USE OF REMOTE SENSING TECHNIQUE IN THE LANDUSE/LANDCOVER EVALUATION OF DRY RAIN FOREST OF SOUTHWESTERN NIGERIA

BY

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ABSTRACT

The dearth of up-to-date information on the Nigerian natural resources is a major hindrance to their optimal and sustainable use for national development. Remote sensing technique enables faster and more accurate acquisition of information than that of conventional approach to natural resources survey. However, their uses are yet to be fully exploited. This study was therefore designed to produce LandUse/LandCover (LULC) maps of Southwestern Nigeria using remote sensing technique and also evaluate soils of the same area for crop production.

Multidate maps (1975, 1986 and 2002 of LULC covering 23,629.2 ha for Ife and 13,653 ha for Ilesha areas were derived from aerial photographs of 1975 using mirror stereoscopes and Landsat thematic mapper data for 1986 and 2002. The changes in the LULC were evaluated for built-up, hill/water, fallow/cropland and forest areas. Semi-detailed soil maps of the two areas were produced using aerial photographs and Systeme Probatoire Pour Observation de la Terre (SPOT) Imagery to evaluate the degree of concordance between them. The soil series identified using FAO guidelines were evaluated for potential crop suitability using Land Evaluation Computer (LEC) system. Data were analyzed using descriptive statistics.

In LULC of Ife area, there was a general increase of 4.2% (1975 – 1986) and 5.6% (1986 – 2002) in built-up areas; 1.4% (1975 – 1986) and 4.2% (1986 – 2002) in the fallow/crop areas; 0.88% (1975 – 1986) and 3.7% (1986 – 2002) in Hill/Water areas; and a decrease of 3.7% (1975 – 1986) and 5.0% (1986 – 2002) in the forest areas. Concordance between the two soil maps of the area was 32.0%. Thirteen soil series were identified out of which four (Araromi, Itagunmodi, Owena and Egbeda) series were moderately suitable (S2) for maize; seven were moderately suitable (S2) for upland rice (Iregun, Araromi, Itagunmodi, Owena, Olorunda, Oba and Egbeda); eight were moderately suitable (S2) for yam (Okemessi, Erin-Oke, Etionni, Iregun, Araromi, Itagunmodi, Owena and Egbeda) and for cassava five (Iregun, Araromi, Itagunmodi, Owena and Egbeda) were moderately suitable (S2). Similarly in Ilesha area, there was a general increase of 4.0% (1975 – 1986) and 0.3% (1986 – 2002) in the built-up areas; 2.3% (1975 – 1986) and 8.8% (1986 – 2002) in the fallow/crop land areas, 2.1% (1975 – 1986) and 2.6% (1986 – 2002) for Hill/Water areas; and a decrease of 8.4% (1975 – 1986) and 6.5% (1986 – 2002) for forest areas. Concordance between the two soil maps of the area was 54.9%. Fourteen soil series were identified out of which ten were of the same suitability class as those of Ife area. Of the remaining four series (Omo, Jago, Ondo and Irapa), two (Ondo and Jago) were marginally suitable (S3) for maize and upland rice. Ondo series was moderately suitable (S2) while Omo and Jago series were marginally suitable (S3) for yam. Three (Omo, Ondo and Jago) soil series were marginally suitable (S3) for cassava while Irapa series was not suitable for any of the crops.

Massive forest depletion and conversion of good agricultural lands to urban built-up existed in the area. The soil series identified were of varying degree of suitability in both areas for crop production.

Keyword: Landuse/Landcover, Land Evaluation, Fertility capability classification, Remote Sensing.

DEDICATION

In memory of my eldest sister, Mrs. Modupe Eghosa Osasuyi who went through a lot of material denials to get me educated and to God Almighty who is my Savior and Provider.

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CERTIFICATION

I certify that this work was carried out by Mr. Lawrence Nosa Edosomwan in the Department of Agronomy, University of Ibadan, Ibadan.

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CHAPTER ONE

INTRODUCTION

In most developing countries, Nigeria inclusive, the dearth of adequate resource information has been identified as one of the problems hindering the process of growth and development. This has been found to be very critical in the areas of soil survey, landuse/landcover, land evaluation and environmental degradation evaluation. In these environments, basic information on the type of crops grown, crop yield, farming practices, fertilizers and pesticides usage, etc are difficult to obtain and often unreliable when available (Anon, 1981; Arimoro, *et al*., 2002; Mengistu and Salami, 2007).

Nigeria, a country that depended solely on agricultural produce for its foreign exchange earnings and sustenance until the advent of crude oil, has only recently produced a national reconnaissance soil map. Where soil surveys were done, they were restricted to small project sites like in Ilesha Farm Center, Cocoa Research Institute, Ibadan and Esa-Oke Farm Settlement (Ojanuga, 1981). Given that many of these projects were contracted to foreigners, knowledge of the methods used and the information collected are in general better known by the foreign experts, and such knowledge is usually lost when they leave.

The country is still not fully covered by large scale topographic maps. There is no complete series of medium scale geological map. Vegetation and landuse map produced in 1977, was on a scale of 1:250,000. Agricultural agencies lack data on which to base rational planning; they do not know the extent of good agricultural land and they have little information on the increasing rates of destruction of prime agricultural lands (Adeniyi, 1986; Fanan *et al.,* 201l).

Many factors are responsible for the lack of natural resources information. These include the wrong perception of inexhaustibility of land resources and the poor economic situation. The system of land cultivation in Nigeria has made acquisition of land resources data nearly impossible. Most of the farm holdings vary in size, the boundaries are irregular, widely scattered, and plot size changes from year to year. Inadequate road network, difficulty of movement and visibility in forest areas also hindered in no small measure to resource data acquisition (Mostert, 2008; Alabi, 2009).

The rapidly expanding global population and the increasing world demand for food place the limited arable land, mineral, vegetation and water resources of the world under pressure. Industrialization during the past decades has further increased the stress on these resources and the environment. Never before in human history has the need been greater for sound planning and management of these resources and for environmental protection. One of the vital elements of any effort to meet these needs is the inventory of the renewable and non-renewable resources of the earth and monitoring of environmental changes (Abdullah, 2006; Turner *et al.*, 2006).

The crucial necessities to combat the world food and energy shortages and the expansion of environmental deterioration include monitoring the changes in the environment, forecasting crop yields and detection of land degradation and pollution of water resources. The usefulness of remote sensing for resource data collection has been demonstrated starting with the early application of aerial photographs after the Second World War. The arrival of satellite imageries such as Side-Looking Airborne Radar (SLAR) and Landsat 1, 2 and 3 increased the scope and usage of remotely sensed data (Adeniji, 1986). The recent generation satellites, Landsat 4 and 5 and the French *Systeme Probatoire Pour Observation de la Terre* (SPOT) 1 and 2, have completely revolutionized the application of remote sensing to resource data collection. These latter sensors have the added of advantage of synoptic view that is provided and the monitoring capability. SPOT has an improved spatial resolution of 20 meters for the multispectral scanner and 10 meters for the panchromatic which have proved useful for detail agricultural mapping and urban analysis (Fagbami, 1986; Ademiluyi *et al.*, 2008; Abbas *et al.*, 2010).

In addition, SPOT can be ground-controlled to view either vertically or at an angle. In the latter position, the sensors are focused in an across-track direction in order to allow rapid access to any point lying within the arc $\pm$ 27^{o} from the satellite ground track, thereby providing very flexible multiple-look capability. This innovation also allows the acquisition of stereoscopic image pairs from different satellite passes.

The application of remote sensing to natural resource survey in Nigeria started in the early 1960s. Oyelese, (1968) used aerial photographs to map landuse patterns in the forest zone of Ibadan while Adeniyi, (1980, 1986) and Adeniyi and Olugbile (1987) used sequential aerial photographs in landuse change analysis and urban growth. Fagbami, (1980, 1981a and b, 1986a and b) applied remote sensing data in soil survey and landuse inventory in southwestern Nigeria and the Benue valley while Fapohunda (1986), mapped the soils of former Bendel state using Side Looking Air-borne Radar (SLAR). In the applications above, none has applied both aerial photographs and satellite imageries at the same time to see the degree of concordance in their results nor did they go a step further to recommend which of the remote sensing data will be most suitable in reconnaissance and semi-detailed surveys.

The objective of this research was to evaluate the effectiveness of Aerial Photo Interpretation, SPOT and Landsat imageries in soil survey and landuse/landcover mapping of the rainforest areas of Ife and Ilesha on the Basement Complex Soils of South Western Nigeria. The specific objectives of the investigation are:

i. To produce a soil map of Ife and Ilesha areas with aerial photo-interpretation and the SPOT analogue data, by defining the Terrain Mapping Units (TMUs) and describe the component soils.

ii. To evaluate the degree of concordance between the visually interpreted SPOT image soil map and the soil map produced from aerial photo-interpretation.

iii. To evaluate the changes in landuse/landcover of Ife and Ilesha areas using aerial photographs and Landsat imageries.

iv. To assess the cropping potential of the component soils of the Terrain Mapping Units (TMUs) defined from SPOT imageries by Land Evaluation Computer System (LECS).

CHAPTER TWO

LITERATURE REVIEW

2.1 The need for resource information in developmental processes

2.1.1 Current status

Many Researchers have observed that developing countries, especially those in Africa South of Sahara, lack data for good decision and management of their natural resources (National Academy of Science, 1977; Berg, 1983; Areola, 1982, and Adeniyi, 1986, Dwivedi, *et al*., 1998; Nagamani & Ramachandran, 2003) Under these conditions, poor decisions regarding resource allocation and use, can contribute to rapid decline in resource quality and economic productivity (Turner *et al.*, 2006; Mengistu and Salami, 2007).

The rainforest belt of West Africa is gradually being destroyed and turned into fallow land through crop rotation. In many of these areas, the carrying capacity of the land is continuously been reduced by a combination of rapid population growth and misuse/abuse of the land and ecosystem. Other factors contributing to reduction in land quality are degradation of farmlands, forest depletion, accelerated erosion, increased flooding and extinctions of fauna and flora (Cant, 1986; Bentley, 1987; Schmidt, 1990; Ufoegbune *et al.*, 2008; Avram, 2009). Many developing countries including Nigeria have long been aware of the increasing pressures that rapidly growing populations are exerting on the capacity of their resource base to sustain production over a long term (Helleiner, 1960; Bhat, *et al.*, 2009). The Federal government of Nigeria, in its Third Development Plan (1975-1980), stated that:

> *"….one of the main weaknesses of Nigeria planning efforts has been its heavy emphasis on sectoral and financial planning almost to the total neglect of information for physical planning. The effect of this is now becoming increasingly reflected in the form of disorderly spatial and environmental development…"*

Despite the acknowledgement of these problems, little effort was made to correct the situation, because of the continued low priority given to environmental issues in many developing countries. Two cases that easily come to mind is Nigeria's "Operation Feed the Nation (OFN) and the Green revolution programme which attempted to apply universal solutions to promote increased agricultural production without accounting for the varied soil and environmental conditions that existed throughout the country. It is not surprising, therefore, that the strategies of attaining self-sufficiency in food production by 1985 failed (Famoriyo and Raza, 1982).

It took Nigeria forty three years after independence (September 2003) to launch its first satellite into orbit (Nigeriasat-1). The 98kg Microsatellite was jointly designed and built by a team of Engineers from Surrey Satellite technology Limited (SSTL) of the United Kingdom and Nigeria. It was designed and built for Disaster Monitoring Constellation (DMC) with a lifespan of five years (Ogunbadewa, 2008).

In order to stamp its feet on the consciousness of the global community as a nation to be reckoned with in Information Communications Technology (ICT), Nigeria launched another satellite (NigComSat-1) into orbit in May, 2007. The Satellite which cost the country N40 billion dropped off the orbit in November 2008 due to a cut in fuel supply linkage of the Panel resulting in a Solar flare. Undaunted by this loss, Nigeria built a third Satellite (NigeriaSat-2) that was expected to be launched into orbit in the first quarter of 2010 (Nkanga, 2009).

2.1.2 Information requirements

There is absolute need for resource information in all countries but this varies from one region to another. The differences can be due to the size of the country, its geography, its development strategies and objectives, the type of resource information already available, the degree of detail that is needed, the present capacity of the country to use resource information and if data is required repetitively or not (Willard, 1983, Kumaraswamy & Narayanakumar, 2005). As a result of these differences, developmental decisions are often related to specific developmental projects with different phases of such projects requiring information at a variety of spatial and temporal scale. Pierre and Blandon (1978), identified four development project phases, categorizing them as project identification, project planning, project implementation and project evaluation. The means of acquiring resource information at each phase may vary with respect to methodology, spatial and temporal scale requirements. When surveying natural resources, however, three main methodological approaches are generally recognized: inventorying, monitoring and forecasting (Haefner and Schock, 1982).

2.1.3 The Nigeria Situation

In the context of South Western Nigeria, resource information required to help in agricultural development planning must integrate knowledge of the physical constraints that a humid environment poses for agricultural production. These constraints relate primarily to climate, soil, vegetation and rainfall distribution (Scott, 1978). Although temperatures are generally sufficient in humid regions to allow plant growth year-round, uneven distribution of rainfall and high evapotranspiration rates limit cultivation to the wet seasons except in valley bottomlands. In addition, the unpredictable annual variability of climatic factors in these regions implies a low degree of security for agricultural production (Kelly, 1975). The soils are often vulnerable to erosion unless appropriate management and conservation is practiced (Prothero, 1962; Sogunle and Fagbami, 1990). The vegetation cover in most of these areas has been and continues to be seriously altered by persistent human activities (Adejuwon, 1971; Edosomwan and Osifo, 2003). Such denudation of the landscape has contributed to increased degradation of these areas.

Constraints of this nature suggest that there is need to acquire relevant data on climate, soil, water and vegetation to help ensure self-sufficiency in the production of food. Such information will further enhance the growth and yield of agricultural crops and livestock develop water resources to increase yields and control fluctuations in agricultural production and ensure rational development of all natural land and subsoil resources (Beaumonts, 1984; Mooney and Hobbs, 1989; Akingbade, 2006; Adekayode, 2007).

Unfortunately, much of this information is not readily available in developing countries. In Nigeria, much of the country is still not fully covered by large-scale topographic maps, and many of those that exist, even of recent publications, are based on aerial photography of the early 1960's and so are seriously obsolete. Also, there are no complete series of medium scale, geological, landuse and soil maps that are essential for developmental projects. Where statistical data exist, they are at least five years behind at the time of publication. As a result, most of the available data are unsatisfactory as a base for development decisions (Freeland, 1983; Townsend *et al.*, 1991).

Agricultural agencies in developing countries often lack data on which to base rational planning; they do not know the extent of agricultural land, and they have little information on the increasing rates of destruction of prime agricultural areas. Agricultural Institutes responsible for specific crops do not know precisely the size of the holdings or the quality of the crops. In short, it remains difficult to identify the spatial structure of land use and land capability on which relevant models and practical land use planning and management can be based (Morain, 1991; Lambin *et al.*, 2001; Goldewijk and Ramankutty, 2004). Other problems associated with data collection in developing countries relate to the lack of adequate infrastructure such as roads, from which to establish accurate ground control as well as associated problems related to access to remote and sparsely populated rural areas (Hutchinson, 1985).

In those areas where data are collected, agencies or government departments often gather them separately. The compatibility between such data sources is often low due to differences in scale and level of detail. Also, the incompatibility could also be ascribed to differences in the systems of data collection from one time to another or from one region to another. Consequently, there exists within a country, various incompatible definitions of resources and duplication of effort. In addition, the sectoral nature of many government agencies within developing countries has provided little incentive or effort to produce an easily accessible, comprehensive and integrated representation of the nation's resource base as a decision – making tool for national and regional development (Nash, 1980).

In Nigeria, this dearth of accurate landuse and land resource information is primarily due to problems of obtaining and analyzing resource information as well as the unavailability of modern procedures for the collection and presentation of these types of data (Agboola, 1979; Fagbami, 1986).

2.2 Application of Modern Technology to Resource Development

2.2.1 Remote Sensing

One useful tool, which could aid decision makers in improving resource base information, is remote sensing. Remote sensing can broadly be defined as the collection of information (photographic and non-photographic) about an object without being in physical contact with it (FAO, 1974; Navalgund *et al.*, 2007). The term remote sensing is restricted to methods that employ electro-magnetic energy as a means of detecting and measuring target characteristics (Sabins, 1978; Hathout, 2002; Omuto and Shrestha, 2007). This involves aerial photography, Radar imagery and satellite imageries, Landsat and the French SPOT imageries. Remote sensing describes the range of techniques used to record information about an object from a distance. The sensor or sensing instrument is not in physical contact with the object and normally measures some properties of its reflected, emitted or transmitted electromagnetic energy.

Radiant energy moves with the constant velocity of light (3 x 10^8m5^{-1}), in a harmonic wave pattern. It ranges from very high frequency gamma and cosmic rays through X-rays, ultraviolet radiation, visible, infra-red and micro-waves radiation to low frequency radio waves. In a restricted sense, remote sensing is the measurement that makes use of visible, infra-red and micro-wave radiation in the acquisition of environmental information which is stored in the form of images or digital tapes (Cochrane, 1986).

Not only is remote sensing used to acquire data, it also processes them into usable format. This involves display, and subsequent analysis of data which are frequently in the form of images. This is why in image analysis, techniques which can either be manual, machine assisted or totally automated play an important part (Lillesand and Kiefer, 1979; Marsett *et al.*, 2006).

In summary, remote sensing comprises of data collection, their display, analysis or interpretation and subsequent use for purposes of inventory, survey, monitoring, planning and management. Remote sensing is especially useful where speed, repetitive observation and broad synoptic views are required (Bhalla *et al.*, 1984; Rashmin, 2004; Micale and Marrs, 2006; Serbin *et al.*, 2009).

Regardless of the diversity in remote sensing instrumentation, there are four major components: the energy source, the platform / sensor, the object of interest and the data which are generated by the energy stored in the object. The atmosphere can modify the energy flux between the energy source and the object and also between the object and the sensor (Siewell, 1987; Lu and Weng, 2007).

2.2.2 Types of Remote Sensing:

Aerial Photography

After the initial military application, the application of aerial photography to natural resource data collection started after the Second World War. Of the various kinds, black and white photographs are the most common and record details of the landscape in a range of gray tones between black and white. The gray scale differences within an aerial photograph provide spectral records of specific objects, and so recognition of their tonal variation is critical in any interpretation.

Most of the black and white photographic coverages are vertical, taken with wide-angle-lens from low altitude aircraft; hence their scales range from 1:40,000 – 1:5,000. Inevitability is coalesced into just a few categories of gray tones (Cochrane, 1986). Texture and pattern provide additional details, which aid the interpreter in discriminating between various surface conditions.

Colour aerial photography has significant advantage over panchromatic film in that it greatly increases range of information on the colour film, more accurate analysis is possible and records features in their natural colour as seen by the human eye. In addition to the above two, is the infrared aerial photography. This has an advantage of being responsive to changes in the infrared reflectance which signal disease or stress in plants and crops.

In most developing countries, only manual interpretations are possible. A systematic study of aerial photography normally involves a consideration of several basic characteristics of the photographic images. These generally include shape, pattern, shadow, tone, texture and site. A review of this concept is contained in Carrol *et al.*, (1977) and Lillesand and Kiefer (1979).

Soil changes may be seen on air photos as changes in tones, related to differences in soil surface, colour or texture or to differences in crop response. The time to record these variations are either when the ground is bare of crops or when crops are in full growth (Evans, 1974) Burnt surfaces left after harvest obscure tonal changes. Tonal changes are often related to changes in soil parent material and are usually obscured by crop growth.

The major advantages of conventional aerial photography are the high resolution, the wide choice of methods, instruments and trained personnel. The major disadvantage as applied to agriculture results from environmental repetitive coverage, non uniform and uncalibrated intensity measurements that obstruct automatic density processing and the relative high lost per kilometer especially for large scale aerial surveys (Pacheco, 1980; Goetz, 2006).

According to White (1977), interpretation of aerial photographs to define boundaries of soil units or landforms corresponding to them is one of the survey operations and cannot be substituted for fieldwork. It however enables work in the field to be reduced, better planned or otherwise rendered more effective.

Side-Looking Airborne Radar (SLAR)

The SLAR is a newer and more complex remote sensing technology than aerial photography. Radar, unlike aerial photography is dependent upon successive short pulses of microwave – frequency energy which are directed in a narrow beam orthogonal to the aircraft or satellite path. Successive strip of ground to the side of the platform are illuminated and the spectral return or backscatter is used to make up a continuous swath of microwave imagery.

Most radar systems operate at wavelengths between 0.86 and 3.3cm (k and x – bands), (NIRAD, 1978) and more lately, on seasat and the shuttle flights, at 23cm (L-band). SLAR penetrates clouds, light rain showers and harmattan dust with no reduction of the quality of the imagery. It was first developed for military reconnaissance purposes in the early 1950's, and later improved upon for non-military capacities and applied research by earth scientists, through 1960's. Its imageries became available on commercial basis in 1967 (NIRAD, 1978).

SLAR found a ready source for resource data acquisition in the equatorial regions because of its ability to penetrate clouds and haze (Fagbami, 1981a and b; Fagbami and Olaniyi, 1982) and can operate both day and night. Although it has been successfully used in many fields of application such as vegetation and landuse mapping of Nigeria, mapping of the soils of Bendel State (Fagbami and Fapehunda, 1986), the spatial resolution which varies with range and determined by the size of the antenna, is coarser than low and medium scale aerial photographs. The interpretation of SLAR imageries are therefore not made on scales much larger than 1:125,000 (Lillesand and Kiefer, 1979). Therefore, SLAR is more of a reconnaissance mapping tool than for detail mapping.

Landsat

Landsat, formally called Earth Resources Technology Satellite (ERTS) is an unmanned remote sensing system, launched in the USA in 1972 (Sabin, 1978; Stefanov *et al.*, 2001). This was followed successively by Landsat 2 and 3 in 1975 and 1978 respectively (Table 2.1). The Multispectral Scanner (MSS) on Landsat 1, 2 operates from an orbital altitude of 913km, recording in four different wave length bands, 0.5 – 0.6 mm, 0.6 – 0.7 mm, 0.7 – 0.8 mm and 0.8 – 1.1 mm, over a swath width of 185km. Landsat 1 – 3 carried Return-Beam Vidicon (RBV) cameras and Multispectral Scanners (MSS) (Tucker *et al.*, 2004).

The MSS data are recorded in electronic form and relayed by radio to earth, where images are reconstituted at ground receiving stations. The ground resolution of the system is 80m. Landsat 4 and 5 otherwise known as Thematic Mapper (T.M.) has greatly improved spatial and spectral resolutions. It has recordings in seven wavebands and a ground resolution of 30 m for six of its bands. Landsat 4 – 5 carried the MSS as well as the Thematic Mapper (TM), a more advanced scanner. Landsat 7 has an enhanced Thematic Mapper plus (ETM+). Landsat 7 was launched in April 15th, 1999 and was designed to last for five years (Cohen and Goward, 2004).

Landsat satellites follow near-polar orbits that are inclined approximately 8° to the poles. Landsats 1, 2 and 3 orbited at 920 km altitude 14 times per day. Over a period of 252 orbits, or every 18 days, a satellite covered every portion of the Earth, except for Polar Regions above 82° latitude. Landsats 4, 5 and 7 orbits at 705 km altitude with a 16-day repeat interval for global coverage. The Landsat orbit is designed to be sun synchronous. In other words, the satellite crosses the equator at the same local sun time with each orbit. This provides for some uniformity of lighting conditions.

The multi-spectral scanner (MSS) detects reflected solar energy in two bands of visible light and two bands of short-infrared energy. Scanning is accomplished by a mirror that oscillates back and forth across the scene. Energy is measured in four bands for six lines with each scan of the mirror. Energy intensities are sampled every 57 m along scan lines, and the data are recorded as digital values: 0-127 for bands 1, 2 and 3; 0-63 for band 4 (Holkenbrink 1978). The thematic mapper operates in seven bands of visible and infrared energy with a resolution of 30 m. Data are recorded on byte-binary scale (0-255). The ETM+ adds a panchromatic band (0.5-0.9 µm) at 15 m resolution.

A complete image takes about 25 seconds to scan, during which time the Earth rotates eastward beneath the satellite path. To compensate for this, scan lines are slightly offset in the resulting image, which is shaped like a parallelogram. The orientation of a scene depends on latitude; at about 50° the scene is tilted approximately 10° from true north.

Landsat 7 is the latest satellite of the Landsat program. It was launched on April 15, 1999 (Yuan *et al.*, 2005). The primary goal of Landsat 7 is to refresh the global archive of satellite photos, providing up-to-date and cloud free images. Although the Landsat Program is managed by NASA, data from Landsat 7 is collected and distributed by the USGS. The NASA World Wind project allows 3D images from Landsat 7 and other sources to be freely navigated and viewed from any angle.

Landsat 7 was designed to last for five years, and has the capacity to collect and transmit up to 532 images per day. It is in a polar, sun-synchronous orbit, meaning it scans across the entire earth's surface. With an altitude of 705 kilometers +/- 5 kilometers, it takes 232 orbits, or 16 days, to do so. The satellite weighs 1973 kg, is 4.04 m long, and 2.74 m in diameter. Unlike its predecessors, Landsat 7 has a solid state memory of 378 gigabits (roughly 100 images). The main instrument on board Landsat 7 is the Enhanced Thematic Mapper Plus (ETM+) (Yang and Lo, 2002).

The value of Landsat imagery for reconnaissance soil mapping in the cloud-free regions of West Africa has been demonstrated in several studies such as in (Fagbami, 1980; Ojanuga, 1980; Fagbami, 1986a; 1986b). This, however, has not been found a handy resource-mapping tool in the cloud-covered tropical regions (Judex, *et al.*, 2006).

Systeme Probatoire Pour Observation de la Terre (SPOT)

The success of U.S. LANDSAT System in the early 1970s stimulated the interests of scientists in other nations. The French in particular, designed an earth observation satellite modeled after some of the fundamental features of Landsat system. Systeme Probatoire Pour Observation de la Terre (SPOT) was conceived and designed by the *Centre National d'Etudes spatiales* (CNES) in Paris with the co-operation of other European groups. SPOT 1 was launched in 1986 and SPOT 2 in January 1990. SPOT 3 was launched in September 1993, SPOT 4 in March 1998 and SPOT 5 in May 2002 (Chevrel, *et al*., 1981 and ResMap, 2010) Table 2.2.

The SPOT system is planned to have capabilities for landuse studies, assessment of renewable resources, exploration of geologic resources and cartographic work at scales of 1:50,000 – 1: 100,000. It is the first commercial remote sensing satellite designed to provide high quality service and data for an operational user community worldwide. The improved spatial resolution to 20m for the multispectral (Xs) and 10m for the panchromatic (PA) in the SPOT system has proved valuable for detailed agricultural mapping and urban analysis. SPOT simulation studies by CNES, other government agencies and individuals like Sogunle and Fagbami (1990), Edosomwan and Fagbami (1992) and Akinbola (1993) have demonstrated the potential of SPOT data for detailed agricultural, forestry, coastal and urban studies as well as for other resource application.

Additionally, SPOT is ground controlled to view either vertically (nadir-viewing) or at an angle (off-nadir viewing). In the latter mode, the sensors are directed in across track direction in order to allow rapid access to any part lying within the arc $\pm 27^{o}$ from the satellite ground track, thereby providing a very flexible multiple-look capability (Cochrane, 1986). This innovation also allows the acquisition of stereoscopic image pairs from different satellite passes (Table 2.3).

Table 2.1. Landsat Characteristics

Satellite	Launched	Decommissioned	Sensors
Landsat 1	July 23, 1972	January 6, 1978	MSS and RBV*
Landsat 2	January 22, 1975	February 25, 1982	MSS and RBV*
Landsat 3	March 5, 1978	March 31, 1983	MSS and RBV*
Landsat 4	July 16, 1982	June 30, 2001	MSS and TM
Landsat 5	March 1, 1984	(Operational)	MSS and TM
Landsat 6	October 5, 1993	(Did not achieve orbit)	ETM**
Landsat 7	April 15, 1999	(Operational)	ETM**

* The return beam vidicom (RBV) was essentially a television camera and did not achieve the popularity of the MSS sensor.

** The sensor onboard Landsat 6 was called the enhanced thematic mapper (ETM). Landsat 7 carries the enhanced thematic mapper plus (ETM+).

Source: Tucker, *et al*., 2004

Table 2.2. SPOT Products

SPOT Product	Satellite	Spectral Mode	Spectral Bands	Ground Pixel Size
2.5 meters colour	SPOT 5	THR + HX	B1, B2, B3	2.5 meters
2.5 meter B&W	SPOT 5	THR	P	2.5 meters
5 meter colour	SPOT 5	HM + HX	B1, B2, B3	5 meters
5 meter B&W	SPOT 5	HM	P	5 meters
10 meter colour	SPOT 5	HI	B1,B2,B3,B4	10 meters
	SPOT 4	M + XI	B1,B2,B3,B4	10 meters
10 meter B&W	SPOT 4	M	M	10 meters
	SPOT 1 & 3		P	P 10 meters
20 meter colour	SPOT 4	XI	B1,B2,B3,B4	20 meters
	SPOT 1 & 3	XS	B1,B2,B3	20 meters

Source: ResMap, 2010

Table 2.3. SPOT Satellites

SPOT Satellite	Spectral Bands	Ground Pixel size	Spectral Resolution
	P: panchromatic	2.5 meters or 5 mtrs	0.48 – 0.71µm
	B1: green	10 meters	0.50 – 0.59µm
SPOT 5	B2: red	10 meters	0.61 – 0.68µm
	B3: near infrared	10 meters	0.78 – 0.89µm
	B4: short-wave infrared	20 meters	1.58 – 1.75µm
	M: monospectral	10 meters	0.61 – 0.68µm
	B1: green	20 meters	0.50 – 0.68µm
SPOT 4	B2: red	20 meters	0.61 – 0.68µm
	B3: near infrared	20 meters	0.78 – 0.89µm
	B4: short-wave infrared	20 meters	1.58 – 1.75µm
SPOT 1	P: panchromatic	10 meters	0.50 – 0.73µm
SPOT 2	B1: green	20 meters	0.50 – 0.59µm
SPOT 3	B2: red	20 meters	0.61 – 0.68µm
	B3: near infrared	20 meters	0.78 – 0.89µm

Source: Cochrane, 1986.

General Characteristics of SPOT Image

The SPOT "bus" with its sensors is placed in a sun-synchronous orbit at a height of about 832km with a 10.30am equatorial crossing time. For vertical observations, successive passes occur at 26 day intervals but because of the ability of SPOT sensors to view areas at the oblique, successive imagery can be acquired on the average at 2½ days interval (Chevrel, *et al.,* 1981). The SPOT payload consists of two identical sensing instruments, a telemetry transmitter and magnetic tape recorders.

The two sensors are known as HRV ("high resolution visible) instruments. HRV sensors use "Pushbroom" scanning technology based upon charge couple devices (CCDS) that can simultaneously image an entire line of data without mechanical movement. An important advantage over conventional technology is the absence of moving parts, which in principle should provide greater reliability, more uniform scanning speed across the image swath and greater stability of the satellite thereby assuring high geometric accuracy (CNES, 1987).

The HRV can be operated in either of two modes. In the panchromatic (PA) mode, the sensor is sensitive across a broad spectral band from 0.51mm to 0.72mm. It images a 60 km swath with 6,000 pixels per line, for a spatial resolution of 10m x 10m. In this mode, the HRV instrument provides a fine spatial detail but of coarse broad spectral region.

In the other mode, the multispectral (Xs) configuration, the HRV instrument senses three spectral regions, Band 1, 0.5mm – 0.59mm (green), Band 2, 0.61 – 0.68mm (red) and Band 3, 0.79 – 0.89mm (near infrared). In this mode, the sensor images a strip 60km wide using 3,000 samples for each line, at a spatial resolution of about 20m x 20m. Thus in the Xs mode, the Sensor records fine spectral resolution but coarse spatial resolution. The three images from the Xs mode can be used to form false colour composites (SPOT Newsletter, 1988).

Data Processing

SPOT PA and Xs scenes can be processed to any of four basic levels (CNES, 1987):

Level IA

This is essentially a raw data level apart from normalization of CCD detector response in each spectral band. Interband relative sensitivity coefficients are also given but no geometric correction.

Level 1B

This includes full radiometric and geometric corrections taking into account, the systematic distortions due to the system effects (rotation and curvature of the Earth), viewing angle and desmearing).

Level 2

This is a precision processing level apart from the corrections on the basis of Ground Control Points (GCPs). The image is thus rectified according to a given cartographic projection. However, this level does not take account of distortions due to terrain relief. This means that the closer the viewing direction to the vertical and the less pronounced the relief, the more accurate the product Level 2 Scenes are oriented towards geographic North and processing can only be performed if a sufficiently accurate map is available for GCP extraction. This points out one of the reasons why the topographic maps in Nigeria, compiled since 1966 need a review.

Level 2S

These scenes are rectified using control points for registration with a SPOT reference scene. Registration accuracy is 0.5 pixels when 2 scenes are recorded at the same viewing angle. The product is intended primarily for multidate studies.

2.2.3 Aerial Photo Interpretation

Among the various kinds of air photographs, black and white or panchromatic is the most commonly used and most easily available. Most of the black and white photographic coverage of Nigeria is vertical, taken with wide angle lenses from low altitude aircrafts; hence their scale ranges from 1: 40,000 to 1: 5,000. In this range, and based on the scale specifications of Mitchell, (1968), only land facets can conceivably be delineated.

The only mode of interpretation used in Nigeria before now is manual since the denatometric technology for converting analog photographs into digital format is not available (Fapohunda, 1986; Goetz, *et al.*, 2004). Successes in manual interpretation which is a technical art, varies with the training and experience of the interpreter, terrain spatial complexity, and the quality of photographs being used.

Characteristics of photographic images considered during interpretation include shape, size, pattern, shadow, tone, texture and site. A comprehensive review of these characteristics is contained in Carols, *et al.*, (1977) and Lillesand and Kiefer (1979). Pattern relates to the spatial arrangement of objects or features in a scene while drainage pattern is indicative of the complexity or otherwise of landscapes. Likewise, shape which is the general form, configuration or outline of individual valleys are indexes of the slope variability on landscapes. The tone refers to the relative brightness of objects and when light tones show up, it is indicative of good internal drainage.

2.2.4 Methods of Image Interpretation for Soil Survey

There are three principal methods of image interpretation for soil surveys

Pattern Analysis

The pattern elements, which according to Frost (1960) are indicative of surface and subsurface conditions are: erosional features, drainage, landform, vegetation, photographic tone and cultural features. Pattern analysis is based on the identification of major landscape units and the division of these units into smaller units, characterized by the so-called "local pattern elements" (FAO, 1967). It starts from the assumption that each pattern element is correlated with certain soil conditions.

Frost describes the principle as follows "Having grasped the original context of the soil to be studied, the interpreter divides the major landscape units into smaller units and examine local pattern elements under the stereoscope. Each element should be studied independently. If all the findings agree, the soil can be identified and described with reasonable accuracy. So, two or more different pattern elements may point to the same smaller land units. This is similar to what Lueder (1959) describes as "converging evidence". This method requires a thorough knowledge of geomorphology or adequate representations of the landforms in a guide or key" (Frost, 1960).

In general, the use of pattern analysis is reliable in areas of known geomorphological history and where conditions like cloud cover are not visible on the photograph. Its use in unknown areas can be rather dangerous as wrong conclusions are easily reached.

Element Analysis

The analysis of imagery according to individual elements, as developed by Buringh (1960) is based on the fact that most of the features of the earth's surface are in some way connected with soil conditions. For some elements, the connection is direct, as in the case of relief, for others, such as landuse, the connection is more loose. All the elements considered are supposed to be related to the soil forming factors, climate, organisms, parent material, relief, time and human activity.

The underlying principle of the analysis is that any element may be related to a certain soil mapping unit and therefore, a change in the element may correlate, with a soil boundary (FAO, 1967). The aspect of interest for soil survey has been grouped (Bennema and Gelens, 1969), into:

- Basic aspects individually visible on the image e.g. slope, relief, vegetation, crops, soil and rock surfaces.
- Compound aspects visible on the image through a combination of two or more of the basic aspects e.g. land types, drainage way and pattern, faults and joints.
- Inferred aspects not directly visible on the images but deduced from basic and or compound aspects e.g. soil depth, parent material, drainage and erosion condition.

It should be noted however, that the classification of the elements into different groups is artificial (FAO 1967), as certain elements may in certain case belong to one group, but in another case, may shift into another group, depending on the local conditions. The interpretation of the imagery by element analysis starts with the elimination of those elements that have no relation at-all to soil (FAO, 1967).

This method can be applied universally, particularly beneficial to surveyors who are yet to build up much experience in interpretation of photo or imagery. However, the pure form of aspect analysis is time consuming since a lot of field checking of tentative boundaries is required.

2.2.5 Physiographic Analysis

Physiographic analysis of imagery is based upon a thorough knowledge of the relationship between physiography and soils, and upon the recognition of dynamic processes rather than of static elements (FAO, 1967; Lillesand, 2006). Physiographic analysis according to Bennema and Gelens (1969) restricts itself to the external features as shown in the stereo image. It includes the analysis of basic compound aspects, such as relief, slope as well as vegetation and landuse as aspects important for the description of the drainage system (Mulders, 1987).

The elements are just as important as in "element analysis", however, many of them are not used primarily to draw boundaries but are used as basic for understanding the interaction of physiographic processes (FAO, 1967). The most important physiographic processes in relation to soil are erosion and sedimentation, of which many subdivisions can be made and many local factors may influence these processes.

The most important step in physiographic analysis is to recognize and identify the basic process acting on any specific case (FAO, 1967). The method has universal application but can only be applied by surveyors with very high reference level of image interpretation.

2.2.6 Contributions of Remote Sensing to Management of Renewable Resources

Remote sensing has made considerable contributions to the management of renewable resources in and outside the tropics. Some of the major contributions of the technology are in the areas of:-

a) Soil survey and land classification,

b) Mapping and monitoring of landuse/landcover

c) Land degradation mapping.

Soil survey and Land Classification

Information about soil is basic for efficient and sustained agricultural production. Soil characteristics, although can be modified to some extent, generally determine the type of crop that can be grown and the production potential of that crop. Information on soil is particularly important in an area in which new land is being brought into production (Liney *et al.*, 1970; Manchanda *et al.*, 2002). In many areas, pressing agricultural development takes place without the essential data on the soil needed for assessing the potential for successful development. The consequences of such attempts have always been low productivity and outright crop failure in some cases.

The need for increasing agricultural production in the developing countries necessitates the production of a good soil map, in addition to the analysis of other physical parameters in the environment (Fagbami, 1981a). Mapping of soils in most part of the world using remote sensing technology was initiated by organizations such as Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia and New Guinea (Stewart, 1968) and in developing countries by United Kingdom Ministry of Oversea Development (Ollier *et al.*, 1969) and Food and Agricultural organization in eastern Columbia (FAO, 1965; Shukla *et al.*, 2009).

The first aerial photographs, taken from balloon at about 1850 were perhaps first used for large area soil survey of the Jennings country, Indiana about 1929 (Bushnell, 1932). The value of the air photo interpretation, according to Deut and Young (1981), in soil survey was first recognized for reconnaissance studies of large areas, both in developing countries and in the desert areas of northern Australia.

Aerial photography has been preferred to satellite imagery in semi detailed and detailed surveys and this has been found to produce accurate soil maps especially with large scale black and white photos (Fagbami, 1986a). This special attribute of aerial photo is hinged on the stereoscopic view produced by this technology which enables the interpreter to observe the terrain features in three-dimensional forms and provide accurate delineations, observations and measurements (Asiamah, 1982). Aerial photo interpretation was employed by Bawden *et al.*, (1972) for reconnaissance survey of northern Nigeria. Mudock *et al.*, (1976) also made use of aerial photographs for land resource survey of the South Western Nigeria.

Using side-looking Airborne Radar (SLAR) imagery, Fagbami and Fapohunda (1986) identified and demarcated different land types of Bendel State (now Edo and Delta States) and derived many aspects of lithology, relief, drainage pattern, moisture regime and vegetation cover while Olaniyi (1988) carried out same for Central Western Nigeria. The largest land classification and evaluation survey (the Radar project of Brazil) covering about 4 million kilometer square, used SLAR imagery to provide information on geology, morphology, soils, vegetation and landuse during the 1970's and offered the first over-view of natural resources within the vast region (Hammond, 1977; Lee *et al.*, 1988).

The arrival of Landsat in early 1970s further enhanced and widened the applicability of remotely sensed data to soil and resource survey. Landsat MSS was used by Fagbami (1980) to identify major land types in the Federal Capital Territory (Abuja, Nigeria) and also of Makurdi areas. He observed that it is not only easier but also faster than with air photo interpretation if large area is involved.

The ability of Landsat to classify sub-surface features especially in humid tropics depends on the influence of the soil on the cover and the identification of the soil. The reflectance characteristics of the cover type have very low reliability as most of the resulting groups are known to be far from homogeneous (Fagbami, 1986; Kudrat *et al.*, 2000). Even though it is not possible to attain a high degree of homogeneity within the land facets, they could be sufficiently grouped for agricultural planning. Landsat imagery has been used for soils and land resource survey purposes in other parts of the tropics as illustrated by the works of Elberson, (1973); in Columbia, Odenyo (1979) in Kenya and Kudrat *et al.*, (2000) in India.

The relatively low spatial resolution of this first generation satellites; Landsat 1, 2 and 3 (79m) has limited the application of the data to small scale survey but the sensor capability of later generation Landsat 4 and 5 (30m) and the more recently SPOT (Xs = 20m; PA = 10m) has a capability for stereo coverage and frequent access to user-specified sites (Chevrel, *et al.*, 1981).

Similar studies using SPOT by CNES and other individuals have demonstrated that SPOT imagery is nearly as interpretable as small and medium scale aerial photography in the mapping of soils (Buttner *et al.,* 1988) while Edosomwan and Fagbami (1992) observed that SPOT imagery compared favourably with medium scale aerial photographs in the mapping of terrain features in the eastern part of Ilesha.

Mapping and monitoring of landuse/landcover

Landuse is defined as any kind of permanent or cyclic human intervention on land usually with emphasis on the functional role of land in economic activities (Campbell, 1983; Lambin *et al.*, 2001). According to Sys (1985) man, an inherent part of the ecosystem tries to manipulate land either in very intensive manner as with permanent cropping or in very intensive way as under shifting cultivation. Land cover on the other hand describes the vegetational and artificial construction covering the land surface (Burley, 1961; Nagamani and Ramachandran, 2003). One of the most important aspects of land cover is the one concerning natural vegetation, agricultural crops and animal life. The pattern of land cover is often used to make inference about human activities and land use.

Up to date information on major landuse acreage and distribution of crops is a basic need in agriculture throughout the world (Vink, 1975; Garcia-Gigorro *et al.*, 2007). These data are essential for efficient management of agricultural resource. Information on present extent, location and productivity of land used for different purposes is needed for analysis and planning. Competition for use of land is currently attracting attention. Urban development, need for more recreation areas, and the preservation of wildlife habitats are matters of great interest to those concerned with the use of land resources (Liney *et al.,* 1970; Dewan and Yamaguchi, 2009).

Land use inventory data consist of data compiled by census from personal interview, mail questionnaire, study of sample areas or some combination of these. Generally, these methods take a long time because of the number of trained scientists are limited or because the number of well-trained people required is large. These factors account for the relative large interval between census projects in many countries.

Pressing needs for land use inventory in many developing countries have already prompted the use of remote sensing. Smyth and Montgomery (1962), carried out one of the earliest landuse surveys in Central Western Nigeria. Adeniyi (1980) used sequential air photographs for landuse change detection in Lagos while Fagbami *et al.*, (1988) applied aerial photo interpretation technique to map landuse of Akwa-Ibom State.

Landuse pattern of Ibadan division was mapped by Oyelese (1968) using small scale aerial photographs. Although he concluded that this technology was able to overcome problems associated with field transverse as enumerated by Wikkramatileke (1959), he noted that availability of recent air photo of suitable scale is a limitation to the use of aerial photos. The system of agriculture in Nigeria makes identification and mapping of landuse difficult. Adeniyi (1986) observed that farm plots are of variable size, widely scattered, boundaries are irregular and plot size frequently changing from season to season and from year to year.

Recent land resource studies in Nigeria contain information on both land systems and land use. SLAR imagery was used to map vegetation and landuse of Nigeria in 1979 by the British Hunting Technical Service limited and was also mandated to train Nigerian staff on its use (Travett, 1978).

Of all the sensor systems, landsat is so far, the most extensively used for landuse and landcover mapping. Under a bilateral arrangement with University of Waterloo in Canada, Adeniyi and Olugbile (1987); Pilon *et al.*, (1987) Omojola *et al.*, (1987) and Goetz *et al.*, (2004) used Landsat imagery to map and monitor landuse/Landcover change of the large-scale irrigation project in the Sokoto – Rima area of Sokoto State. In other parts of the world, Landsat imagery has been used to map the sugar cane and forest plantations in south eastern Brazil, (Mendonca, 1981) and parts of Thailand and Laos (Omakupt *et al.*, 1980). In many parts of the tropics, the relatively poor spatial resolution of landsat MSS has limited the precision of such surveys particularly in the areas of small-scale subsistence farming (Manandhar *et al.*, 2009).

The improved spatial capability of SPOT and its cross-trade pointing capability and stereoscopic coverage, enables a location to be revisited every 3-4 days at Equatorial latitudes (Chevrel, *et al.*, 1981), and therefore increase the chances of obtaining cloud-free imagery in tropical areas. These special attributes makes SPOT image a better sensor for landuse land cover survey in small scale farming areas of the tropics over Landsat.

Sogunle and Fagbami (1990), used SPOT image acquired in 1986 to map the landuse of Ibadan city. Akinbola (1993), used the same imagery to monitor urban growth of the same area. The landuse/landcover of the rice producing area, east of Ilesha was mapped by Edosomwan and Fagbami (1992). Working on landuse in the north eastern India, Balder-Sahai (1988) and Helmschort and Flugel (2002), reported that in the humid tropical vegetation, SPOT was very striking in the identification of Mangrove and Secondary vegetation for which considerable improvements have been brought about by the multispectral classifications. He was quick to add that the 20m ground resolution of SPOT is still not sufficient to provide information on primary forest patterns, neither was it adequate for identifying properly logged over areas.

Land degradation mapping

Land degradation can be perceived as a complex combination of many processes (physical, biological and chemical). These act to force on the land, a condition less suitable to man, compared to its condition under natural equilibrium. The principal types and causes of land degradation are soil erosion, flood, siltation, draught, desertification, deforestation, loss of fertility, pollution, land scarification and overgrazing (Igbozurike *et al.*, 1988; Velayutham, 2000).

The abuse of land in any country can indeed affect the economy especially in developing countries whose foreign exchange earning depend on produce from the land and on the environmental quality of others (Soil Science of Society of America, 1984). This view of abuse of land in a global context places into a sober perspective, the importance of preserving prime agricultural lands wherever they may be and implementing polices and management practices which maintain productivity and minimize land degradation.

Soils under humid conditions are very vulnerable to degradation and therefore constitute a serious problem threatening the various ecosystems in Nigeria. In one of such situations, Fagbami (1976), noted that the construction of new roads and highways without adequate and appropriate drainage system in Ibadan City, often lead to irreparable damage to the lands on both sides of the highway.

Soil erosion by running water and wind, is easily the most important type of land degradation in Nigeria. Practically, all parts of the country are directly affected. The northern quarter or some 231,000 km^2 is affected mainly by wind erosion, while the Southern three-quarter (693,000km^2) suffers from that caused by rainfall (Igbozurike *et al.*, 1988). Soil erosion consists of rill, sheet and gully. While soil removal by running water occurs primarily during the rains between May and October, in the South while the north experience wind erosion during the dry season.

These seasons are greatly aided or often sparked off by many human activities; Vegetation burning, land clearing for various purposes, road construction, agricultural tillage etc. In all of the Southern three-quarters of the country affected by sheet erosion, the rate of soil removal varies from 3 tones per-hectare per year on poorly consolidated sloping sandy soils to one tone per hectare per year down to zero in regions of flat terrain (Lal, 1990).

On the other hand, soil loss via gully erosion is particularly high in parts of Nigeria where the annual rainfall exceeds 1,500mm (120,00km^2). Single gully erosion can start overnight and develop within three or four raining months into a massive scar, 50m long, 4m deep and over 5m at the widest section. It is hardly surprising that in Anambra State, for instance with rural population density in excess of 1000 people per square kilometer, and intensive agriculture activities, well over 441 autonomous communities are ravaged by gully erosion. That state's Agulu-Nanka gully erosion complex is certainly one of the very largest in the world (Igbozurike *et al.*, 1988; Holden *et al.*, 2005).

In the northern quarter of Nigeria with the extended dry season (October to May), the removal of topsoil by wind is very pronounced. During this period, much of the grass cover not consumed by the large roaming herds of livestock, or by bush fire naturally wither. The remaining few green are far too scattered leaving the stage for a practically unimpeded sweep, day and night by strong winds from the Sahara desert (Jeje, 1988).

Although Mordi, (1990) reported that degraded soils are more common in the rural areas where agricultural activities, exploration and exploitation of the soil resources are high, Urban land is reported by Akinbola (1993), to be subjected to degradation due to the pressure of various demand or lack of planning with adverse effects on the urban dwellers. Ofomata, (1981) lamented that the siting of industrial and Urban activities is guided exclusively by economic and technological considerations rather than the capacity of the land.

The distribution of erosion risk is an important consideration in the analysis of the erosion problems in Nigeria. While areas already experiencing erosion damage require remedial measures, it is necessary to identify areas of erosion risk in order to take preventive measures (Ologe, 1988). The fastest, most accurate and reliable means of achieving the objective of generating data on past and present landuse/landcover and forecast future uses to avoid land degradation is by remote sensing (Fagbemi, 1986). According to Holz (1985), many dynamic, geomorphic processes occurring in remote locations are difficult to reach and survey, thus restricting the minority of changes to the use of remote sensing.

Most of the research dealing with the use of remote sensing for erosion studies has been done in the context of soil surveying. Remotely sensed data have been used by many workers to evaluate land degradation and environmental impact of landuse (Curran, 1985; Patrick, 1987).

Mathews *et al.*, (1973) used images collected by airborne multispectral scanner to map erosion classes of soil series by means of computerized pattern recognition technique. The result compared favorably with a detailed field map prepared from a 1:6,000 colour aerial photographs.

Using image processing technique with Landsat MSS data, Kaminsky *et al.*, (1979) found that areas of moderate to severe erosion correlated almost 100 percent with one spectral class while Seubert *et al.*, (1979) used an unsupervised approach to produce a map of ground cover and evaluate its usefulness in delineating severely eroded cultivated soil areas in the United States. These results were consistent with those of Latz *et al.*, (1981), and Weismiller *et al.*, (1985) which reported that the class with the highest reflectance correlated with the severely eroded upland soils.

However, Seubert *et al.*, (1979) concluded that even though soils may have different parent materials or be widely separated geographically, certain properties such as clay mineralogy, soil texture, iron, soil moisture and organic matter are important factors that control soil reflectance and ultimately erosion mapping by remote sensing technique. This approach according to Fagbami *et al.*, (1991) is very relevant to developing countries like Nigeria where the time lag between project identification and implementation is very wide and the fund for conservation measures is limiting.

Land Evaluation

The importance of soil survey and classification lies in understanding and remembering the properties and behaviour of soils. It also plays a vital role in communication among scientists. However, taxonomic names convey very little information to any land users due to the obscure terminology containing many conventions and hidden assumptions (Dent and Young, 1981; Ogunkunle and Babalola, 1986). The information on a soil map must be explained in a way that has meaning to the user (Klingebiel and Montgomery, 1961). Land evaluation is supposed to provide such relevant information (Kilic, *et al*., 2005).

Land evaluation means different things to different people. Several definitions of land evaluation have therefore been attempted. FAO (1983), defined land evaluation as the assessment of land performance when used for specific purposes. Land evaluation thus involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of landuse (FAO, 1976; USDA, 2001).

Beeks (1978), distinguished two types of land evaluations: Physical and integral. Physical land evaluations concerned primarily with the physical or ecological aspects of land and its use without elaborating on the non-physical aspects. Integral land evaluation on the other hand, is the synthesis of information obtained from physical land evaluation with pertinent socio-economic factors.

Land evaluation, normally expressed in land suitability or capability classes (Kellog, 1961) can either be qualitative or quantitative (FAO, 1976). A qualitative evaluation assesses the suitability of the land in general physical terms like soil, topography or climate while quantitative approach emphasizes the inputs such as fertilizer, seeds etc and the output like crop yield in addition to physical factors.

Many systems of land evaluation exist. A few of such land evaluation systems that have been widely adopted all over the world are: Land capability classification (LCC) of Klingebiel and Montgomery (1961); FAO framework of land evaluation (FAO, 1976); Productivity rating (Storie, 1983) Irrigation capability classification (ICC) of the U.S. Bureau of Land reclamation (1953); Fertility capability classification (FCC) of Buol *et al.*, (1975) and Sanchez *et al.*, (1982) and Land evaluation computer system (LECS) of Wood and Dent (1983).

Land Capability Classification (LCC)

Land capability classification, developed in USA by Klingebiel and Montgomery (1961) for farm planning, is based on the grouping of soil units, with comparable potentials and limitations from detailed soil survey. It is an interpretative soil grouping expressing the potential of the land for agriculture especially arable use without permanent damage. Although originally developed for farm planning, Moss (1972) and Wong (1974), believed that this system has found world-wide adaptation and application with regard to relevant ecological differences as a basis for modification. The prominent characteristics suggested by the authors and modified by Ogunkunle and Babalola (1986), Oluwatosin *et al.*, (2006) are slope angle (degrees), rock outcrop, wetness, effective depth, texture, permeability, available water capacity and effective cation exchange capacity (ECEC).

The classification of the system is structured into three categories of capability classes, sub classes and units. The classes are usually numbered I – VIII with I – IV as being arable classes while V – VIII are referred to as non-arable. Capability classes consist of capability sub classes or capability units that have the same relative degree of hazard or limitation. The risk of soil damage or limitation in use becomes progressively greater from class I to class VIII (Steel, 1967). The capability sub class is also a group of capability units which have the same conservation problems which are commonly denoted as: e – erosion; w – excess water; s for root zone limitation and c for climatic limitations. Therefore, the capability subclass is specific on the type of soil conservation or limitation problem involved.

According to Steele (1967), a capability unit is a grouping of one or more individual soil mapping units with similar potential mapping units with similar potentials and limitations. The soils in that capability unit are said to be homogenous enough to produce similar kinds of cultivated crops and pasture, require similar conservation treatment and management under same kind and condition of vegetative cover.

Capability classification has been applied both in reconnaissance surveys and in project feasibility surveys but Dent and Young (1981) observed that the system is not well suited to either of these purposes as it is for farm planning for which it was originally developed. The system has been widely adopted with modification to suit local conditions as shown by the works of Bibby and Mackney (1969) in Great Britain, Canada Department of Forestry (1965) in Canada, Haentjens (1963) in Papua New Guinea, and Fagbami *et al.*, (1987) in South Western Nigeria. Land capability classification has been criticized for its apparent rigidity (Christian and Stewart, 1968; Murdoch, 1970) but the possibility and ease of adoption to local conditions should be seen as a credit for the system (Menjiver, et al., 2003).

FAO framework for land evaluation

The need to develop a standard and generally acceptable method of land evaluation to replace those that was in existence, led FAO into a series of consultation among World experts between 1970 – 1976. This has the sole objective of putting an end to the proliferation of the system of land evaluation and its attendant barrier in exchange of information (FAO, 1976). The FAO Framework on Land suitability evaluation is the product of a six years exercise. Land suitability evaluation (LSE) is defined as the process of assessing the fitness of a parcel of land for a specified kind of land use (FAO, 1976). The system defines the landuse and land utilization types on one hand, and land qualities on the other in the course of surveying.

The quality of a land unit is assessed through its characteristics. A land characteristic is an attribute of land that can be measured or estimated e.g. slope angle, rainfall, texture, structure and cation exchange capacity. A land quality is a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use (FAO, 1976; Bouma, 1996).

The suitability of given land for specific use is determined by the ratings of individual land qualities, singly or in combination and matching against the land utilization requirements. The system is hierarchical with four categories of decreasing generalization: (1) suitability order (2) suitability class (3) suitability sub class and (4) suitability units.

Suitability order:

There are two suitability orders: Suitable (S) and not suitable (N). The "S" order has been defined by FAO (1976), as lands on which sustained use for defined purpose in the defined manners is expected to yield benefits that will justify the inputs without major damage to land resources. The "N" order denoting "not suitable" is defined as lands having characteristics which appear to preclude its sustained use for the defined purpose in defined manner or which would create production, upkeep and/or conservation problems requiring a level of recurrent inputs unacceptable at the time of interpretation.

Suitability classes:

They indicate the degree of suitability within the orders and FAO (1976) recommended 3 classes within the order "S" and two within the order "N". They are (1) S1 – highly suitable (2) S2 – moderately suitable and (3) S3 – marginally suitable. N1 – currently not suitable but potentially suitable and N2 – Actually and potentially unsuitable are the other classes.

Suitability subclasses

These distinguish the nature of the class determining limitations or main kind of investment measures needed within the classes. They are donated by lower case letters placed after the class symbol e.g. S2e indicating class 3 lands with limitation of erosion. According to Ogunkunle (1987), symbols for denoting limitations have not been standardized and so they vary from Institution or body to another. They are all however defined. The following limitations have been defined and widely accepted: c – climatic limitation; w – wetness; t – topography; n – salinity/alkalinity; f – fertility and s – physical soil conditions.

Suitability units

These are divisions of subclass that differ from each other in detailed aspects of their production characteristics or management requirements e.g. S2e-1 and S2e-2 refers to suitability units within the S2e subclass but differ in the degree of erosion as the limitation character. Land within the same suitability unit requires the same management practices and have the same production potential. FAO (1976), outlined a six-step approach for carrying out LSE and they are as follows:

a. Definition of the land utilization type
b. Establishing the crop requirements
c. Collection of relevant environmental Data in terms of (b) above
d. Matching of land qualities with requirements of the land utilization type. This according to FAO (1979) is beyond mere comparisons. It is an interactive process of mutual adoption of the definitions of the landuse types and the land conditions as they become better known. This step can result in provisional suitability classes.
e. Checking with existing landuse pattern and yield data to estimate the productive capacity of the provisional suitability classes.
f. Confirmation of suitability classes, current and potential.

This system has been fully tested, applied and proven in developing countries and also applied on a trial basis to farming system in the Netherlands. The approach can be used for agricultural and non-agricultural purposes. From this view point suitability evaluation is far superior to land capability classification for most purposes (Dent and Young, 1986; Oluwatosin, 2005; Olaleye *et al.*, 2008).

Productivity index

Land evaluation by productivity rating makes use of productivity indexes. In this method, the effect of land is assessed individually and multiplied arithmetically. Examples of productivity indices are Storie index rating (Storie, 1976), methods of productivity rating proposed by Riquier *et al.,* (1970) and Sys and Frankart (1971). They are all developed with bias to tropical conditions. Riquier *et al.,* (1970), approach which is a modification of the Storie index system calculates the productivity index from nine factors (as against five in the original Storie index) for determining soil productivity. They used an equation such as this:

IP = H x D x P x I x N/S x O x A x M

Where

H = drainage

D = effective soil depth

P = texture/structure

T = base saturation

N/S = absolute salt concentration

O = organic matter content

A = CEC

M = Mineral reserve

The structure of these systems involves estimating percent ratings for individual characteristic on a scale in which 100% represents optional condition and 0% represents the most unfavourable. The conversion of characteristics/qualities to productivity rating is a two stage process. First, each soil property is scored for the possible range of values e.g. 0 – 100.

Secondly, the scores of the relevant properties are combined into an overall index by multiplication. This system however has its own limitations. One of such limitations is that differential scales are based on judgment of the relative importance or contribution of the soil properties to yield e.g. soil depth 55%, slope 15%, drainage 5%, moisture 20% (Ogunkunle, 1987; Behzad *et al*, 2009). Secondly, uniform scoring for all properties may not be realistic. In addition to the above, Young (1976) pointed out two additional limitations of these parametric methods.

a. The rating requires substantial alteration as soon as the system is transferred to a substantially different climate.

b. The rating becomes more complex as attempts made to allow for interactions between factors.

In spite of these limitations, productivity index methods have been used successfully and good correlations have been reported between the productivity index and yields of particular crop within the area for which the index was designed (Fasina, 2008; Obi *et al.*, 2008).

Mathematical models have not found much place in land evaluation. It has been suggested that modeling and simulations are likely to be beyond the scope of routine land evaluation. In addition, Ogunkunle (1987) pointed out that the use of models seems too complex to satisfy practical land purpose for now. However, attempts have been made to apply modeling to land evaluation and many authors reported that models will be a tool for the study of specific land qualities and landuse processes (Fasina *et al.*, 2007; Jafarzadeh *et al.*, 2008).

Land Evaluation Computer System (LECS)

All the systems of land evaluation so far discussed, require local, site-specific modifications to acquire wide range applicability. Their results are usually valid, only for a given geographical area. They therefore have limited spatial validity and become time consuming when applied to a large area. These lapses therefore call for a method of land evaluation with a wide coverage, objectivity and reliability at the reconnaissance to semi detailed level (Fagbami, 1989).

The Land Evaluation Computer System (LECS) of Wood and Dent (1983), was developed in Indonesia by FAO, as a planning tool. The system was tested by Elberen *et al* (1988), for incorporation in the Integrated Land and Watershed Management Information System (ILWIS).

LECS is actually a database couple with modules for erosion prediction and yield prediction for both natural condition (stage 1) and under defined management system (stage 2). LECS's evaluation method is based on the FAO's agro-ecological zone approach (FAO, 1978) and built according to the principles of FAO framework for land evaluation.

The system is made up of three module groups. The first group is used for data entry and validation of the agro-ecological data. The second module group covers agro ecological crop suitability (LECS stage 1) in which land qualities represented by land characteristics are matched with the specific crop requirements. The requirements are obtained from the data on Bunting (1981) table.

The evaluation is a two-step approach in which Liebig's "Law of minimum" (Wood and Dent, 1983) is applied twice. The law of minimum sets the suitability at the mid-class values corresponding to the worst characteristic of each quality. The mid-class value of the worst quality is subsequently multiplied by the average of the other qualities to come to the final rating. The result is expressed quantitatively by suitability classes. The suitability level is defined as a range of yield in relation to non-constrained yield (Maximum Possible Yield).

Suitability score = $Xm \sum Xn/100$

Xn = min land characteristic, Xn = average of remaining land characteristics

Its data requirements are supposed to be satisfied by small scale reconnaissance type of survey. LECS is a basically quantitative system that depends on fine tuning to obtain quantitative results. LECS is unique in the sense that it treats annual crops (including paddy rice), perennials, tree crops and wood species all within one system. The widely varying requirements of these crops are introduced via the crop requirements like temperature regime, nutrient retention, nutrient availability etc. The treatment is general however and not well suited to cater for the requirements of the different crops.

From the ILWIS project in Indonesia, Elbersen *et al* (1988) observed that the adjusted results of LECS Stage 1 when compared with data obtained for five soils, four out of the five LECS results were within 5% of the observe yield for cassava and all the five results were within 10% of the observed yield for ground nut while coffee had nine out of the sixteen predicted yields within approximately 20% of the observed values. In summary, it was concluded that LECS is capable of producing realistic predictions of no – input crop yields for a large number of soil/crop combinations.

Data obtained from mapping of natural resources in the tropics south of Sahara has been unreliable but the coming of remote sensing has not only made the acquisition of data faster but also more accurate. Even with the advent of remote sensing, acquisition of resource data has been limited by unavailability of modern procedures for the collection and presentation of data, inadequate infrastructure, irregular boundaries of farm plot size and varying plot size from year to year.

Despite these set back, many authors have successfully carried out natural resource inventory using remote sensing imageries in Nigeria and other parts of Africa at reconnaissance level. Only on specific project sites were inventory of resources carried out at semi-detailed level. Few workers have attempted to do a comparative study on the use of multiple data on resource data inventory. This could be attributed to inaccessibility to remote sensing data and cost of acquisition. Even the data from Nigeria satellites are hardly available to scientists for use.

This study however is an attempt to compare multiple remote sensing data sets for soil survey, Landuse/Landcover mapping and land evaluation at semi-detailed level with the hope to making recommendations on which is better for a particular resource inventory.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of study area

3.1.1 Location

The study area is located in the Dry Rainforest Zone of Osun State in South-Western Nigeria. It is made up of Ife and Ilesha hereinafter referred to as sites A and B respectively (Figs. 3.1 and 3.2). Site A is an area of about 190 km^2 with Ile-Ife as the main town at the center, and goes from latitude 7^o 25' to 7^o 33' N and longitude 4^o 30' to 4^o 39' E. Network of roads connect Ile-Ife to villages like Itagunmodi in the northeast, Toba and Elekolo in the south east, Itapa and Wanisanni in the southwest while Adesunmi, just outside the Obafemi Awolowo University, Ile-Ife boundary is at the northwest corner. Site B which occupies an area of about 150 km^2 is from latitude 7^o 34' to 7^o 38' N and longitude 4^o 45' to 4^o 55' E. Ilesha, the major town in the area is situated at the northwest corner of the area with other prominent towns and villages of Erin-Odo and Erin-Oke to the southeast. Erimo is to the northeast while Olorogba and Ijemba are in the southwest.

3.1.2 Climate

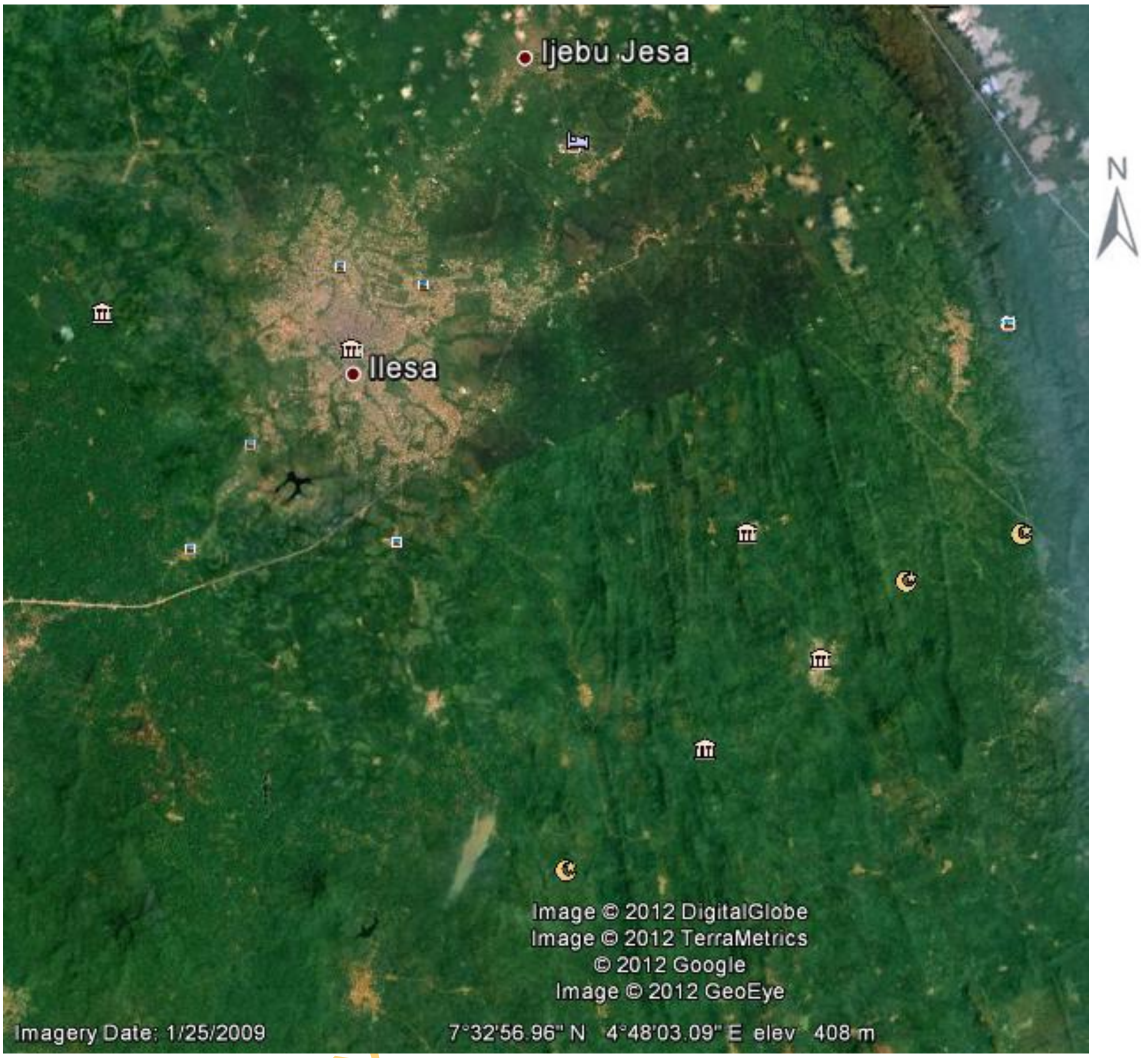
The climate of the area has been extensively described by many workers amongst whom are Oyebande and Oguntoyinbo (1970). The climate pattern is under the influence of the movement of the Inter Tropical Discontinuity (ITD) separating the two major air masses. These are the moisture-laden southwestern air mass from the Atlantic Ocean which influences the area from April to October and the dry northeastern air mass from the Sahara Desert that dominates the area from November to March. It is dry, cold and dust laden, a phenomenon known as harmattan. The southwestern air mass dominates during the growing season while the northeastern winds dominate during the dry season. This leads to the creation of two distinct seasons wet and dry corresponding to when the air masses dominates. The wet season is associated with the westerly wind although interrupted by a short dry spell in August usually referred to as "August break" (Smyth and Montgomery, 1962). However, the "August break" has been irregular in recent years, most probably due to the global climate change.

Fig. 3.1: Location of study sites in Ife area

Source: Google Earth, 2012.

Legend

- Forest
- Cropland
- Built-up
- Water



0 2.4
Kilometers

Fig. 3.2: Location of study sites in Ilesha area

Source: Google Earth, 2012.

Legend

- Forest
- Cropland
- Built-up
- Water

The dry northeastern trade winds dominate during November to March giving rise to harmattan between late December and January when the atmosphere is filled with dust and haze.

Rainfall

The survey areas fall entirely within the zone with distinct wet and dry seasons. The rainfall distribution is characterized by two peaks separated by a dry spell of "August break". The peaks are normally in July and September (Table 3.1). Site A has a mean annual rainfall (1995 – 2005) of 1270mm while site B has a mean annual rainfall of 1358mm.

Contrary to expectations the amount of rainfall in Ilesha for the ten years recorded is more than that of Ile-Ife even though the former is more to the north than the latter which is expected to experience the south westerly winds more than Ilesha. The rainfall in Ilesha is more than Ile-Ife because of the hills, some of which are as high as 700m against the highest point in Ile-Ife area which is about 400m. As a result, the Ilesha area experience Orographic (relief) rainfall because the area is on the wind-ward side of the hills.

The wet season which starts around March is usually associated with heavy storms during the early part of the rain. The sky is usually overcast during the raining season which spans for a period of about eight months with June, July and September being the wettest months. The dry season commences in November.

Table 3.1: Mean monthly rainfall (mm) of Ilesha and Ile-Ife areas (1995 -2005)

Month	Ilesha	Ile-Ife
January	00	4.5
February	52.9	52.9
March	156.3	81.5
April	143.8	89.8
May	124.3	101.5
June	174.0	116.8
July	188.5	262.2
August	52.3	139.6
September	254.3	230.9
October	153.0	181.9
November	59.5	8.8
December	00	00
Total	1358.9	1270.4

Sources: Ilesha Grammar School, Ilesha, and Obafemi Awolowo University (OAU) Ile-Ife, 2008.

Temperature

From the data available, temperature is high throughout the year with the difference between the coldest and warmest months seldom exceeding 5^{o}C. The lowest and the highest monthly temperatures are 24.7^{o}C and 27.9^{o}C recorded in December and February respectively in Ile-Ife while in Ilesha, 24.9^{o}C and 29.6^{o}C represent the lowest and highest temperature for the months of December and February respectively (Table 3.2). The monthly trend of temperatures shows that temperatures fall as the rains commence and reach their minimum in September and begin to rise again when the dry season sets in. The very low temperature in December is attributed to the cold harmattan that increases the evaporation rate (Table 3.2). Relative humidity as with rainfall and temperature is also very high and rarely varies from the average value of 82 percent during the wet months; resulting in relatively low evapo-transpiration. Data for relative humidity and evaporation is however not available for Ilesha area.

3.1.3 Vegetation

The original vegetation of the area is tropical rainforest. As a result of human inference, the forest is now restricted to the hilltops around Ilesha. These native forests consist of three strata of trees, the first or top stratum having trees of about 40 metres or more, with wide spread but often isolated crowns; the second consist of trees about 16-40 meters high; and the understorey consists of trees about 16 meters high, forming a rather dense canopy which protect the ground from the direct rays of the sun and impact of rain drops.

Apart from the forests, there are fallows at various stages of maturity. These areas have been subjected to one form of use or another and were later allowed to recuperate to be used again. Plantations of cocoa and few of kola nuts are mainly found around Ile-Ife. The undulating nature of the lands in Ilesha area has reduced the development of tree crop plantations except along the lower slopes of riverbanks.

The riparian vegetation is found along the narrow valleys. It comprises of tall gallery trees and at times dense rich flora communities of *Elaesis guineensis*, *Lancehor pussericans*, *Paulina pinnata* and *Khaya ivorensis.*

3.1.4 Geology

The study area has been a focus of attention by geologists for a very long time since gold was discovered there in the 1940s. The Ife/Ilesha areas are underlain by metamorphic rocks within the southwestern part of the Precambrian Basement Complex of Nigeria. These rocks show great variation in grain size and mineral composition, ranging from very coarse grained pegmatite to fine grained schist and from quartzite to basic rocks consisting largely of amphibole (Plate 3.1).

There have been many classifications of these rocks as there have been workers (Table 3.3), but the classification of Smyth and Montgomery (1962), that has pedological focus is more relevant for the present study. The greater part of Ilesha town forms a gently undulating plain at an average elevation of about 365 meters above the sea level. East of Ilesha, persistent north-south trending steep-sided ridges forming impressive topographic features break the monotony of the plain. The ridges may reflect the highly resistant nature of some of the quartzite rocks. These rocks vary from massive coarse crystalline to fine grained granular quartzites. Elueze (1977), observed that it is mainly a quartzite rock with quartz accounting for over 90% with garnet and iron ores occurring as accessory minerals.

Ife town and its environs are underlain by finely-grained biotite gneiss and schist. These rocks occupy the central and more than one-third of the study area. The rocks form the parent material of Egbeda Association of Smyth and Montgomery (1962), and give rise to an undulating topography with very few rock outcrops. They are composed of a mosaic of plagioclase, feldspar and quartz with abundant biotite mica. Veins of resistant quartz or feldspar are associated with the gneisses in varying quantities.

Table 3.2: Mean monthly temperature, relative humidity for Ile-Ife and Ilesha

	Ile-Ife		Ilesha
Month	Mean Temp. (^oC)	Rel. Humidity (%)	Mean Temp (^oC)
January	27.4	81.8	28.5
February	27.9	74.5	29.6
March	27.9	86.1	28.2
April	27.5	85.2	27.6
May	26.7	85.5	27.7
June	26.2	84.0	26.6
July	25.4	83.8	25.6
August	25.1	87.9	25.9
September	25.1	85.5	25.1
October	25.4	85.6	25.5
November	26.4	85.0	27.3
December	24.7	68.6	24.9
Mean	26.4	82.8	26.9

Source: Obafemi Awolowo University, Ile-Ife,
Ilesha Grammar School, Ilesha, 2008.

Running north-south along Iwaraja/Idado axis, east of Ilesha is the coarse-grained granite and gneisses. This also occurs along the Wanisanni/Adafarakan axis west of Ile-Ife and a small oval area around Igbara and Ita-Osa villages. This rock consists of a genetically wide range of rocks which give rise to a region with many topographic features. These rock types include the granite gneisses, porphyritic granite and pegmatite. Iwo Association of soils is derived from this parent rocks (Smyth and Montgomery, 1962).

Far east of Ife study area, running north-south and underlying towns like Itagunmodi, Eteko, Toba, Saga and immediately west of Ilesha but running along a north east/south west areas are amphibole and related basic rocks. They form the parent materials of Itagunmodi Association of Smyth and Montgomery (1962). The amphibole generally outcrops poorly and is commonly found as boulders. Majority of the rocks weather easily giving rise to a rolling, deeply dissected topography while in some places, the rocks have been protected from erosion by a thick cap of iron stone (Plate 3.1).

3.1.5 Landuse

The original vegetation has been greatly disturbed by man for various uses, principally agriculture. The agricultural pattern is bush rotation where the fallow period has been reduced as a result of pressure on land. The major landuse type is peasant agriculture characterized by the cultivation of small parcels of land with simple tools (hoes, cutlasses, etc) and minimal use of fertilizers and chemicals.

The farmers in Ife area grow mainly plantations of kola nuts. This is however mixed with food crops like maize, melon and cassava during the early years. In contrast, the Ilesha farmers grow mainly food crops like rice, maize, cassava, yam and plantain, with few plantations of cocoa along stream banks.

Plate 3.1: Caps of Iron Stone found over Amphiboles around Itagunmodi village

Source: Field work, 2009.

Table 3.3: Studies on the geological formations of the study area

Authors	Location and aspect of study	Major contribution
De-Swardt A.J. 1953	Ilesha Area	Produced detailed geological map on Scale 1:100,000
Jones, A.A and Hockey, R.D 1964	Part of South Western Nigeria	Classified Nigerian Basement Complex into four units. Recognized some Meta-morphic and Sedimentary rocks.
Rahaman, 1973	South Western Nigerian Rocks	Recognized Barrovian type metamor-phism of green schistamphibolite focus
Hubbard, F.H 1975	Crustal Development in Western Nigeria	Established that Ilesha area is largely underlain by Meta sedimentary units
Elueze, A.A 1977	Ilesha Schist Belt	Proposed a four unit classification for the basement complex rocks of the area
Elueze, A.A 1981	Geochemistry and Petrotechonic setting of Ilesha Belt	Recognized that the principal Meta sedimentary varieties merged into each other, so that separating them was not feasible.

Source : Ajayi, 1980

3.2.1 Sources of data and their characteristics

SPOT (HRV) Imagery

The SPOT (HRV) imagery subscene of Ilesha area with identification mark K069-J335, taken on the 19th, May, 1986 was generated from the Computer Compactable Tape (CCT) on the image analysis system at the Regional Centre for Aerospace Surveys (RECTAS) at Ile-Ife, using the multiscope processing software. Before the extraction, the different bands were examined separately on the monitor to show which of them amplified certain physiographic and ecological features best (Plate 3.3).

The month of May in which the scene was acquired, coincided with the period of planting in the area. The ground cover in most farm plots could be put at 60% while in a few cases, it was still bare. It is however, a good data for assessing the landuse pattern for the area than the air photograph.

In contrast to the scene in Ilesha (Plate 3.3), the Ife scene (Plate 3.2) was acquired on the 18th December, 1986 and carried identification mark K068-J335. The subscene, although also extracted at RECTAS, was not subjected to separate examinations with the bands to see which one amplifies the feature best between bands 2 or 3. The subscene was already created and was the only one available for the research (Plate 3). This is part of the problems of Remote sensing data acquisition in developing countries as outlined by Fagbami (1986). In addition, the data was acquired in December when most arables had already been harvested.

Landsat Thematic Data

Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) images (with path 188 and row 056) acquired on December 19th, 1986 and December 17th, 2000, respectively were employed in the land use/land cover mapping. The original satellite images used for this project were Landsat TM (Thematic Mapper) from the Landsat home page http://www.landsat,org/ortho/index.htm. These images are representations of the available features and land covers over the particular area covered. The images consist of different bands and each band registers wavelengths that are used for different purposes.

Aerial photographs

Panchromatic black and white aerial photographs of both Ife and Ilesha areas at a scale of 1:25,000, taken in February 1975, were obtained from Federal Surveys Department, Lagos. The photos were cloud free but the cropping sequence in the area shows that at the time the photographs were taken, most of the crops had already been harvested and the land left to fallow except plantation crops; such prints might not be the best for landuse mapping.

Topographical map

The Nigerian topographical map, Ilesha sheets 243, S.E. and Ondo 263 NW on a scale of 1:50,000 produced in 1966 were obtained from Federal Surveys, Lagos. This was used in the creation of physiographic base maps, the general orientation and geometric registration of the imagery.

Geological map

The geological map of the area on sheet 30 was obtained from the Geological Department, Kaduna. This was used in the identification of the different geologic units and in the selection of sample points.

Vegetation and landuse map

The vegetation and landuse map sheets No. 31 – 4 compiled from Side Looking Airborne Radar (SLAR) in 1977 was obtained from the Federal Department of Forestry, in Ibadan. This was used in the identification of the different vegetation and landuse types in the area although there were a lot of differences between the landuse in the maps and what was obtained during ground truthing. The differences could be attributed to human influence.

Other ancillary data

The book, "The soils and landuse maps of Central Western Nigeria", produced by Smyth and Montgomery (1962) was obtained from Government Printers in Ibadan. This assisted in the description and selection of the profile points.

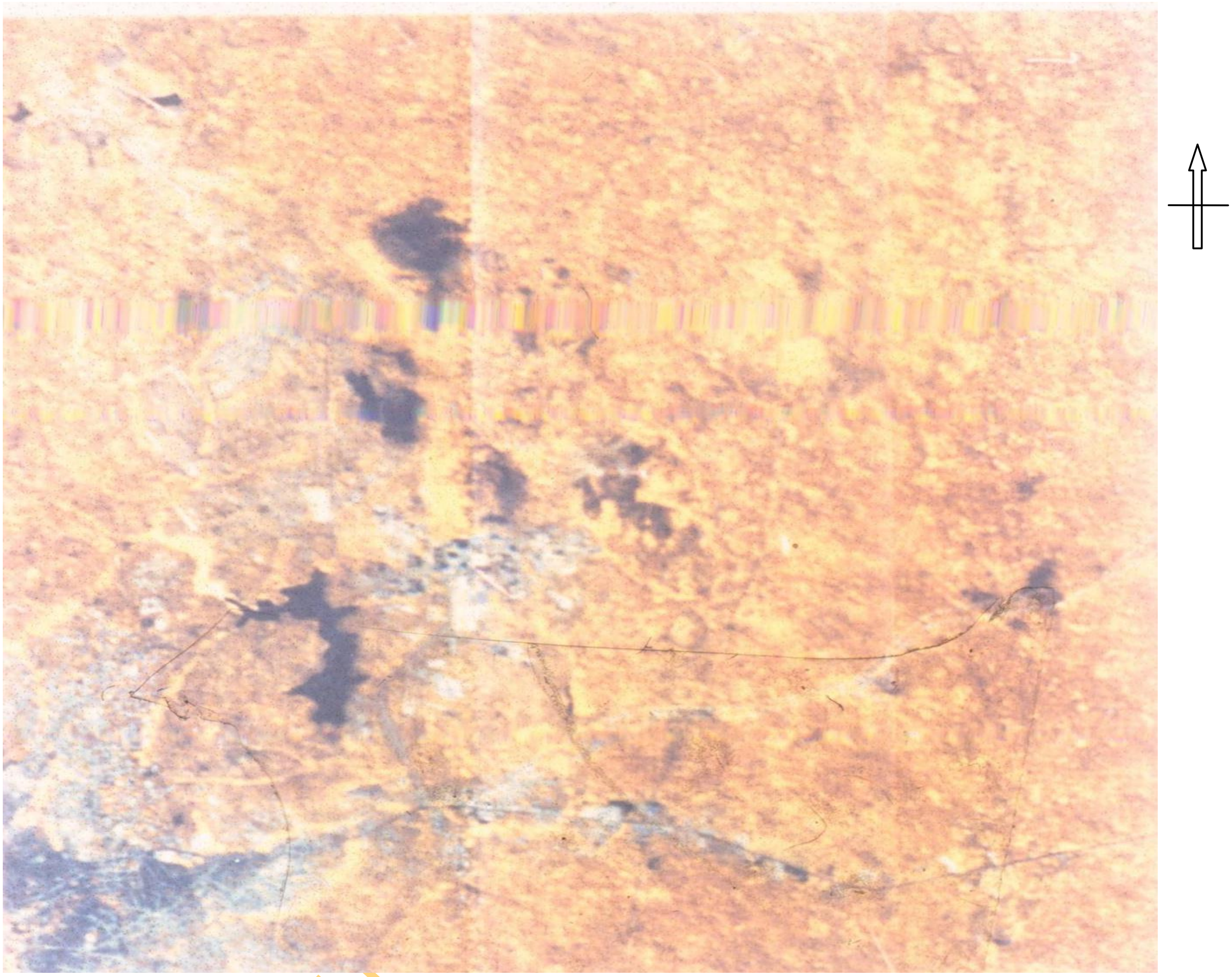


Plate 3.2: A SPOT sub scene of Ife area

Source: Rectas, Ile-Ife 2007.

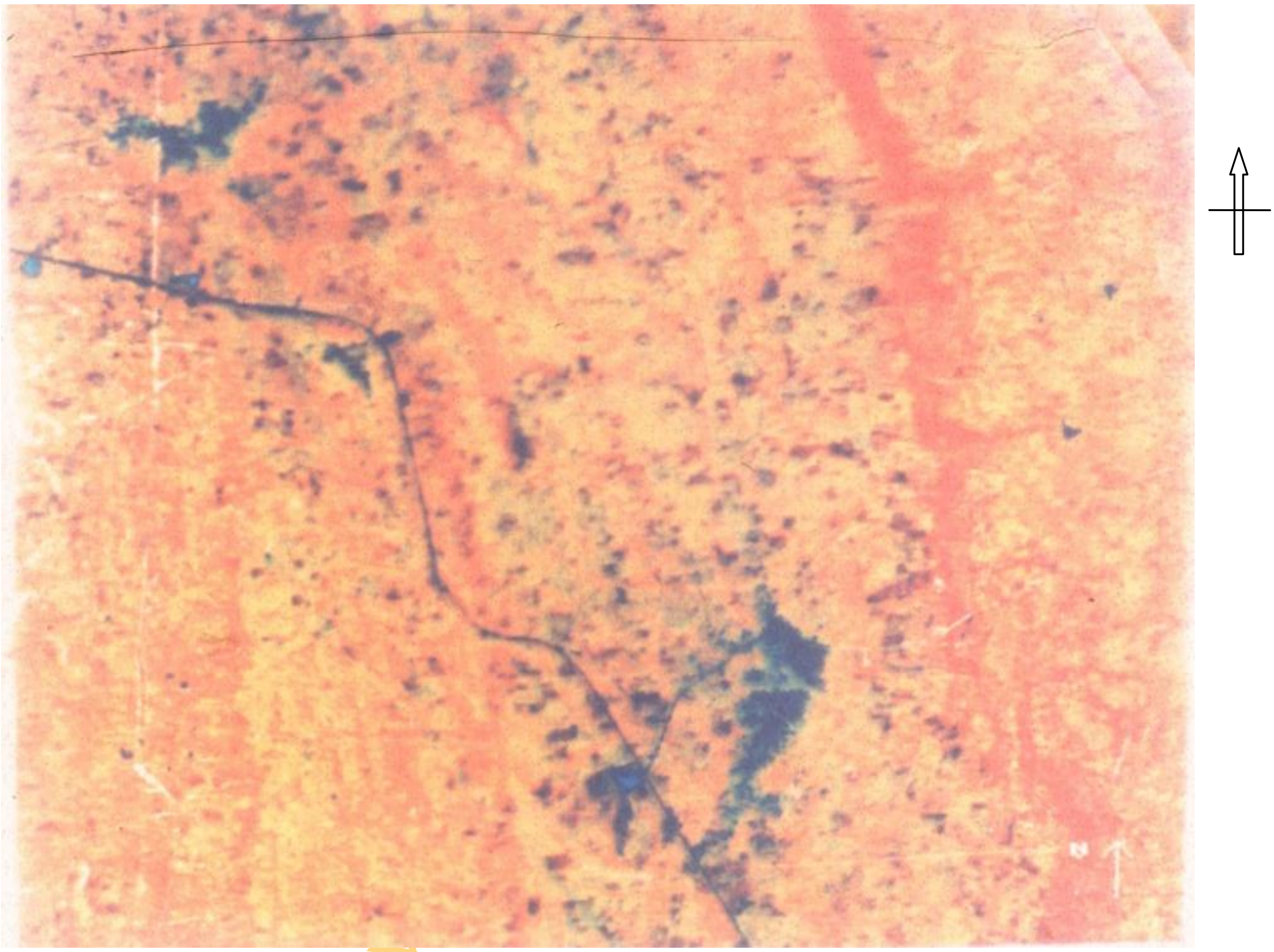


Plate 3.3: SPOT (HRV) imagery of Ilesha area. Erin-Odo hill is the dark red strip (Forest) running N-S on the extreme right, while the new Ife - Akure road almost runs across the scene.

Source: Rectas, Ile-Ife 2007.

3.2.2 Interpretation of imageries

At the on-set, a reconnaissance trip to the two areas was undertaken using topographical maps as the base map. This was done along the network of roads and paths. During this trip, auger examinations of the soils were made to have a general over-view of the soils in the areas.

Notes were also made of the geomorphology and agricultural practices. These gave a good insight about the area before the interpretation of the aerial photographs, SPOT and landsat imagery.

Aerial Photo Interpretation (API) for Soil Survey

The mosaic of the two areas were created with Aerial Photographs (APs) being arranged from left to right throughout the study area. The base maps and control points were created using the topographical maps of Ilesha South East, sheet 243 SE, and Ilesha South West sheet 243 SW and Ondo North West sheet 263 NW for Ilesha and Ife areas respectively. The set of APs were interpreted strip by strip, starting with the topmost run.

Taking two contiguous photographs at a time (starting from the left end of each strip), the interpretation was done with the aid of Wild Heerbrugg Mirror Stereoscope applying the physiographic approach as outlined by Goosen (1967) and Vink (1968). It requires a good knowledge of the drainage pattern, relief and vegetation of the area.

The boundaries between the physiographic mapping units were delineated with Wax pencil on the photographs. The interpretation was done on stereo photographs. A total of sixty four (64) photographs were analyzed for Ife Area and forty eight (48) for Ilesha area. With the aid of the topographical maps, grid lines were constructed on a large sheet of tracing papers. Control points were selected and transferred to the sheets of tracing papers. These sheets were overlain on the layout of interpreted photographs. Necessary adjustments/orientations were made on the tracing sheets and photographs to fit the control points correspondingly. The tracing papers were then pinned down on the photographs and the outlines of the various units were traced out.

Aerial photo Interpretation for Landuse/landcover

The panchromatic black and white photographs of the two areas were also interpreted for landuse/landcover. Anderson *et al.,* (1976) classification scheme was modified (Table 3.4) up to the II level and adopted for this purpose.

Thereafter, the transfer of the interpretations to the overlay was done in the same manner as those described above for soil survey.

Landsat Thematic Data

Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) images (with path 188 and row 056) acquired on December 19th, 1986 and December 17th, 2000, respectively were employed in the land use/land cover mapping. The original satellite images used for this project were Landsat TM (Thematic Mapper) from the Landsat home page http://www.landsat,org/ortho/index.htm. These images are representations of the available features and land covers over the particular area covered. The images consist of different bands and each band registers wavelengths that are used for different purposes.

The acquired images were processed and interpreted using ERDAS IMAGINE 9.1 and ArcGIS 9 software. On the acquired images, water appeared deep blue, vegetation (forest and cultivated land) showed up in red and settlements and road showed up in shades of Cyan. At the resolution of the images used, it was not possible to differentiate between settlements.

Image classification

Image classification is the process of sorting pixels into a finite number of individual classes or categories of data based on their data file values. If a pixel satisfied a certain set of criteria, then the pixel is assigned to the class that corresponds to those criteria.

Table 3.4: Modified Landuse / Landcover classification scheme for mapping of Ilesha and Ife areas from aerial photos

Level I		Level II	
10	Built-up	11	Settlement
20	Agriculture	21	Plantations
		22	Fallow
30	Water Body	31	Dams
		32	Rivers/streams
40	Forest	41	Riparian Forest
		42	Rain Forest

Source: Anderson *et al.*, 1976

In this study, the unsupervised classification was used, in which a thematic raster layer map was created by letting the software-ERDAS IMAGINE, identify statistical patterns in the data. The land use/land cover mapping was done by relying heavily on the differences in spectral characteristics of the landscape for separation into meaningful land use and land cover classes (Table 3.5). Multispectral reflectance data or remotely sensed imagery from satellite sensors serve as surrogate data representative of landscape feature or attributes. The ISODATA algorithm was used to perform the classification, in which a clustering method using the minimum spectral distance formula was used to form clusters.

A modified landcover classification scheme that was consistent with the one developed by Anderson *et al* (1976), was used as the classifications scheme. This same scheme has been used by Akinyemi (2005), for land cover classification in different parts of Nigeria. The modified scheme developed for this study consists of four (4) classes.

Interpretation of SPOT imagery for soil survey

The SPOT (HRV) images (Plates 2 and 3) were visually interpreted on PROCOM – 2, a product of Gregory Geoscience Limited, Ottawa, Canada at the Cartography, Remote Sensing and GIS Laboratory of the Department of Geography and Regional Planning, University of Lagos.

The data was generated from the CCT, at RECTAS, in Ile-Ife. The imagery was super-imposed on the topographical map for the registration of its coordinate pixels on the control features (i.e. roads, settlements, etc.). Using the basic interpretation elements of colour variation, size, texture and association, a systematic search for major landforms in each subscene was carried out using teleconverter lens of 60 – 300mm. The images were interpreted and terrain mapping units (TMUs) mapped.

A Terrain Mapping Unit (T.M.U) was differentiated on the basis of photomorphic properties in the imageries. According to Meijerintz (1988), "a TMU differs from another adjoining unit because either the landforms are evidently different or the phenomena associated with the landforms (nature of the lithology, type of soil, weathered zone) differ". The different units were delineated directly on the base map created from the topographical maps using different symbols. Immediate recording of limitations and features that needed further verification on the field were done.

3.2.3 Quantitative Estimation of the Concordance between the Aerial Photographs and SPOT Image Soil Maps

The commonest qualitative method of assessing the degree of concordance between two soil survey maps of the same area is by the method of overlay especially on a light table. This was done to evaluate how close the same units are on the two maps i.e. the proportion of the same unit in maps A and B. Other ways of determining the accuracy and usefulness of these units is by the uniformity (or variance) of soil properties, crop yield etc within these mapping units. These methods however have been claimed to be expensive and time consuming (Ogunkunle, 1991).

A simpler and quicker method of evaluating soil survey quality is to appraise the maps based on the cartographic characteristics as spelt out by Laker (1981). This was adopted. The procedure involves drawing a 15 x 15cm square on a transparent tracing paper. The square was fixed on position over one selected area of each of the two map sheets. The total number of delineations in this 15 x 15cm "Mini-map" was then counted. The number of delineations per cm^2 (or its intensity) was counted for each "mini-map". This was the absolute figure for each mini-map and was used as the basis against which the method was tested.

Out of the six methods proposed by Laker (1981), the most accurate 2.5cm radius circle (area 19.64cm^2, circumference: 15.71cm) was adopted. This involves the determination of the number of delineations within a circle. Where two or more areas actually formed parts of one large delineation, they are counted as only one delineation. The circle counts are then made for each selected block in turn. The positioning of the circle in each block is done as follows: The circle (drawn on transparent paper) is held a few cm above the center of the block. It is then lowered onto the map sheet while looking away. The circle must not be shifted after it has been put down. These steps are intended to avoid conscious selection of certain map intensities or type of soil patterns.

Table 3.5: Landuse / Landcover classification scheme for mapping of Ilesha / Ife areas from Landsat imagery (Modified from Anderson *et al.*, 1976)

Level I		Level II	
10	Built-up	11	Settlement
20	Agriculture	21	Plantations
		22	Fallow
		23	Crop Land
30	Hills/Water	31	Dams/Rivers/Streams
		32	Hills
40	Forest	41	Riparian Forest
		42	Rain Forest

Source: Akinyemi, 2005.

The actual number of delineations per cm^2 on the soil map sheet was calculated by means of Equation (1):

$$n = (0.0353\ AN - 0.106)\ del/cm^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 1$$

where n = actual number of delineations per cm^2 on the map sheet and

AN = average number of delineations per circle.

Equation (1) was derived by combining Equations (2) and (3).

Equation (2) gives the average number of delineation as per cm^2 in the circles:

$$y = \frac{AN}{19.64}\ del/cm^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 2$$

Where y = the average number of delineations per cm^2 in the circles.

AN = the average number of delineations per circle, and

19.64 = the area of a circle with a radius of 2.5 cm (in cm^2).

Equation (3) is the regression equation which gives the relationship between the average number of delineation per cm^2 in the circles and the actual average number of delineations per cm^2 on the map:

$$n = (0.693y - 0.106)\ del/cm^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3$$

where *n* and *y* are as in Equation (1) and (2).

Equation (1) was obtained by substitution of Equation (2) into Equation (3).

$$n = (0.693y - 0.106)\ del/cm^2$$

but $y = \frac{AN}{19.64}\ del/cm^2$

therefore: $n = (0.693 \frac{AN}{19.64} - 0.106)\ del/cm^2$

Thus $n = (0.0353\ AN - 0.106)\ del/cm^2$.

3.2.4 Field Work

Ground truthing:

The soil map interpreted from the aerial photographs was subjected to boundary checking. This was done along access routes. This involves intensive augering on both sides of the boundary line on the map and adjusting the boundary where necessary. After all the necessary adjustments, the corrected (final) map was produced by tracing.

Four mapping units were identified from the SPOT image of the Ilesha area and three from the Ife area. This might be due to the nearly flat terrain of Ife areas apart from the few hills on the University campus and Modakeke area. In contrast, the Ilesha area has undulating landform which gave different signatures on the imagery.

The study area being generally thick forests or tree crop plantations, the transects were chosen in such a way as to avoid extensive traverse cutting; to minimize cost. The transects were aligned along the net-work of roads and bush paths. Augering along the transects was done to identify the component soils of the TM Us.

For the observation of soil morphological properties, mini-pits measuring 50 x 80 cm x 80 cm were dug at representative points of the major soil types of each TMU. The site information collected includes:

i. Slope, measured with Abney level
ii. Micro-relief; assessed by visual observation
iii. Vegetation
iv. Ground surface appearance; amount of leaf litter and soil appearance
v. Stones; presence or absence and abundance
vi. Surface soil moisture condition
vii. Depth to water table
viii. Evidence of erosion
ix. Landuse; type of crops and crop rotation

The minipits were dug and described according to the Food and Agriculture Organization (FAO) guidelines for soils profile description (FAO, 1977). The minipits were sampled in all identifiable horizons within the 80cm depth while further probing with the auger was carried out to 150 cm depth to identify the soil series. The samples were bagged and labeled for laboratory analysis. Soil properties considered at each minipit sites are:

i. Colour; Using the Munsell notation.
ii. Mottles colour; using Munsell notation
iii. Texture, estimated by field feel method

iv. Structure; by visual examination

v. Consistence; assessed at field moisture level

vi. Pores; by visual examination

vii. Roots characteristics by visual assessment

viii. Stones; presence or absence and abundance

Verification of landuse/landcover types

Based on the areas demarcated and some unidentified features from the landsat imageries of Ilesha and Ife areas, twenty sites were selected for verification of the different types of landuse/landcover. The landuse/landcover maps were checked in the field in June. Because of the time difference between the field check period and the acquisition dates of the data, the ground truthing was conducted so that the changes in land use, which occurred between 1975, 1986 and 2002, were not recorded as interpretation error.

In addition, farmers, villagers, government workers, and residents of Ilesha and Ife areas were interviewed. The information so gathered helped to explain the changes in land use of the area.

3.2.5 Laboratory analysis

The soil samples collected from the mini-pits were air-dried and passed through a 2 mm sieve and analyzed using the procedures itemized in Table 3.6.

Automated Land Evaluation

In evaluating the land, the method devised by Wood and Dent (1983) otherwise called Land Evaluation Computer Systems (LECS) was adopted. There are different stages in the system whereby the results obtained at a stage are used as inputs in the next stage where other factors are introduced.

LECS Stage 1

At this stage, the land qualities as represented by land characteristics were matched with specific crop requirements. The land qualities and land characteristics considered (Table 3.7) were for the A horizons since a very high proportion of crop yield variable can be attributed to topsoil properties only. The crop requirement tables (Tables 3.8, 3.9, 3.10 and 3.11) were based on data from Bunting (1981). The data used in the computation is shown in Table 3.12. The suitability level was based on a range of crop yield factor which is percentage of agro-climatically possible maximum yield (non-constraint yield).

In the computation of crop yield factor (Table 3.12), a two-step approach was adapted in which Liebig's "law of minimum" was applied twice and it emphasizes Liebig's philosophy of the weakest chain (Elbersen *et al.*, 1988), as the worst characteristics of the six land qualities were first selected and the least of these was multiplied by the average of the remaining five characteristics and the product was divided by 100 to get the crop yield factor which is a percentage of the agro-climatically possible maximum yield. On the basis of the range of values of crop yield factors, the land suitability was grouped into suitability classes as shown in Table 3.13.

Table 3.6: Soil analytical methods used for the determination of physical and chemical properties

Soil variables	Method of determination
Gravel content	Gravemetric method (% of total weight of soil)
Particle size distribution	Hydrometer method (Gee and Bander, 1986)
Bulk density (g/cm^3)	Core method (Blake, 1965)
Water-holding capacity	Tension table method (Richard, 1965) (cm/cm)
% Organic carbon	Nelson and Sommers (1982) method
% Total nitrogen	Macro-Kjedhal Method (Bremmer & Mulvaney, 1982)
Available phosphorus (ppm)	Anderson and Ingram (1989)
Exchangeable cations	1M NH_40AC method (Udo & Ogunwale, 1982)
Ca++ (cmol/kg)	
K+ (cmol/kg)	
Na+ (cmol/kg)	Atomic absorption
Mg++ (cmol/kg)	
Effective Cation Exchange Capacity (cmol/kg)	Summation method (Chapman, 1964)
pH (H_20 & KCl)	Determined potentiometrically in water and O.1M KCl solution (Udo & Ogunwale, 1986)
% Base Saturation	Calculated as the percentage of ECEC supplied by Ca^{2+}, Mg^{2+}, K^+ and Na+ (Udo and Ogunwale, 1986).

Table 3.7: Land Evaluation Computer System, Stage 1 Data Requirements

No	Land quality	Nos	Land characteristics
1.	Temperature regime	1	Average monthly temperature during the growing season (0^c)
2.	Water regime	2	Length of growing period (days)
		3.	Annual Rainfall (mm/year)
3.	Nutrient retention	4.	Organic matter (g/ha)
4.	Nutrient availability	5.	Nitrogen (g/ha)
		6.	Potassium (kg/ha)
		7.	Phosphorus (kg/ha)
5.	Toxicity	8.	pH
6.	Rooting conditions	9.	Rooting depth (cm)
		10.	Drainage class
		11.	Texture class

Source: Wood and Dent, 1983

Table 3.8: Crop Requirement Table for Maize

Nos	Land quality	Nos	Land characteristics	Suitability ratings S1 100	S2 80	S3 60	S4 40
1.	Temperature regime	1.	Ave. temp over G.P(^{o}C)	22 – 26	26 – 28 20 – 22	28 – 30 18 – 20	>30 <18
2.	Water regime	2.	Length of G.P (days)	>130	100-130	80-100	<80
		3.	Annual Rainfall (mm)	>1,400	1100-1400	800-1100	<800
3.	Nutrient retention	4.	Organic matter (mg/ha)	4800	3200	2000	1200
4.	Nutrient availability	5.	Nitrogen (kg/ha)				
		6.	Phosphorus (kg/ha)	240	160	100	60
				40	30	20	10
		7.	Potassium (kg/ha)	220	150	90	50
5.	Toxicity	8.	pH	6.0-7.0	7.0-7.5	7.6-8.0	>8.0
					5.5-5.9	5.0-5.4	<5.0
6.	Rooting conditions	9.	Rooting depth (mm)	60	41-60	25-40	<25
		10.	Drainage class	4,5	3	2,6	1,7
		11.	Texture class	7-12	6,13	4,5,14	1-3

Modified from Bunting (1981)

Table 3.9: Crop Requirement Table for Upland Rice

Nos	Land quality	Nos	Land characteristics	S1 100	S2 80	S3 60	S4 40
				Suitability ratings			
1.	Temperature regime	1.	Ave. temp over G.P(^{o}C)	24 – 26	26 – 28 22 – 24	28 – 30 20 – 22	>30 <30
2.	Water regime	2.	Length of G.P (days)	>110	100-110	90-100	<90
3.	Nutrient retension	3.	Annual Rainfall (mm)	1,600	1300-1600	1000-1300	<1000
4.	Nutrient availability	4.	Organic matter (mg/ha)				
		5.	Nitrogen (kg/ha)	62	48	30	25
		6.	Phosphorus (kg/ha)	16	12	9	7
				40	30	20	10
		7.	Potassium (kg/ha)	100	60	40	30
5.	Toxicity	8.	pH	5.5-6.5	6.6-7.7	7.6-8.2	78.2
					5.0-5.4	4.5-4.9	<4.5
6.	Rooting conditions	9.	Rooting depth (mm)	>60	41-60	25-40	<25
		10.	Drainage class	4,5	3,2	1,6	>
		11.	Texture class	8-12	6,7,13	5,14	1-4 15-18

Modified from Bunting (1981)

Table 3.10: Crop Requirement Table for Cassava

Nos	Land quality	Nos	Land characteristics	Suitability ratings S1 100	S2 80	S3 60	S4 40
1.	Temperature regime	1.	Ave. temp over G.P(^{o}C)	26 – 28	28-30	30-35	>35
					24-26	20-24	<20
2.	Water regime	2.	Length of G.P (days)	>365	300-365	250-300	<250
		3.	Annual Rainfall (mm)	1,000-1500	1500-3000	2000-2500	>2500
					750-1000	500-750	<500
3.	Nutrient retension	4.	Organic matter (mg/ha)	3,200	2,400	1,800	1,200
4.	Nutrient availability	5.	Nitrogen (kg/ha)	160	120	90	60
		6.	Phosphorus (kg/ha)	30	22	10	60
		7.	Potassium (kg/ha)	250	170	120	80
5.	Toxicity	8.	pH	5.5-6.5	6.6-7.5	7.6-8.2	<40
					5.0-5.4	4.5-4.9	<4.5
6.	Rooting conditions	9.	Rooting depth (mm)	>100	76-100	50-75	<55
		10.	Drainage class	5	4,6	7,3	1,2
		11.	Texture class	7-11	5,6	3,4,4	1,2
					12,13		

Modified from Bunting (1981)

Table 3.11: Crop Requirement Table for Yam

Nos	Land quality	Nos	Land characteristics	S1 100	S2 80	S3 60	S4 40
				Suitability ratings			
1.	Temperature regime	1.	Ave. temp over G.P(^oC)	25-28	28-30	30-35	>35
					23-25	20-23	<20
2.	Water regime	2.	Length of G.P (days)	>365	275-365	180-275	<180
		3.	Annual Rainfall (mm)	1400-1700	1700-2000	2000-2500	>2500
					1200-1400	8000-1200	<800
3.	Nutrient Retention	4.	Organic matter (mg/ha)	3,000	2,100	1,400	800
4.	Nutrient availability	5.	Nitrogen (kg/ha)	150	105	70	40
		6.	Phosphorus (kg/ha)	17	12	80	6
		7.	Potassium (kg/ha)	210	150	100	60
5.	Toxicity	8.	pH	5.5-6.5	6.6-7.5	7.6-8.0	>8.0
					5.1-5.4	4.5-5.0	4.5
6.	Rooting conditions	9.	Rooting depth (mm)	>75	51-75	30-50	<30
		10.	Drainage class	5	4	2,3,6	1,7
		11.	Texture class	7-11	5,6	4,14	1-3
					12,13		

Modified from Bunting (1981)

Table 3.12: Simplified example of computation of land suitability score

Quality	Quality1	Quality 2		Quality 3	Quality 4			Quality 5	Quality 6		
Xtic	1	2	3	4	5	6	7	8	9	10	11
Class	S1	S1	S3	S1	S1	S4	S1	S1	S2	S1	S2
Score	100	100	60	100	100	40	100	100	80	100	80
*	S1		S3	S1		S4		S12	S2		
	100		60	100		40		100	80		

Suitability score = min land Xtic x average of remaining land Xtic/100

[40(100 + 60 + 100 + 100 + 80/5] /100 = 35.2%

Source: Wood and Dent, 1983.

Xtic = characteristic

* Select least characteristic of each quality

Table 3.13: Suitability classes for Land Evaluation Computer System

Suitability score (%)	Suitability	Remarks
0 – 30	N	Unfit
30 – 50	S4	Fair
50 – 70	S3	Good
70 – 90	S2	Very Good
90 – 100	S1	Excellent

Source: Wood and Dent, 1983

CHAPTER FOUR

RESULTS

4.1 Over-view of image interpretation results

4.2 Ilesha Area

Mapping units and their Soils

A combination of many factors such as physiography, reflectance from the vegetation cover, bare soil and rock surface confer on the SPOT imagery a composite of colours on which the interpretation was based. The landscape was marked out into the following Terrain Mapping Units (TMUs).

4.2.1 Terrain mapping Unit D in Ilesha Area

This mapping unit constitutes a series of quartzite and schist hills running north – south of the study area. They are cultivated yearly to arable crops with patches of forest and fallows. For the detailed and locational descriptions; they are mapped D1, D2, D3 and D4 respectively (Fig. 4.1).

Terrain Mapping Unit D1

This mapping unit constitutes the Inselberg running North-South of the study area and has a distinct topography of step-sided ridge rising several hundreds of metres (about 700m) above the general landscape (Plate 4.1). This inselberg forms a continuous landscape without break throughout the seven kilometre width of the study area except for the two prominent groves that constitute water heads for River Oni tributaries.

The inselberg was mapped as unit B1 on the airphoto (AP) map (Fig. 4.2) and its equivalent on the SPOT soil map (Fig. 4.1) as unit D1. The inselberg is made up substantially of quartz materials with small amount of micaceous materials. The rocks vary from fine quartz schist to coarse quartzite (Jones and Hockey, 1964). Presently, the inselberg is being cultivated for arable crops and the vegetation of small trees at the crest is gradually giving way due to human influence. The unit occupies 1,562.5 ha or 6.02% of the study area (Table 4.1).

Plate 4.1. The Erin-Odo Inselberg in Ilesha Area. Note the steep-sided nature of the hill and the secondary forest vegetation on the hill top.
Source: Field work, 2008.

4.2.2 Terrain Mapping Unit D2

The unit mapped D2 constitute series of hills that run parallel to the new Ife - Akure road. At Ijesha-Omo (Aiyegunle) the new road made a sharp turn southwards after Erimo (Plate 4.2). The unit also constitutes the massive hills that run north-south of the Iwaraja village. The hills although not as high (520m) as in unit D1, they are broader (whale-back) and intensively cultivated to arable crops especially rice. At Iwaraja area, the hills do not form a continuous stretch but they are narrow with peak breaks giving different heights at different segments. These hills (Ijesha-Omo and Iwaraja) are separated by a large low plain through which flows a major tributary of the River Atun south wards towards Idado.

Approaching the southern portion of the study area, the Iwaraja hill is extensive even up to Irogbo and Ajuba areas but tapers northwards. The hills are mapped B2 on the aerial photo map. On the SPOT image map, the Iwaraja hills are mapped D2. These hills are made up of fine-grain Biotite Gneisses and Schist and constitute 13,350 ha or 51.40% of the study area (Table 4.1).

4.2.3 Terrain Mapping Unit D3

Unlike the other mapping units, the unit D3 consists of cone shaped ridges. The unit is cut from the northern end of unit D2 by the Atun plain and are scattered on the northern frontier of Erimo town. The hills are made of quartz and micaceous minerals and quartz schist. They rise to about 500m above the general landscape forming a protective feature for the town.

Despite the height, it is well cultivated with yam while one of the primary schools in the town is located at the foot of one of them. They are mapped B3 on the aerial photo and their equivalent on the SPOT map D3. A large percentage of the remaining forest in the study area is located on these hills which is fast disappearing (destruction is 103.82 ha/year, Table 4.9). The reflectance from this foliage makes their identification fairly easy despite the orange and blue mottles on the red colour as result of cultivation. The unit occupies 225 ha or 0.9% of the study area.

Plate 4.2 The Ijesha-Omo and Iwaraja Hills in Ilesha area

Source: Field work, 2008.

4.2.4 Terrain Mapping Unit D4

Unit D4 occupies the south western corner of the study area. The area is bordered by the Ilesha plain in the west and the Afun plain in the east. The hill like others in D units is made up of quartz schist and gneisses with spot heights of about 450 m above sea level. The area is also highly cultivated to plantation crops like cocoa and arable crops like maize and cassava. Villages like Ijemo, Idado are located within this mapping unit.

4.2.5 Soils of the Units

The soils of units D1 – D4 display a wide range in texture but one thing common to them is their coarse sand-fraction. Profile colours are typically grayish-brown while the soil series display a clear topographic sequence in their distribution. In mapping unit D, soil series like Okemessi, Omo, Erin-Oke and Etioni were identified. All the units despite their heights, proved to be good agricultural lands for arable crops especially rice.

4.3.1 Terrain Mapping Unit A

The units designated as plains are not completely devoid of hills but are the nearly level to gentle rolling part of the study area. The high points in these units are relatively low when compared to the units described above. These units occupies about 20-30% of the study area.

4.3.2 Terrain Mapping Unit A1

This unit lies between unit D1 (Erin-Odo hill) to the east and unit D2 (Ijesha-Omo hills) to the west. The unit is drained by the River Oni and its numerous tributaries which flow parallel to these hills. The unit is constricted north wards by the east-ward projection of the D3 unit while in the south; the unit is further reduced by the massive Erin-Odo inselberg forming water-heads for some of the Oni River tributaries. The topography of this unit is low (about 200m) and two major settlements in this area: Erin-Odo and Erin-Oke occupies the southern tip of this unit.

In demarcating this unit from the SPOT imagery, the dark red colour of the vegetation on the unit D1 and the red colour of the vegetation on unit D2 make the effort easy coupled with the orange, light blue and green colours resulting from intensive human interference on these vegetations. Most of the annual bush fire takes place on this plain. It has few scattered palm trees towering over this unit. The unit was mapped C1 on the aerial photo map and A1 on the SPOT map. The unit has a total area study coverage of 2,150 ha or 8.27% of the study area (Table 4.1).

4.3.3 Terrain Mapping Unit A2

The unit A2 designated as Atun plain is the area drained by the River Atun and its tributaries to the west of Ijesha-Omo hills. The area is narrow below Erimo village but assumes a wider dimension west wards towards Iwaraja town. The plain is higher than Oni plain (350m) but provides a fairly level land for Erimo village.

Numerous small streams dissect the area and the highest amount of land quarrying (the largest being the one owned by Chief Omole) takes place on this plain. The bare land left behind as a result of this activity, impact a dark blue reflectance that tend to give the impression of a built-up area. The plain occupies 2,637.5 ha or 10.15% of the study area.

4.3.4 Terrain Mapping Unit A3

The Ilesha plain designated as A3 is one of the largest in the study area. This is a part of the larger plain extending to Ijebu Ijesha and on which sits Ilesha town. The area extends from the west of Iwaraja to the Ile - Olomo in the south-eastern corner of the study area. The hill at the back of Ilesha Grammar School which extends to the periphery of the Trophy Brewery Company forms the northern boundary of this unit.

The unit is low (about 300m) above the general landscape with few high points around the College of Education. As a result of the orientation of this plain, the Ilesha town is developing south-west to engulf the village of Ilerin. The plain is drained by the Erinta River (and its tributaries) and passes through the town thereby providing most of the domestic water requirements for the inhabitants. The blue colour reflectance from the roof of the houses in Ilesha town makes the identification of this unit a little difficult on the SPOT imagery.

The unit is made of sericite schists and amphiboles. On the western part of the unit are coarse grained granite and gneiss. The unit occupies 6050 ha or 23.3% of the study area.

4.3.5 Soils of the A Units

The units (plains) consist of soils derived from fine - grained biotite gneiss and schist to coarse – grained granite. They occupy the eastern half and north western end of the study area. Ilesha town is situated in one of these units. The profiles display brownish grey to red colours. The soils at the crest have red colours which fade to brown at the lower slope. The soil textures vary from fine to coarse sand. Some of the series encountered are Egbeda, Olorunda, Oba, Apomu and the stony Matako series.

4.4 Mapping Unit E

This unit is located between the Ilesha plain to the west and the D4 to the east. The unit is relatively lowland made up of Amphibole. Villages like Ikoromoja and Oke-Odo are located within this unit. The large area of cocoa plantations is concentrated within this unit and few kola nut plantations.

A unique characteristics feature of this mapping unit is the presence of solid Iron stone rubble which is extremely resistant to weathering (plate 3.1). The basic rocks are fine to medium grained gneisses containing high proportion of black minerals. Soil series identified in this unit are Itagunmodi, Araromi, Jago and Owena.

4.5 Mapping Unit F

The mapping unit F is located to the west of unit D4. The unit is made-up of medium grained granites and gneisses. The soil profiles are made up of fine textured brown to brownish red clayey soils. This lowland provides a route for the Erimo - Akure road. Soil series like Mamu, Apomu and Matako were identified in this unit.

4.6 Ife Area

The Ife area is generally a lowland (plain) area with few outcrops. The area is still covered by dense forest that made SPOT imagery interpretation difficult. The area was mapped into the following units (Figs 4.3 and 4.4).

Table 4.1: Area occupied by the different TMUs under AP and SPOT in Ilesha area

TMU	AREA UNDER AP	AREA UNDER SPOT	SOIL SERIES
D	5,545.60	4,714.30	Okemessi, Erin-Oke, Omo and Etioni
A	4,483.40	5,286.50	Egbeda, Olorunda and Matako
E	2,110.60	2,467.10	Itagunmodi, Araromi, Ondo and Jago
F	1,655.40	1,327.10	Mamu and Apomu

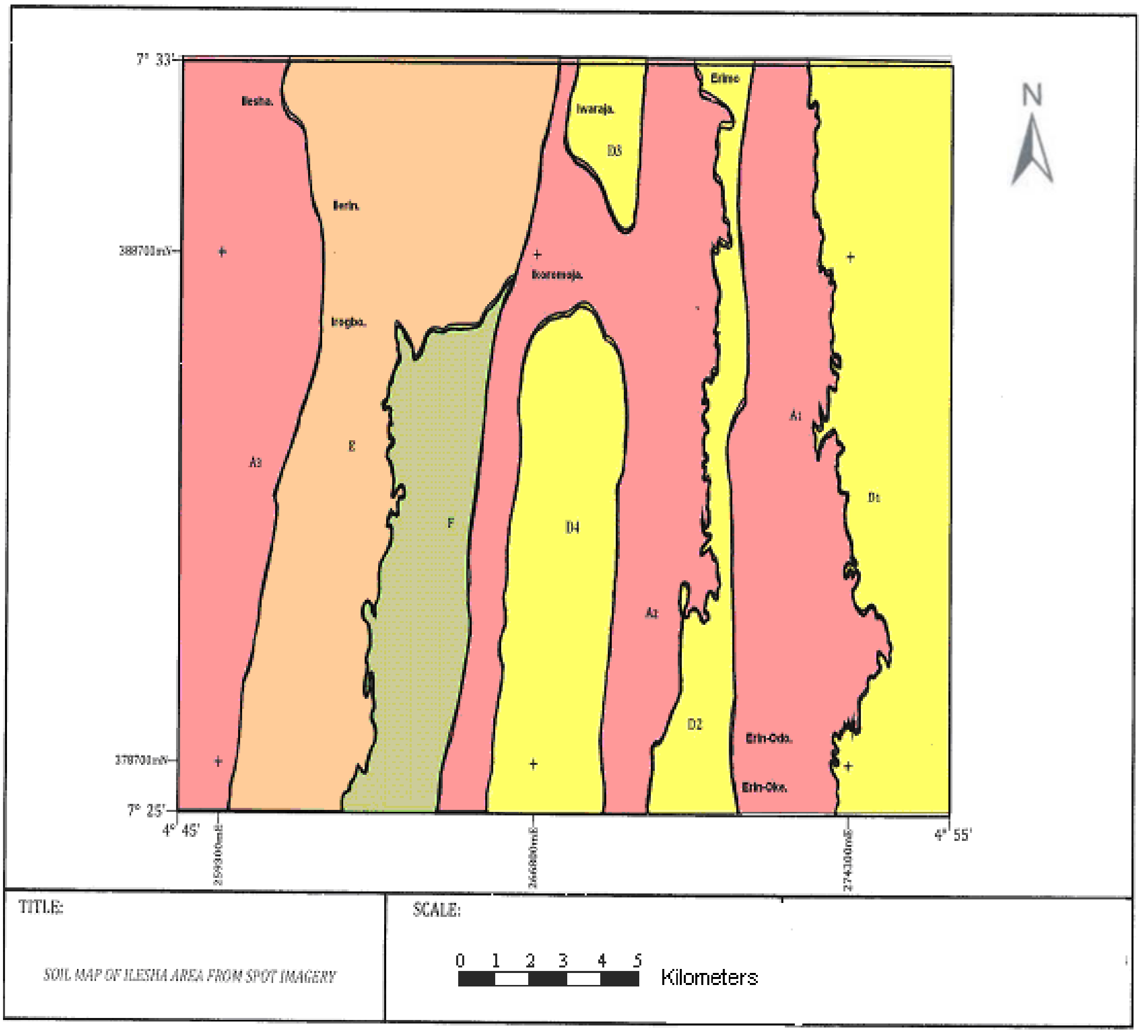
t-cal = 2.98, t-tab = 3.182

Source: Field work, 2009.

Table 4.2: Number of delineations in a 2.5 radius circle in Ilesha area

AP MAP	SPOT MAP
2	3
2	4
4	3
4	2
4	3
3	4
3	3
3	4
3	4
2	3

Correlation coefficient (r) = 54.9%

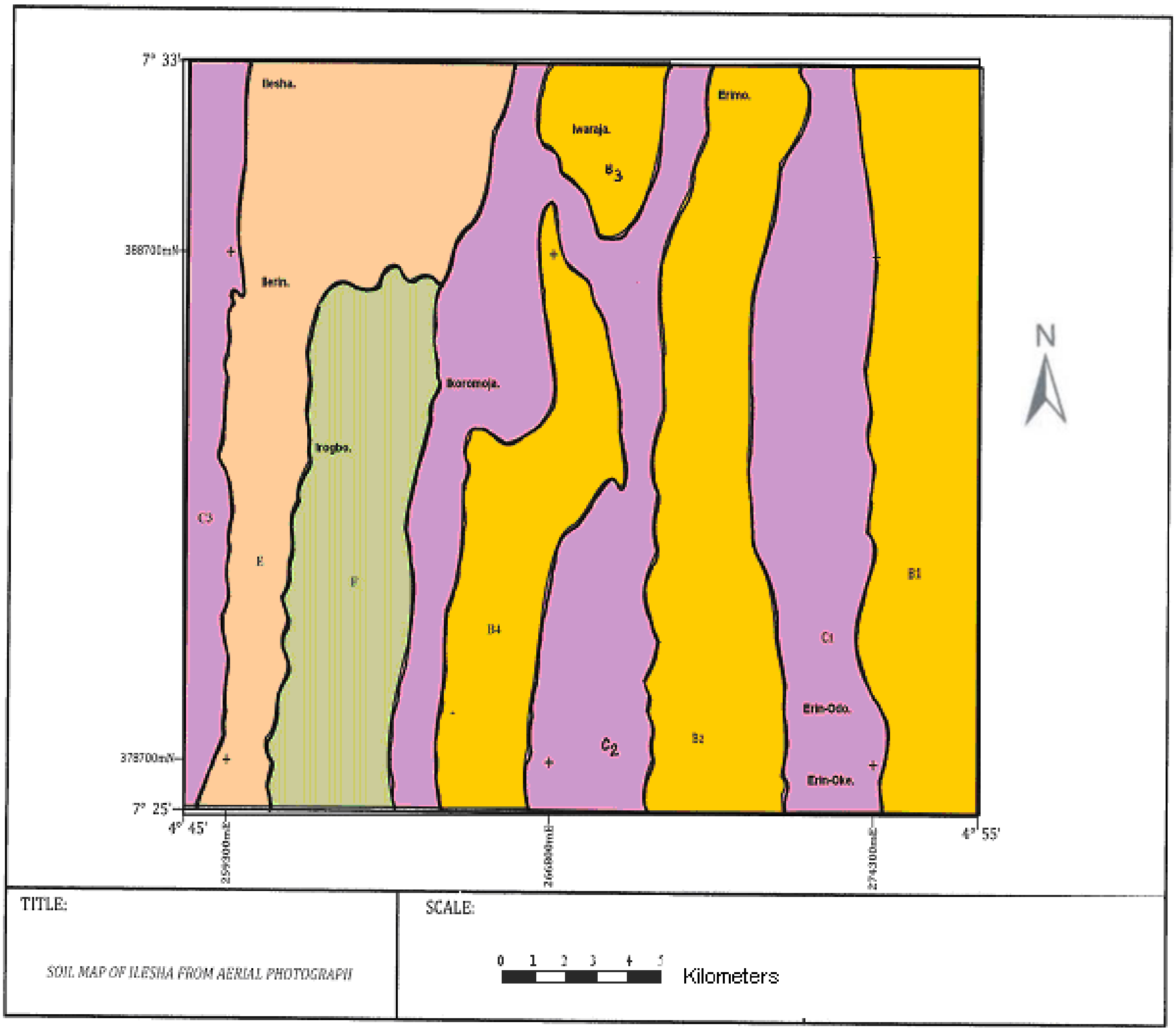


Legend

A – Egbeda, Olorunda and Matako Soil Series
D – Okemessi, Erin-Oke, Irapa, Omo and Etioni Soil Series
E – Itagunmodi, Araromi, Ondo and Jago Soil Series
F – Mamu and Apomu Soil Series

Fig. 4.1: Soil map of Ilesha area from SPOT imagery

Source: Field work, 2009.



Lgend

- B – Okemessi, Erin-Oke, Irapa, Omo and Etioni Soil Series
- C – Egbeda, Olorunda and Matako Soil Series
- E – Itagunmodi, Araromi, Ondo and Jago Soil Series
- F – Mamu and Apomu Soil Series

Fig. 4.2: Soil map of Ilesha area from aerial photographs

Source: Field work, 2009.

4.6.1 Terrain Mapping G

This mapping unit occupies the north-eastern and the western boundary of Ife study area. The unit has outcrops of about 1560 m above the general landscapes which are conical in shape and heavily forested although the presence of human interference is already creeping in. The unit extends from Aba-Fioye in the north to Saga in the south with River Owena separating it from Ifewara hills. On the western axis, the unit extends from the area around the Postgraduate hall in Obafemi Awolowo University (OAU) to the southern fringes of Anidudun. This area of the unit is covered by secondary forest that serves as a natural environment and shade for the animals in the zoological garden of the university.

The geology of the unit consists of medium-grained granites and schist. The unit occupies 3481 or 14.26% of the Ife study area and its mapped B in the aerial photo map and G in the SPOT map.

4.6.2 Terrain Mapping Unit H

The unit occupies the central eastern portion of the Ife study area. The unit is one of the largest with spot height of about 680 m above the general landscape. Owena River runs through nearly the whole length of the unit, providing conducive soil environment for most of the plantation crops especially cocoa, grown in the area. Prominent settlements such as Kojola, Itanjasa and Mosarajo are located within this unit.

The rocks contain high content of ferromagnesian minerals (mainly amphiboles with pyroxenes and black mica). On the unit summits are scattered Iron-stone rubbles, a very resistant rock acting as protective cover to the underlying rock. The unit is mapped C in the aerial photo map and H on the SPOT map. The unit occupies 9417 or 38.8% of the study area (Table 4.3).

4.6.3 Mapping Unit J

This is the largest unit in the Ife study area and occupies the western portion of the area. The Ile-Ife town with other prominent settlements like Itapa, Oke-opa is situated within this unit. The unit although not very high (about 370 m) above the general landscape, consists of granite and gneiss. The unit is densely covered by River Obudu and its numerous tributaries, some of which feed the Dam in the university campus.

The area is also cultivated to cocoa. Most of the luxuriantly grown and well maintained cocoa plantations are located within this unit. The rocks are made up of fine-grained biotite gneiss that forms the parent material of the Egbeda association (Smyth and Montgomery, 1962). The unit was mapped D on the aerial photograph map and J on the SPOT map. The unit occupies 11509.71 ha or 47.16% of the Ife study area (Table 4.3).

4.6.4 Soils of the Units

The soils of these units are derived from the fine-grained biotite gneiss and amphiboles. The soils are clayey in texture and display a little change in the morphology down the profile. Most of the soils are brownish red to dark red with a dark chocolate brown colour on the surface horizons. The soil series found in these units are Owena, Itagunmodi, Araromi, Egbeda, Olorunda, Apomu, Okemessi, Ife, Mamu, Iregun and Irapa.

4.7 Morphological properties of soils

4.7.1 Mapping Unit D

The soils of the mapping unit have colour matrix that ranged from Dark brown/Dark reddish brown (10YR 3/3 – 5 YR 3/2) at the surface horizons to Dark red (2.5 YR 3/6) in the sub soil. The texture of the surface soil ranged from loamy sand in the surface soil to sandy clay in the sub soil (Table 4.5).

The total sand content of the soils, decrease with increasing depth and has a range of 520 – 760 g kg^{-1}. The clay fraction on the contrary increased with increasing depth down the profile. The clay content ranged from 120 g kg^{-1} on the surface to 360 g kg^{-1} in the sub surface. The surface horizon has a clay fraction of between 120 – 180g kg^{-1}, while that of the sub surface horizons ranged from 220 – 350g kg^{-1}. This accumulation of clay down the profile could be attributed to illuviation and flocculation by water. The silt content in this mapping unit ranged from 60 – 120 g kg^{-1} and displayed the same distribution pattern as clay. The profiles are deep (80 – 90 cm) well-drained with well displayed argillic/kandic horizons. The surface soils are friable with concretions and abundant quartz stones down the profiles.

Table 4.3. Area occupied by the different TMUs under AP and SPOT in Ife area

TMU	AREA UNDER AP	AREA UNDER SPOT	SOIL SERIES
G	5,296	4,402.80	Mamu, Ife, Apomu and Etioni
H	9,078.90	9,469.40	Itagunmodi, Araromi, Matako and Jago
J	10,274.80	10,533.50	Egbeda, Owena, Olorunda, Oba and Iregun

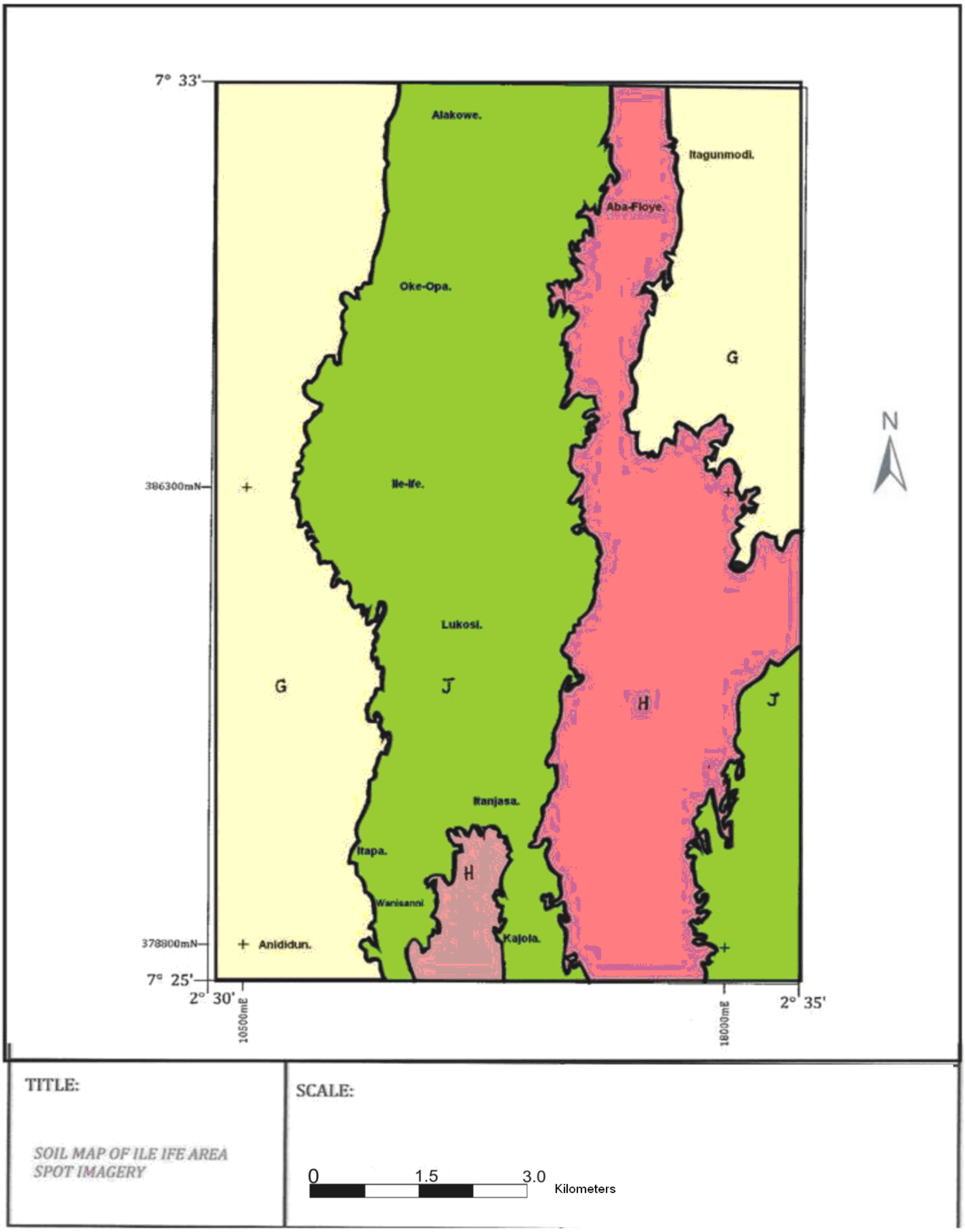
t-cal = 2.66, t-tab = 4.303 at 5% significance

Source: Field work, 2009.

Table 4.4: Number of delineations in a 2.5 radius circle in Ife area

AP MAP	SPOT MAP
3	4
3	4
2	4
2	3
2	3
2	3
2	2
2	3
2	2
2	2

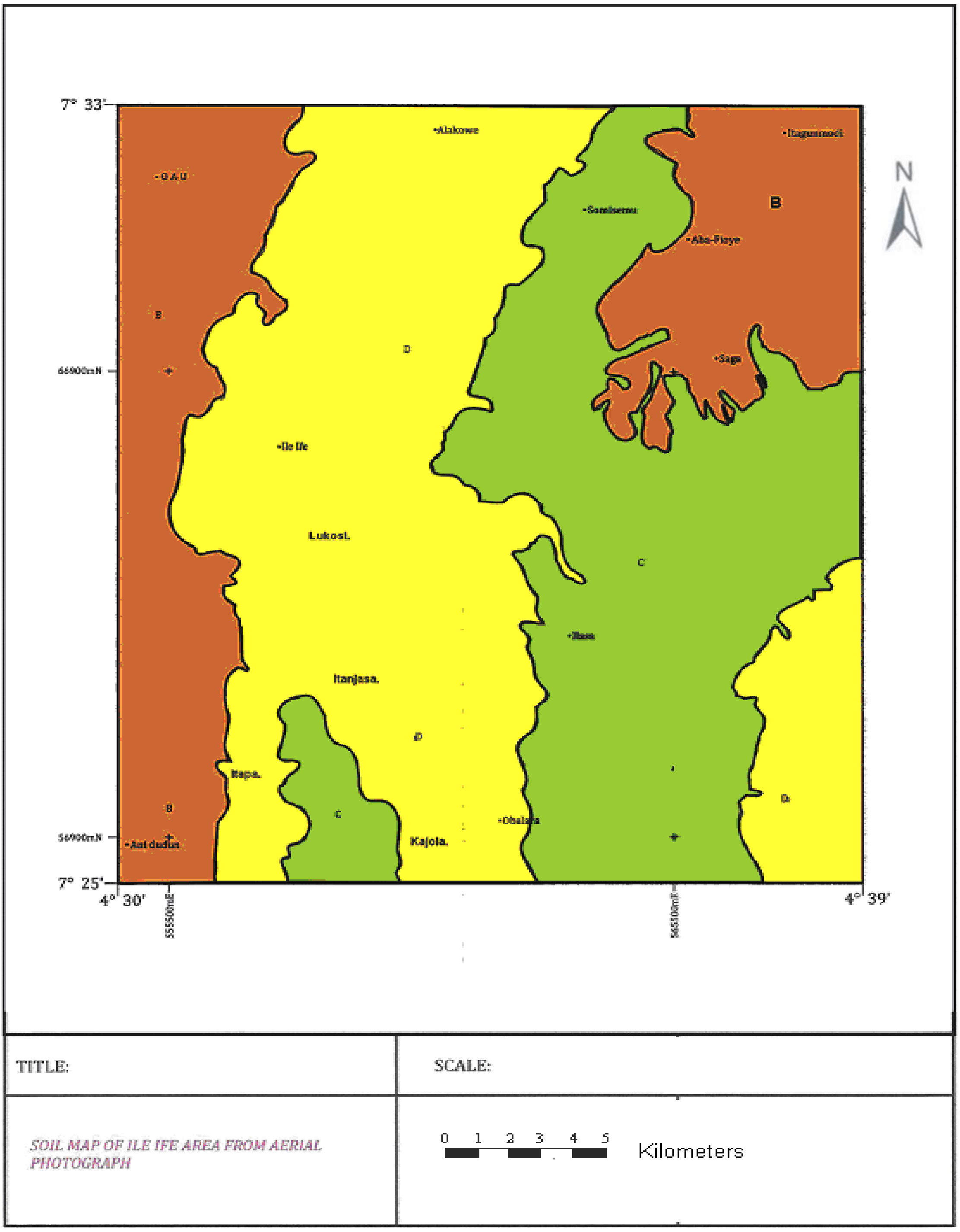
Correlation coefficient (r) = 32%



Legend

G – Mamu, Ife, Apomu and Etioni Soil Series
H – Itagunmodi, Araromi, Matako and Jago Soil Series
J – Egbeda, Owena, Olorunda, Oba and Iregun Soil Series

Fig. 4.3: Soil map of Ile-Ife area from SPOT imagery
Source: Field work, 2009.



Legend

B – Mamu, Ife, Apomu and Etioni Soil Series
C – Itagunmodi, Araromi, Matako and Jago Soil Series
D – Egbeda, Owena, Olorunda, Oba and Iregun Soil Series

Fig. 4.4: Soil map of Ile-Ife area from aerial photographs

Source: Field work, 2009.

4.7.2 Chemical Properties of Soils of Mapping Unit D

The soils are moderately acidic in reaction. The pH (H_2O) of the soils in this mapping unit ranged from 5.8 – 6.1 in the surface and 5.2 – 5.4 in the sub surface (Table 4.6). The high degree of leaching by percolating water, and the dominant Kaolinitic clay type are the likely factors affecting the soil pH. The organic carbon contents are very high with surface values ranging from 26.2 – 34.0 g kg^{-1}. The sub surface values ranged from 7.6 – 9.0 g kg^{-1}. The organic carbon contents are higher in the surface horizons and decreases down the soil profile. The total nitrogen values displayed a similar pattern to organic carbon. The surface concentrations ranged from 2.3 – 3.2 g kg^{-1} while the sub surface values ranged from 0.7 – 0.8 g kg^{-1}. The crops mainly grown in the area are maize, rice and yam and the absence of nitrogen fixing crops like cowpea could be responsible for the low Nitrogen concentrations.

The available phosphorus content in the mapping unit is very low (<15 mg kg^{-1}). The values in the surface horizons are higher and ranged from 4.3 – 6.4 mg kg^{-1}. The values in the subsurface horizons are low with concentrations ranging from 4.4 – 6.2 mg kg^{-1}. The cation exchange capacity (CEC) is generally low with value range of 2.31 – 6.17 Cmol/kg in the soils of the mapping unit. The CEC recorded the lowest value in Etionni series and the highest in Okemessi soil series. Calcium is the dominant cation at the exchange complex, followed by Magnesium and lastly potassium. The base saturation in the profiles of the mapping unit ranged from 54.1 – 98.7%. These values decrease down the soil profile.

4.7.3 Morphological Properties of Soils of Mapping Unit A

The colour matrix of soils in this mapping unit ranged from Dark brown/Dark reddish brown (7.5 YR 3/2, 5 YR 3/2) at the surface horizons or top soil to Strong brown/yellowish red (7.5 YR 5/6, 5 YR 5/6) in the sub soil. The texture ranged sand to loamy sand at the surface to sandy clay in the sub soil.

The total sand content of the soils, decrease with increase depth, with a range of 400 – 850 g kg^{-1} while the clay content increased down the profile. The values of clay ranged from 48 – 480 g kg^{-1} while the silt content did not display a regular pattern as with sand and clay. The soils are well-drained, located at the upper slope except Apomu.

4.7.4 Chemical Properties of Soils of Mapping Unit A

The pH (H_2O) of soils in this mapping unit ranged from 5.5 to 6.3 on the surface to 4.7 – 5.4 on the sub surface soils. These values are strongly to moderately acidic (Table 22). The organic carbon values are moderately high on the surface with a range of 10.5 – 17.9 g kg^{-1} and 1.0 – 6.5 g kg^{-1} in the sub surface. These values decrease with increasing depth down the profile. The total nitrogen concentrations were very low. The surface values ranged between 0.6 – 1.5 g kg^{-1} while the sub surface values recorded concentration as low as 0.1 g kg^{-1}. Available phosphorus content in this mapping unit is very low. There is nowhere in the horizons that a concentration up to 10 mg kg^{-1} was recorded. The range in the soil is 1.20 – 7.40 mg kg^{-1}.

The cation exchange capacity is generally low with values ranging from 1.82 – 9.92 Cmol/kg. Magnesium is the dominant cation, followed by calcium and lastly potassium. All the cations are low and did not display a regular pattern with increasing depth down the profile. The exchange acidity increases down the profile. The values ranged from 0.16 -= 1.12 cmol/kg. Base saturation displayed a distribution pattern opposite to that of the exchange acidity. The values decrease down the profile with a range of 64.89 – 96.64%.

4.7.5 Morphological Properties of Soils of Mapping Unit F

The soils of the mapping unit have colour matrix that ranged from Dark brown/Dark grayish brown (10 YR 3/3, 10 YR 3/2) at the soil surface to Yellowish red/Lighter gray (5 YR 4/6, 5 YR 7/10) in the subsoil. The texture of the soil ranged from sand on the surface to sandy clay at the subsurface horizons.

The total sand content of the soils decrease with depth, with a range of 412 – 912 kg^{-1}. The clay fraction of the soils increased with increasing depth (Table 4.5). The clay values ranged from 1.4 – 10.6% at the surface soils to 5.4 – 31.4% in the subsurface horizons. The silt content of soils in the profiles did not show a defined distribution pattern as sand and clay. The values ranged from 6.0 – 16.0%. Some of the profiles are well drained with the presence of argillic horizons but this cannot be said of Matako.

4.7.6 Chemical Properties of Soils of Mapping Unit F

The soil pH in water in this mapping unit ranged from 5.6 – 6.5 in the surface soils and 5.2 – 6.6 in the sub surface (Table 4.6). These values make the soils to be moderately acidic. The organic carbon contents are moderately high on the surface soils and displayed very low values at the sub surface. These values ranged from 6.0 – 17.9 g kg^{-1} on the surface soils to 1.0 – 5.2 g kg^{-1} in the sub surface soils. The total nitrogen values are very low, with a range of 0.1 – 2.4 g kg^{-1}. Available phosphorus content in the mapping unit is very low with a value range of 2.20 – 6.68 mg kg^{-1}. The cation exchange capacity is also very low. The values decreased with increasing depth down the profiles. The values ranged from 3.19 – 5.40 cmol/kg in the surface soils to 3.19 – 4.68 cmol/kg in the subsoils. The base saturation values are all high (>50%) and ranged from 64.89 – 93.51%.

4.7.7 Morphological Properties of Soils of Mapping Unit E

The soils of this mapping unit have colour matrix that ranged from dark reddish brown (5 YR 3/3) on the surface horizons to yellowish red/Dark red (5 YR 4/5, 2.5 YR 3/6) in the sub surface soils of the profiles in this mapping unit. The texture of the soils ranged between sand and sandy loam. The total sand content of the soils decreased with increasing depth down the soil profile. The values ranged from 812 – 832 g kg^{-1} in the surface horizons to 452 – 612 g kg^{-1} in the subsurface horizons. The clay fraction of the soils in this mapping unit showed an increase with increasing depth. The values ranged from 34 – 74 g kg^{-1} in the surface horizons to 234 – 474 g kg^{-1} in the sub surface horizons. The silt values displayed a distribution pattern similar to that of clay. The values ranged from 114 – 164 g kg^{-1} in the surface horizons to 74 – 294 g kg^{-1} in the sub surface horizons. The soils are loose, friable and sub angular blocky structure.

4.7.8 Chemical Properties of Soils in Mapping Unit E

The pH of soils in water in this mapping unit is moderately acidic. The values ranged from 5.2 – 6.8. Generally, the values decrease down the soil profile. The values for the surface horizons ranged from 5.6 – 6.7 while the sub surface values ranged from 5.2 – 6.4. The organic carbon content of the soils is moderately high. The values like sand decrease down the soil profile. The values ranged from 17.9 – 24.0 g kg^{-1} in the surface soils to 4.9 – 6.5 g kg^{-1} in the sub surface soils. However, the total nitrogen content is very low. The values decrease with increasing depth. The values ranged from 0.4 – 2.4

g kg^{-1}. The values for available phosphorus were lower than 15.0 mg kg^{-1}. The distribution did not follow any pattern. The values ranged from 3.98 – 8.30 mg kg^{-1}. The cation exchange capacity values were low. Only one horizon had a value more than 10.0 cmol/kg. The values ranged from 3.70 – 12.57 cmol/kg in the surface soils and 3.19 – 5.40 cmol/kg in the sub surface soils. The base saturation was very high and more than 50% in all the horizons. The values ranged from 64.89 – 99.36%.

4.7.9 Morphological Properties of Soils of Mapping Unit G

The soils of this mapping unit consist of colour matrix that ranged from dark brown/Dark grayish brown (10 YR 3/3, 10 YR 4/2) at the surface soils to Dark red/Yellowish red (2.5 YR 3/6, 5 YR 5/4) in the sub soils. The texture of the soils ranged between sand at the surface to sandy clay loam/sandy clay in the subsurface (Table 4.5).

The total sand content of the soils decreases down the soil profile with increasing depth. The sand values ranged from 812 – 912 g kg^{-1} in the surface soils and 452 – 832 g kg^{-1} in the sub soils. The clay fraction displayed a contrary distribution pattern to that of sand. The values ranged from 14 – 74 g kg^{-1} in the surface soils and 54 – 474 g kg^{-1} in the sub soils. The silt content also displayed an increase in values with increasing depth. The values ranged from 74 – 374 g kg^{-1}. The soils are deep (>90 cm) fairly well-drained, and sub angular blocky structure.

4.7.10 Chemical Properties of Mapping Unit G

The pH (H_2O) of the soils in this mapping unit ranged from 5.90 – 6.70 in the surface and 6.30 – 6.90 in the sub surface (Table 4.6). These values make the soils to be moderately acidic. The organic carbon content is high on the surface layers and decreased down the profile. The values ranged from 6.5 – 30.8 g kg^{-1} in the surface soils and 4.9 – 7.8 g kg^{-1} in the sub soils. The total nitrogen content of the soils is very low with values ranging from 0.4 – 2.6 g kg^{-1}. Available phosphorus are all low and below 10.0 mg kg^{-1}. The values ranged from 5.00 – 8.30 mg kg^{-1}. The cation exchange capacity is moderately high with some values above 15.00 cmol/kg. The cation exchange capacity values ranged from 3.19 – 12.57 cmol/kg in the surface soils and 3.57 – 9.95 cmol/kg in the sub surface soils. Calcium is the dominant cation in the exchange complex. The base saturation is high with values ranging from 64.89 – 99.53%.

4.7.11 Morphological Properties of Soils of Mapping Unit H

The colour matrix of soils in this mapping unit ranged from Dark brown/Dark reddish brown (7.5 YR 3/2, 5 YR 3/2) at the surface horizons or top soil to Strong brown/yellowish red (7.5 YR 5/6, 5 YR 5/6) in the sub soil. The texture ranged sand to loamy sand at the surface to sandy clay in the sub soil.

The total sand content of the soils, decrease with increasing depth, with a range of 400 – 850 g kg^{-1} while the clay content increased down the profile. The values of clay ranged from 48 – 480 g kg^{-1} while the silt content did not display a regular pattern as with sand and clay. The soils are well-drained, located at the upper slope except Apomu.

4.7.12 Chemical Properties of Soils of Mapping Unit H

The pH (H_20) of soils in this mapping unit ranged from 5.5 to 6.3 on the surface to 4.7 – 5.4 on the sub surface soils. These values are strongly to moderately acidic (Table 4.6). The organic carbon values are moderately high on the surface with a range of 10.5 – 17.9 g kg^{-1} and 1.0 – 6.5 g kg^{-1} in the sub surface. These values decrease with increasing depth down the profile. The total nitrogen concentrations were very low. The surface values ranged between 0.6 – 1.5 g kg^{-1} while the sub surface values recorded concentration as low as 0.1 g kg^{-1}. Available phosphorus content in this mapping unit is very low. There is nowhere in the horizons that a concentration up to 10 mg kg^{-1} was recorded. The range in the soil is 1.20 – 7.40 mg kg^{-1}.

Cation exchange capacity is generally low with values ranging from 1.82 – 9.92 cmol/kg. Magnesium is the dominant cation, followed by calcium and lastly potassium. All the cations are low and did not display a regular pattern with increasing depth down the profile. The exchangeable acidity increases down the profile. The values ranged from 0.16- 1.12 cmol/kg. The base saturation displayed a distribution pattern opposite to that of the exchange acidity. The values decrease down the profile with a range of 64.89 – 96.64%.

4.7.13 Morphological Properties of Soils of Mapping Unit J

The soils of this mapping unit have a colour matrix that range from dark brown/Dark reddish brown (10 YR 3/3, 5 YR 3/2) at the surface layers to Yellowish red/Dark red (5 YR 5/6, 2.5 YR 3/6) in the sub soil of the profiles in this mapping unit. The texture of the surface and sub-surface soils ranged between loamy sand and sandy clay (Table 4.5). The sand content of the soils is high and decreased with increasing depth. The values ranged from 665.0 – 810 g kg^{-1} in the surface soils and 400 – 600 g kg^{-1} in the sub surface soils. The clay values increased with depth down the profile. The clay value ranged from 70 – 200 g kg^{-1} in the surface layers of the soil and 240 – 480 g kg^{-1} in the sub soils. The silt contents did not follow any definite distribution pattern but the values ranged from 3.0 – 220 g kg^{-1} (Table 4.6). The profiles are deep (>90 cm). The structure of the soils is sub angular blocky and consist of no stones except the Ife series.

4.7.14 Chemical Properties of Soils of Mapping Unit J

The pH (H_20) of the soils in this mapping unit ranged from 5.40 – 6.30 in the surface horizons and 4.70 – 5.40 in the sub surface (Table 4.5). These values make the soils to be moderately acidic. The organic carbon values were moderate with higher values in the surface than in sub soil horizons. These values ranged from 8.2 – 17.9 g kg^{-1} in the surface and 1.0 – 7.8 g kg^{-1} in the sub surface soils. The total nitrogen concentration is very low with values ranging from 0.5 – 1.7 g kg^{-1}. Available phosphorus values were low and none was as high as 10.0 mg kg^{-1}. The values ranged from 1.20 – 7.63 mg kg^{-1}.

The cation exchange capacity is low with value range of 2.75 – 8.93 cmol/kg on the surface horizons and 1.22 – 5.43 cmol/kg in the sub soils. Calcium is the dominant cation in the exchange complex, followed by magnesium and lastly potassium. The base saturation in the profiles of this mapping unit range from 59.30 – 99.28%. These values however did not assume any definite distribution pattern in the profile.

Table 4.5: Some Physical Properties of the Soil Series from the study area

Series	Depth (cm)	Sand	Silt g/kg	Clay	Silt/ Silt+Clay	Bulk Density (kg/m3)	Textural class
Omo	0 – 5	760	60	180	0.25	1.14	Loamy sand
	5 – 25	710	100	190	0.35	1.36	Loamy sand
	25 – 55	650	150	200	0.34	1.64	Sandy clay loam
	55 – 80	620	160	220	0.42	1.62	Sandy clay loam
Okemessi	0 – 10	760	120	120	0.50	1.09	Loamy sand
	10 – 20	680	160	160	0.50	1.12	Sandy loam
	20 – 50	640	170	190	0.47	1.26	Sandy loam
	50 – 80	620	60	300	0.17	1.64	Sandy clay loam
Erin-Oke	0 – 10	740	120	140	0.46	0.78	Loamy sand
	10 – 30	660	160	180	0.47	1.30	Sandy loam
	30 – 60	600	210	190	0.53	1.49	Sandy loam
	60 – 90	540	120	340	0.26	1.53	Sandy clay loam
Etionni	0 – 15	720	110	170	0.39	1.17	Loamy sand
	15 – 35	660	150	190	0.44	1.57	Sandy loam
	35 – 55	530	90	380	0.19	1.62	Sandy clay
	55 – 80	520	120	360	0.25	1.76	Sandy clay

Apomu	0 – 15	710	170	100	0.63	1.05	Loamy sand
	15 – 35	550	060	390	0.13	1.22	Sandy clay
	35 – 65	600	030	370	0.08	1.52	Sandy clay
	65 – 90	600	060	340	0.15	1.51	Sandy clay loam
Iregun	0 – 10	650	150	200	0.43	1.06	Sandy clay loam
	10 – 20	610	170	220	0.44	1.24	Sandy clay loam
	20 – 40	540	170	290	9.37	1.54	Sandy clay loam
	40 – 80	600	160	240	0.40	1.58	Sandy clayloam

Source: Field work, 2009.

Table 4.5. Some Physical Properties of the Soil Series of the study area (cont'd)

Series	Depth (cm)	Sand	Silt	Clay	Silt/ Silt+Clay	Bulk Density (kg/m3)	Textural class
		→	g/kg	←			
Itegunmodi	0 – 15	812	164	34	0.8	1.2	Sand
	15-30	623	254	114	0.7	1.5	Loamy sand
	30-45	572	374	154	0.7	1.7	Sandy loam
	45 – 80	472	294	234	0.4	1.8	Sandy clay loam
Araromi	0 – 15	832	114	54	0.7	1.5	Sand
	15 – 30	492	134	374	0.3	1.5	Sandy clay
	30 – 40	472	94	434	0.2	1.6	Sandy clay
	40 – 55	452	74	474	0.1	1.6	Sandy clay
Apomu	0 – 15	812	114	74	0.6	1.1	Sand
	15 – 35	672	114	214	0.4	1.2	Sandy clay loam
	35 – 65	672	94	234	0.7	1.5	Sandy clay loam
	65 – 90	412	74	514	0.1	1.5	Sandy clay
Matako	0 – 10	912	74	14	0.8	1.2	Sand
	10 – 30	832	114	54	0.7	1.5	Loamy sand
	30 – 55	832	114	54	0.7	1.6	Loamy sand
Olorunda	0 – 10	858	94	48	0.7	1.3	sand

	10 – 28	778	114	108	0.5	1.4	Loamy sand
	28 – 50	638	114	248	0.3	1.7	Sandy clay loam
	50 – 85	628	74	298	0.2	1.8	Sandy clay loam
Egbeda	0 – 15	810	100	90	0.5	1.1	Loamy sand
	15 – 30	710	170	120	0.6	1.1	Loamy sand
	30 – 50	440	140	400	0.3	1.3	Sandy clay
	50 – 92	400	120	480	0.2	1.6	Sandy clay
Mamu	0 – 15	734	160	106	0.6	1.3	Loamy sand
	15 – 47	814	60	126	0.3	1.5	Loamy sand
	47 – 82	734	80	186	0.3	1.6	Sandy loam
	82 – 120	734	80	186	0.3	1.6	Sandy loam

Table 4.5. Some Physical Properties of the Soil Series of the study area (cont'd)

Series	Depth (cm)	Sand	Silt	Clay	Silt/ Silt+Clay	Bulk Density (kg/m3)	Textural class
		→	g/kg	←			
Owena	0 – 18	892	74	34	0.7	1.3	Sand
	18 – 39	552	94	354	0.2	1.6	Sandy clay loam
	39 – 55	552	94	374	0.2	1.6	Sandy clay loam
	55 – 83	532	94	434	0.2	1.7	Sandy clay
Oba	0 – 30	780	150	70	0.7	1.0	Loamy sand
	30 – 55	720	80	200	0.3	1.2	Sandy loam
	55 – 84	460	220	320	0.4	1.5	Sandy clay loam
	84 – 108	400	220	380	0.4	1.5	Sandy clay loam
Ife	0 – 20	770	140	90	0.6	1.3	Loamy sand
	20 – 44	694	80	226	0.3	1.4	Sandy loam
	44 – 62	554	80	366	0.2	1.7	Sandy clay
	62 – 96	494	40	460	0.1	1.8	Sandy clay

Ondo	0 -10	660	130	210	0.4	1.2	Sandy clay loam
	10 – 25	640	110	250	0.3	1.4	Sandy clay loam
	25 – 58	540	100	360	0.2	1.6	Sandy clay
	58 – 90	450	110	440	0.2	1.8	Sandy clay

Source: Field work, 2009.

Table 4.6: Some chemical characteristics of the soil Series

Depth (cm)	pH	Org C ($g\ kg^{-1}$)	Total N ($g\ kg^{-1}$)	Av. P mg/kg	Ca	Mg	Na cmol/kg	K	Exchange Acidity	ECEC	Base Sat. (%)	ECEC clay (%)
Omo												
0 – 15	5.8	28.2	2.4	4.29	1.90	2.38	0.87	0.46	0.08	5.69	98.6	54.0
5 – 25	5.6	13.0	1.1	7.30	0.30	2.71	0.43	0.69	0.08	4.21	98.1	52.0
25 – 55	5.4	7.2	0.6	6.30	0.30	1.01	0.87	0.15	0.56	2.89	80.6	28.0
55 – 80	5.4	9.0	0.8	5.64	0.20	1.92	0.48	0.17	0.72	3.47	79.3	29.0
Okemessi												
0 – 10	6.1	34.0	2.9	6.40	4.40	1.03	1.74	0.92	0.08	6.17	98.7	97.0
10 – 20	5.7	13.2	1.1	5.70	0.55	0.70	0.74	0.31	0.64	2.94	78.2	21.0
20 – 50	5.4	9.0	0.8	6.38	0.20	0.76	0.74	0.12	0.72	2.54	71.7	17.0
50 – 80	5.2	8.1	0.7	6.22	0.20	0.67	0.96	0.23	0.72	2.78	54.1	15.0
Erin-Oke												
0 – 10	6.0	26.2	2.3	6.08	2.25	1.01	0.83	0.61	0.08	4.78	98.3	52.0
10 – 30	5.4	13.0	1.1	6.16	0.50	0.59	0.96	0.28	0.72	3.05	76.4	20.0
30 – 60	5.3	7.6	0.7	5.56	0.25	0.48	1.04	0.09	0.80	2.66	69.9	20.0
60 – 90	5.3	7.6	0.7	4.44	0.30	0.44	0.87	0.19	0.56	2.36	76.3	11.0
Etionni												
0 – 15	5.8	27.1	3.2	5.83	2.34	1.03	0.96	0.55	0.57	5.45	89.5	45.0
15 – 35	5.6	14.8	1.3	5.20	0.80	0.51	0.79	0.21	0.32	2.62	87.8	15.0
35 – 55	5.4	8.3	0.7	3.84	0.45	0.59	0.87	0.18	0.48	2.57	81.3	12.0

55 – 80	5.4	8.3	0.7	4.69	0.40	0.82	0.53	0.08	0.48	2.31	79.2	10.0
Apomu												
0 – 15	5.6	17.9	1.5	4.00	1.10	1.25	0.96	0.15	0.24	3.70	93.5	59.0
15 – 35	5.4	8.5	0.7	3.98	0.60	0.82	0.74	0.10	0.48	2.74	82.5	13.0
35 – 65	6.3	6.7	2.4	6.20	0.65	0.88	0.69	0.12	0.08	2.42	96.7	16.0
65 – 90	5.2	6.5	0.6	6.40	0.40	0.81	0.78	0.08	1.42	3.49	59.3	15.0
Iregun												
0 – 10	5.6	15.5	1.7	7.63	0.67	0.57	0.77	0.26	1.73	3.00	75.7	5.0
10 – 20	5.5	15.2	1.3	6.32	0.60	0.51	0.74	0.21	0.48	2.54	81.1	9.0
20 – 40	5.4	5.6	0.5	4.28	0.30	0.41	0.99	0.09	0.48	2.27	78.9	15.0
40 – 80	5.4	5.2	0.5	5.09	0.30	0.38	0.78	0.08	0.80	2.24	64.3	13.0

Table 4.6. Some chemical characteristics of the soil Series (cont'd)

Depth (cm)	pH	Org C (g kg^{-1})	Total N (g kg^{-1})	Av. P mg/kg	Ca	Mg	Na cmol/kg	K	Exchange Acidity	ECEC	Base Sat. (%)	ECEC clay (%)
Itagunmodi												
0 – 15	6.7	21.5	1.9	5.30	8.00	3.07	1.04	0.38	0.08	12.57	99.36	96.0
15 – 30	6.8	7.8	0.7	7.79	4.20	1.81	0.96	0.17	0.16	7.29	97.81	20.0
30 – 45	6.6	7.8	0.7	7.00	4.35	1.68	1.04	0.15	0.08	7.27	98.90	15.0
45 – 80	6.3	6.5	0.6	6.30	3.10	1.17	0.96	0.09	0.08	5.40	98.52	7.0
Araromi												
0 – 15	6.20	24.0	2.1	6.60	4.75	3.04	1.13	0.31	0.96	10.19	90.58	44.0
15 – 30	6.30	13.0	1.2	8.30	3.15	2.28	1.04	0.12	0.16	6.75	97.63	52.0
30 – 40	6.30	6.0	0.5	5.00	1.60	1.19	1.04	0.07	0.16	4.06	96.06	27.0
40 – 55	6.40	4.9	0.4	6.95	1.15	1.27	1.00	0.07	0.08	3.57	97.76	22.0
Apomu												
0 – 15	5.60	17.9	1.5	4.00	1.10	1.25	0.96	0.15	0.24	3.70	93.51	84.0
15 – 35	5.40	8.5	0.7	3.98	0.60	0.82	0.74	0.10	0.48	2.74	82.48	24.0
35 – 65	6.30	27.3	2.4	6.20	1.05	1.41	1.39	1.02	0.08	4.92	99.19	22.0
65 – 90	5.20	6.5	0.6	6.40	0.40	0.81	0.78	0.08	1.12	3.19	64.89	10.0

Matako												
0 – 10	5.90	6.5	0.6	6.40	0.40	0.81	0.78	0.08	1.12	3.19	64.89	36.0
10 – 30	6.00	21.1	1.8	6.68	0.90	0.87	0.78	0.17	0.24	2.96	91.89	4.0
30 – 55	6.60	5.2	0.5	6.10	0.15	0.25	2.96	0.07	0.24	3.69	93.46	19.0
Olorunda												
10 – 28	5.50	3.6	0.3	4.58	0.20	0.43	0.96	0.07	0.16	1.82	91.21	41.0
28 – 50	5.40	3.2	0.3	6.19	0.25	0.44	1.65	0.09	0.56	2.99	81.27	76.0
50 – 85	5.40	1.6	0.1	4.56	0.10	0.38	1.04	0.08	0.56	2.16	74.07	17.0

Table 4.6. Some chemical characteristics of the soil studies (cont'd)

Depth (cm)	pH	Org C (g kg^{-1})	Total N (g kg^{-1})	Av. P mg/kg	Ca	Mg	Na cmol/kg	K	Exchange Acidity	ECEC	Base Sat. (%)	ECEC Clay (%)
Egbeda												
0 – 15	6.30	10.5	0.6	7.40	4.70	2.44	0.17	0.32	0.30	8.93	96.64	30.6
15 – 30	5.50	2.5	0.1	1.80	1.05	1.08	0.21	0.23	0.30	2.87	89.54	7.6
30 – 50	5.1	2.0	0.1	1.50	1.70	2.60	0.32	0.38	0.20	5.20	96.15	4.4
50 – 92	4.7	1.0	0.1	1.20	1.60	2.70	0.36	0.47	0.30	5.43	94.48	3.9
Mamu												
0 – 15	6.5	6.0	0.3	4.00	2.20	2.00	0.23	0.23	0.12	5.40	86.30	15.8
15 – 47	6.2	3.0	0.2	3.90	1.80	2.22	0.20	0.15	0.08	4.80	90.60	12.5
47 – 82	5.5	1.0	0.1	3.00	1.60	2.04	0.14	0.07	0.08	4.65	82.80	8.6
82 – 120	5.6	1.0	0.1	2.20	1.60	1.15	0.40	0.10	0.08	4.68	69.40	8.6
Owena												
0 – 18	6.2	30.8	2.6	6.30	10.00	1.84	1.09	0.22	0.08	12.23	99.40	94.1
18 – 39	6.6	23.5	2.0	7.00	13.50	1.60	1.13	0.23	0.08	16.54	99.52	14.0
39 – 55	6.9	13.9	12	5.00	14.00	1.65	1.17	0.23	0.08	17.13	99.53	14.7
55. – 83	6.9	7.8	0.7	5.00	7.00	1.77	0.96	0.14	0.08	9.95	99.20	7.4

Oba												
0 – 30	5.4	8.2	0.7	6.42	2.30	2.11	1.13	0.20	0.40	6.14	93.49	26.6
30 – 55	5.3	4.8	0.4	6.40	2.10	0.46	0.96	0.07	0.80	4.39	81.78	6.8
55 – 84	5.0	4.7	0.4	5.39	1.80	0.44	1.04	0.06	0.72	4.60	84.35	4.5
84 – 108	5.0	3.0	0.7	3.20	1.60	0.31	0.80	0.05	0.02	2.78	99.28	2.3
Ife												
0 – 20	5.9	16.0	0.7	4.10	1.35	0.80	0.22	0.30	0.08	2.75	97.09	4.5
20 – 44	5.6	4.0	0.3	3.00	1.05	0.60	0.30	0.20	0.05	2.20	97.73	2.8
44 – 62	5.3	3.0	0.2	2.15	0.90	0.60	0.15	0.05	0.08	1.78	95.51	1.4
62 – 96	5.2	1.5	0.1	1.20	0.50	0.50	0.15	0.03	0.04	1.22	96.724	0.8
Ondo												
0 – 10	5.2	22.0	3.7	7.50	1.10	1.86	0.15	0.28	0.18	3.57	94.95	2.3
10 – 25	5.0	6.0	1.6	3.05	0.60	0.70	0.07	0.04	0.66	2.07	68.12	2.1
25 – 58	5.0	1.8	1.0	2.20	0.50	0.50	0.03	0.03	0.70	1.76	60.23	1.5
58 – 90	5.2	1.6	1.0	1.10	0.40	0.50	0.02	0.03	0.75	1.70	55.88	1.2

4.8 Soil classification

4.8.1 Soil taxonomic classification

The soils of the study area were classified using the Keys to Soil Taxonomy 10th Edition (USDA, 2006) classification guidelines. Using the Soil taxonomy (2006) the soils were classified at the order, sub-order, great group and sub group levels based on specific characteristics as outlined in the Keys to Soil taxonomy (USDA, 2006). The following is an account of the main characteristics used in classifying the soils at the various categorical levels listed above (Table 4.7).

Omo, Okemessi, Erin-Oke, Etioni, Apomu, Itangunmodi, Olorunda, Ife and Egbeda qualified for Alfisol order as they possess either an argillic or kandic horizons. In the case of Omo, Etioni, Apomu and Olorunda soil series, they have argillic horizon, while Okemessi, Erin-Oke, Itangunmodi and Egbeda have a kandic horizon. All soil series above fell into sub-order udalf because they have well-drained profiles and the soil temperature is more than 8^{0}C. The lowest temperature during the year is about 24^{0}C. The study area is also not in any way located near the Mediterranean climate.

Apomu and Etioni fitted into the Great Group Paleudalf because they have an argillic horizon with more than 50 percent of the horizon matrix and in more than half of the total thickness, a hue of 2.5YR and a value of 4 or less when dry. There were no cracks, but sandy throughout the profil; well drained and no plinthite. This fitted them into sub group of Typic Paleudalf. In the FAO system, they were classified as Eutric Nitosol.

Omo and Olorunda were classified as Hapludalf under the Great Group since they do not have a paralithic contact nor a texture finer than loamy sandy above the argillic horizon. In the sub group level they were classified as Inceptic Hapludalf as a result of the argillic horizon less than 35 cm thick. In the FAO system, the soil series were classified as Orthic Luvisol.

Okemessi, Erin-Oke, Ife, Itagunmodi and Egbeda were classified as Udalf under the sub order and Kandiudalf under the Great Group level as a result of the presence of Kandic horizon. Ife and Okemessi series has a kandic horizon with a hue of 2.5 YR and a value of 2 to make them Rhodic kandiudalf and Chromic Luvisol in the FAO, system.

The remaining three: Erin-Oke, Itangunmodi and Egbeda were classified as Typic kandiudalf because they do not possess any sandy class extending from the surface to 100 cm, no mollic epipedon nor plinthite in any horizon. In the FAO system, they were classified as Orthic Luvisol.

Owena, Araromi, Jago, Iregun and Mamu fell under the order Inceptisol because they did not possess any of the other diagnostic horizons except a Cambic subsurface horizon. They were also grouped under sub order Udepts and as a result of base saturation that is more than 60%, Araromo, Owena and Jago were grouped under Eutrudept Great Group while Mamu and Iregun came under Dysteudept.

The very low CEC values for Iregun and Mamu, the absence of any lithic contact within 50 cm of the mineral soil surface, and well drained profiles made them to be classified as Ruptic-Ultic Dystrudepts with the corresponding FAO classification of Dystric Cambisol. Araromi was classified as Lithic Eutrudept because of the lithic contact within 50 cm of the mineral soil surface of the sub group level. The corresponding FAO classification was Eutric Cambisol. Owena soil series was classified as Dyustric Eutrudept as a sub group with an FAO equivalent of Dystric Cambisol. Jago soil series was classified as Ruptic Alfic Eutrudept as a subgroup as a result of high illuvial material that met argillic horizon. The FAO equivalent was Eutric Combisol.

Matako was the only soil series that fell under Entisol order as it did not possess any distinct horizon except a weak A horizon arising from slight organic matter accumulation. It fell into the Psamments sub order because of coarse sand texture within the specified depth. The udic moisture regime of the location further placed it in the udipsamment great group. Under the sub group level, the series is classified as Oxyaquic Udipsamment because of the shallow water level that lasted more than 20 consecutive days and the FAO equivalent is Dystric Gleysol.

Table 4.7: Classification of the Soil Series identified in the study area

	Soil Taxonomy	FAO/ISRIC/IUSSS	Local Series
1	Inceptic Hapludalf	Orthic Luvisol	Omo
2	Rhodic Kandiudalf	Chomic Luvisol	Okemessi
3	Typic Kandiudalf	Orthic Luvisol	Erin-Oke
4	Typic Paleudalf	Eutric Nitosol	Etioni
5	Typic Paleudalf	Eutric Nitosol	Apomu
6	Ruptic-Ultic Dystrudept	Dystric Cambisol	Iregun
7	Typic Kandiudalf	Orthic Luvisol	Itegunmodi
8	Lithic Eutrudept	Eutric Cambisol	Araromi
9	Oxyaquic Udipsamments	Dystric Gleysol	Matako
10	Inceptic Hapludalf	Orthic Luvisol	Olorunda
11	Typic Kandiudalf	Orthic Luvisol	Egbeda
12	Ruptic-Ultic Dystrudept	Dystric Cambisol	Mamu
13	Dystric Eutrudept	Dystric Cambisol	Owena
14	Ruptic-Alfic Eutrudept	Eutric Cambisol	Jago
15	Rhodic Kandiudalf	Chromic Luvisol	Ife

Source: Field work, 2009.

4.9 Landuse/landcover mapping

The two maps resulting from LU/LC mapping using the aerial photographs (AP) (Figs. 4.5 and 4.6) and the four plates from the unsupervised and supervised mapping using the Landsat imageries are represented below. The area coverage and the dynamics in the LU/LC are documented in the tables below and hereunder discussed.

4.9.1 LU/LC situation in 1975 in Ilesha Area

Majority of the area was under forest vegetation (Table 4.8). This made up of the dry and riparian forests (7465 ha) constituting 54.68% of the total land area. Most of these forests occupy the Ajubu and Irogbo areas and extending to Idado village in the south eastern corner of the project zone.

Another landuse with large coverage is the fallow/crop. This covers an area of 3050 ha or 22.34% of the total land area. This Landuse was scattered all over the study area with some concentrations on the Oni plain outside the gallery forest and also in some areas around the villages. The likely reason for this large coverage is that the aerial photographs were acquired in the month of December when most of the cultivated arable has been harvested from the field and the land is left as fallow so as to regain the nutrients taken up by the crops during the previous cropping season.

The Hills/Forest landuse type occupies 650 ha of land which constitutes 4.76% of the total area of the project. This landuse type is concentrated on the Erin-Odo and Ijesha-Omo hills in the Eastern end of the project area. Other areas of concentration of this landuse type are the Iwara hill to the north and Ijemo hill in the central portion of the project area. These areas have been protected from human interference because of steep slope and inaccessibility.

The built-up area, largely Ilesha town, Eromo, Irin-Odo and Ijesha-Omo occupied 2488 ha or 18.22% of the total project area. Ilesha alone occupy 1400 ha or 10.25% of the area. The study area is sparsely inhabited. The villages were few and small in size. This could be attributed to the undulating nature of the landscape.

4.9.2 Landuse/Landcover Situation in 1986

The Lu/Lc situation in the study area was mapped with Landsat Imagery. As in 1975, the largest segment of the study area was still under forest vegetation (Table 4.8) occupying 6323 ha or 46.31% of the total area.

During this time, the built-up area grew from 2488 ha or 18.22% to 3035 ha or 22.23%. This growth occurred mainly in Ilesha town, along the Ijebu-Ijesha road. Out of the 3035 ha of the built-up land, Ilesha town alone occupied 2550 or 18.68% (84% of the built up area) of the total area. The area occupied by the fallow/crop lands was 3358 ha or 24.60% while 937 ha or 6.86% were occupied by Hills/Forest landuse type.

4.9.3 LU/LC situation in 2002

The forest (both dry land and riparian forests) maintained the largest coverage in the study area in 2002 (Table 4.8). The forest had 5440 ha or 38.85% of the total area. The built up area expanded gently over the 1986 figures from 3035 or 22.23% to 3277 ha or 24.00%. This growth was stimulated by the construction of a new highway from Gbongon through Ilesha to the Erimo – Akure road. A lot of inhabitants then moved closer to the highway for economic purposes.

Fallow/crop land covered 4552 ha or 33.34% of the total area while the Hill/forest land covered 584 ha or 4.28%. The decrease in the Hill/forest landuse type could be attributed to the deforestation and urban expansion close to the hilly areas.

4.9.4 Changes that occurred between 1975, 1986 and 2002

The changes in landuse types that occurred between 1975 and 1986 are shown in Table 4.9. The figures show a tremendous change for this eleven-year period. There was an increase from 2488 ha to 3035 ha (547 ha or 21.99%) of the built up area. This represents an annual growth rate of 49.73 ha. Majority of this growth took place in Ilesha town. According to Soneye (1990), Ilesha town was 700 ha in 1963 but doubled in size to 1400 ha in 1977 and 2550 ha again in 1986. This shows that for every 11 – 12 years, Ilesha town double its built-up area.

From 1986 – 2002, a period of 16 years, the built-up area expanded by 42 ha or 1.38%. This represents an annual growth rate of 2.63 ha (Table 4.10). Most of the land built-up was in the western fringes of the town that had a new highway from Gbongon, passing through the outskirt of the Ile-Ife, through Ilesha to meet the Erimo – Akure road. There was a drift from the town towards the new road for economic reasons.

Although the forest continuously dominated the cover of the area for the 1975 and 1986 periods, 1142 ha or 15.30% of the forest area changed into other types of uses. This amounted to 103.82 ha of forest depleted annually. Between 1986 and 2002, 883 ha representing 13.96% of the forest were cleared. This amounted to annual depletion of 55.19 ha.

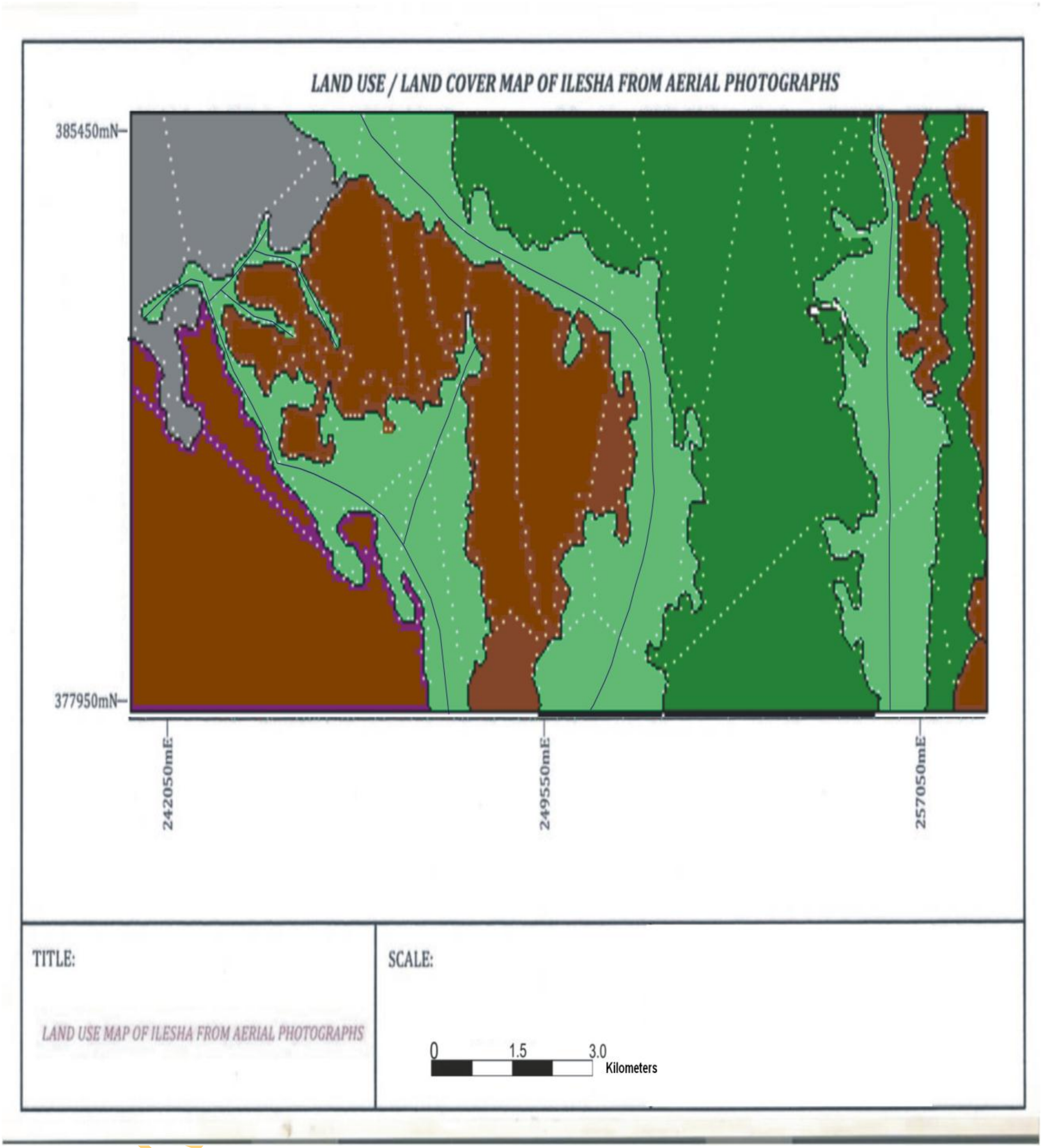
Coming next to forest and built-up areas in terms of coverage is the fallow/crop land. Between the periods 1975 to 1986, the landuse increased in area with 308 ha representing 10.10% of the fallow areas. On annual basis, 28.0 ha were going into fallow or cropland. The magnitude was not the same in the period 1986 – 2002. The amount of land gained by fallow/cropland was larger. A total of 1194 ha or 35.56% of the fallow area was added to this landuse resulting in 74.63 ha annually.

The least among the landuse types in terms of area coverage was Hills/forests. This type of landuse increased by 287 ha between 1975 to 1986 representing 44.15% of the hill/water area and an annual gain of 26.09 ha. In the period between 1986 and 2002, 353 ha representing 60.4% of the hill/water area were cleared for other types of land use. This amounted to an annual depletion of 22.06 ha.

4.9.5 The Lu/Lc Mapping Of Ife Area

4.9.5.1 The Situation in 1975

The situation of landuse/landcover in Ile-Ife area in 1975 using aerial photographs was similar to that of the landsat imagery of 1986 since both were acquired at the same time of the year (December) when most arable crops have been harvested.



Legend
- Built-up
- Mainly fallow and crop land
- Fringing forest
- Mainly secondary forest

Fig. 4.5: Land use map of Ilesha area from aerial photographs of 1975

Source: Field work, 2009

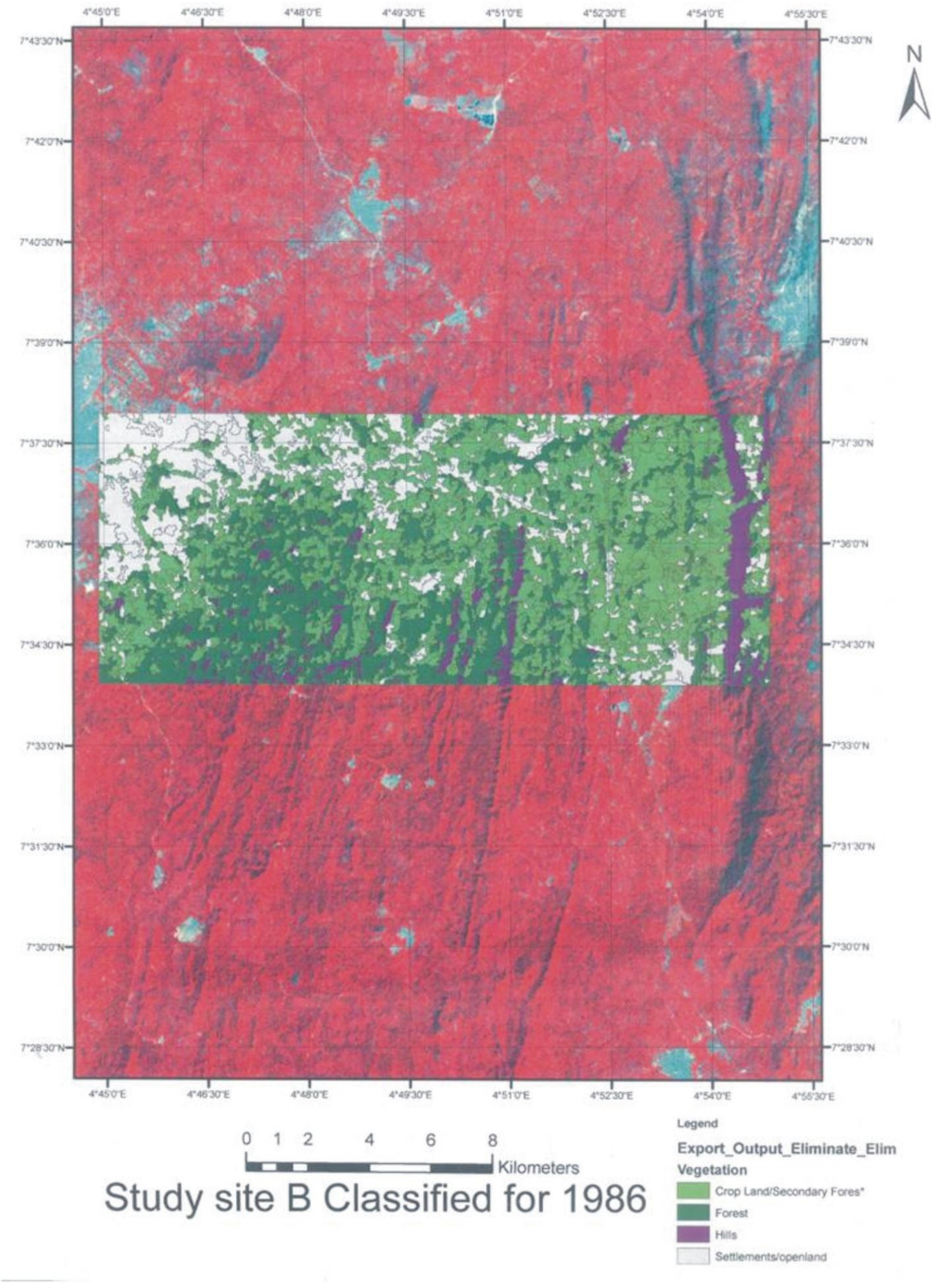


Plate 4.3: Landsat sub-scene of Ilesha Area taken in 1986

Source: Nuga, 2007.

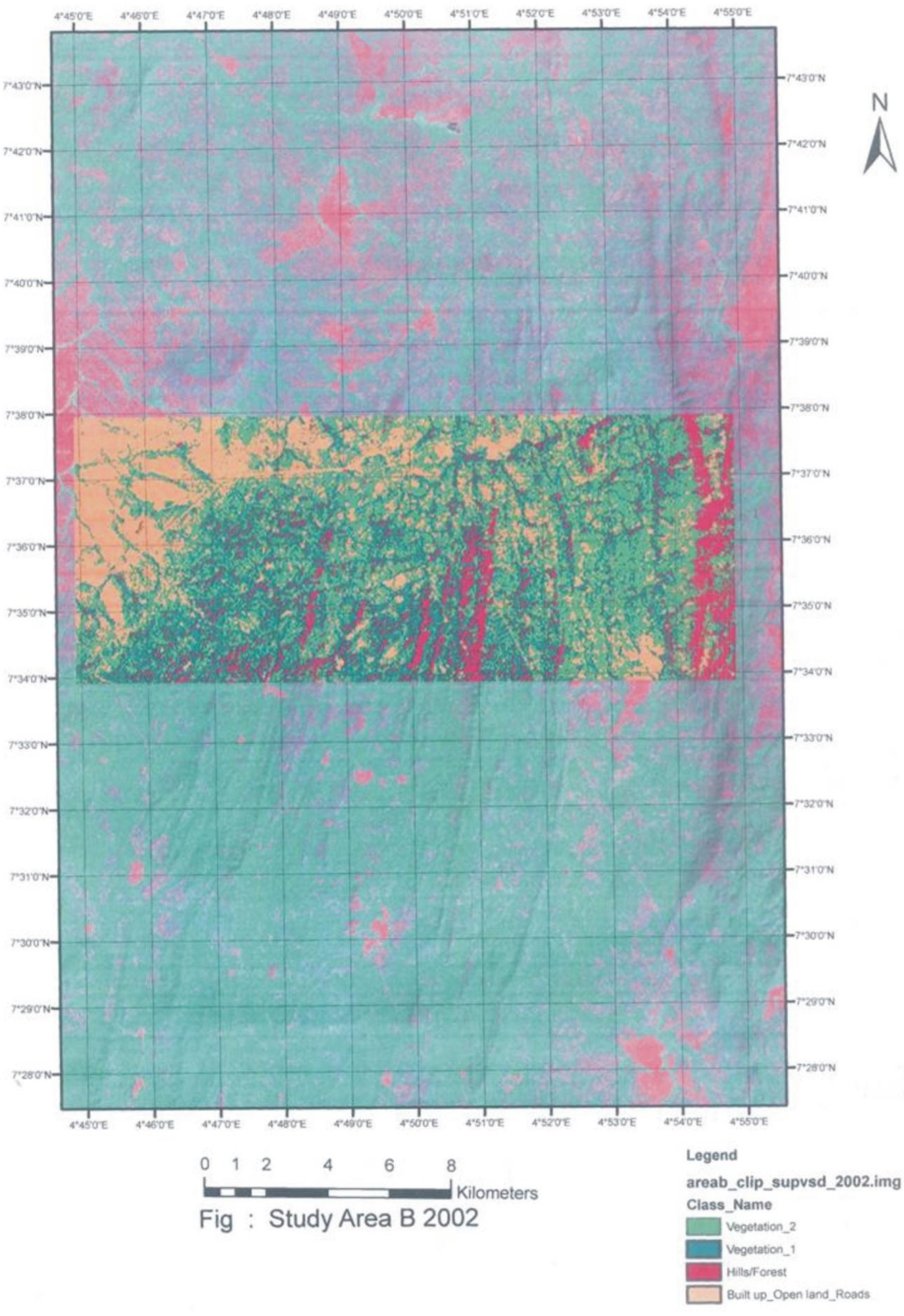


Plate 4.4: Landsat sub-scene of Ilesha area taken in 2002

Source: Nuga, 2007.

Table 4.8: Area Coverage by the different LU/LC types in 1975, 1986, and 2002 in Ilesha area

LU/LC Types	From AP 1975 (ha)	% of total	From Landsat 1986(ha)	% of total	From Landsat 2002(ha)	% of total
Built-Up	2488	18.22	3035	22.23	3277	24.00
Hill/water	650	4.76	937	6.86	584	4.28
Fallow/crop cover	3050	22.34	3358	24.60	4552	33.34
Secondary/Riparian Forest	7465	54.68	6323	46.31	5240	38.38

Source: Field work, 2009.

Table 4.9: Differences between Landsat Image and Aerial photographs in Ilesha area 1975 – 1986

LU/LC Types	AP 1975 (ha)	Landsat 1986 (ha)	AP - Landsat (ha)	% difference	Rate\year (ha)
Built-up	2488	3035	+547	21.99 (4.01)	49.73
Hill/water	650	937	+287	44.15 (2.01)	26.09
Fallow/crop cover	3050	3358	-308	10.10 (2.26)	28.0
Secondary/Riparian Forest	7465	6323	-1142	15.30 (8.37)	103.82

Source: Field work, 2009.

Table 4.10: Differences between Landsat Images of 1986 and 2002 in Ilesha Area

LU/LC Types	Landsat 1986 (ha)	Landsat 2002 (ha)	Landsat 2002-1986 ha	% difference	Rate/year (ha)
Built up	3035	3077	+42	1.38 (0.31)	2.63
Hill/water	937	584	-353	60.4 (2.59)	22.06
Fallow/crop cover	3358	4552	+1194	35.56 (8.75)	74.63
Primary/Riparian Forest	6323	5440	-883	13.96 (6.47)	55.19

Source: Field work, 2009.

In this area, the highest percentage of the landcover was by forest which occupied 11,754 ha or 48.16% of the total area (Table 4.11). Most of these forest cover extends from Kukoro in south, towards Aba-Fioye in the north and westwards immediately before Itegumodi village. A lot of the riparian forests were located along the numerous streams in the University campus towards Ife - Ilesha road at Ayiwe.

Coming next in area coverage to forest, is the fallow/cropland which covered 8137 ha or 33.34% of the study area. Majority of the fallow land were located around Itanjasa, although the outskirt of Ile-Ife town equally had fallow lands. Majority of the plantations were located around Kajola, Taba axis in the southern end of the study area and also in Itanjasa – Aiyedade areas on the way to Ifewara.

The built-up area consisting mainly the Ile-Ife town and the numerous villages occupied 4074 ha or 16.69% while the Hill/water occupied 439 ha or 1.80%. The hills were mainly located around Alakowe on the way to Ilesha, the University Campus and Ifewara area.

4.9.5.2 The Situation in 1986

The landuse/landcover mapping during this period was done with landsat image (plate 4.5). As in 1975, the Forest in 1986 still cover the largest portion of the landscape accounting for 10,854 ha or 44.46% of the total study area, (Table 4.10) Like in 1975, most of these forest occupied the north east corner of Itagunmodi in the study area. The built-up area which becomes the third largest this time around occupied 5103 ha or 20.91% of the area with Ile-Ife town accounting for more than half of the area coverage.

The area left to fallow and those planted to crops in 1986 was 7797 ha or 31.94% (Plate 4.7). The crop land was mainly cocoa plantation (Plate 4.10) with some cassava farms (plate 4.9). The hills/water body occupied 654 ha or 2.68% of the total land area. The water dam in the University campus came into existence during this period while some of the hills previously covered with vegetation were now cleared and opened for some social/religious activities (Plate 4.11).

4.9.5.3 The Situation in 2002

The Landsat image analysis (Plate 4.6) showed that the forest consistently occupied the largest part of the study area with 9597 ha or 39.32% (Table 4.11). The concentration of the forest was still around Itagunmodu area. The built-up centering around Ile-Ife town occupied 6465 ha or 26.40% while the fallow/crop land cover an area of 6780 ha or 27.78% Plate 4.7). The hill and the water bodies covered 1566 ha or 6.42%.

4.9.5.4 Changes that occurred between 1975 and 1986

The landuse dynamics during this period are shown in Table 4.12 for a period of eleven years, 1029 ha or 25.26% was added to the built-up area. This represented an annual growth rate of 93.55 ha. The forest lost a total of 900 ha or 7.66% of the forest area representing an annual depletion rate of 81.82 ha. 340 ha or 4.18% of the area representing the fallow/cropland were converted into other forms of landuse especially those close to the homestead were built-up. The hills/forest landuse gained 215 ha or 48.89% of the area representing hill/water.

4.9.5.5 Changes that occurred between 1986 and 2002

Of all the landuse types, the forests suffered the greatest loss. The forests were depleted by 1257 ha representing 11.58% of forest in the study area (Table 4.13). This amount of forest translated to 78.56 ha of forest depleted annually. Some of the losses from the forest were gains recorded in the built-up areas. The built-up lands gained 1362 ha or 26.69% of the total area. This amounted to 85.13 ha of land built-up annually.

1017 ha or 13.04% of the fallow area were converted from the fallow/cropland to other uses. This represent 63.56 ha annual conversion while the hills/water landuse increased by 912 ha. This gain represents 57 ha annually. This expansion can be attributed to the destruction of the riparian forest to expose the water bodies.

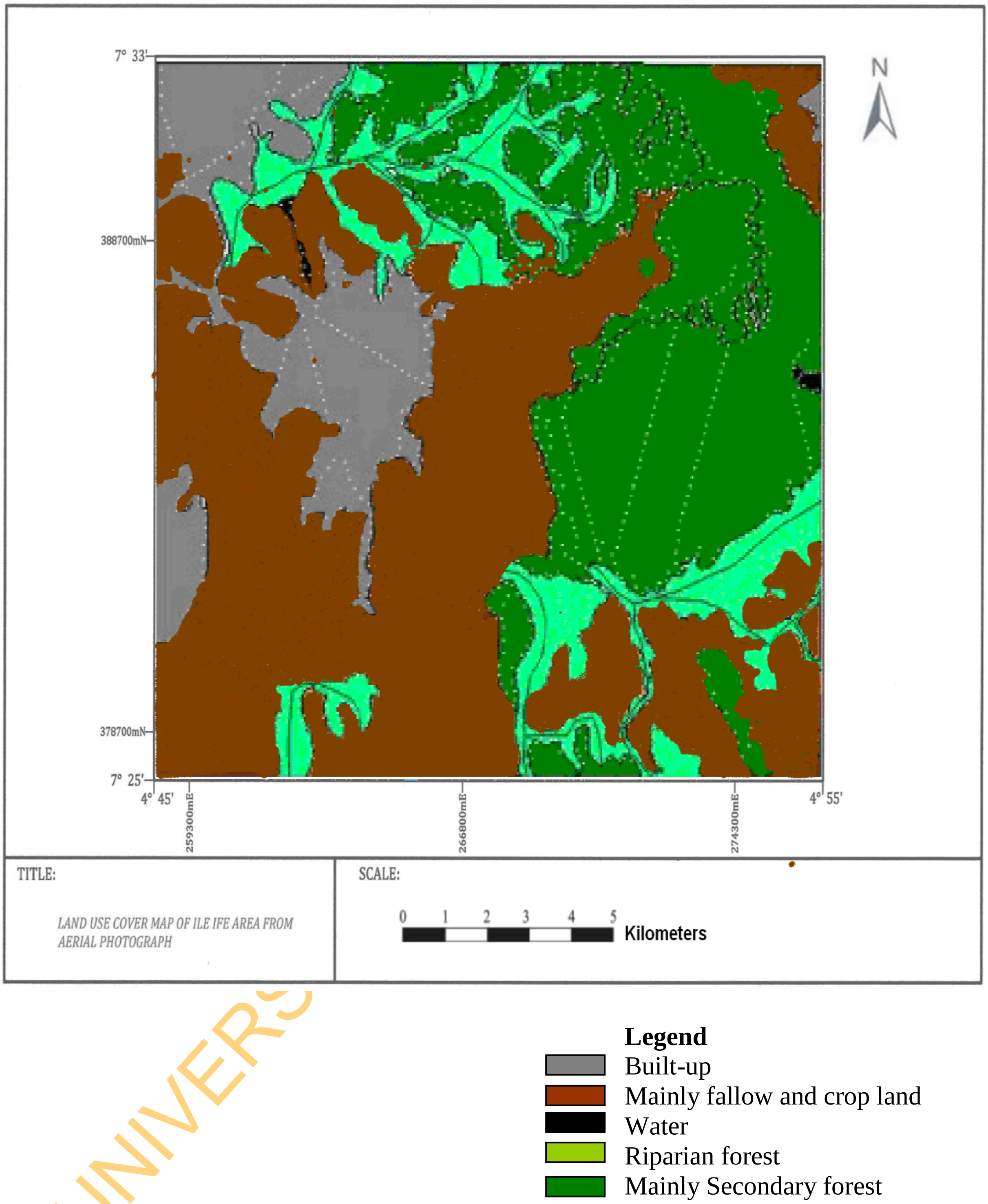


Fig. 4.6: Landuse/Landcover map of Ile-Ife area from aerial photographs of 1975

Source: Field work, 2009.

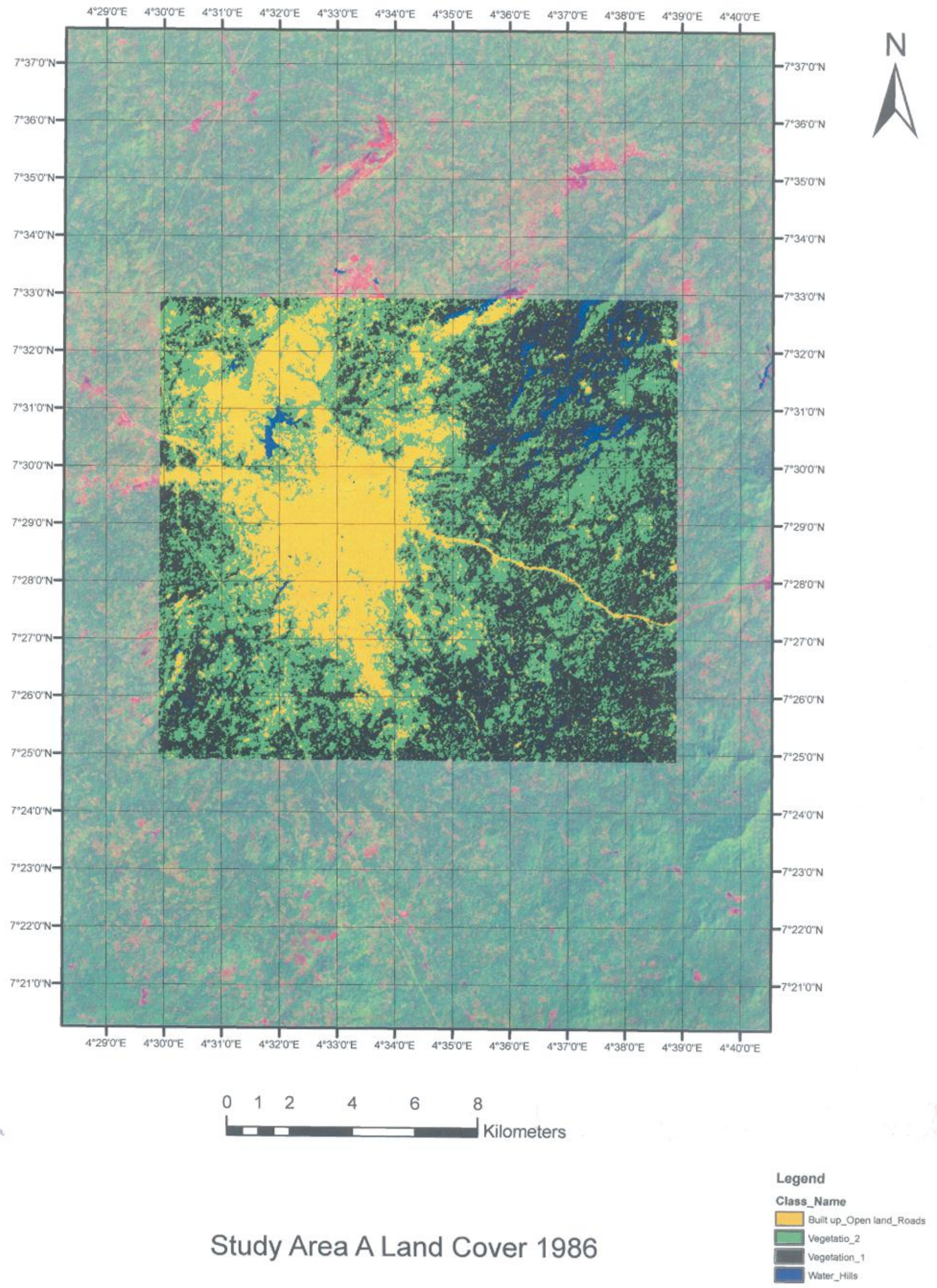


Plate 4.5: Landsat sub-scene of Ife area taken in 1986

Source: Nuga, 2007.

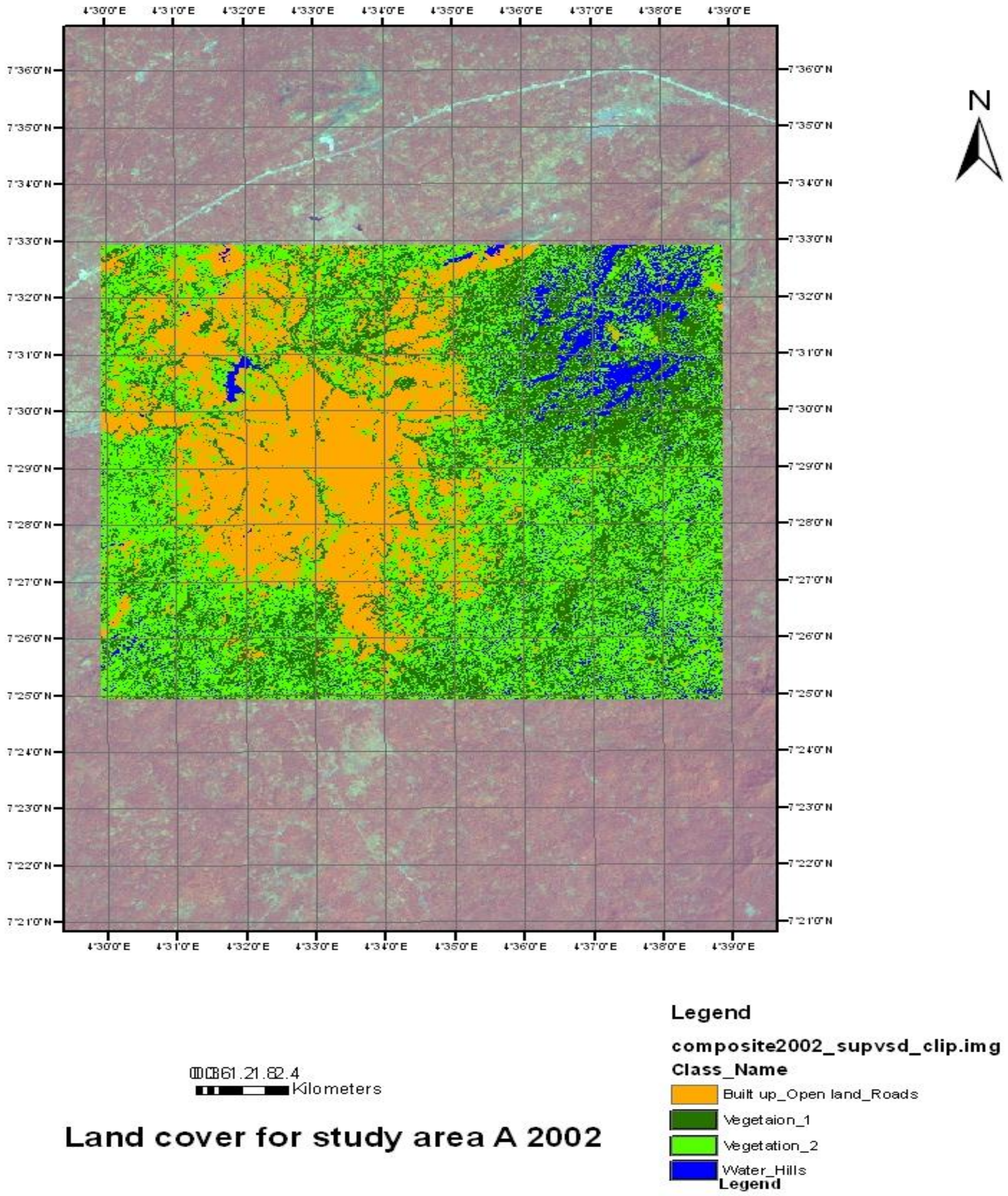


Plate 4.6. Landsat sub-scene of Ife area taken in 2002

Source: Nuga, 2007.

Table 4.11. Area Coverage by the different LU/LC Types in 1975, 1986 and 2002 in Ife Area

LU/LC Types	From AP* 1975 (ha)	% of total	From Landsat 1986(ha)	% of total	From Landsat 2002(ha)	% of total
Built-Up	4074	16.69	5103	20.91	6465	26.49
Hill/water	439	1.80	654	2.68	1566	6.42
Fallow/crop cover	8137	33.34	77.97	31.94	6780	27.78
Secondary/Riparian Forest	11,754	48.16	10,854	44.46	9597	39.32

* AP = Aerial photographs

Source: Field work, 2009.

Table 4.12. Differences between Landsat and AP in Ife Area 1975 – 1986 (ha)

LU/LC Types	AP* 1975 (ha)	Landsat 1986 (ha)	AP– Landsat (ha)	% difference	Rate\year (ha)
Built-up	4074	5103	+1029	25.26 (4.22)	93.55
Hill/water	439	654	+215	48.98 (0.88)	19.55
Fallow/crop cover	8137	7797	-340	4.18 (1.39)	30.91
Secondary/Riparian Forest	11,754	10854	-900	7.66 (3.69)	81.82

* Aerial photograph

Source: Field work, 2009.

Table 4.13. Differences between Landsat 1986 and 2002 in Ife Area

LU/LC Types	Landsat 1986 (ha)	Landsat 2002 (ha)	Landsat 1986-2002 ha	% difference	Rate/year (ha)
Built up	5103	6465	+1362	26.69 (5.58)	85.13
Hill/water	654	1566	+912	139.44 (3.74)	57.00
Fallow/crop cover	7797	6780	-1017	13.04 (4.17)	63.56
Secondary/Riparian Forest	10854	9597	-1257	11.58 (5.15)	78.36

Source: Field work, 2009.

Plate 4.7. A young fallow situated along Ile-Ife – Lukosi Road

Source: Field work, 2009.

Plate 4.8. A recently harvested Maize farm left to fallow

Source: Field work, 2009.

Plate 4.9. A cassava crop land along Ile-Ife – Itanjasa Road

Source: Field work, 2009.

Plate 4.10. A cocoa plantation close to Kajola Village

Source: Field work, 2009.

Plate 4.11. The hill crest at Alakowe on Ile-Ife – Ilesha used for religious activities

Source: Field work, 2009.

Plate 4.12. Human encroachment on the Riparian Forest along River Owena

Source: Field work, 2009.

4.10 Land Evaluation

Land characteristics belonging to the various soil series are described in Tables 4.14 – 4.16. Tables 4.17 – 4.18 show the land suitability ratings for soil series in Ife and Ilesha area. The predicted yield at this stage represents the maximum yields obtainable when only the actual land qualities as indicated by land characteristics of the mapping units are considered. The land characteristics were compared with the crop requirements to get the suitability score for each crop in the mapping units.

The suitability of the soils for maize cultivation (Table 4.17) ranged from 32.0% (Ife series) to 76.8% (Araromi, Itagumodi and Owena series). In nearly all the series evaluated, phosphorus contributes the least score to the suitability class. This is followed by texture for four series, potassium for three and pH for Jago series alone. In the land suitability rating, Araromi, Itangumodi, Owena and Egbeda are moderately suitable for maize production while Iregun, Olorunda, Oba and Jago are marginally suitable. Omo, Okemessi, Erin-Oke, Etioni, Apomu, Matako, Irapa and Ife are currently not suitable for maize production.

In the case of upland rice, the suitability score varied from 35.2% in Ife series to 80.0% in Iregun (Table 4.17). Whereas Length of growing period and average temperature over growing period were found to be at optimum level as they contribute 100 to nearly all the series, texture and annual rainfall contributes either 40 or 60 respectively.

The suitability for yam (Table 4.17) like the case of upland rice is low and varied from 33.6% (Ife series) to 80% in Iregun series. Whereas temperature regime is at optimum level as it contributes 100 to the score in nearly all the series, potassium, phosphorus and texture contributes between 40 - 60 to the suitability in all the series. Drainage was poor in Jago and contributes 60 to the score.

The suitability of the series for cassava (Table 4.17) varied from 33.6% (Ife series) to 76.8% in Egbeda series. The average temperature, length of growing period and annual rainfall were found to be optimum, thereby contributing between 80 – 100 to the score, potassium contributed between 40 – 60 while phosphorus, rooting depth, drainage and texture contributed 60.

Table 4.14. Description of land characteristics of the soil series of the study area

Land Quality	Land Characteristics	Omo	Okomessi	Erin-Oke	Etionni	Apomu	Iregun
Temperature	Av Temp over Gp (^oC)	27	27	27	27	27	27
Water regime	Length of Gp (days)	304	304	304	304	304	304
	Annual rainfall (mm/year)	1360	1360	1360	1360	1360	1360
Nutrient Availability	Organic matter (kg/ha)	56,400	68,000	52,400	54,200	35,800	31,000
	Nitrogen (kg/ha)	4,800	5,800	4,600	6,400	3,000	3,400
	Phosphorus(kg/ha	8.58	12.80	12.16	11.66	8.00	15.26
	Potassium (kg/ha)	359.72	719.44	447.02	430.10	117.3	203.32
Toxicity	pH	5.8	6.1	6.0	5.8	5.6	80
Rooting Condition	Rooting depth (cm)	80	100	100	100	90	80
	Drainage class	5	5	5	5	4	4
	Texture class	5	5	5	5	5	5

(1) Key to drainage class 4 = moderately well drained, 5 = well drained

(2) Key to Texture Class 5 = loamy sand

(3) Gp = Growing period

Source: Field work, 2009.

Table 4.15. Description of land characteristics of soil series of the study area

Land Quality	Land Characteristics	Araromi	Itagunmodi	Owena	Matako	Irapa	Mamu
Temperature	Av Temp over Gp (^{o}C)	27	27	27	27	27	27
Water regime	Length of Gp (days)	304	304	304	304	304	304
	Annual rainfall (mm/year)	1270	1270	1360	1360	1360	1360
Nutrient Availability	Organic matter (kg/ha)	82,560	73,960	103,888	72,584	97,696	27,500
	Nitrogen (kg/ha)	4,200	3,800	5,200	3,600	5,000	800
	Phosphorus(kg/ha	132	106	126	134	106	16
	Potassium (kg/ha)	242	297	172	133	477	516
Toxicity	pH	6.2	7.0	6.9	5.6	6.2	6.1
Rooting Condition	Rooting depth (cm)	80	80	80	65	82	86
	Drainage class	5	5	5	5	4	5
	Texture class	5	5	5	5	3	5

(4) Key to drainage class 4 = moderately well drained, 5 = well drained

(5) Key to Texture Class 5 = loamy sand

(6) Gp = Growing period

Source: Field work, 2009

Table 4.16. Description of land characteristics of soil series

Land Quality	Land Characteristics	Olorunda	Oba	Jago	Egbeda	Ife	Ondo
Temperature	Av Temp over Gp (^oC)	27	27	27	27	27	27
Water regime	Length of Gp (days)	304	304	304	304	304	304
	Annual rainfall (mm/year)	1360	1360	1360	1360	1360	1360
Nutrient Availability	Organic matter (kg/ha)	48,816	44,720	28,208	113,520	27,520	44,000
	Nitrogen (kg/ha)	2,400	3,000	1,400	5,600	800	7,400
	Phosphorus(kg/ha	108.2	108.0	68.4	135.0	8.20	15
	Potassium (kg/ha)	70.38	62.56	156.4	359.72	39.10	110
Toxicity	pH	5.5	5.7	5.4	6.9	5.9	5.2
Rooting Condition	Rooting depth (cm)	90	85	55	95	50	90
	Drainage class	5	5	3	5	5	5
	Texture class	7	6	4	8	4	8

(7) Key to drainage class 4 = moderately well drained, 5 = well drained

(8) Key to Texture Class 5 = loamy sand

(9) Gp = Growing period

Source: Field work, 2009.

Table 4.17. Land suitability rating of the major soil series in Ife and Ilesha area

Land Characteristics	OLORUNDA				OBA				JAGO			
	Maize	U. Rice	Yam	Cassava	Maize	U. Rice	Yam	Cassava	Maize	Upland Rice	Yam	Cassava
1. Av Temp	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
2. Length of GP	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1	S2	S2
3. Annual Rainfall	S2	S2	S2	S1	S2	S2	S2	S1	S2	S2	S2	S1
4. Organic Matter	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
5. Nitrogen	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
6. Phosphorus	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
7. Potassium	S3	S2	S4	S4	S3	S2	S4	S4	S2	S1	S2	S2
8. pH	S2	S1	S1	S1	S2	S1	S1	S1	S3	S1	S2	S2
9. Rooting Depth	S1	S1	S1	S2	S1	S1	S1	S2	S2	S2	S2	S3
10. Drainage Class	S1	S1	S1	S1	S1	S1	S1	S1	S2	S2	S3	S3
11. Texture Class	S1	S1	S1	S1	S2	S2	S2	S1	S3	S4	S3	S3
12. Limiting Characteristics	S3	S2	S4	S4	S3	S2	S4	S4	S3	S4	S3	S3

Source: Field work, 2009.

Table 4.17. continues

Land Characteristics	IFE				ARAROMI				EGBEDA			
	Maize	U. Rice	Yam	Cassava	Maize	U. Rice	Yam	Cassava	Maize	U. Rice	Yam	Cassava
1. Av Temp	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
2. Length of GP	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1	S2	S2
3. Annual Rainfall	S2	S2	S2	S1	S2	S2	S2	S1	S2	S2	S2	S1
4. Organic Matter	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
5. Nitrogen	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
6. Phosphorus	S4	S3	S4	S3	S1	S1	S1	S1	S1	S1	S1	S1
7. Potassium	S4	S3	S4	S4	S1	S1	S1	S2	S1	S1	S1	S1
8. pH	S2	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1
9. Rooting Depth	S2	S2	S2	S3	S1	S1	S1	S1	S1	S1	S1	S2
10. Drainage Class	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
11. Texture Class	S3	S4	S3	S3	S2	S2	S2	S2	S1	S1	S1	S1
12. Limiting Characteristics	S4	S4	S4	S4	S2	S2	S2	S2	S2	S2	S2	S2

Table 4.17. continues

Land Characteristics	ITAGUNMODU				OWENA				MATAKO			
	Maize	U. Rice	Yam	Cassava	Maize	U. Rice	Yam	Cassava	Maize	U. Rice	Yam	Cassava
1. Av Temp	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
2. Length of GP	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1	S2	S2
3. Annual Rainfall	S2	S2	S2	S1	S2	S2	S2	S1	S2	S2	S2	S1
4. Organic Matter	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
5. Nitrogen	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
6. Phosphorus	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
7. Potassium	S1	S1	S1	S2	S1	S1	S2	S2	S2	S1	S2	S3
8. pH	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1	S1
9. Rooting Depth	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
10. Drainage Class	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S2	S2
11. Texture Class	S2	S2	S2	S2	S2	S2	S2	S2	S4	S4	S4	S3
12. Limiting Characteristics	S2	S2	S2	S2	S2	S2	S2	S2	S4	S4	S4	S3

Table 4.17.continues

Land Characteristics	OMO				OKEMESSI				IRAPA			
	Maize	U. Rice	Yam	Cassava	Maize	U. Rice	Yam	Cassava	Maize	U. Rice	Yam	Cassava
1. Av Temp	S2	S2	S1	S1	S2	S2	S1	S1	S1	S1	S1	S1
2. Length of GP	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1	S2	S2
3. Annual Rainfall	S1	S1	S12	S2	S1	S1	S2	S1	S2	S2	S2	S1
4. Organic Matter	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
5. Nitrogen	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
6. Phosphorus	S4	S3	S3	S3	S4	S2	S2	S3	S1	S1	S1	S1
7. Potassium	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
8. pH	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
9. Rooting Depth	S1	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1
10. Drainage Class	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S2	S2
11. Texture Class	S3	S3	S2	S2	S3	S3	S2	S2	S4	S4	S4	S3
12. Limiting Characteristics	S4	S3	S3	S3	S4	S3	S2	S3	S4	S4	S4	S3

Table 4.17.continues

Land Characteristics	ERIN-OKE				ETIONI				APOMU			
	Maize	U. Rice	Yam	Cassava	Maize	U. Rice	Yam	Cassava	Maize	U. Rice	Yam	Cassava
1. Av Temp	S2	S2	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1
2. Length of GP	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1	S2	S2
3. Annual Rainfall	S1	S1	S2	S1	S1	S1	S2	S2	S1	S1	S2	S1
4. Organic Matter	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
5. Nitrogen	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
6. Phosphorus	S4	S2	S2	S3	S4	S2	S2	S3	S4	S3	S3	S3
7. Potassium	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S3	S3
8. pH	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1	S1
9. Rooting Depth	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
10. Drainage Class	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
11. Texture Class	S3	S3	S2	S2	S3	S3	S2	S2	S3	S3	S2	S2
12. Limiting Characteristics	S4	S3	S2	S3	S4	S3	S2	S3	S4	S3	S3	S3

Table 4.17. continues

Land Characteristics	IREGUN				MAMU				ONDO			
	Maize	U. Rice	Yam	Cassava	Maize	U. Rice	Yam	Cassava	Maize	U. Rice	Yam	Cassava
1. Av Temp	S2	S2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
2. Length of GP	S1	S1	S2	S1	S1	S1	S2	S2	S1	S1	S2	S2
3. Annual Rainfall	S1	S1	S2	S1	S2	S2	S1	S1	S2	S2	S1	S1
4. Organic Matter	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
5. Nitrogen	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
6. Phosphorus	S4	S1	S1	S2	S3	S3	S1	S2	S3	S3	S1	S2
7. Potassium	S1	S1	S1	S2	S1	S1	S1	S1	S3	S1	S3	S3
8. pH	S2	S1	S1	S1	S1	S1	S1	S1	S3	S2	S2	S2
9. Rooting Depth	S1	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1
10. Drainage Class	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
11. Texture Class	S1	S1	S1	S1	S3	S3	S2	S2	S1	S1	S1	S1
12. Limiting Characteristics	S4	S2	S2	S2	S3	S3	S2	S2	S3	S3	S3	S3

Source: Field work, 2009

Table 4.18. Summary of land suitability classification of LECS for soils series

Soil series	Suitability score (%)			
	Maize	Upland Rice	Yam	Cassava
Omo	35.2 ($S4_f$)	52.8 ($S3_{fs}$)	55.2 ($S3_f$)	55.2 ($S3_f$)
Okemessi	35.2 ($S4_f$)	55.2 ($S3_s$)	73.6 ($S2_{fsc}$)	55.2 ($S3_f$)
Erin-Oke	35.2 ($S4_f$)	55.2 ($S3_s$)	73.6 ($S2_{fs}$)	55.2 ($S3_f$)
Etionni	33.6 ($S4_f$)	55.2 ($S3_s$)	73.6 ($S2_f$)	52.8 ($S3_f$)
Apomu	32.0 ($S4_s$)	52.8 ($S3_{fs}$)	55.2 ($S3_f$)	55.2 ($S3_f$)
Iregun	52.8 ($S3_f$)	80.0 ($S2_c$)	80.0 ($S2_c$)	73.6 ($S2_{fs}$)
Araromi	76.8 ($S2_c$)	76.8 ($S2_{cf}$)	76.8 ($S2_{cs}$)	73.6 ($S2_{fcs}$)
Itagumodu	76.8 ($S2_f$)	76.8 ($S2_c$)	76.8 ($S2_c$)	73.6 ($S2_{fs}$)
Owena	76.8 ($S2_{cs}$)	73.6 ($S2_{cs}$)	73.6 ($S2_{fcs}$)	73.6 ($S2_{fcs}$)
Matako	35.2 ($S4_s$)	38.4 ($S4_s$)	36.8 ($S4_s$)	52.8 ($S3_{fs}$)
Irapa	35.2 ($S4_s$)	38.4 ($S4_s$)	38.4 ($S4_s$)	57.6 ($S3_s$)
Olorunda	50.4 ($S3_f$)	73.6 ($S2_{fc}$)	36.8 ($S4_f$)	33.6 ($S4_f$)
Oba	50.4 ($S3_f$)	73.6 ($S2_{fcs}$)	36.8 ($S4_f$)	33.6 ($S4_f$)
Jago	50.4 ($S3_{fs}$)	38.4 ($S4_s$)	52.8 ($S3_s$)	52.8 ($S3_s$)
Egbeda	76.6 ($S2_c$)	73.6 ($S2_{cf}$)	76.8 ($S2_{cf}$)	76.8 ($S2_{cs}$)
Ife	32.0 ($S4_f$)	35.2 ($S4_s$)	33.6 ($S4_f$)	33.6 ($S4_f$)
Mamu	52.8 ($S3_{fs}$)	52.8 ($S3_{fs}$)	76.8 ($S2_{cs}$)	73.6($S2_{fcs}$)
Ondo	52.8 ($S3_f$)	52.8 ($S3_f$)	55.2 ($S3_f$)	55.2($S3_f$)

Limiting Characteristics

S1 = Highly suitable — c = climatic
S2 = Moderately suitable — w = wetness
S3 = Marginally suitable — t = topography
N1 = Presently not suitable — f = fertility
s = physical soil conditions

Source: Field work, 2009.

CHAPTER FIVE

DISCUSSION

The Ilesha and Ife areas of the Southwestern Nigeria were evaluated in terms of soils, landuse/landcover and land suitability for some common arable crops. The soil maps of the two locations – Ife area and Ilesha – were generated from the interpretation of aerial photographs and SPOT imagery and the resulting soils classified according to USDA (Soil survey staff, 2006), FAO/UNESCO (1990) and local systems.

At Ilesha, four Terrain Mapping Units (TMUs) were delineated and identified as D (Okemesi, Erin-Oke, Irapa, Omo and Etioni soil series), A (Egbeda, Olorunda and Matako soil series), E (Itagunmodi, Arorom, Ondo and Jago soil series), F (Mamu and Apomu soil series). Egbeda, Okemessi, and Itangunmodi, qualified for the order Alfisol as they possessed kandic horizons and a Base saturation > 35% at the specified depth. All soil series above fell into the sub-order udalf because they had udic moisture regime and the soil temperature was more than 8^0C.

Okemessi, Itagunmodi and Egbeda were classified as Kandiudalfs under the Great Group level as a result of the presence of Kandic horizons. Okemesi series had a kandic horizon with a hue of 2.5 YR and a value of 2 to make it Rhodic kandiudalf and Chromic Luvisol in the FAO/UNESCO system. Another two - Itangunmodi and Egbeda - were classified as Typic kandiudalf because they did not possess any sandy class extending from the surface to 100 cm, no mollic epipedon nor plinthite in any horizon. In the FAO system, they were classified as Orthic Luvisol.

Mamu fell under the order Inceptisol because it did not possess any of the other diagnostic horizons except a Cambic subsurface horizon. It was also grouped under sub order Udept because it was developed under an udic moisture regime and as a result of base saturation that was less than 60% thus making it a Dystrudept. With the low CEC values for this Mamu series and the absence of any lithic contact within 50 cm of the mineral soil surface, and the well drained profile status qualify it as Ruptic-Ultic Dystrudept with the corresponding FAO classification of Dystric Cambisol.

TMU D under spot imagery occupied a land area of 4,714.3 hectares (34.17%) and was 5,545.6 hectares under AP (40.20%); TMU A, was 5,286.5 hectares (38,32 %) under Spot and 4,483.4 hectares (32.5 %) under AP; TMU E was 2,467.1 hectares (17.88 %) under SPOT and 2,110.6 hectares (15.3 %) under AP; and TMU F occupied some 1,327.1 hectares (9.62 %) under SPOT and 1,655.4 hectares (12.0 %) under AP.

For the Ife area, TMU G, TMU H and TMU J were also identified by both methods of AP and SPOT. TMU G occupied a land area of 4,402.8 hectares (18.04 %) by SPOT and 5,296 hectares (37.2 %) under AP; TMU H was 9,469.4 hectares (38.8 %) under SPOT and 9,078.9 (37.2 %) by AP; while TMU J was 10,533.5 hectares (43.16 %) by SPOT and 10,274.8 hectares (42.1 %) under AP.

Inevitable differences were however expected arising from the peculiarities of the two methods. The method of interpretation of the two maps differed. While the AP was interpreted with a 3 X stereoscope, looking at the pictures in three-dimensional position of length, width and depth in demarcating the soils into their corresponding TMUs, the SPOT imagery was interpreted using a procom-2 where the stereoscopic vision was unavailable and signatures were viewed in length and width dimensions. In interpreting the AP, vegetation played a little role in the demarcations. Apart from using the riparian vegetation to map valley bottom soils, nowhere was vegetation used but the interpretation of SPOT imagery was based on the vegetative cover which completely shades the soil from being sensed. The cover especially the forest is known to be constantly under attack for human cultivation at an annual rate of 107ha/year in Ilesha area. At this rate, a soil map from SPOT in 1986 may likely be different from a map from SPOT image acquired in 1992 because the boundaries of these covers must have changed during the interval.

The AP in Ilesha area was shot in December while the SPOT was acquired in May. During the December period, the sky is clear with less cloud cover but in May, the vegetation is just starting to turn green resulting in diffused reflectance and the soot left behind by the bush burning has no boundary with any landscape features least of which is soil. The situation in Ife posed some problems. The flatness of the terrain coupled with the large forest and plantation areas completely covered the ground thereby making the demarcations more difficult.

Considering the TMU's individually, the mapping unit D1 in Ilesha area showed up very well in both AP and SPOT maps. The area occupied by the hill in AP map is larger than that of

SPOT. This is because, the stereoscopic interpretation separated the hill into the crest, interfluve and valley but only part of the interfluve and the crest still carrying the dense vegetation was mapped in SPOT. Despite the area difference, there was enough evidence to show the presence of a hill running north-south along that axis.

The mapping unit D2 in both AP and SPOT maps almost occupied the same area. This could be attributed to the numerous streams flowing in between the various hills that form Ijesha-Omo hills. The riparian forest along these streams together with the forest on top of these hills impact the red colour which made mapping of these hills easy. The mottle colour of yellow, blue and orange peculiar to the Oni and Atun plains on both sides of the hills also contributed in no small measure. The Oni, Atun and Ilesha plains showed up very well on the SPOT map and the TMU were clearly demarcated but it was difficult or impossible to demarcate valley bottom soils from the hill soils on the SPOT imagery.

In Ile-Ife area, the forest and the preponderance of cocoa plantations, in addition to the almost uniform level of the land gave a somewhat almost completely covered land that proved difficult for the landscape to be demarcated on the SPOT image. As can be seen from the degree of correlation between the two maps, the low correlation coefficient value compared to what was obtained in Ilesha can be attributed to the fact that the opportunity to examine the landscape with the different bands as in Ilesha did not exist in addition to the reasons earlier stated above.

The topography in Ife areas is almost flat. This gave easy access to land users for development, thus resulting in the same colour (reflectance) from nearly the whole area due to fallow. Even the few heights that showed up were not in any way as extensive as the hills in Ilesha to make their impact on the signatures. Individually, the Araromi hill made its impact as black parches dominated by the yellow colour of the forest on the crest. In terms of area coverage, the hill covered far more area in AP than in SPOT.
The hills in OAU, showed up as three black cycles and occupied almost the same area in SPOT as well as in AP maps. This might be due to the fact that the original vegetation must have been cleared and the resultant secondary vegetation did not make much impact on the reflectance from the hills. The Modakeke hills devoid of vegetation are distinct on AP as well as in SPOT imageries. Apart from these hills, the Oke-Opa plain showed up clearly.

However, correlation and t-test evidence showed that these mapping units produced by both methods for each location are really not too different in size. Thus if both methods produced and identified the same number, type and virtually the same size of mapping units for both locations, it means that the use of any of them becomes a matter of choice. If, however, the cost of acquision and interpretation rigours become a factor for choice it would appear that the AP would be a more economical choice than SPOT in terms of the production of soil maps for these two locations.

The Landuse/Landcover changes that occurred between 1975 and 2002 in Ilesha area present a unique picture, probably as a result of differences in cropping activities associated with dates of data acquisition. The Aerial Photographs (AP) was shot in December when virtually no farming activity was going on in the field and the Landsat in May when planted crops were still young. The situation in Ife area was equally not so dramatic considering the fact that the two data sets were acquired in the same month. This is what is recommended when mapping landuse/landcover of an area with remote sensing so as to reduce errors in interpretation and field checks (Fagbami, 1986).

Tables 18-20 show that a total of 2025 ha of forest land, representing 27.13% of the total forest area, were converted into other landuses – 1142 ha (15.30%) between the period 1975 – 1986 and 883 ha (13.06%) from 1986 to 2002 - in Ilesha area. This gives an annual destruction of forest land of 103.82 ha for the period 1975-1986 and 55.19 ha for 1986-2002. The aggressive depletion of forest land may be attributed to the influence of ADPs in encouraging farming and also the influence of College of Education staff in subsistence farming. The construction of the Gbongan/Ife/Ilesha expressway in the year 2000 virtually shifted the development of these three prominent towns towards the road thereby destroying the original forest land.

In terms of the built-up area there was an increase of 547 ha or 21.99% within the period of 1975 – 1986, translating to 49.73 ha/yr and 42.0 ha or 1.38% in the same landuse for the period 1986 – 2002, amounting to buildup rate of 2.63 ha/yr. The massive increase in shelter in Ilesha area, especially during the latter period, could be attributed to the creation of Osun State in 1991. Ilesha is very close to Oshogbo and many workers in Oshogbo, especially indigenes of Ilesha, preferred going to work from their town where they could put up shelters as against the high tenancy rate and prices of land that the new status of state capital bestowed on Oshogbo. In the period 1975 – 1986, the increase in built up could be attributed to the increase in population in the area. Soneye (1990), working in the same area, reported that Ilesha town doubled its size from 700 ha to 1400 ha in the period 1963 – 1977. This was also attributed to the increase in population. The establishment of the College of Education and the School of Agriculture in Ilesha also brought about an influx of workers and students that brought pressure on existing shelter. Also some factories, such as Trophy Brewery, also attracted some additional workers. All these put together resulted in high demand for shelter and consequently the built-up areas increased in size.

Fallow and cropland is another landuse of prominence in Ilesha area in the period 1975 – 1986. There was a gain of 308.0 ha or 10.10% of the total fallow area under study, representing an annual growth rate of 28 ha/year. Most of the new land must have come from the loss in forest land as a result of the bush rotation system of farming in which the land is allowed to fallow and regain its lost native fertility after 2 – 3 years of consecutive cultivation. In the period 1986 – 2002 (16 years) there was an astronomical increase in fallow/cropland by 1194.0 ha which is 35.56% of the fallow area under consideration, with an annual growth rate of 74.63 ha. A possible reason for the increase in fallow/cropland landuse could be attributed to government policies on some crops. The Obasanjo regime of 1999 – 2007 emphasized massive crop production such as the cassava initiative. This led to the putting large areas of land under cassava and rice.

Ife area

The forest landuse lost a total of 2,157 ha or 18.35 % of the total forest land from 1975 to 2002. Out of this, 900 ha (7.7%) was lost within 1975 and 1986, at an annual loss of 81.82 ha while 1,257 ha (11.58%) was lost from 1986 to 2002 at an annual rate of 78.36 ha. Most of the losses in forest were the gains in crop lands and built-up areas. In the period 1986 – 2002, forest loss could be attributed to the construction of the express way from Gbongan to Ilesha. This resulted in the shift towards the new road for commercial purposes. Also, the crisis between Ife and Modakeke made the latter people to leave Ife town and developed new abodes in the forest area of Modakeke.

In Ife area, 1029 ha or 25.26% of land was put under built-up landuse within the period of 11 years (1975 – 1986), with an annual rate of 93.55 ha while it was 1362 ha (26.69%) within the 1986 - 2002 period, at an annual rate of 85.13 ha. Most of this expansion took place within the university with the construction of undergraduate and post graduate halls, Faculties of Health Sciences and Pharmacy, the University Press and RECTAS. Also, the government gave a directive to universities to increase their student intake in 1975. This increase in student population resulted in the increase in built up areas especially in private hostels for students in Ife town when the accommodation within the university could not cope.

Fallow/cropland landuse was depleted in both periods of 1975 – 1986 and 1986 – 2002. In the former period of 11 years, this landuse lost 340.0 ha or 4.18% of the total fallow area, at a depletion rate of 30.91 ha while in the 16 year period of 1986 – 2002, the landuse lost 1017 ha or 13.04% of the fallow area under study with an annual depletion figure of 63.56 ha. This loss could be attributed to the fact that fallows, especially those close to homesteads, are the first to go when considering expansion for built-up landuse. The availability of white-collar jobs, especially in the university, and the attendant economic opportunities made young men not to be interested in farming.

The hill/water landuse gained 215 ha or 48.98% of this landuse in the period 1975 – 1986, at an annual rate of 19.55 ha while it as 912 ha (3.74 %), representing an annual rate of 57 ha within the period of 1986 - 2002. The construction of large bodies of water for the provision of domestic water supply especially the dam in the university campus as well as some large fish ponds by individuals increased the water bodies in the area. This expansion could also be attributed to the destruction of riparian forest to expose more water bodies that were previously covered by forest and classified as such.

Generally, therefore, the trend in both locations is for the other land use types to increase at the expense of secondary/riparian forests. If this is not controlled on time, it portends grave danger because of its negative impact on soil erosion, climate change and other general land degradation.

In terms of land evaluation, table 4.18 shows that the soils of the two locations are of varying degrees of suitabilities for the four different crops of interest (maize, upland rice, yam and cassava).

For the Ilesha area, maize was found to be moderately suitable in about 2,467.1 ha, representing some 17.88 % of the total land area, in the TMU E (Itagunmodi, Araromi, Ondo and Jago soil series), with the main limitation being texture and its consequences on drainage, rooting depth and fertility. The main fertility problem was low potassium. Maize was also marginally suitable in the TMU A (Egbeda, Olorunda and Matako soil series), covering some 5,286.5 ha or 38.32 % of the total land area. The limitations were mainly texture and fertility problems. The land area occupied by the TMU F and D (Mamu, Apomu, Okemessi, Erin-Oke, Irapa, Omo and Etioni soil series), some 6,041.4 ha or 43.79 % was found to be currently not suitable for maize production with limitations bothering on texture and fertility.

Upland rice was found to be only marginally suitable in some soils of Ilesha area (Omo, Okemessi, Erin-Oke, Etioni, Apomu) and presently not suitable in Matako and Jago with the major limitation being somewhat loose textures and low phosphorus values.

For yam 2,467.1 ha or 17.88 % of the total land area was found to be moderately suitable for the cultivation of this crop and restricted to TMU E (Itagunmodi, Araromi, Matako and Jago soil series), with limitations of texture and drainage.

For cassava production, nearly the whole Ilesha land area was found to be only marginally suitable (except Okemessi, Itagunmodi, Egbeda and Araromi soil series) with soil defects in texture, fertility (P, K and pH), depth and drainage. Thus the production of maize and yam, on a profitable basis, is restricted to 2,467.1 ha or 17.88% in TMU E areas of Ilesha.

For the Ife land area, maize was found to be marginally suitable in TMU J and H (Egbeda, Itagunmodi, Owena, Olorunda, Oba, Jago, Araromi, Matako and Iregun) covering a total land area of 20,003 ha (81.96 %) and with defects bothering on rainfall and slightly loose textures. Some 4,402.8 ha (18.04 %), found almost exclusively within the TMU G (Mamu, Ife, Apomu soil series) were found to be currently not suitable for maize cultivation mainly because of limitations in fertility (P and K) and texture.

10,533.6 ha, representing 43.16 % of the total land area and mainly in TMU J (Egbeda, Owena, Olorunda, Oba and Iregun soil series) was found to be moderately suitable for upland rice cultivation, with slight defects in pH. The remaining 56.84 % or 13,872.2 ha, located within the TMU J and G was considered marginally suitable for the cultivation of upland rice, with limitations being loose textures and low phosphorus values.

For the cultivation of yam, it was observed that the entire Ife land area was only marginally suitable with major limitations being texture, fertility (K and P) and some drainage imperfections. Similarly, the entire Ife land area was found to be marginally suitable for the cultivation of cassava, having defects in texture, fertility (K and P), drainage and soil root depth. Thus for Ife area, for profitable agriculture, it would appear that it is only 10,533.6 ha, representing some 43.16 % of the total land area TMU J that can be put into the commercial production of upland rice.

Put together, therefore, for the two locations, it would appear that TMU E in Ilesha (Itagunmodi, Araromi, Ondo and Jago), occupying some 2,467.1 ha or 17,88% of the total land area is the most suited for the commercial production of maize and yam while TMU J (Egbeda, Owena, Olorunda, Oba and Iregun soil series) of Ife land area, covering some 10,533.6 ha or 43.16 % of the total land area can be so exploited for the commercial cultivation of upland rice.

CHAPTER SIX

Summary and Conclusions

The need to monitor landuse/landcover dynamics has become urgent, especially now when uncontrolled deforestation and consequent desertification and the attendant green house effects, among others, have become a growing threat to our national life. Remote sensing techniques remain, for now, one of the most credible methods of generating landuse/landcover information because of speed and areal coverage advantage.

The study area (Ife and Ilesha) is located in the dry rainforest zone of Osun state in southwestern Nigeria. It is made up of Ife and Ilesha areas. The SPOT (HRV) imagery, Panchromatic black and white aerial photographs of both Ife and Ilesha areas, topographical maps, geological maps, vegetation and landuse maps, and soils and landuse maps were obtained from different and relevant agencies. They were interpreted in terms of soils, built-up, hill/water, fallow/crop cover and secondary/riparian forest areas yielding a total of four terrain mapping units (TMUs).from the SPOT imagery of the Ilesha area and three from the Ife area. Ground truthing was done through augering along the transects to identify the component soils of the TM Us. For the observation of soil morphological properties of each soil type, minipits measuring 50 x 80 cm x 80 cm were dug at representative points of the major soil types of each TMU. The pits were described, sampled and taken to the laboratory where standard methods were used for the analysis.

In Ilesha area four TMUs were delineated and identified as D (Okemesi, Erin-Oke, Irapa, Omo and Eti-Oni series), A (Egbeda, Olorunda, and Matako series), E (Itagunmodi, Araromi, Ondo and Jago series), and F (Mamu and Apomu series) using both methods. TMUs A, D and E with their component series qualified as alfisols while the TMU F and its component soil series was classified as an inceptisol. TMU D, under SPOT imagery occupied a land area of 4,714.3 hectares (34.17%) and was 5,545.6 hectares under AP (40.20%); TMU A was 5,286.5 hectares (38.32%) under SPOT and 4,483.4 hectares (32.5%) under AP; TMU E was 2,467.1 hectares (17.88%) under SPOT and 2,110.6 hectares (15.3%) under AP; and TMU F occupied some 1,327.1 hectares (9.62%) under SPOT and 1,655.4 hectares (12.0 %) under AP.

For the Ife area, TMU G (Mamu, Ife, Apomu and Etioni series), TMU H (Itagunmodi, Araromi, Matako and Jago series) and TMU J (Egbeda, Owena, Olorunda, Oba and Iregun series) were also identified by both methods of AP and SPOT. TMU G occupied a land area of 4,402.8 hectares (18.04%) by SPOT and 5,296 hectares (37.2%) under AP; TMU H was 9,469.4 hectares (38.8%) under SPOT and 9,078.9 (37.2%) by AP; while TMU J was 10,533.5 hectares (43.16%) by SPOT and 10,274.8 hectares (42.1%) under AP.

Landuse/landcover results for the Ilesha area showed that a total of 2325 ha of forest land, representing 14.84 % of the total land area, were converted into other landuses – 1142 ha (8.37%) between the period 1975 – 1986 and 883 ha (6.47%) from 1986 to 2002. This gives an annual destruction of forest land of 103.82 ha for the period 1975-1986 and 55.19 ha for 1986-2002. In terms of the built-up area there was an increase of 547 ha or 4.01% within the period of 1975 – 1986, translating to 49.73 ha/yr and 42.0 ha or 0.31% in the same landuse for the period 1986 – 2002, amounting to 2.63 ha/yr. Fallow and cropland is another landuse of prominence in Ilesha area in the period 1975 – 1986. There was a gain of 308.0 ha or 2.26% of the total area under study, representing an annual growth rate of 28 ha/year.

In the Ile Ife area, the forest landuse lost a total of 2,157 ha or 8.84% of the total from 1975 to 2002. Out of this, 900 ha (3.69%) was lost within 1975 and 1986, at an annual loss of 81.82 ha while 1,257 ha (5.15%) was lost from 1986 to 2002 at an annual rate of 78.36 ha. Most of the losses in forest were the gains in crop lands and built-up areas. Fallow/cropland landuse was depleted in both periods of 1975 – 1986 and 1986 – 2002. In the former period of 11 years, this landuse lost 340.0 ha or 1.39% of the total area, at annual depletion rate of 30.91 ha while in the 16 year period of 1986 – 2002, the landuse lost 1017 ha or 4.17% of the area under study with annual depletion figure of 63.56 ha. The hill/water landuse gained 215 ha or 0.88 of the study area in the period 1975 – 1986, at an annual rate of 19.55 ha while it has 912 ha (3.74%), representing an annual rate of 57 ha in the period of 1986 - 2002.

Generally, therefore, the trend in both locations is for the other land use types to increase at the expense of secondary/riparian forests. If this is not checked on time, it portends grave danger because of its negative impact on soil erosion and climate change.

In terms of land evaluation, the soils of the two locations were of varying degrees of suitabilities for the four different crops of interest (maize, upland rice, yam and cassava). For the Ilesha area, maize was found to be moderately suitable in about 2,467.1 ha, representing some 17.88 % of the total land area, in the TMU E (Itagunmodi, Araromi, Ondo and Jago soil series), with the main limitation being texture and its consequences on drainage, rooting depth and fertility. The main fertility problem was low potassium. It was marginally suitable in the TMU A (Egbeda, Olorunda and Matako soil series), covering some 5,286.5 ha or 38.32 % of the total land area. The limitations were mainly the inadequate and poorly distributed rainfall, texture and fertility problems. The land area occupied by TMUs F and D (Mamu, Apomu, Okemesi, Erin-Oke, Irapa, Omo and Etioni soil series), some 6,041.4 ha or 43.79% was found to be currently not suitable for maize production with limitations bothering on texture and fertility.

Upland rice was found to be only marginally suitable in all the soils of Ilesha area with the major limitation being coarse texture and low phosphorus values. For yam, 2,467.1 ha or 17.88% of the total land area was found to be moderately suitable for the cultivation of this crop and restricted to the TMU E (Itagunmodi, Araromi, and Jago soil series), with limitations of texture and drainage. And for cassava production, the entire Ilesha land area was found to be only marginally suitable with soil limitations in form of texture, fertility (P, K and pH), depth and drainage. Thus the production of maize and yam, on a profitable basis, can only be restricted to 2,467.1 ha – the TMU E (Itagunmodi, Araromi, Ondo and Jago soil series) area of Ilesha.

For the Ife land area, maize was found to be marginally suitable in TMUs J and H(Egbeda, Itagunmodi, Owena, Olorunda, Oba, Jago, Araromi, Matako and Iregun) covering a total land area of 20,003 ha (81.96 %) and with defects bothering on rainfall and slightly loose textures. Some 4,402.8 ha (18.04 %), found almost exclusively within the TMU G (Mamu, Ife, Apomu, and Etioni soil series) were found to be currently not suitable for maize cultivation mainly because of limitations in fertility (P and K) and texture.

10,533.6 ha, representing 43.16 % of the total land area and mainly of the TMU J (Egbeda, Owena, Olorunda, Oba and Iregun soil series) was found to be moderately suitable for upland rice cultivation, with slight defects in pH and rainfall pattern. The remaining 56.84 % or 13,872.2 ha, located within the TMUs J and G (Egbeda, Owena, Olorunda, Oba Iregun, Mamu, Ife, Apomu, and Etioni soil series), was considered marginally suitable for the cultivation of upland rice, with limitations being loose textures and low phosphorus values.

For the cultivation of yam and cassava, it was observed that the entire Ife land area was only marginally suitable with major limitations being textures, fertility (K and P) and some drainage imperfections. Thus for the Ife land area, for profitable agriculture, it would appear that it is only 10,533.6 ha, representing some 43.16% of the total land area (TMU J - Egbeda, Owena, Olorunda, Oba Iregun soil series) that can be put into the commercial production of upland rice.

In view of the above considerations, the following conclusions have become obvious:

- In terms of soil identification, survey and classification, as expressed in the soil maps, AP has proved to be more economical than SPOT. This is because if both methods produced and identified the same number, type and virtually the same size of mapping units for both locations, it means that the use of any of them becomes a matter of choice. And if the costs of acquision and interpretation rigours become a factor for choice then AP is at an obvious advantage.

- For landuse/landcover evaluation, the trend in both locations revealed that other land use types increased at the expense of secondary/riparian forests. If the trend is not controlled on time, it portends grave danger because of its negative impact on soil erosion and climate change.

- In terms of land suitability assessment for the cultivation of some common annual crops of interest, for the two locations, it would appear that TMU E in Ilesha (Itagunmodi, Araromi, Ondo and Jago soil series), occupying some 2,467.1 ha or 17,88% of the total land area is the most suitable for commercial production of maize and yam while TMU J (Egbeda, Owena, Olorunda, Oba and Iregun soil series) of Ife land area, covering some 10,533.6 ha or 43.16% of the total land area can be so exploited for the commercial cultivation of upland rice.

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APPENDIXES

MORPHOLOGICAL PROPERTIES OF SOIL PROFILES FROM STUDY AREA

Soil Series:	Omo
Profile No:	420
Author:	L. Edosomwan
Location:	Omo-Ijesa along Ilesha – Akure Road
Geomorphology:	Slope with slightly undulating terrain
Topographic Position:	Upper Slope

Soil Pedon characteristics

Soil depth:	80 cm
Surface feature:	Flat
Drainage:	Well drained
Root depth:	55 cm
Rockiness:	None
WT Level:	Below 80 cm
Presence of salt/alkali:	None
Stoniness:	Stony
Depth Conor:	80 cm

Horizon description

0 – 15	Dark brown (10 YR 2/3) dry, loamy sand, friable Many hard Fe/Mn Concretions, abundant quartz stones, many fibrous and Woody roots, clear smooth boundary.
15 – 25	Reddish brown (5YR 5/3) dry, loamy sand sub angular blocky, Fe/Mn concretions, many fibrous and woody roots, abundant quartz stones
25 – 55	Reddish brown (2.5 YR 4/4) sandy clay loam abundant quartz stones, few fibrous roots, sub angular blocky
55 – 80	Reddish (2.5 YR 4/6) sandy clay loam, abundant small quartz stones, medium angular blocky.

Information on Site

Soil series:	Okemessi
Author:	L. Edosomwan
Location:	Aiyegunle village, along Ilesha – Akure Road
Geomorphology:	Concave slope with steep gradient 18^0
Parent Material:	Quartz schist and Gneisses
Pedon No:	430
Topographic Position:	Upper
Landuse:	Rice farm

Pedon characteristics

Soil Depth:	80 cm
Surface features:	Flat
Drainage:	Well drained
Root Depth:	50 cm
Rockiness:	None
WT Level:	Below 80 cm

Horizon description

0 – 10	Dark Reddish brown (5 YR 3/2), dry, loamy sand, friable, many fibrous roots, may small quartz stones, gradual smooth boundary.
10 – 20	Reddish brown (5 YR 4/3) dry, sandy loam, many fibrous roots, few quartz pebbles with many small stones, gradual wavy boundary.
20 – 50	Reddish brown (5 YR 4/4) dry, sandy loam, moderate fibrous roots, big quartz Pebbles, clear smooth boundary medium sub angular blocky.
50 – 80	Dark red (2.5 YR 3/6), dry, sandy clay, few small quartz, smaller than upper layer.

Information on Site

Soil series:	Erin-Oke
Author:	L. Edosomwan
Location:	16 km from Erimo, along Ilesha – Akure Road
Geomorphology:	Slope with slightly undulating terrain
Parent Material:	Quartz schist and Gneisses
Pedon No:	440
Topographic Position:	Middle
Landuse:	Rice farm

Pedon characteristics

Soil Depth:	90 cm
Surface features:	Flat
Drainage:	Well drained
Rockiness:	None
WT Level:	Below 90 cm
Stoniness	Few

Horizon description

0 – 10 Dark reddish brown (5 YR 3/2) dry, loamy sand weak find crumbs, many fibrous roots slightly friable, clean smooth boundary.

10 – 30 Dark reddish brown (5 YR 3/3), dry sandy loam many fibrous roots, many small quartz stones with few pebbles, clear smooth boundary.

30 - 60 Yellowish red (5 YR 4/6) dry, sandy clay few fibrous roots, many big pebbles with quartz stones, medium sub angular blocky clear wavy boundary.

60 - 90 Yellowish red (5 YR 4/8) dry, sandy clay few quartz pebbles and stones. Has a decay parent material.

Information on site

Soil series	Etioni
Author:	L. Edosomwan
Geomorphology:	Concave slope
Parent material:	Quartz schist with gneisses
Pedon No:	450
Topographic Position:	Lower middle slope
Slope steepness:	14^0
Landuse:	Fallow

Pedon characteristics

Soil depth:	80 cm
Surface feature:	Low ridge
Drainage:	Well drained
Root depth:	55cm
Rockiness:	None
WT Level:	Below 80 cm
Stoniness:	Stony
Concretion:	None

Horizon description

0 – 15 Dark reddish brown (5 YR 3/2) dry, loamy sand, many fibrous roots, few quartz stones, gradual smooth boundary.

15 – 35 Reddish brown (5 YR 4/4) dry, sandy loam, many fibrous roots, abundant of quartz stones and gravels, gradual wavy boundary

35 – 55 Yellowish red (5 YR 4/6) dry sandy clay with big quartz gravels and many fibrous roots. Clear smooth boundary.

55 – 80 Yellowish red (5 YR 4/6) dry sandy clay. Few big quartz gravels, few patches of decaying parent materials.

Information on site

Soil series:	Apomu
Author:	L. Edosomwan
Location	18 km from Erimo, along Ilesha – Akure Road
Geomorphology:	Concave slope with undulating terrain
Pedon No:	320
Landuse:	Fallow
Topographic Position:	Lower
Slope:	7^0

Pedon characteristics

Soil depth:	90 cm
Surface feature:	Concave
Drainage:	Well drained
Root depth:	65 cm
Rockiness:	None
WT level:	Below 90 cm
Stoniness:	None
Parent material:	Quartzite schist

Horizon description

0 – 15 Dark brown (7.5 YR 3/2) dry loamy sand, no stone, no gravel, moderate amount of fibrous and woody roots, weak and granular.

15 – 35 Dark brown (7.5 YR 4/4) dry sandy clay. No stone with moderate amount of fibrous and woody roots, clear smooth boundary.

35 – 65 Strong brown (7.5 YR 5/6) dry sandy clay, no stone, no gravel, few woody roots medium angular block.

65 – 90 Strong brown (7.5 YR 5/6) dry sandy clay, firm angular blocky, wavy boundary

Information on site

Soil series:	Iregun
Author:	L. Edosomwan
Location:	10 km from Erin-Odo along Ilesha – Akure Road
Geomorphology:	Concave slope, slightly undulating 3^0
Parent material:	Quartz schist:
Profile No:	220
Topographic position:	Valley bottom
Landuse:	Riparian forest
Erosion:	Deposition

Pedon characteristics

Soil depth:	80 cm
Surface features:	Low ridge
Drainage	Moderately drained
Root depth:	55 cm
Rockiness:	None
WT Level	Below 80 cm
Stoniness:	None

Horizon description

0 – 20	Dark brown (10 YR 3/3) dry sandy clay, many fibrous and woody roots, irregular wavy boundary
20 – 50	Dark yellowish brown (10 YR 4/4) dry sandy clay, abundant fibrous and woody roots irregular wavy boundary. No stone/gravel
50 – 80	Dark yellowish brown (10 YR 4/4) dry sandy clay, woody roots, few boulders, irregular wavy boundary.

Information on site

Soil series:	Itagunmodi
Author:	L. Edosomwan
Location:	1 km from Itagunmodi village, off Ife – Ilesha Road
Geomorphology:	Convex, denudational slope
Parent material:	Amphibole
Pedon No:	012
Landuse:	Cocoa plantation

Pedon characteristics

Soil depth:	80 cm
Surface feature:	Low ridge
Drainage:	Well drained
Root depth:	60 cm
Rockiness:	None
WT level:	Below 100 cm
Stoniness:	None

Horizon description

0 – 15 Dark reddish brown (5 YR 3/3) dry loamy sand friable and loose, hard concretions with abundant woody and fibrous roots, gradual irregular boundary.

15 – 30 Dark reddish brown (5 YR ¾) dry, sandy loam. Firm consistence with tubular pores. Hard concretions with abundant fibrous and woody roots. Gradual irregular boundary.

30 – 45 Yellowish red (5 YR 4/6) sandy loam, weak and friable structure, loose consistence, hard concretions with woody roots, gradual irregular boundary.

45 – 80 Yellowish red (5 YR 4/6) dry sandy clay loam, friable structure with tubular pores and firm consistence.

Information on site

Soil series:	Araromi
Author:	L. Edosomwan
Location:	3 km from Itagunmodi village, off Ife – Ilesha Road
Geomorphology:	Denudational slope with undulating terrain
Pedon No.	014
Topographic position:	Upper slope
Landuse:	Cocoa farm

Pedon characteristics

Soil depth:	55 cm
Surface feature:	Concave
Drainage:	Well drained
Root depth:	35 cm
Rockiness:	Few
WT level:	Below 55 cm
Stoniness:	Very stony

Horizon description

0 – 15	Dark reddish brown (5 YR 3/2) dry sandy loam weak and friable structure, firm consistence with hard concretions, abundant fibrous and woody roots, gradual irregular boundary.
15 – 30	Dark reddish brown (5 YR 3/3), dry sandy clay loam, firm consistence, tubular pores, evidence of decomposing rocks, gradual irregular boundary.
30 – 40	Dark reddish brown (5 YR 3/3) dry sandy clay, weak structure, firm consistence with hard concretions, few woody roots, many stones.
40 – 55	Dark reddish brown (5 YR ¾) dry sandy clay with abundant stones. Firm consistence with hard concretions. Some woody roots.

Information on site

Soil series:	Matako
Author:	L. Edosomwan
Location:	2 km from Erimo, near a quarry site
Geomorphology:	Convex slope with deposited materials
Pedon No.	330
Topographic position:	Valley bottom
Landuse:	Cocoa plantation

Pedon characteristics

Soil depth:	55 cm
Surface feature:	Concave
Drainage:	Well drained
Root depth:	50 cm
Rockiness:	None
WT level:	55 cm
Stoniness:	None

Horizon description

0 – 15 Dark grayish brown (10 YR 3/2) moist sand weak friable structure, loose consistence with abundant fibrous roots, diffuse broken boundary.

10 – 30 Gray (5 YR 6/1) wet loamy sand, weak structure, loose consistence with moderate fibrous roots, diffuse broken boundary.

30 – 55 Light gray (5 YR 7/1) wet, loamy sand water table (55 cm) loose consistence, no concretion.

Information on site

Soil series:	Olorunda
Author:	L. Edosomwan
Location:	3 km from Erin-Odo on a path road to Ikogosi
Geomorphology:	Denudational convex slope with undulating terrain
Pedon No.	510
Topographic position:	Lower upper slope
Landuse:	Forest vegetation

Pedon characteristics

Soil depth:	85 cm
Surface feature:	Flat
Drainage:	Well drained
Root depth:	40 cm
Rockiness:	None
WT level	Below 85 cm
Stoniness:	None
Weatherable mineral:	Moderate

Horizon description

0 – 15	Dark brown (7.5 YR 4/2), dry sand with abundant fibrous and woody roots, weak fine crumbs, slightly hard and friable, clear smooth boundary.
10 – 28	Brown (7.5 YR 5/2) dry loamy sand with many fibrous and woody roots, gradual irregular boundary, weak fine crumbs, slightly hard and friable.
28 – 50	Strong brown (7.5 YR 5/6) dry sandy loam, weak fine crumb with woody roots. No concretion, clear smooth boundary.
50 – 85	Reddish yellow (7.5 YR 7/6) dry, sandy clay loam, medium sub angular blocky, slightly hard, firm and moderately shaky. Few quartz stones without mottles.

Information on site

Soil series:	Egbeda
Author:	L. Edosomwan
Location:	1 km from Erin-Odo, off Ilesha – Akure Road
Geomorphology:	Long and gentle denudational slope
Pedon No:	560
Slope steepness:	3^0
Landuse:	Fallow

Pedon characteristics

Soil depth:	92 cm
Surface feature:	Flat
Drainage:	Well drained
Root depth:	50 cm
Rockiness:	None
WT level:	Below 92 cm
Stoniness:	None
Topographic Position:	Middle slope

Horizon description

0 – 15	Dark reddish brown (5 YR 3/2) loamy sand, fine sub angular blocky structure, soft, very friable, many fine tubular pores, many fibrous and woody roots, clear smooth boundary.
15 – 30	Reddish brown (5 YR 4/3) loamy sand, moderate fine sub angular blocky structure, soft friable, many fine and medium tubular pores, many woody roots, gradual smooth boundary.
30 – 50	Reddish brown (5 YR 5/4) sandy clay, strong coarse sub angular blocky structure, slightly hard, firm sticky, many coarse irregular pores, many coarse biotite Gneiss, clear smooth boundary.
50 – 92	Yellowish red (5 YR 5/6) sandy clay, moderate fine sub angular blocky structure, very hard, firm, sticky, many fine tubular pores.

Information on site

Soil series:	Mamu
Author:	L. Edosomwan
Location:	500 m from Ikoromoja village
Geomorphology:	Concave slope with denudation
Pedon No:	560
Topographic position:	Lower slope
Landuse:	Forest vegetation

Pedon characteristics

Soil depth:	120 cm
Surface feature:	Flat
Root depth:	47 cm
Rockiness:	None
Stoniness:	None
WT level:	Below 120 cm

Horizon description

0 – 15	Dark brown (10 YR 3/3) loamy sand, moderate fine sub angular blocky structure, soft, friable, common coarse tubular pores, many fine and woody roots, gradual smooth boundary.
15 – 47	Dark reddish grey (5 YR 4/2) loamy sand, moderate fine sub angular blocky structure, soft, friable, many fine tubular pores, many fibrous and woody roots, gradual smooth boundary.
47 – 82	Reddish brown (5 YR 4/3) sandy loam, moderate coarse sub angular blocky structure, hard, fir, slightly sticky; gradual smooth boundary.
82 – 120	Yellowish red (5 YR 4/6), sandy loam; weak, very coarse sub angular blocky structure; very hard, firm, slightly sticky, common tubular pores.

Information on site

Soil series	Owena
Author:	L. Edosomwan
Location:	2 km from Itangunmodi village, off Ife – Ilesha Road
Geomorphology:	Convex
Undulating slope:	8%
Pedon No:	022
Topographic position:	Middle slope
Landuse:	Cocoa plantation

Pedon characteristics

Soil depth:	83 cm
Surface feature:	Convex
Drainage:	Well drained
Root depth:	55 cm
Rockiness:	None
WT level:	Below 80 cm
Stoniness:	None
Parent material	Amphibole

Horizon description

0 – 18 Dark reddish brown (5 YR ¾) dry, sand sub angular blocky structure, granular, firm with coarse tubular pores; irregular, wavy boundary.

18 – 39 Dark red (2.5 YR 3/6) dry, sandy clay loam; moderate sub angular blocky structure, firm, weak, fibrous and woody roots clear smooth boundary.

39 – 55 Dark red (2.5 YR 3/6), dry, sandy clay loam, weak, firm sub angular blocky structure, fine irregular pores, many woody roots, clear smooth boundary.

55 – 83 Dark red (2.5 YR 3/6) sandy clay, coarse sub angular blocky structure, irregular tubular pores.

Information on site

Soil series:	Oba
Author:	L. Edosomwan
Location	3 km from Erin-Odo, close to River Oni
Geomorphology:	Fluvial deposit of river channel
Pedon No:	025
Parent material:	Basement complex alluvia
Topographic position:	Middle slope
Landuse:	Riparian forest

Pedon characteristics

Soil depth:	108 cm
Surface feature:	Flat
Root depth:	40 cm
Rockiness:	None
Drainage:	Moderately drained

Horizon description

0 – 30	Dark grayish brown (10 YR 4/2), moist, loamy sand, weak medium crumbs, very friable, many fine fibrous and woody roots; gradual smooth boundary.
30 – 55	Very pale brown (10 YR 7/4), moist, sandy loam, gray mottles, slightly sticky, many fibrous and woody roots, clearly smooth boundary.
55 – 84	Light brownish grey (10 YR 6/2) we sandy clay loam, dark brown and gray mottles, moderately sticky with few quartz stones clear smooth boundary.
84 – 108	Light grey (10 YR 7/2), wet sandy clay loam, abundant rusty mottles, moderately sticky, few quartz stones.

Information on site

Soil series:	Ife
Author:	L. Edosomwan
Location:	500 m from Oke-Opa village, off OAU Staff quarters
Geomorphology:	Concave
Denudated:	Hill slope of 80%
Pedon No:	610
Topographic position:	Upper slope
Landuse:	Fallow

Pedon characteristics

Soil depth:	96 cm
Surface feature:	Flat
Drainage:	Well drained
Root depth:	44 cm
Rockiness:	None
WT level:	Below 96 cm
Stoniness:	Very stony

Horizon description

0 – 20 Dark reddish brown (5 YR 3/3) dry sandy loam, moderate sub angular blocky structure; soft, friable, slightly plastic, common fine tubular pores; common rock and stone, fine fibrous and woody roots.

20 – 44 Red (2.5 YR 5/6), dry sandy loam, moderately sub angular blocky structure soft, friable and slightly sticky, few woody roots; clear smooth boundary.

44 – 62 Dark red (2.5 YR 3/6), dry sandy clay, medium sub angular blocky structure, moderately sticky and slightly plastic, abundant stones and rock fragments, clear smooth boundary.

62 – 96 Dark red (2.5 YR 3/6) dry sandy clay medium sub angular blocky with abundant rock fragments, sticky and moderately plastic.

Information on site

Seed series	Mamu
Author:	L. Edosomwan
Location:	Ajubu
Geomorphology:	Concave slope with 6^0 slope
Parent material:	Schists
Pedon No.:	127
Topographic position:	Upper
Landuse:	Fallow

Pedon characteristics

Soil depth:	86 cm
Surface features:	Sloppy
Drainage:	Well drained
Root depth:	43 cm
Rockiness:	None
WT. Level:	Below 86 cm

Horizon description

0 – 12	Dark brown (10 YR 3/3) loamy sand, fine sub angular blocky structure, coarse tabular pores, fine and medium size roots, smooth boundary
12 – 43	Dark reddish grey (5 YR 4/2), sandy loam moderate sub angular blocky structure, friable, fine and moderate size roots, gradual smooth boundary.
43.68	Reddish brown (5YR 4/3), sandy loam slightly sticky, moderate coarse sub angular blocky, medium size roots, gradual smooth boundary.
68 – 86	Yellowish red (5 YR 4/6) sandy loam very coarse sub angular blocky structure, slightly sticky moderate size roots.

Information on site

Soil series:	Ondo
Auhtor:	L. Edosomwan
Location:	Ilerin
Geomorphology:	Slightly undulating
Parent material:	Granite and Gneisses
Pedon No.:	232
Topographic position:	Upper
Land use:	Secondary forest

Pedon Characteristics

Soil Depth:	90 cm
Surface feature:	Almost flat
Drainage:	Well drained
Root depth:	40 cm
Rockiness:	None
WT. Level	Below 90 cm

Horizon description

0 – 10	Dark Brown (10 YR 3/3), dry loamy sand, many fibrous and tap roots, gradual smooth boundary.
10 – 25	Brown (10 YR 4/3) dry sandy loam, few fibrous root with many tap roots, medium friable, wavy boundary.
25 – 58	Yellowish brown (10 YR 5/4) sandy clay, few taproots, wavy boundary.
58 – 90	Yellowish brown (10YR 5/8) sandy clay, medium angular blocky, well drained concretions.