An assessment of the Pull between Landuse and Landcover in Southwestern Nigeria and the Ensuing Environmental Impacts

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SUMMARY

The entire land mass area of the earth (removing the desert areas, water bodies, exposed rock surfaces, built-up areas and other significant non-vegetation cover surfaces) could be imagined to have been originally covered by vegetation when human population was small and the global environment was in its "ideal" state. As population increased, coupled with technological advancement, the quest for economic development gained ground and the demand for forest and other vegetation resources kept rising. Thus landuse for different purposes emerged and the landscape as well as the original vegetation cover continued to be modified. This paper examined the pull between landuse and landcover (LULC) in our contemporary time with a view to highlighting some of the attendant environmental consequences, using satellite multi-temporal datasets of the study area. The computed average rate of deforestation of the selected forest reserves in the study area is about 2.55% per year while the average rate of township expansion is about 2.9% per year. The vegetation landscape has been considerably modified over the years showing different agro-forests, exotic plantations, arable crop lands, forest reserves and cultural centres as dominant landuses. The environmental consequences (including urban land erosion, flooding, increase in the extent of impervious surfaces, environmental pollution, biodiversity loss, global warming, rainfall regime variability, unstable dry/wet season period, low crop yield, etc.) have been highlighted. Some suggestions have been put forward to weaken the pull between LU⟷LC for optimum environmental and economic developments.

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1. INTRODUCTION

Land has been described as an area of the earth's surface which is characterized by a distinctive assemblage of attributes and interlinking processes in space and time of soils and other surface materials, their atmosphere and water, the landforms, vegetation and animal populations, as well as the results of human activity; also included to the extent that they directly influence the characteristics of the land under consideration are suprasurface properties of the atmosphere, subsurface geological characteristics and the nature of the immediately surrounding land and water (Townshend, 1981). This encompassing definition of land will help to clearly understand the concept of landuse and landcover.

The two terms "landuse" and "landcover" (popularly abbreviated LULC) have been subjects of controversy and confusion among scientists and specialists in environmental studies (including planners, geographers, geologists, ecologists, foresters, developers, soil scientists, pastoralists, agriculturalists, environmental experts, etc.). While many experts see the two as meaning the same thing, many others are of the opinion that the two terms mean different things. For the purpose of this study, an attempt has been made to distinguish between the two terminologies. Landcover has been defined here as the biological (not including humans, fauna and aquatic lives) and physical features (including infrastructural facilities) that cover the earth's surface or portions thereof at a given point in time. For example, forest types, lakes, built-up areas, grassland/savannas, exposed rock surfaces, snow, ponds, games reserves, etc. are different types of landcover. Landuse, on the other hand, is the use to which a landcover is put for one purpose or the other in order to derive some benefits or perform some functions. It is characterized by the set of activities that humans undertake in a given landcover so as to meet their needs or maintain their environment. Townshend (1981) also agrees with these definitions and stated that it is quite improper to use the two terms interchangeably. He succinctly puts it that landcover describes the vegetation and artificial covers of the land surface whereas landuse are man's activities on land which are directly related to the land. FAO (2005) also defines landcover as the observed bio-physical cover on the earth's surface while landuse is characterized by the arrangements, activities and inputs people undertake in a certain landcover to produce, change or maintain it. In this context, examples of landuse include forest reserves, built-up areas, orchards, roads and railways, educational institutions, industrial lands, commercial lands, administrative areas, hydro-electric reservoirs, farmlands, rangelands, agro-forest lands, plantation lands, recreational parks, sacred lands, airport lands, High Voltage Tension Line (HVTL) strip lands, oil and gas pipeline strip lands, inland waterways, military zones/barracks, police barracks, air force bases, etc. It is easily seen here that virtually all human activities for various purposes take place on land.

LULC as two of the eight layers appearing on the global map are important because they are highly dynamic as a result of changing human activities that influence them and they in turn influence the environment of humans, fauna and organisms. As noted by Foody (2003), landcover change is one of the most important variables of environmental change and abuse of it represents the largest threat to ecological systems and their services. It is now a common thinking that LULC changes are a major contributor responsible for the current climate change and global warming (Lawrence and Chase, 2010). Therefore, landuse and landcover dynamics call for the development of a comprehensive understanding of changes in LULC, which are critical to bio-geochemical cycling, ecosystem functioning and services as well as human welfare (Tappan *et al.*, 2002). Improved information on/and understanding and sound knowledge of landuse and landcover dynamics are thus essential for the society to respond effectively to the recent and perceived unfavourable future environmental changes and to manage human impacts on the environmental systems. Also, landcover information is needed to monitor the impact and effectiveness of management strategies and action plans associated with sustainable development policies. Beside this, natural resources management and environmental monitoring are claimed to be strongly linked to food security and poverty alleviation strategies in the African countries, in particular.

LULC change over time is indispensable in our contemporary societies all over the world. It is an unavoidable phenomenon due to both temporary and/or permanent interest of the inhabitants in any given geographical area. This is apart from natural phenomena such as global warming, natural wild bush fires, large scale flash flooding, drought, desertification, landslide, tsunami, erosion, earthquake, subsidence, among other natural disasters. It is necessary to point out here that LULC changes occur essentially for socio-economic and ecological reasons at local and national levels especially for a country to improve her Gross Domestic Product (GDP), Inclusive Wealth Index (IWI) and raise the Human Development Index (HDI). In fact, it may be held that landuse anchors the development and growth of national economies from year to year. Following from the *technocentric* school of thought, the environment should be totally explored and exploited to meet the societal needs using the modern technology to meet societal needs. In the past two centuries, the impact of human activities on land has grown enormously, altering the landscapes and ultimately impacting the earth's nutrient, hydrological cycles and climate. To sum it up, landcover is continually transformed by landuse change (De Sherbinin *et al.*, 2002), suggesting that landuse is the cause of landcover change and the major underlying driving forces are socio-cultural, economic, technological, institutional, recreational, infrastructural and demographic factors.

The major landuse characteristics of southwestern Nigeria have been identified. It has been established that landuse change in the study area is unstoppable while there is mounting pressure on the vegetation resources through agricultural development, increasing demand of the wood-based industries, construction firms and similar organisations. There is increasing and pressing demand – supply of modern infrastructural facilities, Nigeria being a developing country with a stock of significant natural resources. The forest reserves of southwestern Nigeria have been found to be decreasing at an average rate of 2.55% per year (Oyinloye, 2008) while urban expansion is taking place at an average rate of 2.9% per year (Oyinloye, 2003). Also, un-usual devastating flood disaster has become a frequent phenomenon in the study area.

2. STATEMENT OF THE PROBLEM

The global environment is a system of systems comprised principally of the hydrosphere system, biosphere system, lithosphere system and atmosphere system. We know that a system is set of connected units functioning together to achieve a common goal. When related to the environmental system, any disruption in any of the units will cause a modification of the common goal forcing the environmental system to be in a state of dynamic equilibrium. Thus a change in the biosphere, atmosphere, lithosphere or hydrosphere beyond its carrying capacity will result in the modification of the global environment. And the most endangered species is the human due to his fragile characteristics.

The second major landcover of the earth's surface was vegetation after water which covered about 75% (Narayanan, 2007). For example, Nigeria with a total surface area of about 909,890km^2 (Macmillan, 2007) once had an extensive coverage of tropical rainforest which was put at about 45% of the country's landmass many decades ago (WRI, 2003). This reduced to about 16% in 1995 and currently less than 10% (Oyebo, 2006) and is on further decrease. This problem was foreseen in 1968 by the then western State government of Nigeria, which therefore developed a policy which would ensure that the exploitation of the government's forest reserves be controlled so that regeneration could take place in an orderly and profitable manner to the best advantage and that steps should be taken to ensure that the most economic use was made of the forest resources of western Nigeria. However, there was a progressive wide departure from the laid down policy as from 1961 (MANR, 1973). This is attributable to the fact that virtually all human activities require land – a limited and finite non-renewable resource (Agbola and Olatubara, 2001). They went further to emphasize that whether on its surface, beneath it or hanging above it are all traces of human activities, which go a long way to say that land is perhaps the single most important element in development and mankind's most natural resource. Thus it is not far fetched to recognize that humans have been altering the landcover since pre-history age by means of fire and total clearing of patches of landcover essentially for purposes of shelter, animal domestication, agriculture and livestock. The situation has considerably changed since the last few centuries and landuse has dominated and continue to dominate everywhere. While landcover (especially vegetation cover) is defenceless in the struggle, landuse continues to be offensive and aggressive and its impacts also continue to subject the world to untold hardships, disasters, catastrophes and negative environmental changes. But man, with his increasing and large demanding population as well as his great scientific and technological skills, exploits and thus modifies consciously or unconsciously the world environment in which he lives. Without doubt, he is the dominating life-form on the planet earth and his influence is spreading out into the further corners of his local solar system. In recent time, climate change, global warming, flooding, erosion, soil loss, biodiversity loss, environmental pollution (land, air and water), desertification, drought, forest fires, melting of the ice caps, extreme weather events, rise in sea level, acid rain, etc. are some of the consequences of the human activities.

Landuse and landcover form the basis from which past and present human interaction and their impacts on the natural resources and the environment can be understood (Tappan *et al.*, 2002). Similarly, Adeniyi and Omojola (1999) argued that an understanding of the past landuse practices and current landuse and landcover pattern and projections of future landuse and landcover as affected by various factors which include population size and distribution, economic development and technology are used to determine the effects of landuse and landcover change on the earth system. Therefore, landuse and landcover are closely linked to hydro-climatic fluxes in complex ways. In addition to being a driver of earth system processes affecting climate, the carbon cycle and the ecosystem, landuse and landcover change has a significant impact on the feedback of hydro-climatic processes on the surface hydrology (Odunuga and Oyebande, 2007). Furthermore, changes in LULC are central issues in the study of global environmental change simply because they have profound regional implications that can be left during the life span of current generation while also exhibiting cumulative long-term global dimensions as being witnessed worldwide. De Sherbinin *et al.* (2002) indicated that landuse and landcover changes are local and place specific, occurring incrementally in ways that often escape our attention. This situation calls for critical examination, understanding and knowledge of landuse and landcover characteristics at local, national, regional and global levels from time to time. In the same vein, Sedano *et al.* (2005) pointed out that global landuse and landcover products in highly dynamic tropical ecosystems lack the details needed for natural resources management and monitoring at the national and local levels.

This paper examines the landuse and landcover characteristics of southwestern Nigeria (where significant urbanization, tropical rainforest, agro-forestry, shifting cultivation, infrastructural development, exotic plantation development and other forms of LULC features abound) with a view to facilitating improved environmental landscape management of the area. Also, the ensuing environmental impacts of the LULC dynamics over the years for which data are available have been highlighted.

3. THE STUDY AREA

The study area is southwestern Nigeria (also referred to as the south west geo-political zone/region) made up of six States (Ekiti, Lagos, Ogun, Ondo, Osun and Oyo) extending over a surface area of about 76,851km^2, an estimated population of 27,581,993 and population density of 359/km^2 (Macmillan, 2007). Figure 1 depicts the geographical description. The area has been chosen for study because of the serious dynamics of its landuse, rapid urbanization and population growth, rapid socio-economic development and diversity of agricultural practices.

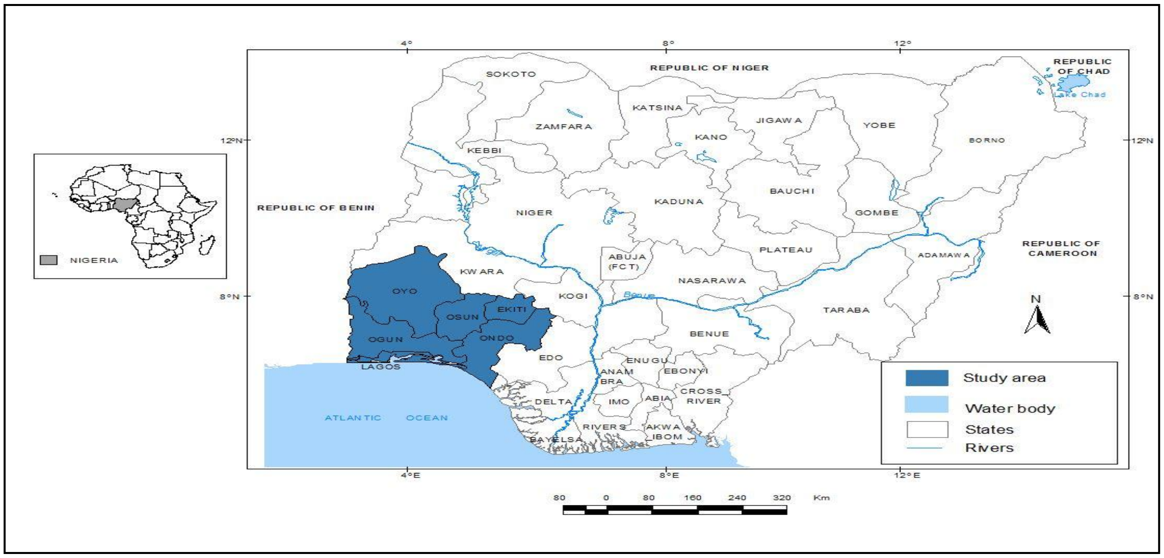

Figure 1: Map of Nigeria Showing the Study Area (in full colours)

Figure 2 is the map of southwestern Nigeria showing the selected study sites. The sites were purposively selected for investigation because of the high to convert the forest reserves within study area to other uses through illegal human activities. All the sites are known to have been sources of enormous economic benefits to the various States over the years (e.g., Okali and Onyeachusim, 1991) because of their rich wood and non-wood resources.

The Akure, Aponmu, Ipetu/Ikeji and Oni forest reserves are within latitudes 07° 10' 06.29"N and 07° 30' 03.28"N, and longitudes 04° 42" 03.12"E and 05° 05' 08.78"E extending over an average area of about 36.7km by 47.7km while Ilaro forest reserve is defined by latitudes 06° 38' 51.36"N and 06° 57' 24.40"N, and longitudes 02° 49" 06.12"E and 03° 10' 43.60"E. This reserve covers an area of about 34.2km by 39.9km. The Omo forest reserve is located within latitudes 06° 35' 09.90"N and 07° 06' 04.94"N, and longitudes 04° 04" 27.28"E and 04° 35' 22.16"E extending over an area of about 57km by 57km.

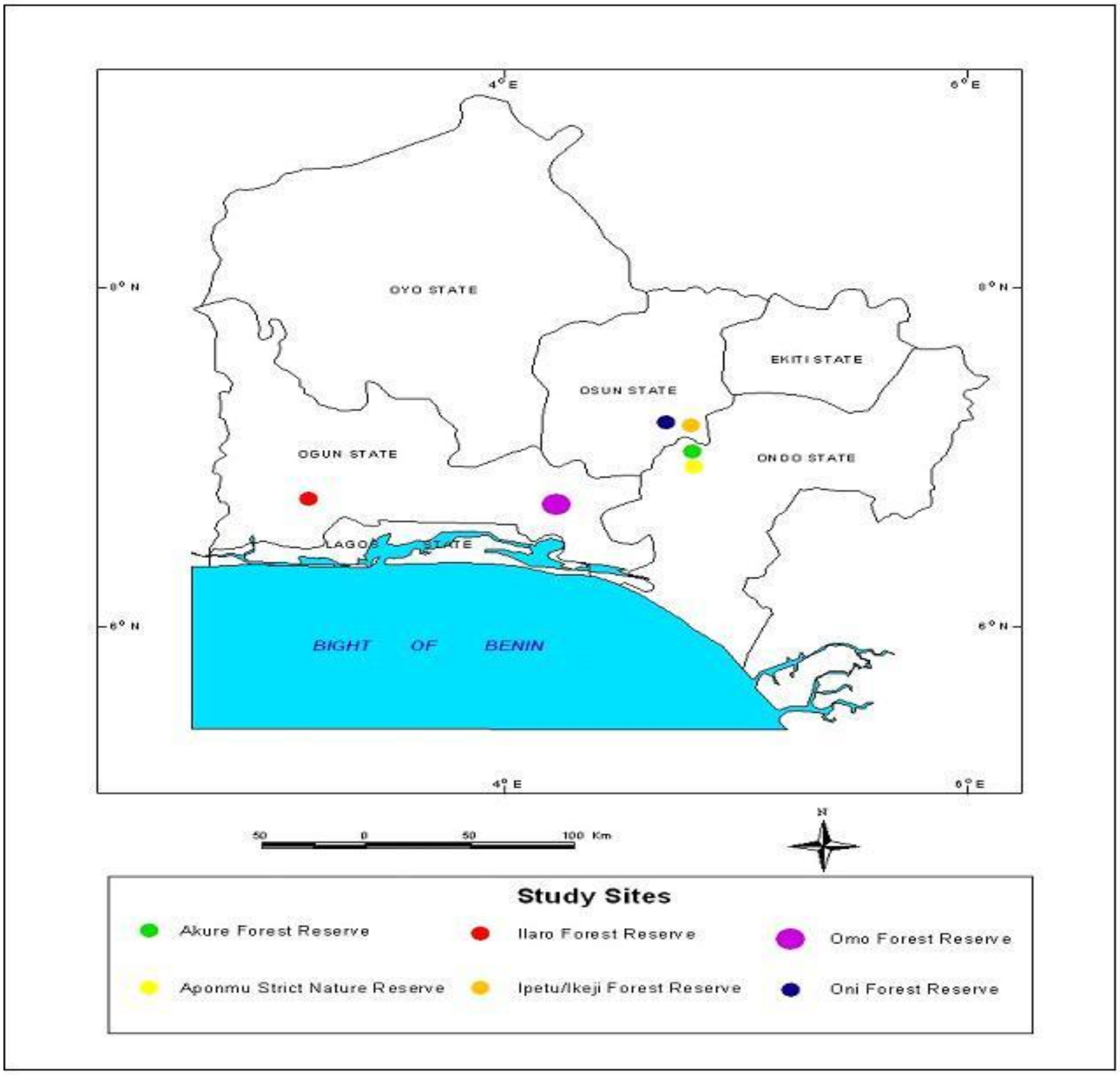

Figure 2: Map of Southwestern Nigeria Showing the Selected Study Sites

3.1 Climate

The climate of the study area is monsoonal in character and like all monsoonal climates; it has a contrast between well-defined dry and wet seasons (Adebekun, 1978) stretching east-west across West Africa, generally called the Inter-Tropical Discontinuity (ITD). It falls within the zone of the tropical humid climate. The dry season is short, lasting generally from December to February (Adejuwon, 1979). Also, it falls within the Köppen's A_f tropical rainforest climate (Trewartha, 1968).

The Köppen climatic classification as described by Trewartha (1968) is based upon annual and monthly means of temperature and precipitation. It accepts native vegetation as the best expression of the totality of a climate (Trewartha, 1968) so that many of the climatic boundaries are selected with vegetation limits in mind. Also, the classification recognizes that the effectiveness of precipitation in plant development and growth depends not only upon amount of precipitation, but also upon the intensity of evaporation and transpiration by which processes water is lost from soil and plants. The part of the rainfall, which is evaporated, is of no direct value in vegetation growth. Köppen's method of indicating evaporation intensity, and hence precipitation effectiveness, is to combine precipitation and temperature in a single formula. Thus the same number of millimetres of rainfall falling in a hot climate or concentrated in a hot season when evaporation is great, is less effective for plants than the same amount falling in a cooler climate or season. Each principal type of climate is described by a formula consisting of a pair of letters with precise meanings.

Thus the formula A_f for "tropical wet climate" may be translated as follows (Trewartha, 1968), where:

A = constantly hot, average temperature of the coldest month above 18^{o}C

f = constantly wet, no month of the year having on the average less than 60mm of precipitation.

During the dry season, the northeast (NE) trade wind prevails whereas the south-westerly wind dominates during the wet season. The average annual rainfall is about 2500mm at the coast and about 1220mm at the northern limit of the study area (Gilbert, 1969). This relatively high annual rainfall usually precipitates widespread flooding in some cities of southwestern Nigeria. However, the use and misuse of the environment have contributed immensely to recent flood incidents. The monthly mean minimum temperature is about 22.49˚C while the monthly mean maximum temperature is about 31.24˚C with an average yearly temperature of about 26.6˚C. Furthermore, the average yearly relative humidity is about 76.05% (Federal Office of Statistics, 1988).

3.2 Geology and Soil

Southwestern Nigeria overlies metamorphic rocks of the basement complex, the great majority of which are ancient being of pre-Cambrian age. These rocks show great variation in grain size and in mineral composition, ranging from very coarse grain pegmatite to fine-grained schist and from acid quartzite to basic rocks consisting largely of amphibolites (Smyth and Montgomery, 1962). The area of basement complex rocks has a number of inselbergs, hills and ridges which are remnants of the African denudational surfaces. The inselbergs are generally bare domes, whale backs or less regular hills with onion-skins and tor-like cappings or boulders. Differential weathering and erosion due to rock lithology has resulted in such structural ranges of hills and ridges like the Effon-Alaye ridge which stretches over 32km in a north-southwest direction (Adebekun, 1978).

The soils of the study area are mainly Iwo, Ondo and Egbeda Associations (Smyth and Montgomery, 1962). The study sites soils are essentially of Iwo, Ondo and Egbeda Associations. They are sub-divided into sedentary, hill-creep and hill-wash soils each. The Iwo Association soils are derived from coarse-grained granitic rocks and coarse gneisses; the Ondo Association from medium-grained granitic rocks and medium-grained gneisses; and the Egbeda Association from fine-grained biotite gneissesand schists. Each of the Associations has a number of soil series among which are the Akure, Ondo, Odigbo, Ife, Egbeda, Olorunda, Makun, Owo, Ibadan and Apomu series. The soils support the development of the lowland rainforest and are also suitable for tree crops particularly cocoa, kola and oil-palm (Ekanade, 2007).

3.3 Relief and Drainage

The southwestern Nigeria in which the study sites lie is dominated by the plain which rises gently from the coast northwards to the area of crystalline rocks where inselbergs rise abruptly above the surrounding plains (Adebekun, 1978). The Idanre hill, the highest of these inselbergs, rises to about 981m above mean sea level. The plains have resulted from alternating denudational and aggradational activities. Generally, this area is referred to as the western plains and ranges. Due to the folding of the rocks, they tend mainly in a north-south direction and typical landforms are the structural ridges and inselbergs protruding from an almost flat plain consisting of pediments and sloping generally from the water divide between the Niger River and the Gulf of Guinea from about 183m to 106.5m (Adebekun, 1978). The plains extend into the western side of the Niger Delta - a swampy area of about 3,885Km^2 composed of the coastal plain sands and lignite series of Cainozoic age in its northern part and of alluvial mud in its southern part (Adebekun, 1978).

The study area falls within the Atlantic system where most of the rivers are short, north-south coastal rivers which follow more or less regular courses (Adebekun, 1978). They drain into the sea. The western plains and ridges constitute the major divide between the rivers in a fairly simple line. On the basement complex of this unit, river directions are largely controlled by the trend of the foliated rocks and by jointing, particularly on the more resistant rocks. This structural control is well displayed by the rivers. Most of the rivers (e.g., *Ogbese, Ogun, Ogunpa, Oluwa, Ominla, Oni, Osun, Owena, Shasha*, etc.) are generally parallel but each river displays a dendritic pattern of drainage with its tributaries. In the area of the coastal plains where the gradient of the river valleys is very low, the rivers deposit their load, thereby giving rise to the formation of braided channels.

4. MATERIALS AND METHODS

4.1 Data Sources

The available satellite data covering the study area were acquired in 1972, 1984, 1986, 1991, 2000 and 2002. The characteristics of these images are given in Table 1.

Table 1: Some Characteristics of the Remote Sensing Data Used for the Study

Landsat Scene	Acquisition Date	Location on WRS	Dimensions (in Pixels)	Actual Spatial Resolution
MSS	07/11/1972	P204R055	3796 x 4204	56m x 79m
TM	18/12/1984	P191R055	6389 X 6939	28.5m x 28.5m
TM	17/12/1986	P190R055	7327 x 7757	28.5 m x 28.5m
TM	05/01/1991	P190R055	5965 x 6967	28.5 m x 28.5m
ETM^+	06/02/2000	P191R055	8525 x 7512	28.5m x 28.5m
ETM^+	03/01/2002	P190R055	7549 x 8707	28.5 m x 28.5m

Some basic premises in the application of multi-date remote sensing (satellite) data for change detection are that changes in landcover characteristics necessarily result in changes in radiance values and that changes in radiance due to landcover characteristics should be larger than those due to other factors. These other factors include differences in satellite sensor conditions, atmospheric conditions, solar angle and soil moisture (Tokola *et al*., 1999 and Sedano *et al*., 2005).

Landsat data sets are used in this study for three main reasons:

(i) They have proved highly suitable for vegetation studies: they are available in many channels including the infrared portion of the electromagnetic spectrum which is sensitive to vegetation. Landsat data can therefore be available as high quality images with little or no cloud cover;

(ii) They give a time series coverage of the study sites in both the wet and dry seasons between 1972 and 2002;

(iii)The data sets guaranteed a reasonable level of data consistency being from the same satellite system.

These datasets were supplemented with ground truth data using Garmin Handheld GPS 76CSx receiver to observe the geographic coordinates of features and points of interest. Photographic coverage for perspective views and pictorial description of the salient areas were taken.

4.2 Data Processing

The satellite data were processed using the ILWIS version 3.3 software package. The full scenes covering the study sites were each loaded onto the computer hard disk memory and converted to ILWIS format. They were respectively displayed and enhanced through the linear contrast stretching technique of the global contrast enhancement method. The spectral channels were combined to obtain false colour composite (FCC) and pseudo-natural colour (PNC) displays, among other multi-spectral combinations as described in Haack and Jampoler (1995). Except for the Landsat-TM data of 1991, all the other Landsat data sets were already geometrically corrected from source. The Landsat-TM of 1991 full scene was therefore georeferenced and geocoded (i.e., geometrically corrected in the adopted UTM map projection system on the WGS84 reference ellipsoid as with the other images) using eleven tie points identified on both TM 1986 full scene and TM 1991 full scene. The tie points, which were in geographic coordinates, were first converted to UTM space rectangular coordinates as required by the ILWIS software. A standard root mean square error (sigma – σ) of 0.550 pixel size was achieved. After the geometric correction, the TM 1991 full scene thus possessed high metrical qualities as with the other full scenes. After the correction, the images became super-imposable on themselves when printed out at the same scale. Thus all the images were of the same datum, the same map projection and in the same ground coordinate system. Thereafter, the extraction of the respective sub-scenes covering each of the study sites followed.

The enhanced sub-scenes covering each of the study sites were then subjected to the "supervised" classification procedure. Vegetation classification is widely accepted as an appropriate analytical technique for estimating changes in vegetation cover and quality of standing biomass. Such classification enables appreciation of the details of physical and structural changes taking place within a vegetation unit such as forest reserve (Cannon *et al*., 1988; Ikhuoria, 1993; ERGO, 1994; Salami, 1999). Vegetation components including normalized difference vegetation index (NDVI), ratio vegetation index (RVI), transformed vegetation index (TVI), enhanced vegetation index (EVI), weighted difference vegetation index (WDVI), moisture vegetation index (MVI), moisture stress index (MSI) and structural index (SI) were performed (Huete *et al.*, 1991; Chen *et al.*, 2005 and Yemefack, 2005).

4.2.1 Digital Image Classification

In the supervised classification process, homogeneous training parcels/training areas numbering thirty or more per cover type (depending on the size and distribution of the cover type over the image area) were demarcated and indexed. The actual name of each cover type was supplied as required by the software. This procedure was repeated for each of the landcover types in the image for each study site. Each of the sub-scenes was classified the same way. It should be noted that the sub-scene of Landsat-MSS of 1972 covering Omo forest reserve was completely covered by cloud and this made it impossible to be used for the study of the reserve in that year. The supervised classification was performed using the Gaussian Maximum Likelihood method (Swain and Davis, 1978). In deriving the nomenclature for the landuse and landcover types, reference was made to the Coordination of Information on the Environment (CORINE) landcover nomenclature (Büttner *et al.*, 1998). Further use was made of a comprehensive and standardized *à priori* landcover classification system developed by FAO and UNEP to meet specific user requirements, which was created for mapping, independent of scale or means used to map (FAO, 2005). The system enables a comparison of classes regardless of data source, thematic discipline or country. Furthermore, the system enhances the standardization of process and minimizes the problem of dealing with a very large amount of pre-defined classes.

The classification accuracy assessment was carried out using two approaches. The first approach relates thirty well distributed randomly sampled field points for each class of feature to the corresponding pixels on the classification result for each of the image dates. Appendix 1 shows the selected field sample points for forest reserve and their observed geographic coordinates using GPS during ground truthing. For each class, the statistical index of validation (SIV), the cartographic index of validation (CIV) and the class purity (CP) were calculated using the following formulae:

$$\text{Statistical index of validation} = \frac{\text{number of pixels in class Ci}}{\text{number of pixels of theme Ti on the terrain}} \quad . \quad . \quad (1)$$

$$\text{Cartographic index of validation} = \frac{\text{number of pixels correctly classified in class Ci}}{\text{number of pixels of theme Ti on the terrain}} \quad (2)$$

$$\text{Class purity} = \frac{\text{number of pixels correctly classified in class Ci}}{\text{number of pixels of the class Ci}} \quad . \quad . \quad . \quad . \quad (3)$$

The second approach used is the evaluation of the validity of classification results when no ground truth data (i.e. actual terrain cover) is available. Here, the confusion matrix is computed in order to validate, reject or improve upon the classification results.

It should be mentioned here that the 1984, 1986, 1991, 2000 and 2002 data sets were of the same spatial resolution of 28.5m x 28.5m while the 1972 data set had a different spatial resolution of 56m x 79m. After the successful classification, the MSS data was resampled to 28.5m resolution using the *Resample function* of the software. This was to enable accurate superposition and crossing of pairs of the classified images for change detection analysis.

4.2.2 Vegetation Indices

Vegetation indices were computed to assess the vegetation in the forest reserves. This was followed by the computation of moisture content and stress of the vegetation. These indices were needed to monitor deforestation in the selected forest reserves. The equations of vegetation indices used are as follows (Huete *et al.*, 1991; De Wasseige and

Defourny, 2003; Maselli, 2004; Freitas *et al.*, 2005; Healey *et al.*, 2005 and Sedano *et al.*, 2005):

Ratio vegetation index: $RVI = \rho(\lambda_{nir})/\rho(\lambda_{red})$ . . . . (4)

Normalized difference vegetation index: $NDVI=(\rho(\lambda_{nir}) - \rho(\lambda_{red}))/(\rho(\lambda_{nir}) + \rho(\lambda_{red}))$ . . (5a)

$= 255 * \rho(\lambda_{nir})/(\rho(\lambda_{nir}) + \rho(\lambda_{red}))$ . . (5b)

where the image data is coded using 8-bits.

Transformed vegetation index:

$$TVI = 100 * [(\rho(\lambda_{nir}) - \rho(\lambda_{red}))/(\rho(\lambda_{nir}) + \rho(\lambda_{red})) + 0.5]^{½} \quad . . . (6)$$

Enhanced vegetation index:

$$EVI = [G(\rho(\lambda_{nir}) - \rho(\lambda_{red}))/(\rho(\lambda_{nir}) + C_1\,\rho(\lambda_{red}) - C_2\,\rho(\lambda_{blue}) + L)] \quad . . . (7)$$

where L is a canopy background adjustment factor based on the nonlinear extinction of red and NIR wavelengths through the canopy, C_1 and C_2 are the adjustment factors for aerosol influences and G is a gain factor. The suggested values for the parameters of the equation are L = 1, $C_1 = 6$, $C_2 = 7.5$, and G = 2.5.

Weighted difference vegetation index: $WDVI = \rho(\lambda_{nir}) - \mathbf{a} * \rho(\lambda_{red})$ . . . . (8)

where **a** is the slope of bi-dimensional plot of $\rho(\lambda_{nir})$ and $\rho(\lambda_{red})$ reflectance

Moisture vegetation index using Landsat's band 5:

$$MVI5 = (NIR - MIR5)/(NIR + MIR5) \quad . . (9a)$$

$$MVI5 = 255 * NIR/(NIR + MIR5) \quad . . . (9b)$$

Moisture vegetation index using Landsat's band 7:

$$MVI7 = (NIR - MIR7)/(NIR + MIR7) \quad . (10a)$$

$$= 255 * NIR/(NIR + MIR7) \quad . . (10b)$$

where the image data is coded using 8-bits.

Moisture stress index (Marchetti *et al.*, 1995):

$$MSI5 = \mathbf{b}*MIR5/NIR \quad . . . . . . (11)$$

$$MSI7 = \mathbf{b}*MIR7/NIR \quad . . . . . . (12)$$

Structural index (Marchetti *et al.*, 1995):

$$SI5 = \mathbf{c}*NIR/MIR5 \quad . . . . . . (13)$$

$$SI7 = \mathbf{c}*NIR/MIR7 \quad . . . . . . (14)$$

where **b** and **c** are multiplying factors which may assume 127.5 and 63.5 respectively but may be empirically reduced as may be found necessary. This will shift the image histogram to the middle of the grey value (DN) axis for the purpose of improving the brightness.

The above indices were computed for each of the Landsat data sets of 1972, 1984, 1986, 1991, 2000 and 2002 for the study sites. Appendix 2 is an example of the **c**omputed vegetation indices for 31 well distributed random quadrats within Omo forest reserve for Landsat-ETM$^+$ data of 2002.

5. RESULTS AND DISCUSSION

Table 2 indicates the overall assessment of the classification accuracy. The approach of using ground truth data for classification accuracy assessment was preferred because it gave a better result and it is close to reality.

Table 2: Overall Assessment of Classification Accuracy

Classification	1st Approach: Using Ground Truth Data (SIV, CIV and CP)	2nd Approach: Using Confusion Matrix Alone
MSS 1972 Sub-scene	0.57	0.75
TM 1984 Sub-scene	0.85	0.64
TM 1986 Sub-scene	0.83	0.66
TM 1986 Sub-scene	0.83	0.62
TM 1991 Sub-scene	0.81	0.68
ETM$^+$ Sub-scene	0.90	0.66
ETM$^+$ Sub-scene etc.	0.79	0.62
ETM$^+$ 2002 Sub-scene	0.78	0.54

SIV = Statistical Index of Validation (measure of reliability**)**
CIV = Cartographic Index of Validation (measure of accuracy**)**
CP = Class Purity (measure of purity, non-corruption or goodness of class**)**

Table 3 presents the landuse/landcover types found in the study area between 1972 and 2002, a period of 30 years only.

Table 3: The Landuse/Landcover Types in the Study Area

Formation	Characteristics
Light Forests	Secondary forests and re-growths with small trees. Tree-like growths, climbers, etc.
Built-Up Area	Settlements which are places of human buildings with varying network of roads; could be medium-sized villages or a hut with only one road passing through.
Agro-forests	Comprise of a complex mixture of tree crops such as cocoa, kola, oil palm and orange with pockets of interspaces cultivated to food crops. There are scattered trees present.
Ridge Forests	High forests on ridges and fractured inselbergs
Forest Reserves	High forests in protected areas for conservation

Gallery Forests	Occur along river courses. They may be evergreen, with considerable number of woody plants.
Exposed Rocks and Bare Lands	Are inselbergs, bare rock outcrops, major or minor roads that are not paved.
Plantations	Exotic trees mainly *Tectona grandis* (teak) and *Gmelina arborea* (gmelina) with low brush undergrowths.
Shrubs/Arable Lands	These are farmlands abandoned for a few years for the purpose of soil recuperation in anticipation of another round of cultivation. They are made up of shrubs, herbaceous plants, seedlings and saplings that compete and grow together in an interlocked manner. They also include Cultivated lands where crops like cassava, maize, yam, plantain and cocoyam are grown.
Burnt/Marshy Areas	Are burnt bushes in preparation for cultivation and waterlogged areas with patches of dark soil rich in organic matter
Mangrove forests	These are fresh water swamps of trees with airy roots near and along the coast
Water Bodies	Open water bodies e.g. reservoir, river and stream

Source: Image analysis and fieldwork (2007)

Figures 3 and 4 are selected examples of the landuse/landcover maps of Omo forest reserve and environs prepared from the classified Landsat images of 1986 and 2002. The Omo forest reserve was originally 132,000ha (Oyinloye, 2008).

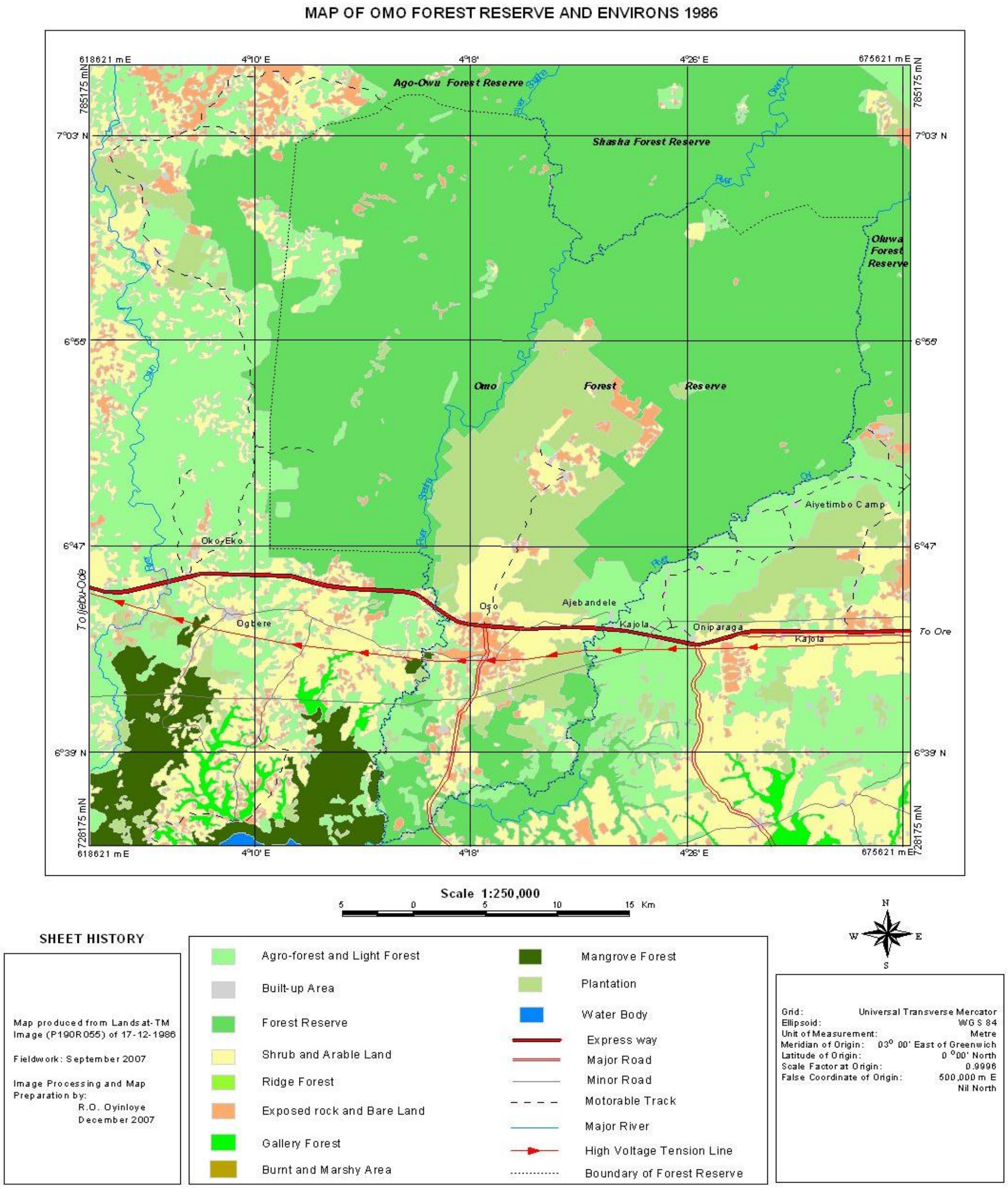

Figure 3: Landuse/Landcover Map of Omo Forest Reserve and Environs in 1986

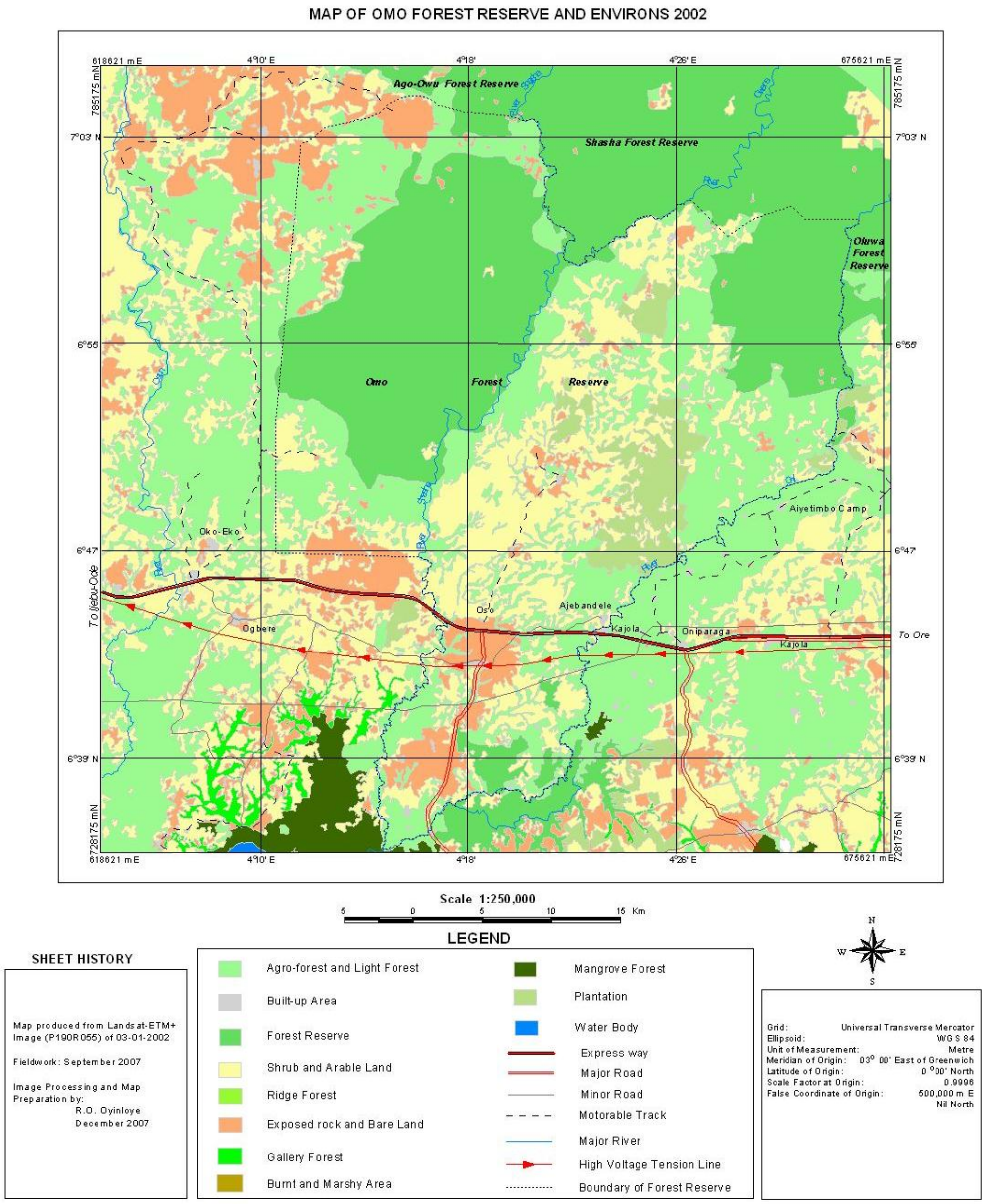

Figure 4: Landuse/Landcover Map of Omo Forest Reserve and Environs in 2002

Similar maps were prepared for Ilaro forest reserve and environs for 1972 and 2000 as well as for the image covering Akure, Aponmu, Ipetu/Ikeji and Oni forest reserves and environs for 1972, 1986, 1991 and 2002. Table 4 provides changes in the surface area of the forest reserves within the study period of data availability (i.e., between 1972 and 2002).

Table 4a: Changes in the Areal Extent of Reserves from 1972 to 2002 and Projection to 2022

Forest Reserve	1972 Area (ha)	1986 Area (ha)	1991 Area (ha)	2002 Area (ha)	Annual Rate of Deforestation (1972 – 2002)	2012 Projection (ha)	2022 Projection (ha)
Akure	4,756.00	3,323.91	2,821.42	1,163.64	**2.52%**	864.07	564.49
Aponmu	2,276.00	1,619.59	1,402.82	1,143.80	**1.66%**	953.93	764.06
Ipetu/Ikeji	3,490.00	2,191.64	1,178.08	Bare Land	**2.21% (1972 – 1991)**	Plantation	Plantation
Omo	132,000.00	95,651.99	68,900.00	49,855.45	**2.07%**	39,535.37	29,215.29
Oni	5,853.00	5,701.16	5,420.96	422.10	**3.09%**	409.06	161.24

Table 4b: Surface Area Dynamics of Ilaro Forest Reserve from 1972 to 2000 and Projection to 2022

Forest Reserve	1972 Area (ha)	1984 Area (ha)	2000 Area (ha)	Annual Rate of Deforestation (1972 – 1984)	2012 Projection (ha)	2022 Projection (ha)
Ilaro	4,844.00	2,681.33	Bare Land	**3.72%**	Plantation	Plantation

Computed Overall Average Rate of Deforestation for the forest reserves is 2.55% per annum

Nb: For computing the rate of deforestation, e.g. between 1972 and 2002, the formula used is: $r = [(Area_{2002} - Area_{1972}) * 100]/[(Area_{1972} * (2002 - 1972)]\%$ **per annum**

Table 5 shows the changes in the spatial distribution and interaction among the different LULC types between 1986 and 2002. The table, which shows the transition from one LULC type to another, was obtained through the *Cross Operation* between the classified images of the two dates as descried in (Oyinloye and Oloukoi, 2012). A comparative examination of Figures 3 and 4 shows that much of the Omo forest reserve landcover, for example, has been converted to other landuse types such as agro-forest, shrub and arable land, exotic plantation and exposed rock/bare land. The table shows that only 50,781.4ha of Omo forest reserve landcover remained unconverted. About 80,416.4ha of it has been lost to other landuse types made up of agro-forest/light forest (40,684.0ha), exposed rock/bare land (3,954.1ha), built-up area (1,968.1ha), exotic plantation (20,846.5ha), shrub and arable land (12,958.2ha) and water body (4.6ha) between 1986 and 2002.

Considering the forest reserve as the striking landcover type, landuse is fast winning the struggle and having upper hand over landcover. This is essentially due to the unstoppable human activities (such as agricultural, settlement, etc. development) in a bid to meeting his socio-economic needs and technological development paying little or no attention to the impacts on the environment.

Table 5: Transition between Landuse and Landcover Types in Omo Forest Reserve and Environs from1986 to 2002 through Change Detection

	ALF	BL	BUA	FR	P	SAL	WB	TOTALS 1986	GROSS LOSS
ALF	**29,270.5**	4,417.2	1,995.8	11,537.9	12,052.7	15,072.4	8.2	74,354.7	45,084.2
BL	1,603.9	**6,057.5**	1,099.3	333.9	998.3	5,258.5	2.8	15,354.2	9,296.7
BUA	270.9	774.9	**901.9**	60.6	176.6	741.9	2.8	2,929.6	2,027.7
FR	40,684.9	3,954.1	1,968.1	**50,781.4**	20,846.5	12,958.2	4.6	131,197.8	80,416.4
P	9,485.1	892.6	425.5	2,539.1	**10,263.2**	11,460.9	13.6	35,080.0	24,816.8
SAL	9,072.2	10,212.7	2,583.0	1,226.9	5,016.9	**25,823.6**	8.2	53,943.5	28,119.9
WB	3,566.6	519.1	648.3	4,660.2	1,331.5	1,132.4	**182.4**	12,040.5	11,858.1
TOTALS 2002	93,954.1	26,828.1	9,621.9	71,140.0	50,685.7	72,447.9	222.6	324,900.3	
GROSS GAIN	64,683.6	20,770.6	8,720.0	20,358.6	40,422.5	46,624.3	40.2		

Actual Total Surface Area of Image = 324,900ha

ALF: Agro-forest/Light forest; BL: Bare land; BUA: Built-up area; FR: Forest reserve; P: Plantation; SAL: Shrub and arable land; WB: Water body

Plates 1 to 5 are some photographic presentations of the conversion of the forest reserves (e.g. Omo forest reserve) in the study area to other landuse types.

Plate 1: Teak and Gmelina Nursery Site within Omo Forest Reserve

Plate 2: On-Going Clearing within the Remaining Natural Vegetation of Omo Forest Reserve for farming

Plate 3: Vast Cassava Farmland Sharing Boundary with Teak Plantation within Omo Forest Reserve

6. ENVIROMENTAL CONSEQUENCES

Deforestation appears to be one of the most striking human activities that has strong link with global warming and climate change. A few of the ensuing consequences have been highlighted as follows:

(i) It is becoming evident more than ever before that climate change is a real phenomenon and that it is threatening to cause the largest refugee crisis in human history. For example, millions of people in the continents of Africa and Asia might be forced to leave their homes to seek refuge in other places or even countries over the next century if the situation of the current climate change remains unaddressed.

(ii) The two most devastating phenomena resulting from climate change are flash floods and wild bush fires. These phenomena in turn lead to significant loss of flora and fauna, loss of fertile soil, extreme weather events, drought, water scarcity, desertification, famine, loss of live and properties, to mention but a few.

(iii) Desertification is another consequence of landcover transformation (being a gradual process) to landuse. It has been perceived within the environmental science community that desert is advancing towards the coast at the rate of 48km in 10 years giving an average of 4.8km per year. Also, known fauna of the world are said to have reduced to 10% of their original population due to loss of natural vegetation. This is essentially due to loss of their habitat, i.e., loss of forest and vegetation cover. In the case of wildlife, for example, reliable information has it that the population of lions has reduced from 450,000 to 20,000 in the last 50 years while some animals have gone into extinction.

(iv) Diminishing and erratic volume and distribution of rainfall is another consequence of climate change. When the volume gets high within a short period, it causes devastating flood where such situation occurs. The examples of flood in Pakistan in 2010, Philippine in 2011, Nigeria and China in 2012 and recently in Australia in 2013 are living witnesses. Furthermore, sometimes the rain starts too early or too late. At other times, it stops too early or too late with irregularity in-between. In Nigeria, for example, the usual two peaks are gradually collapsing into one and getting lower indicating lower volume of rain water in the soil. The effect on agriculture may be enormous.

7. CONCLUSION

It has been recognized that exponential increases in material and energy use globally threaten the earth system stability in many ways through global warming and climate change. Yet societies remain committed to economic growth, reflected in the way publicly traded corporations are legally obliged to maximize shareholders' profits. Ultimately, we seek an overall shift to a stable-state economy – a global economy whose operation sustains rather than threatens the familiar (to humans and our civilizations) stable state of the earth system (Liam.*et al.*, 2012). This study has assessed the competition between landuse and landcover in southwestern Nigeria and highlighted the ensuing environmental impacts using multi-temporal Landsat data sets acquired between 1972 and 2002. The data sets were processed and analyzed using ILWIS version 3.3 software. The major landuse and landcover types have been identified and presented in map form for better visual perception. The landuse types are fast colonizing the forest reserve landcover type in the study area. From the projection made, it has been observed that there would be no forest outside the forest reserves in the area if no measure is taken to check or control the landuse practices within the next two to three decades.

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Appendix 1: Observed Geographic Coordinates of *Forest Reserve* Field Sample Points for Accuracy Assessment of Classification Results of Landsat-MSS 1972, Landsat-TM 1986, Landsat-TM 1991 and Landsat-ETM$^+$ 2002 Akure-Aponmu-Ipetu/Ikeji-Oni Forest Reserves Images

Point	Latitude (N)	Longitude (E)
1.	07° 19’ 08.78”	05° 00’ 38.94”
2.	07° 18’ 34.31”	05° 00’ 44.82”
3.	07° 18’ 14.41”	05° 01’ 04.56”
4.	07° 17’ 32.99”	05° 01’ 25.94”
5.	07° 17’ 08.06”	05° 01’ 14.62”
6.	07° 19’ 19.96”	05° 00’ 41.57”
7.	07° 19’ 38.02”	05° 00’ 47.69”
8.	07° 19’ 33.60”	05° 01’ 11.82”
9.	07° 19’ 30.86”	05° 01’ 48.03”
10.	07° 19’ 34.99”	05° 02’ 26.86”
11.	07° 20’ 04.53”	05° 01’ 27.48”
12.	07° 19’ 57.46”	05° 02’ 07.99”
13.	07° 20’ 20.95”	05° 01’ 14.62”
14.	07° 20’ 26.06”	05° 01’ 27.58”
15.	07° 20’ 54.38”	05° 01’ 48.41”
16.	07° 21’ 10.81”	05° 01’ 32.96”
17.	07° 21’ 10.90”	05° 01’ 13.98”
18.	07° 21’ 20.78”	04° 59’ 41.74”
19.	07° 14’ 51.26”	05° 02’ 59.21”
20.	07° 15’ 12.04”	05° 02’ 36.02”
21.	07° 15’ 45.51”	05° 03’ 00.31”
22.	07° 15’ 22.17”	05° 03’ 20.90”
23.	07° 14’ 43.32”	05° 03’ 42.28”
24.	07° 15’ 28.06”	05° 03’ 54.56”
25.	07° 15’ 05.16”	05° 01’ 54.60”
26.	07° 21’ 44.31”	04° 46’ 05.12”
27.	07° 20’ 46.57”	04° 49’ 50.90”
28.	07° 21’ 30.73”	04° 48’ 50.70”
29.	07° 22’ 12.69”	04° 49’ 50.39”
30.	07° 22’ 22.98”	04° 49’ 59.92”

Appendix 2: Computed Vegetation Indices Using Landsat-ETM$^+$ Data of 2002 – 31 well Distributed Random Quadrats within Omo Forest Reserve

RVI	NDVI	TVI	EVI	WDVI	MVI5	MVI7	MSI5	MSI7	SI5	SI7
1	123	69	0	37	129	168	137	64	67	119
1	119	70	0	37	126	168	135	73	64	117
1	122	69	0	41	129	164	131	71	53	110
1	125	72	0	32	125	171	126	67	61	125
1	125	71	0	35	124	166	133	68	66	118
1	122	73	0	36	129	169	129	78	61	123
1	125	70	0	33	133	162	128	66	64	120
1	126	69	0	33	130	170	133	72	62	120
1	139	71	0	36	130	168	126	69	65	115
1	129	69	0	33	127	169	128	66	64	120
1	116	68	0	32	130	164	129	70	62	118
1	128	72	0	35	128	165	125	65	65	109
1	120	75	0	38	126	166	124	72	61	115
1	123	72	0	31	123	167	141	70	63	123
1	128	70	0	34	130	169	136	67	64	129
1	129	71	0	33	128	166	138	60	60	121
1	130	71	0	31	132	165	129	69	62	112
1	129	71	0	35	124	170	124	67	67	129
1	128	70	0	35	127	163	128	62	63	133
1	131	72	0	32	128	164	133	65	69	118
1	132	71	0	32	124	165	122	68	66	123
1	130	75	0	33	133	169	124	69	61	127
1	130	72	0	30	130	170	133	71	66	116
1	128	69	0	32	125	170	133	63	70	113
1	129	75	0	31	128	164	131	70	63	125
1	131	72	0	35	128	168	130	65	63	123
1	126	71	0	30	130	164	129	65	65	113
1	126	69	0	31	130	171	124	68	74	120
1	128	68	0	35	129	160	132	60	62	123
1	131	70	0	34	124	175	130	62	57	137
1	130	74	0	32	133	167	133	71	62	131
ΣX	**3938**	**2201**	**0**	**1044**	**3972**	**5177**	**4034**	**2093**	**1972**	**3745**
Xmean	**127**	**71**	**0**	**34**	**128**	**167**	**130**	**68**	**64**	**121**
X_{min}	**116**	**68**	**0**	**30**	**124**	**162**	**122**	**60**	**53**	**109**
Xmax	**139**	**75**	**0**	**41**	**133**	**175**	**141**	**78**	**74**	**137**