservation. In developing countries the awareness is just emerging. Presently 115 nations have Environmental Protection Agencies (EPA) and more than 215 international environmental treaties have been signed on issues bothering on global warming, biodiversity, ocean pollution, ozone layer depletion, and export of hazardous wastes (Ibah, 2001).

In Nigeria, government is also taking steps to correct the nation's degenerated environmental condition. One of such efforts is the establishment of Federal Environmental Protection Agencies (FEPA), (now a department under the Ministry of Environment), with its branches in all the states to monitor environmental quality including the forest resources. Very recently, and considering the need for environmental preservation, the government has established the Federal Ministry of Environment to oversee the country's environmental problems. Many Non – Governmental Organizations (NGOs) have also sprung up to discuss environmental degradation and proffer solutions (Ogunsanya, 2000).

The waves of concern on the state of our forest resources and the condition of the environment, have translated into a number of researches. Among the academics, studies have clearly revealed that forests worldwide have been and are being threatened by uncontrolled degradation and conversion to other types of land uses, influenced by increasing human pressure due to uncontrolled increase in human population resulting in agricultural expansion; and environmentally harmful mismanagement, including, for example, lack of adequate forest-fire control and anti-poaching measures, unsustainable commercial logging, overgrazing and unregulated browsing, harmful effects of airborne pollutants, economic incentives and other measures taken by other sectors of the economy (Houghton et al. in WRI, 1987; Sharma et al., 1992; Olofin, 2000; IPCC, 2000; FAO, 2001a; WRI, 2001; Jaiyeoba, 2002). Scholarly writings have also tried to explain the dimension and severity on global environmental changes (Arokoyu, 1999; Ogunsanya, 2000 and Jaiyeoba, 2002).

Studies have also explored the causal factors of deforestation. For example, there is a general agreement that deforestation is due to drought, forest fire, use of fuel wood, spread of extensive agriculture, and rapid urbanization, among others, (Areola, 1994; Olofin, 2000; Meyer and Turner, 1992; Taylor et al., 1994 and Smith, 1993). There are also substantial and growing works on resource management and conservation for the purpose of improving the environment (Areola, 1994; Smith, 1993; Mitchell, 1989; Munro et al., 1986; Olokesusi, 1992; Reed, 1996 and Rees, 1990).

In 2001, FAO published the Global Forest Resources Assessment 2000 (FRA 2000), which was largely based on information provided by the countries themselves and a remote sensing survey of tropical countries. It was supplemented by special studies undertaken by FAO. Among the outputs were two new global forest cover maps, estimates of forest cover, deforestation rates and forest biomass for each country, and several specialized studies on such topics as forest management and forest fires (FAO, 2001).

But Boroffice, (2006) argued that the often-quoted rates of deforestation for Nigeria were based on mere estimates or surrogate data rather than empirical studies. Most of the vegetation maps produced by international organizations, such as FAO, for the country are nothing more than broad generalizations which are not usually in tandem with local realities and are therefore, of little use to local authorities for planning purposes. Thus, the rate of forest loss at both local and national levels is not known with any accuracy.

To further the frontiers of knowledge on the state of the forest resources, which is still an inconclusive issue and to establish the emergence land use pattern from the depleted forest area, this study therefore, examines and analyses the extent of forest loss and land use dynamics; measures the rates of change over the periods of 25 years (1978-2003) in a part of southwestern Nigeria using a set of remotely sensed images and geographic information system (GIS) technology. There is a consensus among scientists that satellite images and GIS provide a reliable means for adequate and regular monitoring of forest estate. According to Ayeni (2001), application of GIS in environmental monitoring in developing world is still at its infancy yet; it has been extensively used in Europe and North America. Recognizing the importance of reliable tool for forest monitoring both for environmental sustainability as well as economic well being, there is, therefore, need to explore the tool in the developing world.

The specific objectives of study are to:

i. identify the categories of land use and land cover from remotely sensed images;
ii. measure the areal extent of each of the land uses/covers
iii. assess the rate(s) of change in land use and forest area and compare the rates of change over time; and
iv. analyze the temporal patterns of land use and changes in forest coverage area over the period 1978-2003

2. The study area

Studies on deforestation can be carried out in any part of the world where growth in human population has taken place, which still has potential for further growth and development. The choice of the study area is however, guided by the primary objective of the study to examine the occurrence of deforestation, which is better perceived in area where there has been rapid urbanization as the case of the study area. The study area is a region located in Southwestern Nigeria, well known for its dense forest resources and fertile soils. However, as a result of rapid population growth, which led to the development of urban centres and increased farming activities, much of the forest areas have been converted to farmlands, perhaps to meet the needs of the teaming population. The emerging concern about the disappearance of forests in the study area therefore presents the reason for a study of this nature. Coincidentally there is a preponderance of various types of data from which the type of study envisaged here can be expected with minimum difficulty. Besides, the concern for sustainability provides the impetus for the choice of the area.

The study area spans part of Osun and Ekiti States (Figure1) and lies within latitude 7° 30´ and 7° 45´ North of equator and longitude 4° 30´ and 5° 00´ East of the Greenwich (Figure 2). It is about 866.25 sq kilometres rectangle in size. On the Nigeria topographical map, it is found in Ilesa sheet 243. The relief is rugged with undulating areas and granitic out-crops in several places. The notable ones among the hills are the Efon-Alaaye hill to the east of the study area, and domed hills in Ilesa area. The climate is of the lowland Tropical rain forest type with distinct wet and dry seasons. Many factors are responsible for the removal of forest resources in the area; among them are intensive agricultural practices, the establishment of more local government areas in recent years, the development of tertiary institutions and location of industrial plants as the case of Ilesa, which led to the influx of people to the area and subsequent development of housing estate and infrastructures.

According to 1991census figure, the study area is a populated area. Because of the dense population, the area has witnessed great structural development and growth, which in effect brought negative impact to the natural resources. The area of major population concentration is Ilesa with population of 130,321 based on 1991 census figure. Other populated areas include Ijebu-Ijesa, Efon-Alaaye, to mention but a few.

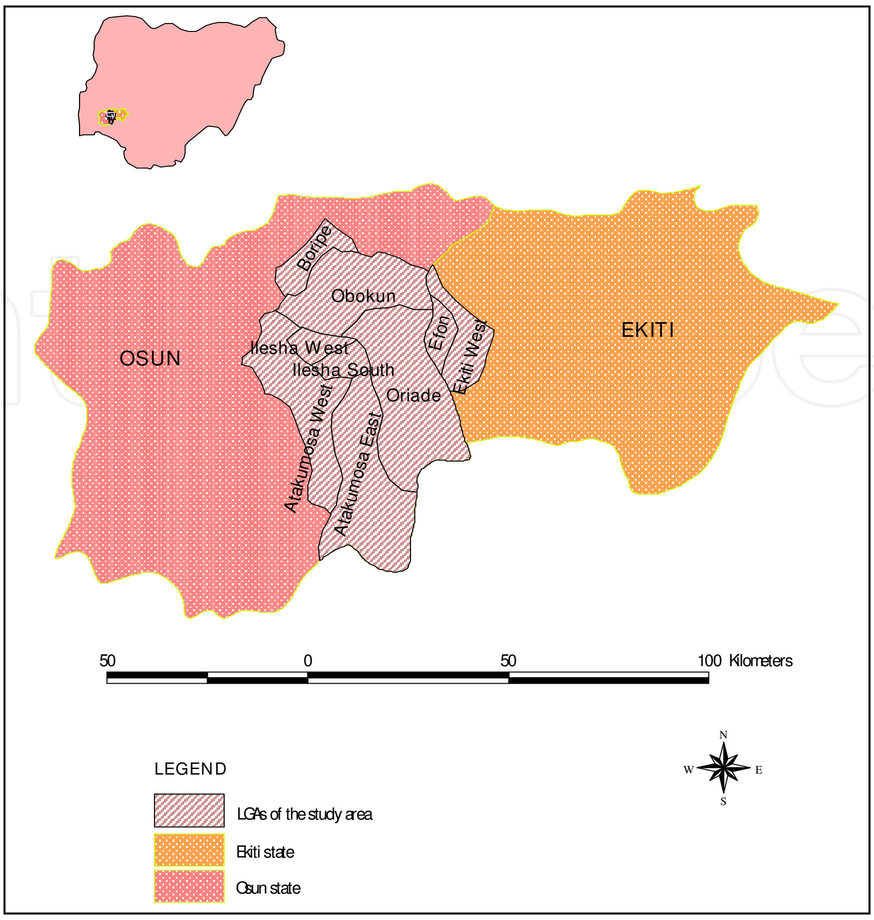


Fig. 1. The LGAs of the study area

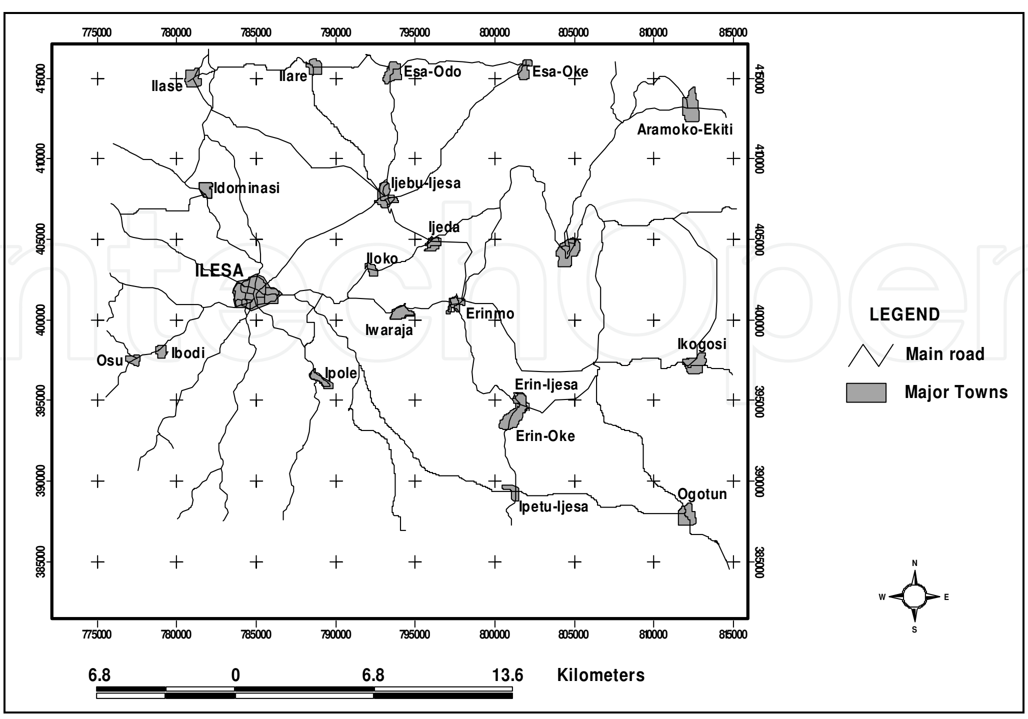


Fig. 2. Major communities of the study area

3. Conceptual clarification

3.1 Deforestation

Deforestation is a complex phenomenon as there is little agreement about the components and its process. FAO (2001a) defined it as 'the conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10 percent threshold'. Deforestation is also referred to as "complete destruction of forest canopy cover through clearing for agriculture, cattle ranching, plantations, or other non-forest purposes" (Poor, 1976; and Mayaux and Malingreau, 1996). Other forms of land-use changes, such as, forest fragmentation (altering the spatial continuity and creating a mosaic of forest blocks and other land cover types), and degradation (selective logging of woody species for economic purposes that affects the forest canopy and the biodiversity) are often included in estimating deforestation. The characterization of forest into one of these categories depends on the temporal and spatial scale of observation. The subjective meaning of the term deforestation is thus not only linked to a value system but also to the nature of the measurement designed to assess it (Poor, 1976; and Mayaux and Malingreau, 1996). Adopting different perspectives of deforestation in data analysis have caused considerable variations in estimation of the area of forest cleared.

3.2 Facts about deforestation

The world's original forest area, estimated at about 6 billion hectares, has been declining steadily. About one-third of the forests have been lost during the past few hundred years (Sharma, et al., 1992). Between 1850 and 1980 about 15 percent of the earth's forests and woodlands disappeared as a result of human activities. While the forests and woodlands of North Africa and the Middle East, declined by 60 percent; those of South Asia by 43 percent that of tropical Africa declined by 20 percent; and of Latin America by 19 percent.

Depletion of forests is of particular significance because in the tropics, about 2.5 billion of her people depend directly or indirectly on natural forest resources for many economic and environmental goods and services. Between 1980 and 1985 the estimated annual rate of tropical deforestation was 0.6 percent or 11.4 million hectares (FAO, 1988). Recent studies estimates deforestation in the tropics at a rate of 17 to 20 million hectares annually (Rowe et al, 1992). Although the world's forest area has been declining for centuries, it is within the last half of the 20th century that the process became accelerated. Since the 1960s, there has been a major change in the rate at which the forests are cleared. A recent study by FAO (1997) puts the annual rates of deforestation in developing countries at 15.5 million hectares for the period 1980-1990 and 13.7 million hectares for the period 1990 - 1995. The total forest area lost during the 15-year period was more than 29.2 million hectares.

In 1999, the FAO reported that 10.5 per cent of Africa's forest had been lost between 1980 and 1995, the highest rate in the developing world and in sharp contrast to the net afforestation seen in developed countries. Forest loss between 1990 and 2000 was more than 50 million hectares, representing an average deforestation rate of nearly 0.8 per cent per year over this period (FAO, 2001a). Between 1990 and 2002, a total of 12 million hectares of forests were deforested, of which sub-regional West Africa accounted for 15% of the countries (UNEP, 2002). The rate of deforestation in Nigeria in the 1980s was of the order of 400,000 ha yearly, while re-afforestation was a mere 3,200 ha. At such rates, Nigeria's remaining forest area would disappear by 2020 (Jaiyeoba, 2002). On the global scale, the rate of tropical deforestation is not known with any accuracy (World Resources Institute, 2003).

This informs gap in our knowledge. However, certain factors have been advanced to be responsible for deforestation and forest degeneration.

3.3 Causes of deforestation

Deforestation occurs for many reasons but it is important to distinguish between the causes that are directly related to deforestation and those that are underlying. The direct causes are those activities (by individuals, corporations, government agencies, or development projects), which clear forests. Underlying causes are those behind the direct causes, which motivate the direct causes. (http://www.wrm.org.uy/deforestation/UN report.html). Direct causes include commercial timber production, clearing of land for agriculture and urban expansion, and harvesting of wood for fuel and charcoal. These activities also open up forests by the construction of access roads to logging sites, fragmenting the forests and facilitating further clearance, resource extraction, and grazing by locals and commercial organizations (Rowe et al., 1992; UNDP, UNEP, World Bank and WRI, 2000; State of the World's Forests, 2001). According to the United Nations Framework Convention on Climate Change, the overwhelming direct cause of deforestation is agriculture. Subsistence farming is responsible for 48% of deforestation; commercial agriculture is responsible for 32% of deforestation; logging is responsible for 14% of deforestation and fuel wood removals make up 5% of deforestation (UNFCCC, 2007).

Indirect (underlying) causes of deforestation include population growth, policies, agreements, legislation, lack of stakeholder participation and market factors that encourage the use of forest products, leading to loss, fragmentation or degradation (Rodgers, Salehe and Olson, 2000). Other causes of forest loss are conflict, civil wars and lack of good governance (Verolme and Moussa, 1999).

In Africa as in all parts of the world, deforestation were caused by a combination of natural and human factors, the chief of which has been the conversion of forest lands to agricultural land (Adesina, 1997; Rowe et al., 1992). As Williams (1990) reported, the introduction of new crops and new methods of exploitations around 1600 radically altered tropical forests. It was reiterated that forests were cleared to make way for cash crops such as, rubber in Malaysia and Indonesia, coffee in Brazil, tea in India and China, sugar cane in the Caribbean, tobacco and oil palm in Asia.

Ola-Adams (1981) attributed the removal of forested areas to intensive agricultural practices. It was reported that approximately 2,000 hectares of western edge of Ogbesere forest reserve in Nigeria had been cut over and replaced by permanent agriculture. The study further revealed that in some other parts of the high forest, several areas of forest estate were being de-reserved for the establishment of agricultural crops. Besides, in the current efforts to diversify the country’s economy, large areas of high forest zones were being cleared and planted with food and tree crops; 45,845 ha. for food crops; 10,000 ha. for oil palm; 73,000 ha. for cocoa and about 140,000 ha. for rubber plantations.

There are many causes of contemporary deforestation, among them are corruption of government institutions (Burgonio, 2008; WRM, 2003), the inequitable distribution of wealth and power (Global Deforestation, 2006), population growth (Marcoux, 2000), and overpopulation (Butler, 2009; Stock and Rochen, 2009), and urbanization (Karen, 2003). Globalization is often viewed as another root cause of deforestation (YaleGlobal, 2007; Butler, 2009), though there are cases in which the impacts of globalization (new flows of labour, capital, commodities, and ideas) have promoted localized forest recovery (Hecht, et al, 2006).

Experts do not agree on whether industrial logging is an important contributor to global deforestation (Angelsen and Kaimowitz, 1999; Laurance, 1999). Some argue that poor people are more likely to clear forest because they have no alternatives, others that the poor lack the ability to pay for the materials and labour needed to clear forest (Angelsen and Kaimowitz, 1999). One study found that population increases due to high fertility rates were a primary driver of tropical deforestation in only 8% of cases (Geist and Lambin, 2002). However, a shift in the drivers of deforestation over the past 30 years has been noted. Whereas deforestation was primarily driven by subsistence activities and government-sponsored development projects like transmigration in countries like Indonesia and colonization in Latin America, India, Java, and so on, during late 19th century and the earlier half of the 20th century. By the 1990s the majority of deforestation was caused by industrial factors, including extractive industries, large-scale cattle ranching and extensive agriculture (Rudel, 2005; Butler and Laurance, 2008).

3.4 Effects of deforestation

Deforestation causes extinction, changes to climatic conditions, desertification, and displacement of populations (Sahney, et al, 2010). It is a contributor to global warming (Fearnsidel and Laurance, 2004) and is often cited as one of the major causes of the enhanced greenhouse effect. According to the Intergovernmental Panel on Climate Change, deforestation mainly in tropical areas, could account for up to one-third of total anthropogenic carbon dioxide emissions (IPCC Fourth Assessment Report). But recent calculations suggest that carbon dioxide emissions from deforestation and forest degradation (excluding peatland emissions) contribute about 12% of total anthropogenic carbon dioxide emissions with a range from 6 to 17% (Van der Werf, et al, 2009). Scientists also state that, Tropical deforestation releases 1.5 billion tones of carbon each year into the atmosphere (Defries, 2007).

Reducing emissions from the tropical deforestation and forest degradation (REDD) in developing countries has emerged as new potential to complement ongoing climate policies. The idea consists in providing financial compensations for the reduction of greenhouse gas (GHG) emissions from deforestation and forest degradation" (Wertz-Kanounnikoff and Alvarado, 2007).

Deforestation results in declines in biodiversity. Estimate shows that rainforest is losing 137 plant, animal and insect species every single day due to deforestation, which equates to 50,000 species a year (Rainforest Facts, 2010). Leakey and Roger, (1996) state that tropical rainforest deforestation contributed to the ongoing Holocene mass extinction. But scientific understanding of the process of extinction is insufficient to accurately make predictions about the impact of deforestation on biodiversity (Pimm, et al, 1995). Most predictions of forestry related biodiversity loss are based on species-area models, with an underlying assumption that as the forest declines species diversity will decline similarly. However, many such models have been proven to be wrong and loss of habitat does not necessarily lead to large scale loss of species. Species-area models are known to over-predict the number of species known to be threatened in areas where actual deforestation is ongoing, and greatly over-predict the number of threatened species that are widespread (Pimm, et al, 1995).

3.5 Control

Major international organizations, including the United Nations and the World Bank, have begun to develop programs aimed at curbing deforestation. The blanket term Reducing

Emissions from Deforestation and Forest Degradation (REDD) describes these sorts of programs, which use direct monetary or other incentives to encourage developing countries to limit and/or roll back deforestation. Funding has been an issue, but at the UN Framework Convention on Climate Change (UNFCCC) Conference of the Parties-15 (COP-15) in Copenhagen in December 2009, an accord was reached with a collective commitment by developed countries for new and additional resources, including forestry and investments through international institutions, that will approach USD 30 billion for the period 2010 - 2012 (UNFCC, 2009). Significant work is underway on tools for use in monitoring developing country adherence to their agreed REDD targets. These tools, which rely on remote forest monitoring using satellite imagery and other data sources, include the Center for Global Development's FORMA (Forest Monitoring for Action) initiative (FORMA, 2009) and the Group on Earth Observations' Forest Carbon Tracking Portal, (GEO FCT, 2010). Methodological guidance for forest monitoring was also emphasized at COP-15 (UNFCC, 2009).

4. Methodology

4.1 Data acquisition and image processing

Remotely sensed data of different sources were used for this study (Figures 1, 2, 3, & 4). This is because of the constraint of the availability of field data in this part of the world. These are Landsat MSS, acquired on March 15, 1978 of 80m spatial resolution; SPOT XS, obtained on May 19, 1986 and SPOT XS acquired on November 28, 1994, of 20m spatial resolution respectively; NigeriaSat_1 acquired on September 23, 2003, of 32m spatial resolution (Table 1).

S/no	Data type	Date/Year obtained	Spatial Resolution	Swath	Spectral bands	Agency
1.	Landsat MSS	March 15, 1978	80m	185km	4 Bands [Blue, Green, Red & Near infrared]	FORMECU, Abuja, Nigeria
2.	SPOT XS	May 19, 1986	20m	60km	3 Bands [Green, Red & Infrared]	RECTAS, Ile-Ife, Nigeria
3.	SPOT XS	November 28, 1994	20m	60km	3 Bands [Green, Red & Infrared]	FORMECU, Abuja, Nigeria
4.	NigeriaSat-1	September 23, 2003	32m	600km	3 Bands [Near-infrared, Red & Green]	NASRDA, Abuja, Nigeria

Source: Author’s field survey

Table 1. Attributes of the images used for the Study

Ideally, studies such as this would be better conceived if images were acquired twice a year to allow for seasonal variation in foliage coverage. In southwestern Nigeria for instance, the rainy season spans the period of eight months that is, between March and October while the dry season starts from November and lasts until February. The images used are both acquired in rainy season (Landsat MSS, 1978, SPOT XS, 1986 and NigeriaSat-1, 2003) and dry season (SPOT XS, 1994). These differences in the date of acquisition may cause disparity in

the results. However, they were used because of the spectral information of the study area they contain.
The data were extracted as a sub-scene from the original dataset. For the purpose of temporal land use/cover change detection, a common window covering the same geographical coordinates of the study area was extracted from the scene of the images obtained. The sub-map operation of ILWIS 3.2 Academic allows the user to specify a rectangular part of a raster map to be used. To extract the study area from the whole scene of the images obtained, the numbers of rows and columns of the area were specified. While Landsat MSS 1978 contained 600 lines and 733 columns pixels, SPOT XS 1986 and 1994 consist of 1373 lines and 2005 columns pixels, respectively, when NigeriaSat_1 2003 has 1083 lines and 1150 columns of pixels.

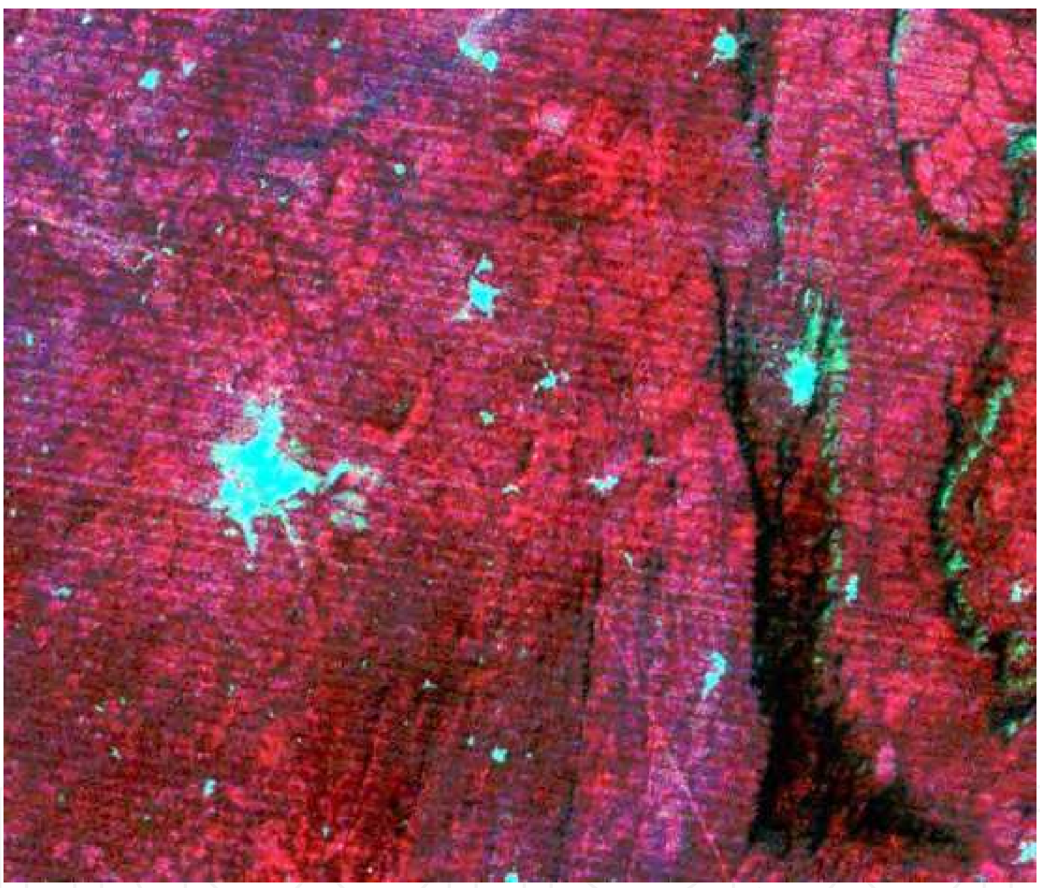


Fig. 3. Landsat Multispectral (MSS) 1978

The false colour composite was used for all the image data to relate colours and patterns in the image data to the real world features. For Landsat MSS 1978, channel 1 was assigned to red plane, channel 2 to green plane, and channel 3 to blue plane. This makes the band Red, Blue, Green (RBG-123) false colour composite. For SPOT XS 1986 and 1994, channel 3 was assigned red plane, channel 2 to green and channel 1 to blue plane. The band combination then consisted of Blue, Green and Red (BGR-321) to produce false colour composite. For NigeriaSat_1 2003 false colour composite, channel 1 was assigned to red plane, channel 2 to green plane and channel 3 to blue plane. This puts the band combination as Red, Green and Blue (RGB-123).

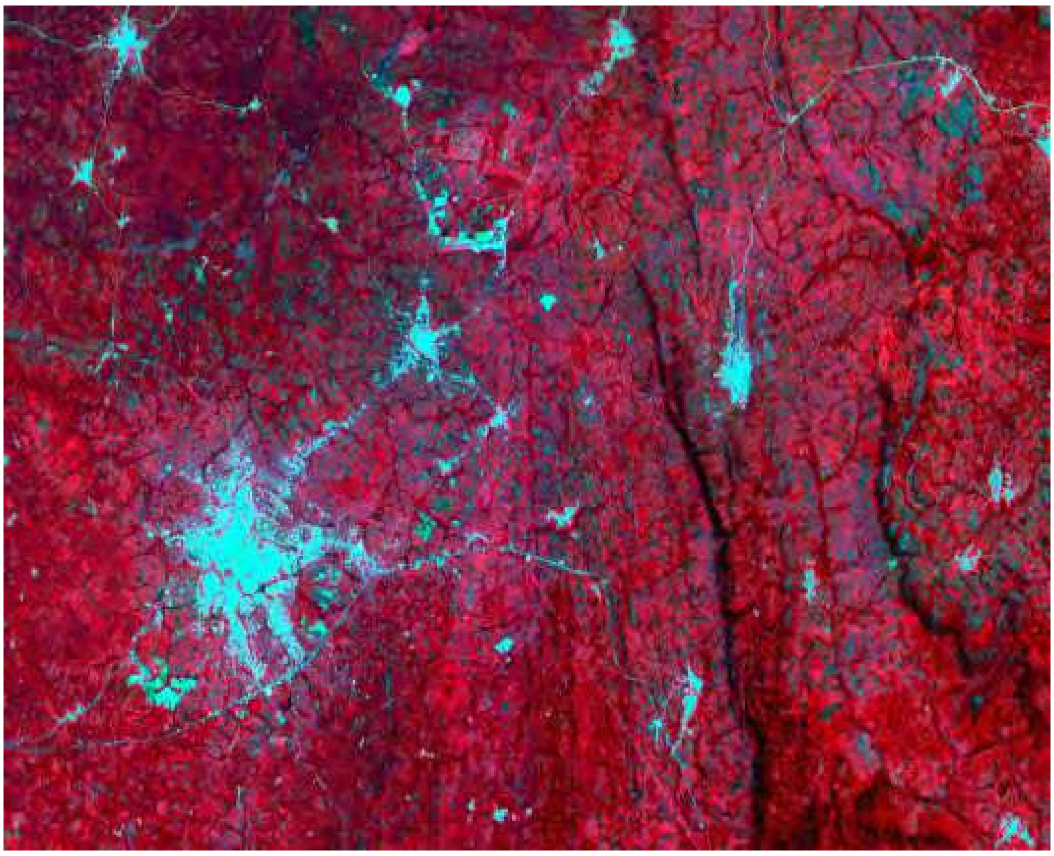


Fig. 4. SPOT Satellite XS 1986

With constraints such as spatial, spectral, temporal and radiometric resolution, relatively simple remote sensing devices cannot record adequately the complexity of the Earth's land and water surfaces. Consequently, error creeps into the data acquisition process and can degrade the quality of the remotely sensed data collected. Therefore, it is necessary to preprocess the remotely sensed data before the actual analysis. Radiometric and geometric errors are the most common types of errors encountered in remotely sensed imagery. The commercial data provider has removed the radiometric and systematic errors of the data used. However, while the unsystematic geometric distortion remains in the image. The geometric errors were corrected using ground control points (GCP).

The process of georeferencing in this study started with the identification of features on the image data, which can be clearly recognized on the topographical map of the study area and whose geographical locations were clearly defined. Stream intersections and the intersection of the highways were used as ground control points (GCP). The latitude and longitude of the GCPs of clearly seen features obtained in the base map were used to register the coordinates of the image data used for the study. All the images were georeferenced to Universal Transverse Mercator projection of WGS84 coordinate system, zone 31N with Clarke 1880 Spheroid. Nearest-neighbor re-sampling method was used to correct the data geometrically. A correlation threshold was used to accept or discard points. The correlation range was within limits that is, 1 pixel size. The x and y corrections were below 0.5 pixel.

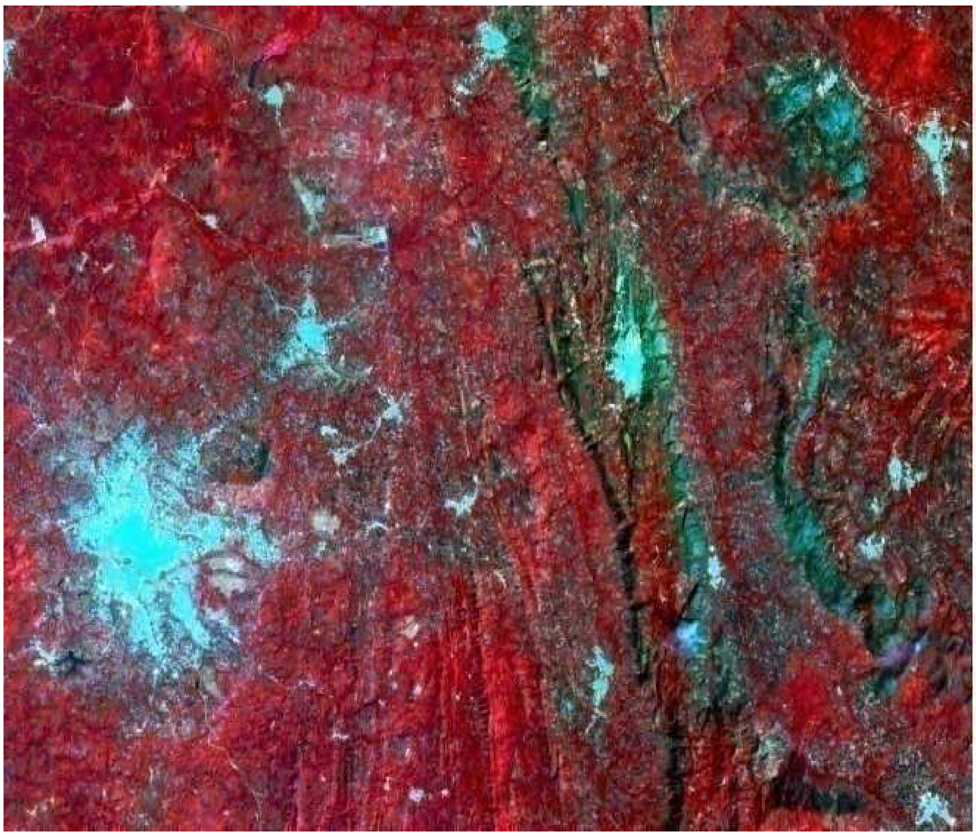


Fig. 5. SPOT Satellite (XS) 1994

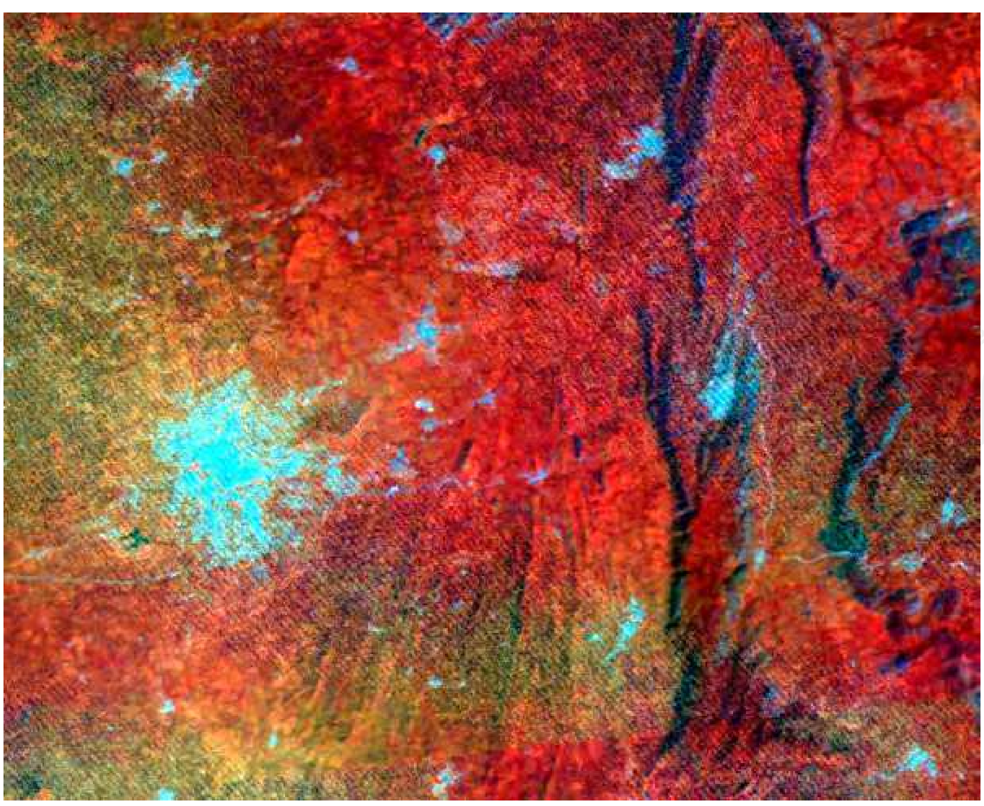


Fig. 6. NigeriaSat-1 2003

4.2 Classification

In this study, the satellite images were classified using supervised classification method. The combine process of visual image interpretation of tones/colours, patterns, shape, size, and texture of the imageries and digital image processing were used to identify homogeneous groups of pixels, which represent various land use classes of interest. This process is commonly referred to as training sites because the spectral characteristics of those known areas are used to train the classification algorithm for eventual land use/cover mapping of the remainder of the images.
To validate the tonal values recorded on the satellite images with the features obtained on the ground and also to know what type of land use/cover is actually present, the study engaged in ground truthing to five communities of the study area. These are Ilesa, Ijebu-Ijesa, Efon-Alaaye, Iloko-Ijesa and Erin-Oke (Figure 2). Before the ground truthing, map of the study area was printed and was used as guide to locate and identify features both on ground and on the image data. The geographical locations of the identified features on the ground were clearly defined. These were used as training samples for supervised classification of the remotely sensed images. Eight categories of land uses and land covers were clearly identified during ground truthing. These are forest/secondary re-growth, agro-forestry, arable farmlands, fallow/shrub, bare soils, water body, bare rocks and built-up areas/settlements.

4.3 Accuracy assessment

Determination of meaningful change categories was conducted by evaluating the classification accuracy. Every classified pixel has accuracy for a particular land use/cover type. The most common and typical method to assess classification accuracy Error Matrix (sometimes called a confusion matrix or contingency table) was used to assess the accuracy assessment for this study. Error matrix compares, on a category-by-category basis, the relationship between known referenced data and the corresponding results of an automated classification. Such matrices are square, with the number of rows and columns equal to the number of categories whose classification accuracy is being assessed (Jensen, 1996).

5. Results and discussion

5.1 Accuracy assessment of satellite images

The accuracy assessment of four temporal data shows that most land use types were classified with acceptable level of accuracies. The low classification accuracies found in Arable farmlands, Agro-forestry and Fallow/Shrub classes was due to the similar spectral characteristics in them and the prevailing season, which posed constraint to the classification process. However, the overall accuracy of the land use categories makes the study reliable for planning. The average reliability of Landsat MSS 1978 was 57.24% while the overall accuracy was 76.20%; SPOT XS 1986 average reliability was 66.46% and the overall accuracy of 67.43%; SPOT XS 1994 average reliability was 65.04 % while the overall accuracy was 60.88%. NigeriaSat_1 2003 average reliability was 63.25 % and the overall accuracy was 72.05% (Tables 2, 3, 4 and 5).

	Agrofo-restry	**Arable farmlands**	**Bare soils**	**Exposed rock**	**Forest**	**Settlement**	**Shrub/ Fallow**	**Water body**	**ACCURACY**
Agroforestry	216	4	0	12	82	0	190	0	0.43
Arable farmlands	13	1801	302	74	1309	0	2782	10	0.29

	Agrofo-restry	Arable farmlands	Bare soils	Exposed rock	Forest	Settlement	Shrub/Fallow	Water body	ACCURACY
Bare soils	3	1460	2417	44	271	74	359	6	0.52
Exposed rock	0	82	77	4580	443	0	1	73	0.87
Forest	70	549	50	2274	45232	0	3011	48	0.88
Settlement	0	0	52	0	0	2695	0	0	0.98
Shrub/Fallow	653	882	54	6	3809	0	5809	0	0.52
Water body	0	55	26	129	274	0	1	33	0.06
RELIABILITY	0.23	0.37	0.81	0.64	0.88	0.97	0.48	0.19	

Average Accuracy = 56.92 %
Average Reliability = 57.24 %
Overall Accuracy = 76.20 %

Table 2. Matrix of land use/land cover for 1978

	Agroforestry	Arable farmland	Bare soils	Exposed rock	Forest	Settlement	Shrub/fallow	Water body	ACCURACY
Agroforestry	2027	0	1	0	1	0	29	0	0.82
Arable farmland	0	1254	241	10	0	0	38	544	0.57
Bare soils	113	5000	3227	238	78	68	1000	3002	0.21
Exposed rock	0	173	367	4052	21	0	29	2303	0.50
Forest	214	15	146	146	23942	0	4431	4	0.72
Settlement	0	3	41	0	0	22488	0	0	0.85
Shrub/fallow	226	559	959	32	511	0	11444	21	0.80
Water body	0	195	85	107	0	0	3	1381	0.78
RELIABILITY	0.79	0.17	0.64	0.88	0.98	1.00	0.67	0.19	

Average Accuracy = 65.68 %
Average Reliability = 66.46 %
Overall Accuracy = 67.43 %

Table 3. Matrix of land use/land cover for 1986

	Agro-forestry	Arable farmlands	Bare soils	Exposed rock	Forest	Settlement	Shrub/fallow	Water body	ACCURACY
Agro-forestry	3763	0	0	0	124	0	109	0	0.78
Arable farmlands	0	33	2	1	0	0	3	0	0.82
Bare soils	5	7825	11370	1222	238	113	2717	274	0.41
Exposed rock	0	139	493	15659	1890	0	940	19489	0.35
Forest	711	4	0	678	22169	4	1071	141	0.87
Settlement	0	0	54	0	0	25244	0	0	0.86
Shrub/fallow	137	1031	466	120	861	3	8163	7	0.70
Water body	0	5	34	64	8	0	33	1926	0.89
RELIABILITY	0.82	0.00	0.92	0.88	0.88	1.00	0.63	0.09	

Average Accuracy = 71.28 %
Average Reliability = 65.04 %
Overall Accuracy = 60.88 %

Table 4. Matrix of land use/land cover for 1994

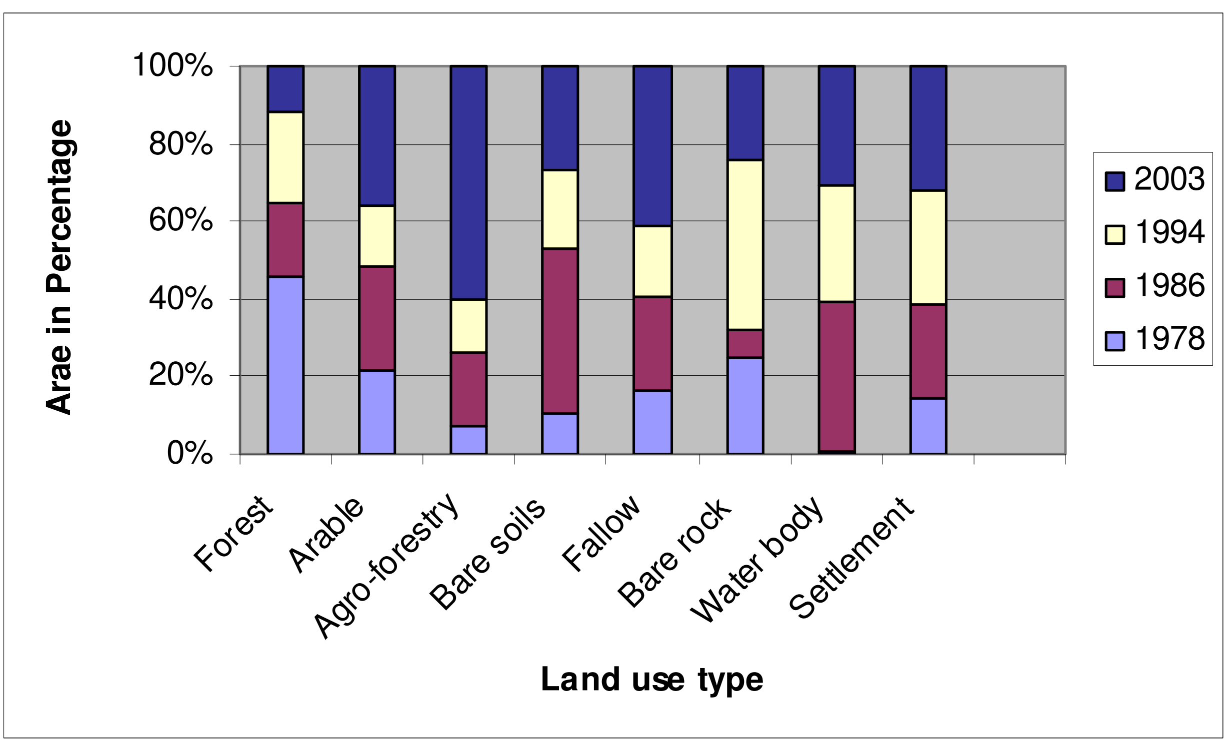
	Agro-forestry	Arable farmland	Bare rock	Forest	Bare soils	Settlement	Shrub/ fallow	Water body	ACCURACY
Agroforestry	1333	0	0	54	0	0	44	0	0.93
Arable farmland	0	5485	363	0	464	0	1662	44	0.68
Bare rock	0	928	13507	0	34	30	19	1530	0.84
Forest	2244	0	10	11412	0	0	4558	26	0.63
Bare soils	1	5174	41	4	10517	720	6118	124	0.46
Settlement	0	174	22	0	1438	13267	7	632	0.85
Shrub/fallow	1475	504	64	657	1351	0	24127	123	0.85
Water body	0	86	207	0	4	58	0	263	0.43
RELIABILITY	0.26	0.44	0.95	0.94	0.76	0.94	0.66	0.10	

Average Accuracy = 70.97 %
Average Reliability = 63.25 %
Overall Accuracy = 72.05 %

Table 5. Matrix of land use/land cover for 2003

5.2 Land use change between 1978 and 2003

The overall results of the study indicate that the area of forestland has been continuously declined, while the area of shrub/fallow, built-up area (settlements) and waterbody was proportionally increased (Table 6).



Source: Author's Data Analysis

Fig. 7. Land use/land cover change 1978-2003

Categories of Land Use (LU)	1978 LU (ha.)		1986 LU (ha.)		% Change in LU 1978-1986	1994 LU (ha.)		% Change in LU 1986-1994	2003 LU (ha.)		% Change in LU 1994-2003	Overall change (hectares)
		% of LU 1978		% of LU 1986			% of LU 1994			% of LU 2003		
Forest	72310.93	60.40	30587.80	28.11	-57.70	36635.75	36.52	-19.77	18841.70	14.44	- 48.57	-53,469 **(Decrease)**
Arable farmlands	9441.88	7.89	11830.08	10.87	25.29	6830.37	6.81	-42.27	15923.20	12.21	133.13	6,482.32 **(Increase)**
Agro forestry	558.76	0.47	1498.87	1.38	168.23	1080.13	1.08	-27.95	4774.30	3.66	342.03	4,215.54 **(Increase)**
Bare rock	7340.62	6.13	2246.29	2.06	-69.40	12979.33	12.94	477.81	7282.28	5.58	- 43.89	-58.34 **(Decrease)**
Bare soils	2213.28	1.85	9347.52	8.59	322.30	4348.26	4.33	-53.48	5814.88	4.46	33.73	3,601.60 **(Increase)**
Water body	139.36 **1.39 km²**	0.12	5782.70 **57.83 km²**	5.31	4060.43	4617.84 **46.18 km²**	4.60	-20.15	4608.72 **46.09 km²**	3.53	-20.00	4,469.36 **(Increase)**
Fallow	23397.91	19.54	35330.25	32.47	51.00	26804.25	26.72	-24.13	59436.85	45.57	121.74	36,038.94 **(Increase)**
Settlement	943.39	0.79	1567.60	1.44	66.17	1947.94	1.94	24.26	2089.57	1.60	7.29	1,146.18 **(Increase)**

Table 6. Land use change between 1978 and 2003

5.3 Forest status between 1978 and 2003

The area of forest in the study area was becoming smaller with time (Table 6). In 1978, forest area was 72,310.93 hectares, which constituted 60.40% of the entire land use. By 1986, the areal extent had decreased from 72,310.93 to 30,587.80 hectares, a decline of 57.7% within the period of 9 years. In 1994, there seems to be an increase in the areal extent of the resources. This is because in 1986, it was 30,587.80 hectares but in 1994 it increased to 36,635.75 hectares. This increase was not an expansion in the coverage but re-growth of the forest area. In 2003, the forest resources in the study area had almost disappeared when the areal extent was reduced to 18,841.70 hectares. This represented a decline of 48.57% within the period of 10 years. From the analysis, a total area of 53,469 hectares of the forest resources was removed.

The decline in the forest area as discovered in the study confirms the report of FAO (2001) that tropical forest including Nigeria was on the decline. According to the United Nations Food and Agriculture Organization (FAO), 93,900 km² of forest were cleared per year during the 1990s, with annual rates of forest loss (positive for all continents with tropical forests): Africa 0.8%, Asia 0.1%, Oceania 0.2%, North and Central America 0.1%, and South America 0.4% (FAO, 2001). The study also upholds the recognition of Cassel-Gintz, and Petschel-Hels (2001) that discovered deforestation in their recent study and concluded that it is one of the core problems of global environmental change. UNDP, UNEP, World Bank and WRI, (2000) associated extensive deforestation with loss of biodiversity, climate change, watershed degradation and these pose threat to cultural survival of indigenous population, economic loss among others. According to the estimates by the Food and Agricultural Organization (FAO 1983), Nigeria through careless exploitation and husbandry, destroys about 600,000 ha of her forest every year, as against the reforestation efforts of about 25,000 ha a year, which replenishes only about 4 percent of the loss. At such rates, Nigeria's remaining forest area would disappear by 2020 (Jaiyeoba 2002).The general effect of timber exploitation mostly from the high forests which cover only about 12.41 million ha of the country's 91.1 million ha of land space, (i.e. about 13.5%), is that the forest areas are fast reducing to savanna vegetation. Consequently, the forest stability is disrupted and its ecosystem has been seriously disturbed.

The disturbances are not only in terms of its ability to regenerate through the natural process, but some species of trees and fauna are being endangered (Okafor 1988).

In recent times, precisely June 1992, the Earth Summit in Rio de Janeiro, Brazil more correctly known as the United Nations Conference on Environment and Development (UNCED) was convened. There was an agreement on a set of "Principles for a global consensus on the management, conservation and sustainable development of all types of forests" and devoted a full chapter of its Agenda 21 to "Combating deforestation". Since this conference, there has been debate on the phenomenon and conscious efforts are being made to carefully use and protect natural resources mostly in the developed countries. But there seems to be limited enthusiasm from developing countries, including Nigeria, where ineptitude, particularly as regards the implementation of environmental laws, has been the greatest bane to a sustainable environmental practice (Lines et al.1997; Ibah. 2001). For instance, between 1995 and 1999 the military junta in Nigeria showed nonchalant attitude to the sustainability of the forest resources. This gave room to illegal lumbermen to penetrate the forest in the country, both reserved (protected) and the opened forest (unprotected), as the case of the study area, thus declined the area of forest nationwide. In poor and developing countries where often the administrative structures are either too weak and/or corrupt to enforce rules and regulations effectively and where tax and incentive systems do not work, forest clearing and environmental degradation has proceeded unabated.

5.4 Arable farmland status from 1978 to 2003

Arable farming is one of the prominent economic activities among the people of the study area as it is reflected in Table 6. The farmlands occupied 9,441.88 hectares, which represented 7.89% of the entire land use in 1978. In 1986, the land area of arable farmlands expanded from 9,441.88 to 11,830.08 hectares, making an increase of 2,388.20 hectares. But there seems to be a decrease in the cultivated area in 1994. This is due to the period at which the image was obtained that is, November, the beginning of dry season in southwestern Nigeria. At this time, most crops had been harvested except few such as, cassava, maize, among others which are left for proper maturation. Thus, majority of the farmlands are abandoned till the next planting season and they are sometimes overgrown with shrubs during this period. Between 1994 and 2003, arable farmlands increased from 6,830.37 to 15,923.20 hectares, representing an increase of 133.13%.

A close assessment of arable farmland areas between 1978 and 2003 shows that, 6,482.32 hectares of the land area was gained. This is negligible if we are going to solve the problem of food insecurity. However, the expansion of farmlands and declining in the forest area affirms the claim of Ola-Adams, (1981) and Williams, (1990). In their studies it was discovered that forests were removed to pave way for food and tree crops. Besides, the United Nations Framework Convention on Climate Change (UNFCCC, 2007) asserted that the overwhelming direct cause of deforestation is agriculture. In their discovery, subsistence farming was responsible for 48% of deforestation; commercial agriculture 32%; logging 14% and fuel wood removals make up 5% of deforestation. This was the observation of the study during the ground truthing. Besides, arable farmlands were scattered all over the study area especially around the settlements and some newly deforested areas and there were no large scale mechanized farming in the area. Again, arable farmlands were common features around the mountainous terrain and crops such as, maize, yam, cassava, rice, among others were mainly grown in the study area.

5.5 Status of agro-forestry between 1978 and 2003

Agro-forestry, otherwise known as tree crop plantation in the study only constituted 0.47% that is, 558.76 hectares of the entire land use in 1978 (Table 6). The improved spatial resolution of the image data (SPOT 1986 and 1994) however, brought a significant difference to what was recorded in Landsat MSS 1978. Also, variation in the period at which the image data were taken influenced the differences in the pixel statistics of the two images. It should be recalled that while SPOT XS 1986 was obtained in May, the beginning of rainy season in southwestern Nigeria, SPOT XS 1994 was acquired in November, the beginning of dry season in the area. In May, tree canopies are just springing up due to the long periods of dryness. On the other hand, the tree canopies are still fresh in November despite the inception of the dry period. This difference in the time period is capable of influencing the canopy characteristics of the farmlands, consequently affecting the result. The estimated area of agro-forestry in 2003 was 4,774.30 hectares, which represented an increase of 342.03%. Although agro-forestry is not commonly found in the study area due to poor topography in some areas, the tree crop plantations are well grown in some areas around Ilesa, Erin-Oke, Aramoko-Ekiti (Figure 2). Because of the economic value of the crops, many deforested areas have been replaced with the cocoa plantations in particular, which confirms the findings of Ola-Adams, (1981) and Williams, (1990).

Although research in agro-forestry especially in Africa, has paid a significant quantum of emphasis on this concept for about three decades, it again is adaptation of earlier system of slash and burn and perennial forest gardens, although on a more scientific basis. The benefits of incorporating trees, especially fast growing legume species, lies in increasing soil fertility, obtaining complimentarity in resource use, reducing environmental stress and protecting crops.

5.6 Bare rock status from 1978 to 2003

The pixel statistics in Table 6 shows that the underlying rocks were being exposed in the study area. For instance, the area occupied by the exposed rock was 7,340.62 hectares in 1978, which was 6.13% of the total land use. The proportional decreased in 1986 was due to the prevailing season that is, wet season. During this period, the whole landscape was covered with vegetation making it difficult for rock to be seen as rock. This constraint in effect influenced the recorded areal extent of 2,246.29 hectares, which represented a decrease of 69.40%. In 1994, the area occupied by rock increased to 12,979.33 hectares, because of the prevailing season that is, dry season. At this time, the vegetation had dried up thus, making exposed rocks visible for classification. The year 2003 showed a decrease of 43.89% in the area of bare rocks. This could be because of the prevailing season at the time the image was acquired that is, September, the peak period of raining season in southwestern Nigeria. It is instructive to note that the rocks of the study area show great variation in grain size and in mineral composition, which enhanced the growth of dense vegetation whenever there is enough moisture. During the field survey, some quarry sites were sighted, which could in effect lead to the reduction in the size of the bare rocks in the study area.

5.7 Status of bare soils from 1978 to 2003

There are continuous exposure of soils to intense solar radiation and direct precipitation in the study area. This is shown by the expansion of bare soils discovered in the study. For example, in 1978, the area occupied by bare soils was 2,213.28 hectares representing 1.85% of the entire land use area. This increased to 9,347.52 hectares in 1986, representing 322.30% increase over the period of 9 years (1978 - 1986). The bare soils decreased by 53.48% in 1994 and expanded by 33.73% in the year 2003. Between 1978 and 2003, the estimated area of bare soils expanded from 2213.3 hectares to 5814.9 hectares, which put an increase at 3601.6 hectares (Table 6).

Although the prevailing season partly influenced the trend, it was obvious some land areas were void of vegetation in the study area. Continuous exposure of soils could pose serious problem to agricultural sector and consequently continuous food insecurity. This is because clearing of forest lands contribute to severe soil erosion, soil infertility and flooding. The multiplier effect on the economy could be severe if quick action is not taken. In the first place, soil erosion would reduce agricultural land area, which in effect could induce food shortages and out-migration of the able-body from the rural community to the urban environment. This claim is already manifesting in most rural communities in Nigeria including the study area. Arokoyu (1999) reported that "environmental devastation has led to the loss of the means of livelihood of people, fall in agricultural outputs, out-migration of able-bodied youths, and engendered social rifts and intensified confusion. Presently, a community in the study area (Efon-Alaaye) has already been devastated by soil erosion and government had sunk millions of Naira to redeem the community from being swept away by erosion. This situation is capable of discouraging the able-bodied youths from the community and induces migration to urban centres, thereby increasing urbanization process.

5.8 Water body status from 1978 to 2003

The drainage basin area in 1978 was 1.39 km^2. This increased to 57.83 km^2 in 1986, which was equivalent to 4060.43% increase. This increment was dictated by the improved spatial resolution of SPOT XS 1986, which is 20m as against 80m spatial resolution of Landsat MSS 1978. In SPOT XS 1986, streams, rivers, ponds and dams were more clearly visible, which enhanced the area calculation. In 1994, the drainage basin area calculated reduced by 20.15%, which consequently put the total area at 46.18 km^2. The reason for this can be traced to the prevailing season. At the time the image data was obtained, the rain had just ended in southwestern Nigeria and the tree canopy was still fresh and dense. Most streams and rivers were covered with riparian forest thus, making it difficult for rivers to be assigned to class ID for eventual classification. In 2003, the area of water body was 46.09 km^2, which was still a reduction in the coverage of water body. The reason for this is connected to the prevailing season that is, wet season and some noises in the image data, which in effect reduced its optimum visual systems. The pixel statistical result of water body in the study does not reflect the situation on ground and does not support the present claim of climate change. High spatial resolution images is therefore, recommended for study on hydrology.

5.9 Status of fallow/shrub from 1978 to 2003

Bush fallow is a periodic relocation of farmland for the purpose of allowing soil to regain its fertility. Table 6 shows that the area of fallow has been increasing over the years, the highest being recorded between 1994 and 2003. For example, between 1978 and 1986, the fallow area increased from 23,397.9 hectares to 35,330.3 hectares, which puts the percentage change within the period of 8 years at 51%. This therefore implies that per year, the land areas that were left to fallow in the study area were 1,492 hectares. The spatial coverage, however, decreased from 35,330.3 hectares in 1986 to 26,804.2 hectares in 1994, which put decline at

24.13%. This indicated that 8,526.1 hectares of fallow lands were used up within the period of 9 years. But between 1994 and 2003, the trend changed as fallow area increased from 26,804.2 hectares in 1994 to 59,436.8 hectares in 2003. This shifted the percentage change over the period of 9 years from 24.13 to 121.74.

The increase in the areal extent of shrub/fallow and a decrease in the forest area suggested that part of the deforested areas were abandoned to secondary re-growth. According to Aweto (1990), in Nigeria, the area previously characterized by continuous forest cover has been converted into secondary re-growth vegetation, mainly as a result of shifting cultivation and lumbering. In study area, some deforested areas were left uncultivated thereby converted to secondary re-growth while some farmlands were left to fallow thus, created a large expanse of fallow lands in the area.

5.10 Built-up area status from 1978 to 2003

The development of settlements in the study area has been rather gradual. This is because the study area comprises of many rural settlements and few urban centres and why major development takes place in the urban settlements, little or no development takes place in the rural settlements. This accounted for the proportion of 943.39 hectares in 1978. Although there was an increase in the areal extent in 1986, it only amounted to an increase of 66.17% over the period of 8 years. Settlements also expanded in their areal extent between 1986 and 1994, (i.e. 1567.6 to 1,947.9 hectares). This shows that within those periods, all the settlements expanded by 380.3 hectares, which constituted 24.26% increase. Between 1994 and 2003, settlements expanded by 142 hectares, which makes the total area covered by settlements to increase from 1,947.9 hectares, to 2,089.6 hectares. This shows that annually, between 1994 and 2003, 15.78 hectares of lands were gained for settlements, which represented 7.29% growth between 1994 and 2003.

The expansion of settlements, due to increased in human population and decrease in forest area shows that forests were been destroyed in the study area to pave way for human habitation. This confirms the findings of the Mather, (1990) and Harcourt, (1992) that reported an inverse relationship between population and forest cover. Geist and Lambin, (2002) also revealed that population increases due to high fertility rates were a primary driver of tropical deforestation in only 8% of cases.

6. Conclusion

The study, through the capability of GIS technology and remote sensing data revealed a steady decline in forest area and land use intensification with the expansion in farmlands, fallow ground and built up/residential areas. This indicates that forests were being converted to agricultural use and housing estate. However, the disappearance of forest resources could pose serious threat to biodiversity. For instance, there has been an underlying assumption that as the forest declines, species diversity will decline similarly. Many such models have been proven to be wrong and loss of habitat does not necessarily lead to large scale loss of species. Study that will give more insight on the process of biodiversity extinction resulted from deforestation will be needed since the scientific understanding of the process of extinction is insufficient to accurately make predictions about the impact of deforestation on biodiversity. Moreover, it should be borne in mind that forest resources preserve ecosystem, offers economic and social opportunity for people. Besides, forests foster medicinal conservation. There is therefore need to protect our forest since unprotected forest will disappear faster than the protected one. Demarcating some forest zones as forest reserve areas could do this. Also, the indigenous participation and the involvement of the community people together with the forest guards in forest monitoring will go a long way to salvaging our forest from total depletion. The approach of GIS in this study was found useful as adequate tool for regular and up-to-date monitoring of forest and earth resources.

7. Acknowledgements

The impetus received from Prof. Bola Ayeni (Department of Geography, University of Ibadan, Nigeria) and Prof. F. A. Adesina (Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria) in contributing a chapter to this book was appreciated. The authors valued the cooperation of the staff of RECTAS, Obafemi Awolowo University, Ile-Ife; NASRDA, Abuja and GIS unit of the Department of Geography where the satellite images used for this study were collected. Finally, the privilege offered the authors by the CEO of INTECH open access publisher to contribute a chapter to this book was treasured.

8. Definition of terms

Deforestation:

Deforestation is the removal of a forest or stand of trees where the land is thereafter converted to a non-forest use. Examples of deforestation include conversion of forestland to farms, ranches, or urban use. Deforestation occurs for many reasons: trees or derived charcoal are used as, or sold, for fuel or as timber, while cleared land is used as pasture for livestock, plantations of commodities, and settlements.

Land use:

Land use is characterized by the arrangement, activities and inputs people undertake in a certain land cover type to produce change or maintain it (FAO, 2005). Land use is the specific activity a piece of land is put into. Various land use patterns emerge after the land has been subjected to use over time. In the rural area for instance, the type of land use include farming, plantation, grazing, etc.

Land cover:

The definition of land cover is fundamental, because in many existing classifications and legends, it is confused with land use. Land cover is the observed (bio) physical cover on the earth's surface (FAO, 2005).

Biodiversity:

Biological diversity or biodiversity means the variety of plant and animal life at the ecosystem, community or species level and even at the generic level, Biodiversity is most commonly measured and reported at species level with characteristics such as species riches (number of species), species diversity (types of species) and endemism (uniqueness of species to a certain area) being the most useful elements for comparison (UNEP, 2002).

Environmental degradation:

Environmental degradation can be defined as any modification of the environment that implies a reduction or loss of its physical and biological quantities caused by natural phenomena or human activities ultimately representing a decrease in the availability of ecosystem, good and services to human populations (Landa et al., 1997).

Spatial & spectral resolution:

The spatial resolution refers to the size of the area on the ground that is summarized by one data value in the imagery. This is the Instantaneous Field of View (IFOV). Spectral resolution refers to the number and width of the spectral bands that the satellite sensor detects (Eastman, 2001).

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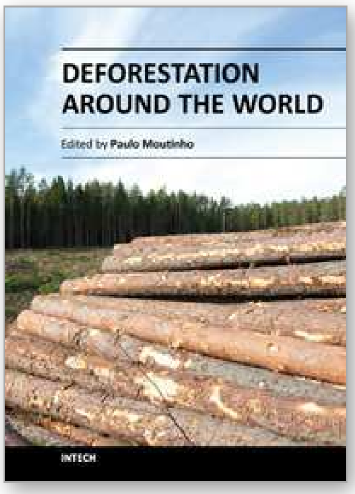

Deforestation Around the World

Edited by Dr. Paulo Moutinho

ISBN 978-953-51-0417-9
Hard cover, 372 pages
Publisher InTech
Published online 30, March, 2012
Published in print edition March, 2012

Deforestation and forest degradation represent a significant fraction of the annual worldwide human-induced emission of greenhouse gases to the atmosphere, the main source of biodiversity losses and the destruction of millions of people's homes. Despite local/regional causes, its consequences are global. This book provides a general view about deforestation dynamics around the world, incorporating analyses of its causes, impacts and actions to prevent it. Its 17 Chapters, organized in three sections, refer to deforestation impacts on climate, soil, biodiversity and human population, but also describe several initiatives to prevent it. A special emphasis is given to different remote-sensing and mapping techniques that could be used as a source for decision-makers and society to promote forest conservation and control deforestation.