THE APPLICATION OF ERS-SAR TO LAND DEGRADATION STUDIES IN THE BORGU NATIONAL PARK

BY

MHUSAYA KHWASHIM CHINDABA
M.TECH/SSSE/600/2000/2001

DEPARTMENT OF GEOGRAPHY
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

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SCHOOL OF SCIENCE AND SCIENCE EDUCATION

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DECLARATION

This is to certify that this Dissertation has been read and approved as meeting the requirements of the award of Masters in Technology in Remote Sensing Applications, Department of Geography Federal University of Technology, Minna.

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Dr. A.A. Okhimamhe Date
(Major Supervisor)

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Dr. M.T. Usman Date
(HOD Geography)

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(External Examiner) Date

Abalaka 20/11/03
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Prof. J.A. Abalaka Date
(Dean P.G. School)

DEDICATION

This Dissertation is humbly dedicated to my beloved wife Leng and, daughters Watarit-de and Rotshang.

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ABSTRACT

The Kainji Lake National Park (KLNP) is supposed to be a wilderness protecting the ecological integrity of the ecosystem but, on the contrary, there are both natural and anthropogenic factors which have led to land degradation. These include agriculture, overgrazing, fuelwood collection, deforestation, water erosion and the activities of the games. The most critical natural factor that precipitated erosion in the Park, is water erosion. The Park being the watershed of most of streams and rivers that drain into the Niger are dissected by rills and gullies. Under such a condition, human activities such as resource exploration and exploitation aggravated land degradation. Considering the size of the Park, it is only the use of ERS-SAR that can efficiently and effectively acquire data of degraded areas, most especially those that are inaccessible in the rainy season or in difficult terrain or thick vegetation cover. The researcher discovered that the ERS-SAR can acquire information on land degradation and mapping such areas of environmental disasters in general. Thereby, it explored ways and methods of ameliorating degradation in the KLNP in particular, and the other National Parks in general.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

The protection of wildlife (strict nature reserve) began with the creation of Nigeria, soon after the amalgamation of the northern and southern parts of Nigeria in 1914. A protected area is defined by the World Commission on Protected Areas (IUCN, 1994) as: "an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal and other effective means". Strict nature reserve is designated as an area under public control in which prohibited activities include: any hunting or fishing activities related to forestry, agriculture or mining; any work which alters the configuration of the soil or the character of the vegetation; any activity which is likely to have flora and fauna and the introduction of any indigenous or imported species. In practice, protected areas are managed for a wide variety of purposes which may include:

- wilderness protection,
- maintenance of environmental services
- preservation of species and ecosystems
- protection of specific natural and cultural features
- scientific research
- tourism and recreation

- education
- sustainable use of resources from natural ecosystems and
- maintenance of cultural and traditional attributes.

Putting the foregoing purposes together, one may be right to say that the Kainji Lake National Park (KLNP) is supposed to be natural land designated to protect the ecological integrity of one or more ecosystems for the present and future generations. It is an area of land where appropriate interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and cultural value. It is also supposed to exclude exploitation or occupation inimical to the purposes of designation of the area. Also, it is supposed to provide a foundation for spiritual, scientific, educational, recreational and visiting opportunities; and safeguarding the integrity of traditional interactions is vital to protection, maintenance and evolution of such an area; while providing at the same time a sustainable flow of natural products and services to meet community needs.

Be that as it may, it is discovered that some factors which may induce land degradation are precipitated in the parks. Land degradation here, implies the wearing down of the land surface. Soil degradation results from processes which lessens current and/or potential capacity of soil to produce goods or services. It is the deterioration, of the stability or the potential biotic productivity of land beyond that which might occur in nature.

Generally, activities which precipitate land degradation are prohibited, but there have been illegal encroachment in areas of forestry, agriculture, grazing, mining, excavation or prospecting, flying over a park at altitudes lower that 200m, levelling of the ground or construction, water pollution, hunting or capturing of any animal, uprooting, burning or damaging any tree or plant, setting fire to any vegetation, cultivation of the soil or making a farm or plantation, obstructing the channel of any river or stream, fishing or attempting to fish, the setting of way snare, trap or other instrument for the purpose of capturing animals, and any act likely to harm or disturb the flora and fauna of such areas.

Satellite remote sensing has become increasingly important for monitoring land resources and provide information on the geo-spatial distribution of land degradation. Human presence across the face of the earth is substantial and growing. Increasingly, from the perspective of outer space we can see the "finger-prints" of human presence on our landscapes. From the herringbone patterns of tropical deforestation, to the large square patches of agricultural fields, to the splotches i.e, irregular patches of urban sprawl, humans have attained the magnitude of a geological force as we reshape our environments scientists estimate that between one-third and one-half of our planet's land surface have been transformed by human enterprises. Yet scientists cannot say what, if any long-term impact, these changes will have on land surface or global climate systems.

Since the Industrial Revolution of 1870, scientists have observed a continued and accelerated soil degradation and the level of green house gases in the atmosphere. Of particular interest is the increase in cultivated areas to feed the industries that sprang up during the Industrial Revolution in both Europe and America. Of particular concern is the increase in cultivated land, increase in built-up of carbon-dioxide which are direct result of urban consumption agricultural produce and fossil funds as well as wide-spread use of fire in the tropics for deforestation. Over the last century, scientists have asked the question: How will plants respond to the accelerated rate of loss of soil? What is the rate of soil degradation? And many more. Scientists could not answer these questions then, but with the launches of European Earth Satellite-1 and 2 (ERS -1 and -2) Synthetic Aperture Radars (SARs) unprecedented new data becomes available to scientists around the world that will help them better understand and predict how earth's changing surfaces affect land degradation as well as how degradational processes will further affect flora and fauna.

ERS-SAR has been acquiring calibrated images since 1991. During the time SAR has acquired large quantities of data over large areas of the earth's surface. Indeed many areas have been imaged at frequent intervals and some even once per repeat period. With such large quantities of acquired data, there are opportunities for SAR images over large areas covering short periods of time to be available.

1.1.2 DEFINING LAND DEGRADATION

Land is the most significant zone of the solid earth's crust averaging about 17 km thickness of the globe as a whole. It contains the continents and the ocean basins and the source of soils and sediment salts of the sea and gases of the atmosphere (Strahler and Strahler, 1978). Land is anything on, above and below the earth's surface. It is composed of the lithosphere (i.e, continent), hydrosphere (i.e, water bodies) and atmosphere (i.e, gases).

Degradation is a process which tends to wear down the land surface; that is, the general reduction of land surface by both natural and man-made processes such as agents of erosion as water, wind, agriculture, mining and so on. Degradation is usually applied to river; it involves the deepening of the valley of the river and removal of materials which are transported elsewhere. The term is more commonly applied to stream or river's down-cutting of its bed when the load of loose, solid materials entering a stretch of river, for instance, is less than the amount it can carry, there the river wears away from its bed a greater amount than it deposits.

Degradation is one of the geomorphic processes which include: gradation, weathering, mass wasting or gravitative transfer, erosion including transportation by: running water, ground water, waves, currents, tides, tsunami; wind among a host of others. These geomorphic processes effect a modification of the earth's surficial form. A geomorphic agent or agency is any natural medium which is capable of securing and transporting earth material.

Unfortunately, there is a confusing variation in usage of the terms that designate the common geomorphic processes. To a certain extent this confusion results from differences in opinion as to what is included under certain processes, but to a considerable degree it is the result of carelessness in thinking and writing. Writers do not agree on what the seemingly simple process of erosion includes. Some include weathering, although there had been an increasing tendency to recognized that weathering is not part of erosion. There also may be a difference of opinion as to weather transportation is a part of erosion but it is usually so considered. Certainly, it is extending the meaning of erosion too far to consider aggradation as a part of it. The following degradational processes will be discussed in the general levelling down of the surface: water erosion, run-off, leaching, compaction, wind erosion and so on.

1.1.3.1 Erosion

Erosion as an environmental problem relating to soil degradation resulting from the interaction of natural factors of climate, topography and parent rock with anthropogenic factors related to land-use pattern. By definition, soil erosion is a geomorphological process through which the surface layer of weathered rock is loosened and carried away by wind or moving water and a lower horizon in the soil is exposed. In many cases, soil erosion is a slow and almost imperceptible process where there are no human activities. Where human activities are noticeable, the rate of erosion far exceeds the rate of soil regeneration by nature. This is due to rapid and thoughtless exploitation based on attempt to obtain maximum yield in minimum time scale in the form of excessive cultivation, over-grazing, improper tillage practices, lack of adequate knowledge of the soil and its performance characteristics, inability or unwillingness to commit other resources to conservation measures. Here, emphasis is on: water and wind erosion.

Water Erosion: This is the erosion in which particles are loosened by water and transported from their previous sites. Depending on the character, water erosion is usually classified as:

(i) Sheet erosion, which means removal of a fairly uniform layer of soil from the land surface.

(ii) Rill erosion, which produces many small channels a few millimetres deep.

(iii) Gully erosion, which produces channels that cut deeply into the soil. Gully is often a second stage following from sheet or rill erosion.

Accelerated soil erosion by water occurs most commonly when human activity, such as farming, cattle rearing, forest harvesting and fuelwood collection, roads, airports and settlements and so on change the ecological balance of an area and leaves the soil unprotected by vegetation. In general, soil erosion by water is accelerated when rainfall is intense and prolonged, run-off is extensive and fast, soils are highly susceptible to detachment and transport, slopes are steep and long, vegetation gives little protection because of ineffective canopy and poor littering or rooting, cultivation or tillage practice are not appropriate for the topography and/or soil types.

Water erosion is found to be prevalent in the whole of Nigeria. It is estimated that over 25% of the total land of Nigeria is under severe erosion by water with over 2000 critical gully sites identified all over the country (Gowon, 1997). Gullies are found in all the Local Government Areas in all the seven states of the south-east, and of Kogi, Niger, Plateau, Benue, Gombe, etc. It is also prevalent in the south western states of Edo, Delta, Oyo, Ondo from mild to severe and many are right in the heart of residential areas, splitting communities into isolated pockets. Without doubt, soil erosion is the best-known among the components of environmental degradation in Nigeria. While the southern three-fifths are eroded by rainfall, the northern quarter is eroded principally by the wind. The impact of soil erosion has wide dimensions. They range from the truncation of transportation bases and routes to the collapse of buildings, from the collapse of wildlife habitats to the diminution of rangeland and farmland, from damage to electricity installations to disruption of water works, and from reduction of soil fertility and recreational potential to loss of livestock and human life.

Wind Erosion: This is the geomorphological process where wind eddies drive sand and dust particles from their previous locations. Soil erosion by wind takes place mostly in arid and semi-arid environments with sparse vegetation or completely absent. Generally, soil erosion by wind is accelerated when strong winds occur during dry periods. Erosion by wind is mostly prevalent in Nigeria in areas 11°N Latitude.

Desertification is a major scourge in large parts of northern one-fifth of Nigeria. Adjacent to the semi-arid fringe of the Sahara desert, this area is subject to the devastating southward advancement of semi-desert conditions. These are more noticeable during the protracted (October to May) yearly dry season, with its peak in the harmattan months, when incredible loads of dust and sand mask the land surface, causing havoc to man and his property, and when the soil becomes bone-dry, making unirrigated-crop farming impossible. Man, of course, actively aids desertification through a myriad of activities: bush burning overgrazing by his livestock (mainly cattle, sheep and goats), and land clearance for different purposes.

1.1.3.2 Run-off

This is the portion of precipitation which ultimately flows into rivers and streams. It consists of the water which flows off the surface instead of sinking into the ground, together with some of the water which originally sank into the ground and joins it later in the rivers and streams. The part of the precipitation which leaves the ground surface at once and enter streams or rivers is called the immediate run-off. Most of the water that sinks into the ground eventually returns to the surface by seepage and from springs and is called delayed run-off. The run-off is faster and greater:

- During heavy rain than during a protracted drizzle.
- On clay soils than on sandy soil
- On frozen soils than on frost less soils
- In treeless areas than in the forests.
- The rate of evaporation over the area

The ratio between run-off and precipitation varies considerably with climatic conditions.

1.1.3.3 Leaching

Leaching is one of the soil degradational processes that occur in this region though is more intense in humid climates. Leaching here is the process of removal of soluble substances such as humus and base from the 'A' horizon downward to 'B' horizon by rain-water. Translocation of materials within the soil takes place in a number of quite different ways, each with a different cause and often uniquely related to a particular soil-water regime. Two simultaneous processes of downward translocation are eluviation and illuviation. Eluviation consists of the downward transport of fine particles, particularly organic and mineral, carrying them out of an upper soil horizon, usually the lower part of 'A' horizon. Eluviation leaves behind coarse skeletal mineral grains. Illuviation on the other hand, is the accumulation of materials in the lower horizon, brought down from a higher horizon-usually from 'A' to 'B' horizons. These processes of eluviation and illuviation as it translucid organic materials downwards the soils become degraded.

1.1.3.4 Salinization

A process in soils resulting in the accumulation of highly soluble salts such as sulphate and chlorides of calcium and sodium. Salinization is intense in dry climates and regions with very distinct dry seasons as in the savanna regions under study, especially in areas where drainage is poor and the rate of evaporation is high. Salinization is also common along low lying coastal stretches in arid climates, and in valley floors and basins in the interior of continents. The reverse process of removal of salts is desalinization.

1.1.3.5 Soil Compaction

In recent times, excavations for laterite have assumed new dimensions occasioned by an ever-increasing tempo of infrastructural development in Nigeria. Most noteworthy are developments in the transportation and the housing sectors. Excavation of laterite for road construction on segments of land adjacent to most highways in Nigeria are a common phenomenon. Such laterite is spread and subsequently compacted to form the base on which gravel or stone clippings and, later, bitumen or asphalt are spread to complete the road construction process. In the housing sector, such laterite materials are invariably used in the filling of the floor space where necessary.

Man has carted tones of earth to aid him in the reshaping and modification of the natural environment. Excavations for sand are more often than not associated with the procurement of sand for the making of sandcrete blocks and for use in other construction jobs. Closely associated with sand excavation is the excavation for gravel which like sand, is indispensable in many construction projects.

Sand and gravel excavations are largely confined to the beds of streams and rivers and their banks. Environmental degradation endangered by these activities is usually exacerbated by excavators of river sand and gravel contractors, tipper lorry drivers and casual labourers. Use of the land in this respect, has enhanced the rate and areal extent of soil erosion, which during the rainy season, is accompanied by landslides along deep excavated portions of the banks. Tipper lorries make their own contributions to land degradation process by constant use of unpaved tracks leading to the stream banks. Such tracks subsequently convert to erosion channels and are thereupon abandoned by the users for yet new and fragile locations.

1.1.3.6 THE SAVANNA WOODLAND AND LAND DEGRADATION

The savanna generally is an expanse of tropical grasslands between equatorial forests and hot deserts. Examples are found in Africa immediately south of the Sahara, in South America on the Guiana Plateau and in northern Australia. The vegetation consists mainly of tall grasses with widely dispersed short trees and thorny bushes. Where ground-water is available, drought-resistant trees like the baobab, acacia, palm and euphoria are found. The appearance of the savanna changes during the year owing to the pronounced rainfall regime. During the long dry seasonal the grass is parched and withered, but with the on-set of the rains the vegetation strives again. (Buchanan, 1974)

The savanna woodland specifically consist of trees spaced rather widely apart, permitting development of a dense lower layer which usually consists of grasses. The woodland has an open, park-like appearance. Although plant formations of this general description can be found in a wide range of latitude, there, the soil-water shortage to an amount too small to sustain a closed-canopy forest. Savanna woodland topically forms or belt adjacent to equatorial rain-forest in which soil-water storage remain's high throughout the year.

In the tropical savanna woodland of Nigeria, the trees are of medium height, the crowns are flattened or umbrella-shaped, and the trunks have thick, rough barks; some species of trees are xerophytic forms with small leaves and thorns; others are broad-leaved deciduous species that shed their leaves in the dry season. In this respect, savanna woodland is akin to monsoon forest, into which it grades in some places (Strahler and Strahler 1978).

In Nigeria, savanna woodland grades into a belt of thorntree-tall grass savanna, a formation class transitional into the desert biome. The trees, largely of thorny species, are more widely scattered and the open grassland is more extensive than in the savanna woodland. One characteristic tree is the flat-topped acacia (Acacia), another is the grosteque baobab (Adansonia digitata), with its barrel-shaped water-storing trunk. Elephant grass (Pennistetum puerperium) is a common species: it may grow to a height of 5 metres to form a thicket impenetrable to humans. Because of the dominance of grassland over the woodland, this formation class may equally well be placed in the grassland biome in terms of structure.

Having seen what the Savanna woodland looks like, it is imperative at this juncture to discuss on the processes that may induce land degradation. Land which is the fulcrum of human existence has been tormented by degradational processes some under humanly induced and others naturally induced. Since the late 1970s, considerable changes have taken place in the proportions of land associated with the type of farming system activity. Increased public and private interest in plantation agriculture, for example, has brought about more land conversion in favour of that sector than hitherto.

Another major component of Nigerian agriculture is the traditional herding of animals such as sheep, goats, cattle, camels, etc, in different parts of the country, but particularly in the northern half of the country. Known as nomadic pastoralism, it involves a seasonal sequence of movements, in search of pasture and water supply for livestock. Pastoralism has serious implications for environmental degradation since it takes place in a geographic region characterized by aridity. The animals pose a serious threat to the regeneration of the natural vegetation and encroach on farms planted with arable crops which they devastate.

Over the past fifty hears, mining and quarrying have equally made their unique demands on the land inventory in Nigeria, no matter how negligible in terms of contiguous areal coverage. Prior to the discovery of crude oil, coal was Nigeria's principal energy source for electric power generation and constituted the fuel for driving the country's railways locomotives.

With respect to the mining industry, most especially the oil drilling industry. Crude oil exploration and aggressive exploitation have led to the discovery of new oil fields leading to disastrous environmental impacts on the environment. For example, much land has been laid bared, and erosion has taken over large expanse of land. Also, the excavations for laterite, sand, and quarry for clay and gravel and stones are common features in many different parts of the country. A few decades ago, excavation for laterite and less lateritic soils were largely associated with the provisions of treated mud for construction and plastering of the earthen walls of traditional dwelling huts, a variant of which is the mud-and-wattle huts characteristic of many cultural groups in Nigeria.

Fire is a frequent occurrence in the savanna woodland during the dry season. The trees of the savanna are of species that are particularly resistant to fire. Many biogeographers hold the view that periodic burning of the savanna grasses is responsible for the maintenance of the grassland against invasion by forest. Fire does not kill the underground parts of grass plants, but it limits tree growth to a few individuals of fire resistant species. The browsing of animals, which kills many young trees, is also a factor in maintaining grassland at the expense of forest. Many rainforest species that might otherwise grow in the wet-dry climate region are prevented by fires from invading. On the other hand, where vegetation is cut-down and burnt by the slash-and-burnt or other deforestation methods leads to land degradation.

1.1.3.7 THE CONTRIBUTIONS OF REMOTE SENSING AND ERS-SAR

Remote sensing is a device that collects information about an object from a distance without touching it, except perhaps with energy emitted from a sensor. That is, it is the art, science and technology that collects information (decoded from electromagnetic radiation- EMR), using sensor (i.e. device that records without physical contact). The technique includes the use of aerial photograph, air- and space- borne images. Presently, it is used in various fields for data collection including soil erosion, desertification encroachment, lakes and dams monitoring, mineral resources targeting, water resources mapping, geological mapping, land-use mapping, soil mapping, oil spillage mapping, forestry mapping, producing topographic maps, to mention but a few.

The main types of sensors include: photographic films, passive electromagnetic devices, active electromagnetic devices and active non-electromagnetic devices. Photographic films are generally from aircraft but can be from spacecraft (shuttle). The sensor is silver crystals and sensitive to light (visible electromagnetic energy- EME). It could be panchromatic (several colours) or single-colour, which may not be visible, for example, in infrared. The product is a photograph. Passive electromagnetic devices are generally from satellites but there are specially-equipped aircrafts. The sensor is an electronic detector, sensitive to electromagnetic energy from a definite part of the spectrum (UV through MIR). The product is digital record of the sensor response, which can be converted to photographs. Digital cameras use similar technology but are aimed at the same uses as photographic film for "near" remote sensing (i.e. remote sensing "close" to object, e.g, infrared heat detectors for home insulation, ordinary photographs). The distinction between these and photographs will disappear soon. Active electromagnetic devices are generally from aircraft but can be from satellites. The apparatus directs energy towards the earth and receives a part of it as a return signal; the energy level time differential, or phase differential are recorded in digital form, example is radar. The product is a digital record of the sensor response which can be converted to photographs. Active non-electromagnetic devices are from aircraft. Spacecraft are too far to receive a non-electromagnetic return signal. The apparatus emits non-electromagnetic energy, e.g, sound waves (sonar), and receives a part in return; the time and phase differentials are recorded.

At this juncture, it is important to state the advantages of remote sensing. Remote sensing is relatively cheap and rapid method of acquiring up-to-date information over a large geographical area. Even with the cost of ground truthing this is very economical. It is the only physical way to obtain data from inaccessible regions, e.g, thick forested region. At small scales, regional phenomena which are visible from the ground are clearly visible. Examples: faults and other geological structures. A classic example of seeing the forest instead of the trees. It is cheap and rapid method of constructing base maps in the absence of detailed land surveys. It is easy to manipulate with computer, and combine with geographic coverages in Geographic Information System (GIS).

On the other hand, the disadvantages of remote sensing is that it is not the direct samples of the phenomenon, so must be calibrated against reality. This calibration is never exact, a classification error of 10% is excellent. It must be corrected geometrically and georeferenced in order to be useful as maps, not only as pictures. This can be easy or complicated. Distinct phenomenon can be confused if they look the same to the sensor, leading to classification error. Example: artificial and natural grass in green light (but infrared light can easily distinguish them). Phenomena which are not meant to be measured (for the application at hand) can interfere with the image and must be accounted for. Examples for land-cover classification: atmospheric water vapour, sun versus shadow (these may be desirable in other applications). Resolution of satellite imagery is too worse for detailed mapping and for distinguishing small contrasting areas. Rule of thumb: a land-use map must occupy at least 16 pixels (picture elements, cells) to be reliably identified by automatic methods. However, new satellites are being proposed with 1 metre resolution, this will have high data volume and will be suitable for land-cover mapping at a detailed scale.

The launch of the ERS-1 SAR in 1991, and the subsequent launches of SAR, ERS-2 SAR, and Radarsat (1995), have changed the course of RADAR remote sensing research worldwide. ERS-SAR is an active system sensor which utilizes the microwave portion of the electromagnetic spectrum. It illuminates the earth's surface and measures the reflected signal, generating microwave images of the surface. SAR emits a pulse of energy and then receives and interprets the echo to produce an image. Earth observation data from the ERS-SAR is helpful in the assessment and/or forewarning of a range of environmental risks and hazards in the wilderness whether natural or man-made.

The European Space Agency (ESA) perceives ERS-SAR as an end to end system combining high on board performances with on-ground performance measurements precise data processing and suitable transmission of data related information to the user community. Such a synergy between ERS space and ground segments is well. Thus traced by the SAR radiometric calibration activities. The combination of internal calibration parameters availability with accurate on-ground measurements gives to ERS user community the first opportunity to work with precisely calibrated SAR products acquired over a long time period.

The merits of ERS-SAR include its weather independent. The microwaves emitted and received by the ERS-SAR are at a much longer wavelengths (5cm) than optical or infrared waves. Microwaves can therefore easily penetrate clouds, and images of the surface acquired irrespective of local weather conditions. Because of its long wavelength, SAR can penetrate clouds, snow, dust, haze, darkness and so on. It enables the collection of data under any atmospheric condition and regardless of solar illumination.

SAR is ideal for monitoring land applications such as agriculture, temperate and tropical forestry, most especially the canopy of trees, thus providing information about hidden features. ERS-SAR is ideal for monitoring changes in crop properties with crop development, including ploughing and tilling activities. It also offers the opportunity to provide mapping, modelling, classification, cartographic mapping, urban planning and development.

SAR instruments with a high temporal coverage capacity of 2 days represent a unique asset in such inhospitable environments. The penetration depends partly on its wavelength. Microwaves penetrate the canopy of a forest, soil and sand, thus, providing information about visible hidden features. The all-weather penetrating capacity of ERS-SAR is particularly valuable in tropical areas such as the Amazon basin area extremely remote and extensive, making mapping and monitoring of forest resources by traditional methods, such as aerial photographs, a formidable task.

ERS-SAR, provides unique parameters. Images provided by optical sensor contain information about the surface layer of the imaged objects (i.e, colour), while microwave images provide information about the geometric and dielectric properties of the surface (e.g, roughness) or volume (i.e, chemical composition, moisture) studied, allowing unique properties of the target to be revealed. Data acquired from slightly different orbit can be combined to produce stereo image. SAR stereo-pairs can be used to view a scene in three dimensions, very useful for geological applications, or monitoring ice movement, relief maps of the earth's surface.

To cap it up, it is important to mention that thee use of ERS-SAR data is providing a marked improvement in the accuracy of maps produced for developing countries. The SAR data are being combined with data from optical sensors such as SPOT (Satellite Probatoire pour C'observation dela Terre), to help increase the thematic and in particular the geolocation accuracy of the latter. The use of interferometric techniques for the production of digital elevation models is potentially a major application of SAR data.

Having seen the advantages of ERS-SAR, it is important to take a look at its disadvantages. At low wind speeds, ocean slicks of natural origin are frequently observed and may cause false alarms unless experienced operators or very advanced pattern recognition methods are used. Also, at high wind speeds the pollutant may be mixed, with sea water and no surface effect is detected by the SAR. ERS-SAR as a sun-synchronous satellite can not be brought to the ground for maintenance and as they continue in space, they disturb clouds when disintegrated. Its repetitive orbiting and sending of the same signals over time certainly cost more. ERS-SAR is costly to be developed and long period to be launched. This makes its development a prerogative of developed and rich nations. Also, the maintenance of equipment and personnel at ground stations are high.

1.2 PROBLEM STATEMENT

Land as a resource has various competing economic uses to which it can be put to in Nigeria. It is taken as the long-term resource of the country. Defined as that solid part of the earth's surface, as we have seen, it supports both plants and animals, including human life both directly and indirectly. This is because it provides physical support and food for plants, which, in turn form the basis of animal nourishment. Other functions include provision of sites for various human activities such as cultivation, and settlements. It is also a source of raw materials industrial production, construction, and a repository of energy resources. However, land sustainable performance for meeting these functions depend on the characteristics of relief and soils, and the manner it is owned and used. One of the features of relief is the observed state of degradation.

In recent years, environmental degradation has become a matter of central concern for humanity in the sub-Saharan region of Africa. Some of the critical environmental problems are deforestation, shifting cultivation, soil erosion, desertification, loss of genetic diversity of flora and fauna, just to mention a few. These problems are interlinked and are gradually leading to series of socio-economic consequences which are bound to impede the progress of prosperity. Major causes of these problems are increased human population and some outside influences . The United Nations Environment Programme (UNEP) estimated in 1991, that 80% of Nigeria's dryland and rangelands were showing significant loss of vegetative cover. Food and Agricultural Organization of the United Nations (FAO), has also predicted that if care is not taken, more than 20% of Nigerians croplands will be lost by the year 2010. Thus, there is the need to reconcile this disastrous conflicts between human efforts and environmental constraints in Nigeria in general and the savanna woodland ecosystems in particular should be viewed with more concern by all and sundry.

By 1970, however, the problem of the environment had become international in scope. The oceans, seas, land and air are seriously polluted. Land degradation has resulted in a decline in the quality of fresh water available for human consumption, agriculture and industry, a reduction of goods and services and significant decline in biodiversity. For addition, land degradation has severe impact on food security, livelihood, economic, socio-cultural activities of an environment and its people. It causes a lot of economic disruption and it is responsible for drastical fall of Gross Domestic Product (GDP) of 18.4% in 1971/72 and of 7.3% in 1972/93 (FAO and UNEP, 1983).

Land degradation has rapidly precipitated drought and desertification and also spread the advancement of desertification southward. This led to migration southwards causing competition on scarce resources and sometimes in communal clashes. It precipitates conflicts over land resources are focused on areas of high productivity, especially those that provide seasonal critical resources such as freshwood, pasture, wetlands which have competitive uses among the various land users, notably farmers, herders, fishermen and hunters. In many places, the flora and fauna have been badly depleted as a result of climatic variability and human mismanagement and/or over-exploitation of the environment. Some fauna species such as antelope, cheetah, lion, giraffe and elephants are endangered. With regard to flora, most of the indigenous plant species are now hard to comeby especially those with medicinal value and edible qualities, such as Khaya senegalisis and Mitrogina spp. Generally, destructive logging practices, over-harvesting of resources lays the surface bare and susceptible to agents of denudation.

Human interference on parks have led to the extinction of both plants and animals. Human activities such as agriculture and grazing have turned many areas into scrub land. Threat to the protected areas include: shifting cultivation and over-exploitation of indigenous species, subsistence an commercial agriculture, illegal grazing in protected areas; cattle migration; poaching, uncontrolled bush-fires; drought, particularly as observed in the savanna regions, an ever- increasing fuel-wood and timber-demand unsuccessful plantation establishment and settlements within reserves; expansion of road net-works, mineral exploration and extraction activities; and local irrigation and damming schemes. Several areas of parks are being deserved for agricultural, industrial or pastoral purposes.

1.3 AIM AND OBJECTIVES

1.3.1 AIM

The aim of this study is to examine the extent of land degradation on the Borgu Sector of the (KLNP) using Earth Resources Satellite-Synthetic Aperture Radar (ERS-SAR).

1.3.2 OBJECTIVES

The objectives of this study are:

(1) To identify and map degraded areas emanating from both natural and anthropogenic factors.

(ii) To identify the main factor causing the increasing land degradation in the Borgu sector of KLNP using Remote Sensing Technology and ERS-SAR.

(iii) To proffer solution towards soil conservation most importantly the National Parks in general, and Borgu Sector in particular.

1.4 JUSTIFICATION

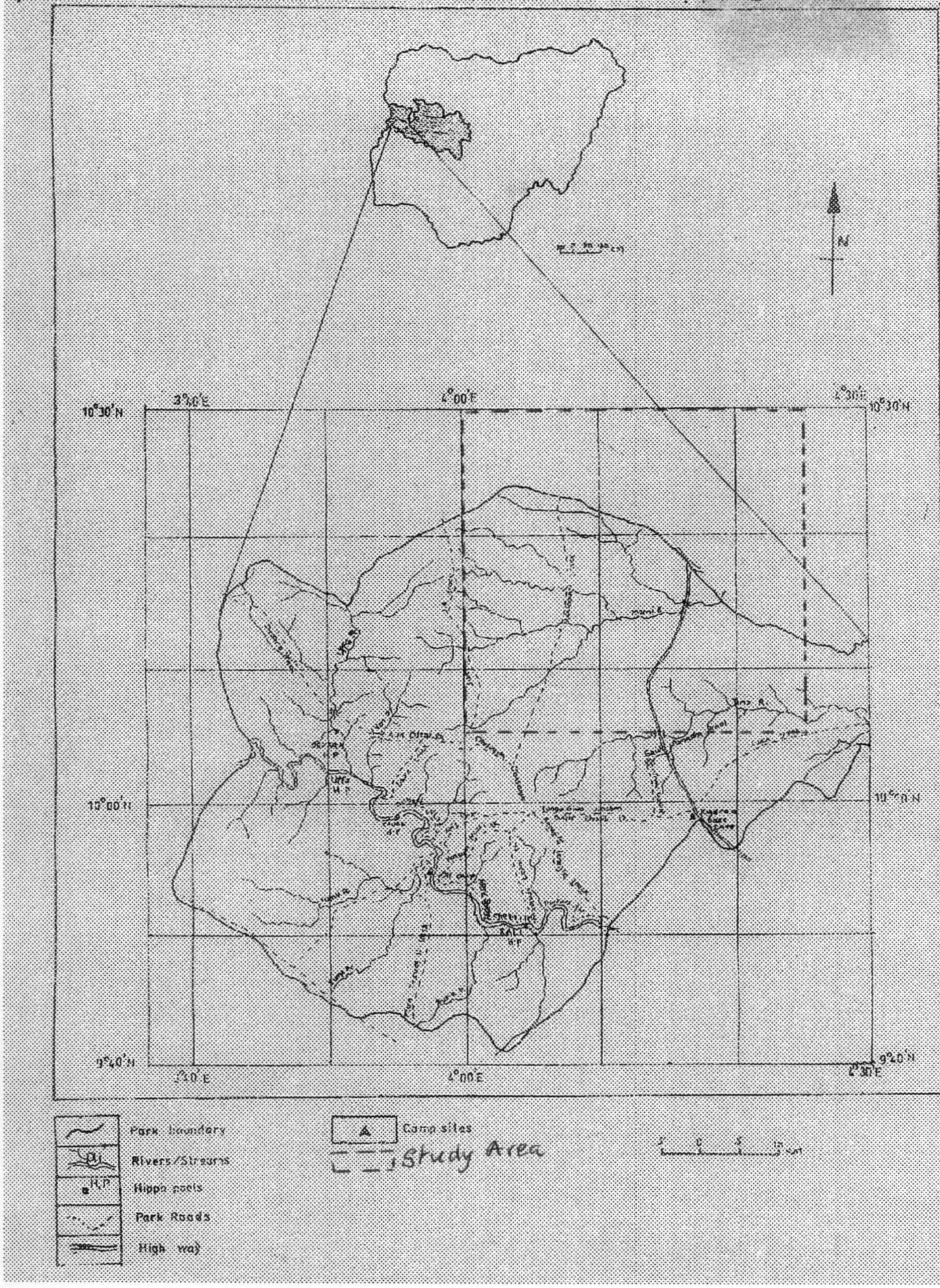
Within the past decades, land degradation resulting from uncontrolled clearing for agriculture, overgrazing, exploitation of mineral and forest resources, accelerated population growth, the dominance of coarse and loose friable soils, excessive and high intensity and so on, have collectively unleashed the most devastating land degradation phenomenon noted anywhere in the world. Government efforts towards the development of appropriate land and/or soil conservation and the protection of both fauna and flora in and around the KLNP have not been successful due to the paucity of available and accurate data. It is very unlikely that any one or group of researchers have ventured to under-take such an investigation in this National Park which is to many considered as a reserve for animal species majority, and plant species tangentially. Little attention is given to the land on which the living things (plants and animals) survive. Most of the information obtained from maps, images, graphs, etc; are much at variance, hence an extensive ground truthing will confirm and bring on board the reality. Therefore, to produce an up-to-date assessment of degraded areas within the park using the ERS-SAR, remote sensing, ground truthing, taking coordinates and elevation of spectacular features of the study area will be used for planning, conservation and utilisation of the KLNP resources thereby contributing to the economy and social development of the country.

1.5 DESCRIPTION OF STUDY AREA

KLNP has a total area of 5,370.82 km^2 which is located between latitude 9.40^{oN} and 10.32^{oN} and longitude 3.30^{oE} and $^{5.50oE}$. Figure 1.1 shows the specific location of the study area, located on the extreme northeast of the map. It is situated some 560km north of Lagos and 385km northwest of Abuja.

KLNP is made up of two non-contiguous sectors, viz: the old Borgu reserve and Zugurma forest reserve. The Borgu sector is to the western end of the River Niger. It covers a land area of 3,970.02 square km with Republic of Benin at its western boundary. It stretches to Angwara and Borgu LGA of Niger state and Kaiama LGA in Kwara State.

FIG 1.1 LOCATIONAL MAP OF THE STUDY AREA



Source: Okhimamhe

The Zugurma Sector has an area of 1,370.89 square km and is situated in Mariga LGA of Niger state and has Mariga river, as its northern boundary while the Kontagora river is its northwestern boundary. The climate of the area is typically that of the continental tropics with marked rainy and dry seasons. The climate is that of the Savanna with temperatures rising as high as 42° C in the months of March and going down as low as 22° C, especially during the harmattan in the months of December and January.

The geographical location of the area, that is, its closeness to the Sahel, makes it generally very hot with temperatures rising as high as 42° C in the month of March and April, and being as low as 22° C in the months of December and January. The harmattan wind which is cold, dry and dusty lasts from November to February.

Under natural condition as a reserve, forest is typical of Guinea Savanna. There are found trees in thick isolated communities, and in some areas are scattered and continuous grass cover. The vegetation has been greatly affected by various edaphic, climatic and biotic factors.

Soil types vary throughout the area but the soil profile has a sporadic composite of sandy/loamy and clayey in the fadama areas. Being a reserved area, they are said to be high in organic-matter, hence very fertile.

1.6 SCOPE AND LIMITATIONS OF THIS RESEARCH.

For the purpose of this study, the researcher concentrates on land degradation on the Borgu Sector of KLNP. Limitations are found in the KLNP authority's operational and legal policies, for example, which would not give complete free hand to poke into some of their internal matters such as prohibiting taking photographs of some special areas in the Park. The study is also limited to non-availability of enough satellite images to enhance good and selective interpretations. Another constraint in the research had to do with inadequate published literature especially using satellite remote sensing ERS-SAR and Landsat ETM in both the field and the study area. These indicate the inadequacy of data, and of course, there are still limited resources especially with respect to digital (computer assisted) image processing and other facilities. Furthermore, the study is limited by time. The researcher had a specific date for completion and submission.

Be that as it may, the Landsat ETM, ERS-SAR images, standard photographic prints, land-use and land-cover maps, and the computer facilities employed are, however, adequate enough to accomplish the tasks of the study. Despite the paucity of literature on the study area (ie the Borgu Sector) and the application of satellite remote sensing, attempts were mad to review several works on land degradation and the contribution of satellite images in degradation evaluation as reviewed in the following chapter.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

World wide, hundreds of countries are facing the threat of soil degradation resulting from both natural and anthropogenetic factors. According to Barrow (1991), Blaikie and Brookfield (1987), Soil degradation, therefore, is an environmental issue of crucial concern to all societies. Its occurrence is generally agreed to be wide spread and its effects threatens the sustainability of human life.

Symptoms of land degradation are different in different types of land-use. In irrigated farm lands it is often due to imbalance between excessive irrigation and inefficient drainage (water lodging - salinization); in rain-fed farm lands, it is often manifest as soil erosion, loss of organic matter or nutrients. In rangelands it includes reduction of bio-productivity, invasion of non-palatable species and poor livestock. According to Food and Agricultural Organisation of the United Nations (FAO, 1993), land degradation accompanies with it a breakdown of the fragile balance that allowed plant, human and animal life to develop in degraded areas. For example, in semi-arid and sub-humid zones.

This breakdown of the equilibrium and of the physical, chemical and biological processes that sustain it, represents the start of a processes of self-destruction for all elements of the life system. Thus, soil vulnerability to wind and water erosion, the lowering of the water table, the impairment of the natural regeneration of vegetation, the chemical degradation of soil themselves, all the immediate result of desertification - worse the situation of desertification feed on itself.

2.2 TYPES OF LAND DEGRADATION

Basically land degradation resulting from the natural and human factors are intertwined. Soil degradation resulting from human activities is one of the major problems facing the wold at this moment. FAO, (1993), reports showed that every five days the human population of the planet earth increases by more than one million. Today, four hundred and fifty million people, roughly one in nine of us, does not have enough to eat. This figure is expected to double by A.D. 2015. This rapid increase in the world's population demand the production of ever increasing quantities of food, fibre, fuel, shelter and so on, from the land. Furthermore, the soil is, and will for the foreseeable future, be the basis for food production. The pertinent question here is, will there be enough of it to feed twice as many people just one generation from now?

Obviously, there is going to be much greater pressure on the land. Even now, many thousands of hectares go out of cultivation annually because they have become too eroded, too saline, too swampy or too infertile. According to FAO and UNEP, (1983), over 5 million hectares of tropical forest are destroyed for shifting cultivation annually. About 30% of the world's exploitable soils are under this form of land use, for example, in Africa, Latin America, Oceania, India and southeast Asia.

Studies by Boerma (1975), estimated on a world wide basis that more than 7 million hectares of new bush in developing countries must be cleared each year to feed the expanding population. Also that due to mechanized agriculture, there is more exploitation and destruction of the vast areas in the savanna zone which were once roamed by grazers. It is important to mention here that the grazers constitute nuisance to land degradation in this area. Agricultural activities are usually affected by factors such as types, climatic parameters and water resources, irrigated arable farming can only take place where there is source of water either within a fluvial system or from ground water. In some environmental conditions such as the Kalahari of Botswana, arable activities are almost totally excluded as a result of degradation caused because of extremely low soil nutrients status and sandy soil, which in all but a few localized areas even preclude irrigation because of their considerable permeability.

2.2.1 Land Degradation by Wind

Studies across some north African countries reveals that grazing pressure leading to reduced plant cover is one of the major causes of wind erosion, affecting large parts of north Algeria and Tunisia where mean annual rainfall is up to 500 mm as well as in the middle of Algeria and south Tunisia where rainfall is below 300 mm. Boerma went further to add that in Libya and Egypt, grazing in northwest and a major part of east Libya and northwest of Egypt induced deflation of top soil is a pervasive problem in these areas. In many areas around water points, the sedenterization of nomadic herders in Libya, Tunisia and Algeria caused a severe degradation of rangeland; changing the rangeland to rain-fed agriculture is other cause of soil degradation by wind erosion. Over stocking of cattle, sheep and goats is the main problem in the northern steppe lands of Algeria, Morocco and Libya. Based upon the activities of these ruminants, Abdelgawad (1999), proposed programmes to control wind erosion and sand encroachment in Magreb countries and range of techniques are in use. One of the well known technique he called the Libyan Experiment, is by planting grasses, trees, petroleum spreading techniques, palm banners to protect threatened settlements and civil structures.

Studies in the Sahel by Warren and Khogali, (1992), indicated that across the northern Sahel are systems of ancient quaternary dunes that are a testimony of more arid climates in the past human pressures, particularly livestock grazing during periods of drought have contributed to the destabilization of aeolian deposits as examples of the Sudanese districts of Dafur and Kordofan Housa in Niger Republic and Burkina Faso. Some studies in Kordofan indicate that overgrazing has led to declining plant species diversity as well as reduced vegetation coverage especially in areas close to permanent population centres.

Wind erosion can have important off site impact. Nickling and Wolfe (1994), in their work, have shown how the Mopti Region of Mali areas of formerly cultivated fertile soils have seen the development of Nebkhas i.e, small sand dunes that develop from accumulation around plants, taking over large crop-lands and rangelands. Large scale sand encroachment is affecting the Gezira Irrigation Scheme in Sudan where the irrigation in certain time is filled with an aeolian deposits.

According to Janzen (1994), the large arid coastal plain and interior rangelands of Somalia are subjected to very high severity wind erosion respectively. Grazing pressures from sheep, goats, camel and cattle especially in areas near the water holes and settlements is the most serious problem in these regions. According to him, Somalia herds had greatly increased in 30 years before the beginning of civil war in 1990 and export of livestock to the Arabian and Peninsular rose. Numbers of small stock (sheep and goats have increased quickly reactively of sand dunes and sand sheets in the coastal region is one of the problems caused by pressure on the stabilization of herbs and grasses.

Wind erosion is a problem in the dry lands of southern Africa. From the coastal areas of the western cap, South Africa, through to northern Botswana in the Kalahari of Botswana, as in many provinces in the Sahel, it is ancient aeolian sands that are susceptible to deflation. Thomas and Shaw (1991), stated that the impact of wind erosion, even where it does occur is lower than might be expected for two reasons. First, the Kalahari sands have very low concentration of nutrients so that the loss of sediments does not necessary result in reduced fertility and similar case occurs in Libya and Tunisia; second, in many areas where wind erosion occurs, it is very localized in occurrence concentrated around boreholes. In the coastal areas of the western Cape South Africa, it is intensively mechanized agriculture and that has contributed to high severity wind erosion. The adoption of soil conservation practices notably strip cultivation whereby areas of natural vegetation alternate with cultivated areas, however, is being widely adopted as a means of reducing the likelihood of aeolian entertainment taking place.

2.2.2 Land Degradation by Water

Land degradation resulting from water is a contemporary challenge in humid rainforest and the savanna regions. This problem is further worsened by human related factors, often population-driven, for example, road construction, civil works, agriculture, deforestation, bush fires and so on.

According to Bassey (1999), urban hydrology indicated that flash floods with huge volumes of run-off occur in urban areas. This is attributed to the large area occupied by roofs which do not retain water but pass them immediately down the drains, and also the large areas that are paved. The paved areas detain every little water and prevent peculation into the groundwater. A combination of these factors, couple with a relatively high drainage system provisions within towns, lead to large volumes of water being generated within a very short time. When the drainage system is not fully functional at the level necessary to handle the storm water thus generated, devastating flooding occurs, thus unleasing erosion. He went on to point out that, the removal of forest floor in a field in Colorado reduced infiltration capacity of the land by 40% from 1.52 to 0.92 inches/hour. He reported again that, a 20% paving of a watershed in Connecticut for urban purposes resulted in a three-fold increase in the peak of flood discharge. Also he said that, a 50% paving of the watershed which he studied, increased the storm run-off 5.9 times.

According to Okoye (1986), short duration of rainstorms which in the rural area may not produce run-off, often give rise to floods of considerable size in urban areas. The roof materials used in most urban areas contribute significantly to the run-off, especially where they are built in close clusters and the surrounding areas are paved. The erosion problems at Nkisi River in Onitsha, in parts of Abia and Makurdi, are pointers to the effect of urbanization and inappropriate and inadequate channelization of storm water owing to lack of perception of the planners to the consequences of the increased flood and concomitant land degradation.

In a study conducted by Nick and David (1997), they concluded that the problem of water erosion is not confined to more humid dry lands but the severe water erosion localities are within dry lands. Almost 50 million hectares in the arid zone have been affected by water erosion in comparison to 30 million hectares in dry sub-humid areas. Examples of affected arid areas are in eastern Namibia and northern Cape province in South Africa. In northern Niger, northern Chad and in western Khartoum in Sudan, as well known, soil type, relief, kind of vegetation, slope, and so on, are main factors affecting soil water erosion.

In Abdelgawad (1999), pointed out that water erosion is a wide spread degradation process in the Magreb region of Algeria, Morocco, Tunisia and Libya with severity highest at the western and eastern and of the Atlas Mountains and in the Rif Mountains. This is because natural vegetation has been damaged by grazing pressure around source of water. The intensification of arable land use and deforestation which led to bad land development on steep slopes, water erosion has been enhanced by population growth in high Algerian Plateau. In Algeria Atlas and Morocco Rif, tree planting programmes have been in operation for more than a decade in order to reduce run-off and soil degradation. The Algeria Green Dam is intended to cover 3 million hectares with a length of 1,000 km as a barrier between Sahara and Atlas Mountains. In the Jabol Al-Akhdor east of Benghazi in Libya, loss of top soils in areas due to deforestation is a real problem (Abdelgawad, 1999). The creation of National Parks, for example, Al Kouf National Park contributed a lot to the protection of areas sensitive to this problem. According to Mainguet (1991), in the lower part of both Algeria and Tunisia, soil conservation has been enhanced because of the break down of traditional soil conservation technique. Rain-fed run-off farming in the Matmata region of eastern Tunisia is dependent on intricate net works of terraces and check dams known as 'Jessour'. The loessic soils of the area are highly erodible, and the soil conservation methods require constant maintenance and about 10 million olive trees have been grown through the use of run-off farming in central Tunisia.

While there are many cases of problems caused by water erosion in north African countries, on the other hand, there are also reported development in land use that appear not to be leading to degradation. An example of this, in the Eckala area in northern Algeria, showed that where mixed livestock and agricultural activities occur, there is little evidence of ecological or soil, degradation even through pastoral activities have been modernized and in some cases intensified.

In the study conducted by Matheson and Ringrose (1994), they showed that sheet wash rilling and gullying features occur particularly on pasture and cultivated lands in Niger and Benin Republics and indicated that even where all environmental criteria favouring vulnerability to water erosion are not fully met, the combination of land-use pressure and drought, especially when enhanced by the effects of post-drought rains falling on bare ground can lead to erosion problems. In Ghana, the Global Assessment of the status of human-induced Soil Degradation (GLASOD), reports indicated that sheet wash erosion is a serious problem affecting leptosols and luvisols in the heavily populated northeastern Savanna Highlands. Tree clearance, livestock and agriculture combine to great significant environmental pressure in this region.

According to Abdelgawad (2000), In Eritrea and northern Tigray in Ethiopia extending into adjacent humid areas, soil erosion by water has reached critical level, a consequence of deforestation of steep slopes as farmers seek new lands to cultivate away from the over crowded areas. Overgrazing is also a cause of water erosion in the region, with a third of Ethiopia's livestock found in highlands, he estimated that soil loss was occurring at a rate between 1 to 2 billion m^3 per annum, with perhaps up to 4 million hectares of highlands irreversibly degraded. More positive practices come from the slope of the Mackhakos and Makueni districts of Kenya; here, changes in land tenure and a resurgence of local land ownership and a good decision making have seen crop yield increase and erosion decrease in some areas due to local farmers activities such as construction of terraces, gulliers filling and recovery of hill slopes. Soil conservation in Kenya is increasingly now part of over all state strategies.

According to Ingram (1991), southern Africa susceptible dry lands experience water erosion caused by both pastoral and arable activities. Water erosion is most significant on communal pastoral lands, for example, in Namibia, eastern Botswana, Zimbabwe,. In southern Zimbabwe where soil erosion is seen at highlands has no effect on pasture areas and arable lands, because these are practised at a lower slopes and valleys enriched with fertile soils from the high slopes. In eastern Botswana, human- induced soil loss very low biota, consequently at current soil erosion rate, the sustainability of present land-use practices will only be brought into question in 300 to 500 years time; but questions can be raised about this estimate because even at this rate, top soil will be eroded first. In Zimbabwe, survey of soil erosion conducted by Whitlow (1988), that included the country's dry lands has shown that the correlation between predicted erosion risk and actual erosion occurrence are poor because human factors are very variable and subjected to changes due to political situations and economic changes. The GLASOD report for Zimbabwe noted that the distribution of erosion problems is heavily influenced by the pre-independence legacy of land tenure, with heavy populated communal lands having the most severe water erosion problems.

2.3 CAUSES OF LAND DEGRADATION

Under natural conditions, free from the effect of human activities, soil is usually covered by vegetation. Leaves and branches guard it from the force of the rain and from the drying effect of the sun and wind. Dead leaves and fallen twigs form a layer of litter on the top which further protects it and fosters a large population of macro and micro organisms. Roots, on and below the surface open up the soil, but also bind it together. Land which has been for a long period under natural vegetation usually has a deep and well defined layer of rich topsoil. This stable an dynamic structure has been distorted by man for his search of golden fleece. If the vegetation cover is removed for cultivation, or by grazing or fire, then changes begin to take place in the soil hence degradation or deterioration sets in.

2.3.1 Agricultural Activities

According to Swearingen (1994), degradation due to poor agriculture management is largely concentrated in semi arid and dry sub-humid areas. Over irrigation and inadequate drainage are the most common problems leading to soil salinization and water logging. Also over exploitation of aquifers, irrigation with water having high salt and sodium content without proper management will cause salinization. Rain-fed agriculture in marginal land is a major cause of soil degradation as what happened in some areas of Tunisia, Libya, Morocco and Nigeria. Expansion of cultivation of rain-fed marginal land due to growing population cause rain-fed agriculture to be unsustainable. The expansion of ground nuts cultivation in Nigeria, Niger, Sudan and parts of Chad have pushed subsistence crops into areas whose sensitivity has been exposed to drought. Short of fallow periods in summer rainfall zone in South Africa, Botswana's Kalahari and eastern Zimbabwe caused a decline in crop yield due to degradation of soil.

2.3.2 Overgrazing

Overgrazing is a major problem of the arid and semi-arid zones. Overgrazing around settlements in north Africa and the Sahel is often related to the sedentarization of nomadic herders. Matheson and Ringrose (1992),posited that in many parts of the Sahel where the transition of herders from a nomadic life style to a more settle one has been taking place for some decades caused range degradation as well as cultivating marginal lands caused more soil degradation by wind and water. Here, the expansion of sorghum and millet cultivation have been primary factors responsible for a decrease in the availability of rangelands. In central Botswana, excessive use of rangelands, during the early stages of drought period by increasing human and livestock population is major factor of soil degradation.

2.3.3 Over-exploitation of Vegetation for Domestic use

According to Parnot (1988), soil degradation due to the over use of vegetation for domestic use such as fuel wood, charcoal making, fencing and construction is almost confined to the Sahel and Savanna. Fuelwood collection is probably the most important domestic reason in Sahelian countries where imported fossil fuel is expensive, woody biomass constitutes the main domestic fuel of sub-Saharan Africa.

2.3.4 Deforestation and Removal of Natural Vegetation

According to Parnot (1988), the expansion of irrigation schemes in the Sudan along the Blue Down Stream, deforestation for expanding grain cultivation in semi arid uplands east of Benghazi in Libya and parts of Atlas Mountains in Tunisia, Algeria, Morocco where fluvial activity is again the main soil degradation process. The clearance of natural vegetation by fire, burning of bushes and grasses is a long established management technique in the Savannas of Africa, for example, the National Parks and Game Reserves.

2.4 VEGETATION AND SOIL DEGRADATION

Vegetation is an important factor in the occurrence of soil degradation as it can act as a buffer between the soil surface and the processes that can cause degradation by soil displacement. In the World Atlas Desertification 2nd Edition (1997), it is stated that vegetation can be characterized in many ways including either by plant community composition and biomass production with the later being used to examine the vegetation degradation and soil degradation relationship. Vegetation and soil degradation was found to be very well correlated with the Global Vegetation Index (GVI) coverage of Africa and vegetation community maps.

From the perspective of soil degradation, however, the GVI map showed a good correlation between biomass and degradation. Severity also between type of degradation and the GVI Map. Wind erosion peaks noticed in areas where the ground has a spares vegetation cover and related to rainfall distribution, water erosion is related to vegetation. The loss of vegetation cover more soil erosion will occur but it is less marked than wind erosion because water erosion is a sheet erosion (sheet wash). Vegetation cover and chemical physical deterioration are not straight forward only under very severe condition.

2.5 REMOTE SENSING APPLICATION TO LAND DEGRADATION

According to Alhussein (2000), remote sensing of the environment comprises the measurement and recording of electromagnetic energy reflected from or emitted by the earth's surface and atmosphere from a vantage-point above the earth's surface and the relating of such measurements to the nature and distribution of earth's surface materials and atmospheric conditions. In its broadest definition, remote sensing refers, to any technique of imaging objects without the sensor being in direct contact with the object or scene itself. The remote sensing satellites are the most widely used and promising remote sensing platforms. These satellites are subdivided into two categories according to their altitude, range and their rotation made around the earth. There are the orbiting and the geo-stationary satellites.

Loulou (2000), grouped the most common used remote sensing techniques in land degradation monitoring as: Visual interpretation of satellite images; digital analysis; aerial photos interpretation. Land degradation monitoring, vegetation degradation and rangeland monitoring. According to

Loulou, much of these work have been done in the arid, semi- arid and mid-western United States; also this was associated with the work on arid and semi-arid lands developed for plague-locust monitoring by the FAO and the biomass monitoring conducted by FAO and UNEP in the Sahelian region. Satellite data are used to produce base maps of overall environmental types within the rangelands. This can be rapidly done and provides for a general understanding of the landform types - vegetation zones, hydrology and geology of the area.

It is also reported that the use of satellite remote sensing for monitoring water erosion in the watershed of Ribeirao Bonito located in Brazil , and its use in mapping erosion sites in Sinonan province of China. He added that expansive potential cultivable lands are degraded by run-off as a result of human activities.

In the cost benefit analysis made by FAO, in terms of efficiency and effectiveness about the use of satellite remote sensing vis-a-vis other conventional methods, it was discovered that the system was almost 3 times better in mapping lands devastated by wind or water erosion. The use of satellite remote sensing in third world countries most especially in Nigeria include lack of appropriate technological know-how to launch own satellites. This is because of high cos of equipment and the cost of maintaining personnel at ground stations. It is also not quite effective in terms of cost benefit in monitoring agricultural lands and agro-forestry projects because holdings as small in size.

2.5.1 LAND DEGRADATION MAPPING USING REMOTE SENSING TECHNIQUE

As noted by Howard (1992), land topography is poorly analysed and could be investigated profitably by using remote sensing techniques. The power of remote sensing for detail analysis of degraded topography is enormous, but little studies allowing classification of landform, distinct topographic features and possibly mapping of spatial concentration of excavated solids and flow lines over inundated areas. Hamilton, et al (1992) demonstrated this potentials using Radar image on the Amazon and Orinoco floodplain. Their measurements indicated that denuded topography can have statistical self-similarity with respect to area, implying that the relief on the denuded area displayed fractal characteristics. Such a result if of general application would have implications for modelling spatial variation in degraded areas.

Studies have also been conducted to determine the possible value of Landsat data for environmental monitoring. Landsat capabilities to recognize discontinuities of coloration in water and to distinguish differences in land-cover over large areas have proved of value in identifying land systems. Landsat image is increasingly being employed in assessing major watershed characteristics that affect run-off and erosion, assessment of grazing and farming conditions of land, monitoring and mapping.

Remote sensing image makes the delineation of degraded areas in a combination with land-use maps, permit the identification of areas proned to degradation and the estimation of economic consequences of erosion, particularly with respect to agricultural experimental results evacuated in the

USGS.

Robinove in 1975 indicated that Landsat images have value for mapping and/or warning and assessing certain types of disaster throughout the world. Comparative analysis of two sets of Landsat scenes covering the state of Orissa in India (dry season, 1973 and Monsoon, 1973, has yielded a substantial volume of land information of direct value to resource manager and agricultural planners. The two scenes highlighted the difference between dry season and wet season agricultural patterns and identified promising areas for conventional irrigated crop production. The data also indicated the extent of forest cutting in the highlands and coastal regions. It also provided new base for checking the accuracy of crop acreage and estimates done by conventional means showed the changing of the Mahadi river and its tributaries as well as changes in sandbars, spits and islands along the coast (Weismulter, 1976).

Degradation mapping with Landsat image was demonstrated with conspicuous success in the case of Mississippi river and Indus river in 1973 (IBRD, 1973). Coastal flooding caused by hurricanes and typhoons, as well as erosion and deposition along the affected coasts were mapped and monitored after the storms.

As noted above, several studies have been conducted on land degradation not only using conventional techniques but also through the use of remotely sensed data on international scene, and studies have attained high level of sophistication which is yet to be matched by local studies. Nigeria has a complete national coverage of aerial photograph obtained in the past 50 years. Having different acquisition dates and scales, but nowadays space sensing permits an adequate triplet data using satellite images, air photographs and ground control. It makes this research relevant in bringing gaps in land degradation mapping. Some other closely related studies include the following: the use of false colour. Near infrared film in a variety of applications, which include mapping of soil. In recent years too, this kind of film has been applied to mapping the relatively inaccessible wetland zone with great success (Frenzee et al, 1973).

The Park areas are regarded as having natural functions and they have economic values. The hydrological and ecological values of these parks have been summarized to function as groundwater recharge and discharge, flood control, nutrient retention and microclimate stabilization. It produces forest resources, wildlife fisheries, and forage. Therefore, a sound data base is greatly needed if we need to successfully manage these resources. The problems plaguing the use of maps to describe geographic phenomena led to the development of Geographic Information System (GIS), which is the geographic system of capturing, storing, checking, integrating, manipulating, analysing and displaying of data which are spatially referenced to the earth. This is normally considered to involve spatially referenced computer database and appropriate application soft ware (Chorley, 1987). The advent of satellite remote sensing has, therefore, brought a new line of research integrating GIS into remote sensing, since satellite images have become valuable integration of some up-to-date information is useful in monitoring and mapping of earth phenomena, as will be applied in this study using both visual techniques and computer assisted methods. This will absolutely fill the gaps created by lack of temporal/remotely sensed data with the use of methods of GIS.

2.6 CONCLUSION

It is a well known fact that, more than one-third of the earth's land area is arid and in this area, the process of degradation has intensified in recent decades. According to the United Nations' Conference on Desertification (UNCOD) 1977, estimated that, desertification threatens the future of more than 785 million people, or 17.7% of the worlds' population who live in this dry lands. It is also estimated that between 50,000 and 70,000 square kilometres of useful land are going out of production every year - through desertification process. The situation presented above has been assessed only generally on the basis of existing geographic estimates. More precise data are required on affected areas, or likely to be affected in the future and on the rate of the degradation process at global, regional and country scales.

Thus more reliable data are required urgently to obtain precise figures on the rate and risk of degradation and to assist future action in planning and guiding anti-degradation activities at national arid regional level as the basis for international action to combat degradation, for co-ordination of research and for transfer of the appropriate technology.

CHAPTER THREE

3.0 DATA AND METHODOLOGY

Research in case studies just like in the topic under investigation, vary in approaches, area of scholarship and knowledge, and level of sophistication, depending on their aim and procedure. The availability of data, application software and digital hardware relevant to the programs enhanced precision and quality of output. Probably no combination of two technologies have generated more interest and application over a wide range of disciplines than the merger of remote sensing and geographic information system (GIS). Although many aspects of the processes are still at infancy and evolving stages, studying the earth and its features from the space have evolved from reason of pure research to that of worldwide and day to day applications. Currently, we depend on space satellite sensors to acquire data about water resources, vegetation type and canopy, hydrology and hydrogeology to diverse applications such as detection, monitoring, modeling and generalization of variables and phenomena. All these have happened in varying short periods of time and the status of satellite remote sensing continues to change as new and/or improved space-borne are placed into the orbit. The flow chart below displays the technical procedure of data collection and image analysis:

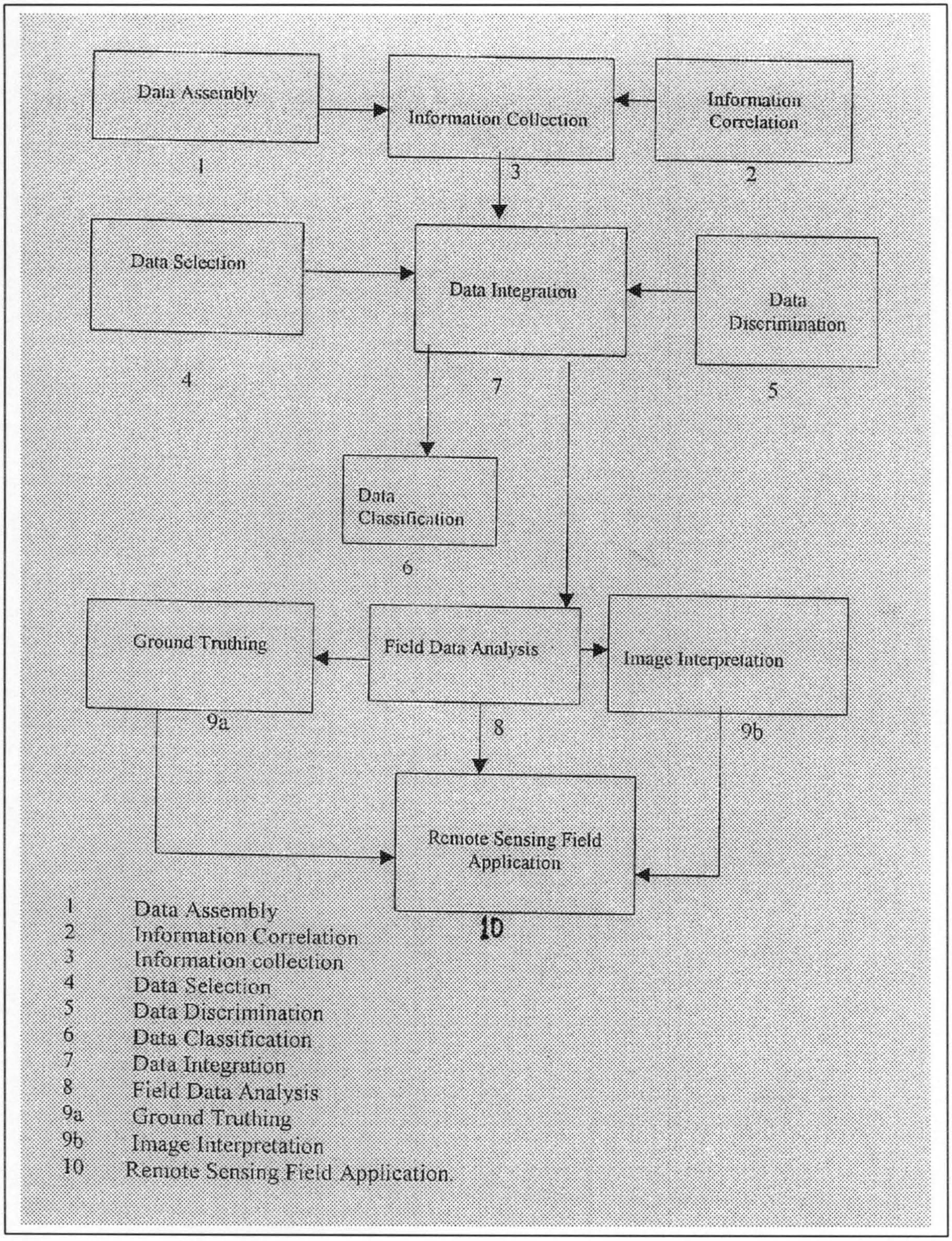


Figure 3.1: Flow Chart of the Technical Procedure of Data Collection and Image Analysis

Source: Chindaba 2002

3.1 DESCRIPTION OF DATA

For the multi-temporal colour composite, three ERS-SAR images which were acquired during descending passes and processed by D-PAF in Oberpfaffenhofen in Germany were used (see Table 3.1). The selection of the scenes based on availability, short time interval of at least two years and seasonality, reflecting main climatic conditions. All images were of no-rain days, so this is not a factor to be considered in the alteration of signal reception by the satellites.

Table 3.1: ESR - SAR Scenes used for the Study

Date	**Season**	**Satellite**	**Orbit/frame**	**Product type**
16 Aug 1994	Late wet season	ERS1	16134/3402	PR1
02 Apr 1996	Late dry season	ERS1	24659/3402	PR1
02 June 1999	Early wet season	ERS2	21519/3402	PR1

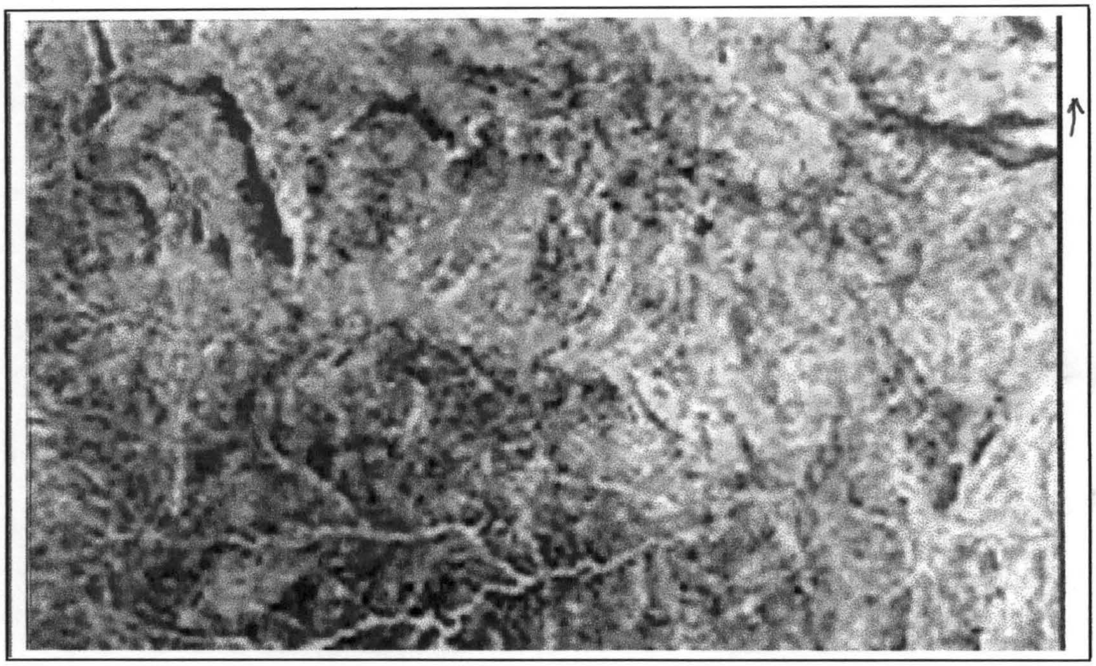
The data collected were categorized into three. This was to suit the aim and objectives, and further address the problem of the research (Plate 3.1 shows ERS-SAR image of the study area).

Plate 3.1

ERS - SAR Image of the Study Area

Source: Okhimamhe

Plate 3.2



Landsat ETM& ERS – SAR image to aid visual interpretation

Source: Okhimamhe

3.1.1 Baseline Data

Thematic map of the Borgu Sector of the KLNP covering the study area and environs was obtained. This was to enhance the visibility of the streams and rivulets hidden as a result of the high resolution of the sensor. It was to clearly bring out the watershed sector of the study area. Thematic map of land-use/land-cover of the study area was acquired. This was to aid in the verification of some natural phenomena and human activities that were not quite visible on the map because image was acquired at high resolution. Hand-held conventional camera photographs of spectacular features were acquired, especially of eroded places and those susceptible to erosion.

3.1.2 Environmental Data

This included satellite imageries. There were two image data available for this study. The first was the ERS-SAR multitemporal image. The sensor being an active one has the capability of penetrating atmospheric barriers - cloud or haze, hence data had 0% cloud cover and was not corrected subject to atmospheric corrections. The Landsat-ETM image of the same period was also acquired ; this was juxtapositioned the ERS-EAR image to assist in the visual interpretation as shown on Plate 3.2.

3.1.3 Image Types

Remote sensing satellites are the most widely used and promising remote sensing platforms. These satellites are subdivided into two categories according to their altitude, range and their rotation made around the earth. They are the polar orbiting satellites and the geo-stationary satellites. All the satellite images used for this study were registered to Nigeria Colony Civil Coordination Map System, and were certified to be efficient and accurate in degradation studies in Borgu Sector of the KLNP. The two images used were the Landsat ETM and ERS-SAR.

The Landsat ETM which was launched by the United States Government in 1998 is both multispectral and panchromatic. It operates in 7 different wavelength bands. Being a polar orbiting satellite it is inclined to an angle of 98.2°. The spatial resolution of this sensor is about 30m except for band 6 which is a thermal band having spatial resolution of 120m. Landsat data are provided in frames or scenes of 185 x 185 km.

The ERS-SARs 1 and 2 were launched by the European Space Agency (ESA) in 1991 and 1995 respectively. ERS is also a polar orbiting satellite; orbiting at an altitude of 785 km at an inclination of 90°. It has higher temporal resolution, but poorer spatial resolution, the swath width is about 500 km.

3.1.4 Multitemporal Image Production

To produce a multi-temporal image, 2^{nd} June 1999 image was assigned to the Red Channel, while 16t August 1994 and 2^{nd} April 1996 images were assigned to the Green and Blue Channels respectively. To aid the interpretation of the product, different low-pass statistical filtering techniques were tested to smoothen larger homogeneous areas of similar tones. This step was necessary because the thematic (environmental) information to be extracted does not significantly depend on the spatial resolution of the image. A visual assessment of the quality of output images resulted in making a difficult choice between gamma-map and median filters (both 5 x 5 iteration). Eventually, the median filtered image was selected because it satisfied the balance between reduced signal to noise (mean/standard deviation) and preservation of the sharpness of the not-so-regular edges of homogeneous land-cover within the study site. In addition to monitoring changes, another advantage of using multi-temporal SAR images is that it enhances ability to identify, map and estimate acreage of degraded areas more accurately.

3.1.5 False Colour Composite (FCC)

The first step was to perform linear contrast stretch on all the bands, with 30 meters-pixel size were combined in order to select the most suitable band combination. A False Colour Composite of bands 4.3 and 2 was chosen as it clearly depicted degraded areas of the study site.

3.2 Field Data Collection

Ground truthing was carried out in two phases. The first was carried out in September, 2001. This was at the peak of the rainy season when degradation work was at maximum, and, the stream sand rivers were at their highest erosive and transportation work. The second visit was in February, 2002. At this period, the rains have ceased and most of the streams and rivers dried up. The aim of the two visits were to enable comparative assessment of the study area in both the rainy season and the dry season, so as to ascertain the dynamism of the features correspondingly from map and images to ground and vice-versa.

3.2.1 Geographic Sampling Technique

Research problem in remote sensing is directed towards environmental phenomena and it is only in rare cases would it be possible to study the entire population. Broadly speaking, all sampling techniques may be grouped into two:

- probability and
- non - probability sampling.

The one used in this study, is the probability sampling also called random sampling involves a body of mathematical theory that allows us to specify chances which every member of the population has of being included in the sample. It is on the probability sampling that this research bases its selection of the study area, that is, the KLNP, Borgu Sector from the numerous National Parks that are also threatened by degradation such as the Yankari, Gashaka-Gumti and other parks.

The advantages inherent in probability sampling are:

- It can cut down on the cost of data collection
- Sampling requires less manpower
- Sampling enables us to collect data more quarterly than total enumeration
- Sampling enables us sometimes to obtain information that would have been impossible to collect in total enumeration.

- By concentrating on fewer individuals sampling enables more comprehensive data to be collected given the same resources (i.e, more detailed information).
- It gives every member of the population an even chance of being selected.
- It ensures that the sample we draw is representative (within sampling error) of the population from which it is drawn.

A sample may be more precise and accurate than a total enumeration because with fewer parameters, the collection can be more tightly controlled.

3.3 Methodology

Remote sensing technology was considered ideal for best of results in this research having the data available. This is to help integrate the conventional and non-conventional data. The field-work provided data for accurate location of phenomena.

Usually, the traditional method of physical data collection about a study area has been by field trip; this is to help in field observations based on reconnaissance source or preliminary surveys, indicating features of interest on more or less primitive maps. After many traverses, a general idea of phenomena of the study area could be presented. It could be expensive and may lack some correct details because of the out dated base map. Therefore, applying a denser network of observation of satellite targets would increase the understanding and also of the more detailed features, which would facilitate location of physical and cultural features of the area under survey. Satellite image interpretation usually involves some field interpretation or ground truthing studies in order to check and correlate the quality of the work and correct mistakes made during image acquisition or image analysis.

Though the digital image processing input in the satellite images which had been processed was much, was still dependent on distinct and clear features for visual interpretation. Before any satellite image was considered good for work, at low profile facility level, whole or part of features/ground targets were visibly defined and spectrally identifiable at least for the first and second level interpretations. The ERS-SAR and Landsat ETM were used to generate colour images that contain the exceptional physical and cultural information across the study area. These colour images were very useful for planning programmes, evaluating terrain conditions and verifying features locations in the study area. These physical and cultural information helped much in the ground truth verifications and served as control targets.

Simple statistical averages and percentages will be used in the data analysis. The ERS-SAR image will be visually interpreted. In the case of the analysis, the ground truthing exercise serves as check and as well, aids the identification of some features during the visual or digital interpretation. The most important reason for ground truthing is to ensure accurate identification and location of phenomena for the purpose of evaluation and suitability assessment. Thus, the knowledge of the basic characteristics of features and conditions on the earth's surface is required. The ground truthing is, therefore, the means through which a useful knowledge about the information contained in the images is obtained with the purpose of verifying the accuracy of the information contained in the images. It refers to the data collected from the actual area covered by the image through field survey. It also established the fact that the games too contribute immensely to land degradation. The ground truth information is sometimes referred to as the reference data. The need for the ground truth or reference data include:

(i) To aid the analysis and interpretation of data from the images

(ii) To verify information extracted from image

(iii) To evaluate the ability of a sensor to obtain information accurately.

3.3.1 Classification System

A classification system provides a means for the researcher to group the degraded areas or cover-types that one wants to recognize. This system becomes the legend or key to the produced map. The system may be designed by the user or the user can select an existing classification system which might be modified to meet specific needs. The United States Geological Society (USGS) is the common reference system. Here, categories and accuracy levels can be altered to meet the needs and interpretation capabilities of the interpreter.

3.3.2 Image Interpretation

This requires a mixture of artistic, scientific and physical abilities and it is learnt through experience. The interpreter was able to make accurate association between a particular land-cover type and its representative colour, tone, pattern, shape, aerial extent and locations on the image. Some key factors that determine the interpreters ability to see, comprehend and synthesize previously mentioned variables include:

- The researchers knowledge base which is the most critical determinant in what the user can or cannot see on the image.

- The researcher must develop the ability to consistently separate colour tones with his eyes and keep them separated in his mind.

-For the interpreter to identify objects following the low resolution of satellite images. Inferences were drawn from clues which are even less specific than those relied upon in the interpretation of images. In image interpretations, three interpretation approaches are commonly used:

(i) The researcher maps solely from the image without referring to any type of supporting materials like images. It is the fastest and cheapest approach which produces fewer categories and may likely have a higher accuracy than other techniques. Familiarity with areas being mapped is required.

(ii) The second method utilizes image as a guide throughout the interpretation processes. This works best for researchers who lack confidence in their works and interpretative abilities.

(iii)This third method relies heavily on supporting aerial photograph and/or land-use and land-cover, and topographic maps as a reference for evaluating what is seen on the satellite image. This method is good for documenting changes in land-use and cover-type over time. It is also the most time consuming. Photographs should be consulted after the image has been interpreted. For this project, the researcher combined the three methods depending in what to do and how to do them.

CHAPTER FOUR

4.0 DATA ANALYSIS AN DISCUSSION OF RESULTS

4.1 INTRODUCTION

This research, the aim of which has been to identify the relevance and contributions that satellite remote sensing can make to the study of land degradation. The way in which the Borgu Sector could be mapped from satellite data - the only practical technique, by which this type of information can be provided, given varied advantages.

The capabilities of SAR data in terrain analysis and mapping of degraded areas in the savanna wood and ecosystem environment has been introduced. Its application in the Borgu Sector has demonstrated its ability to provide comprehensive information on the nature of the landscape and the extent of degradation. It has been demonstrated that satellite remote sensing can provide accurate and comprehensive information for such purposes.

4.3 PRELIMINARY FACTORS CAUSING LAND DEGRADATION IN THE PARK.

Generally, Parks are considered , as reserved areas untempered by human influences. Some of the natural degradational processes in the Park are caused by the animals themselves, this was the discovery made as a result of the ground truthing. First and foremost, are the animal trails, i.e, their foot prints along the route of water holes, sources of food, resting and hiding places aid in soil compaction. It also helped in destroying the vegetation. Their constant passes over, impedes vegetation regeneration. Also, in a colony of plants, called thick shrub forest or pocket shrub forest, the animals find it ideal for hiding from their predators, shading and resting during harsh weather, most especially when the sun is high in the sky. Plate 4.1 shows the colony of plants that serves as resting or hiding enclave for the games.

Plate 4.1

Plant colony for resting and hiding of games

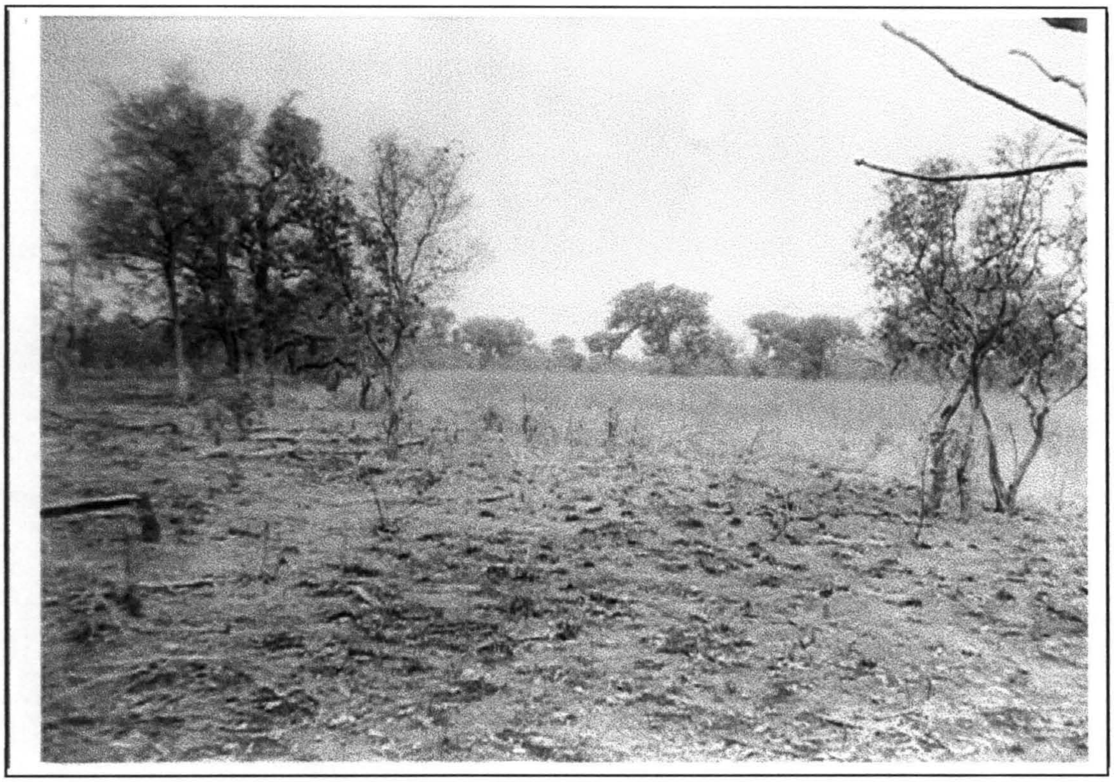
The salt-lick points serve as good location that can induce land degradation caused by the games themselves. The salts which are source of food for the games contain calcium carbonate (Ca $C0_4$) and Thetra Chlorine Form (CCL_4). As the animals continually excavate this substance as a source of mineral food item, the impact left can induce the formation of stream fingers when it rains. The Park is punctuated with such salt lick spots where the animals converge on daily bases.

Important too in inducing erosion, is the activities of burrowing animals such as hedge hogs, bush bugs guinea fowls and squirrels burrowing for food, such as earthworm and crickets. Some animals especially baboons and those with hard paws dig plant roots which they consume as medicinal or tubers as food. The path of the roots removed can induce the formation of rivulets when heavy downpour occurs, so also those of dead and decomposed trees.

It was said that the grazers among the games also cause land degradation, for example their foot print destroy the vegetation, so also their trails induce degradation. Grazers like roan, elephant and hippopotamus and a host of smaller grazers consume large volumes of vegetative matter. The hippopotamus, for example, on the average is said to consume as much as 200kg of grass daily.

The “ecotone” are technically areas of transition of vegetation type in the Park. These are areas which are found in-between two main vegetation types of high canopy. They are areas of dwindling vegetation cover. The “ecotones” are generally areas that are susceptible to land degradation. Plate 4.2 depicts an “ecotone”. The “ecotones” are important to the games because in the early rainy season they provide fresh and low grasses for the games particularly the smaller ruminants. The larger games,

Plate 4.2



An Ecotone – An area of transition vegetation quite ideal as a convergence zone for games for grazing and sunning

especially the carnivores hunt for their preys where this transitional vegetation exist. Being a convergent zone for animals, it becomes threatened and liable to be degraded. The games generally conglomerate for sunning during cold weather conditions, especially during rainy season and the cold windy harmattan.

4.3.1 ERS-SAR IMAGE INTERPRETATION

The ERS-SAR multi-temporal image was the main data visually used for interpretation. Multi-temporal here implies that the image was recorded on different dates which depend on the revisit of the satellite sensor. The interval between two visits of the same scene is called Temporal Resolution. This is important characteristic because it is necessary to follow the dynamic situation and changes in phenomena.

The dot grid system was used in the interpretation of the ERS-SAR multi-temporal image acquired on the 3 different dates in composites of the 3 basic primary colours of Red, Green and Blue (RGB colour composite adapted from 1681). The base map of the study area along side the Landsat -ETM image were correspondingly and simultaneously used for aiding the ERS-SAR image interpretation.

A pragmatic scheme based on the classification for use with remotely sensed data was used. The spatial resolution of the image and the desired results were considered using the classification scheme. The degraded areas were identified by symbols or codes indicating primary category (Level 1) and secondary category (Level 2) of land degradation were interpreted from the image. The degradation factors used for manual interpretation is presented in Table 4.1.

Table 4.1 Factors of Degradation in the Park

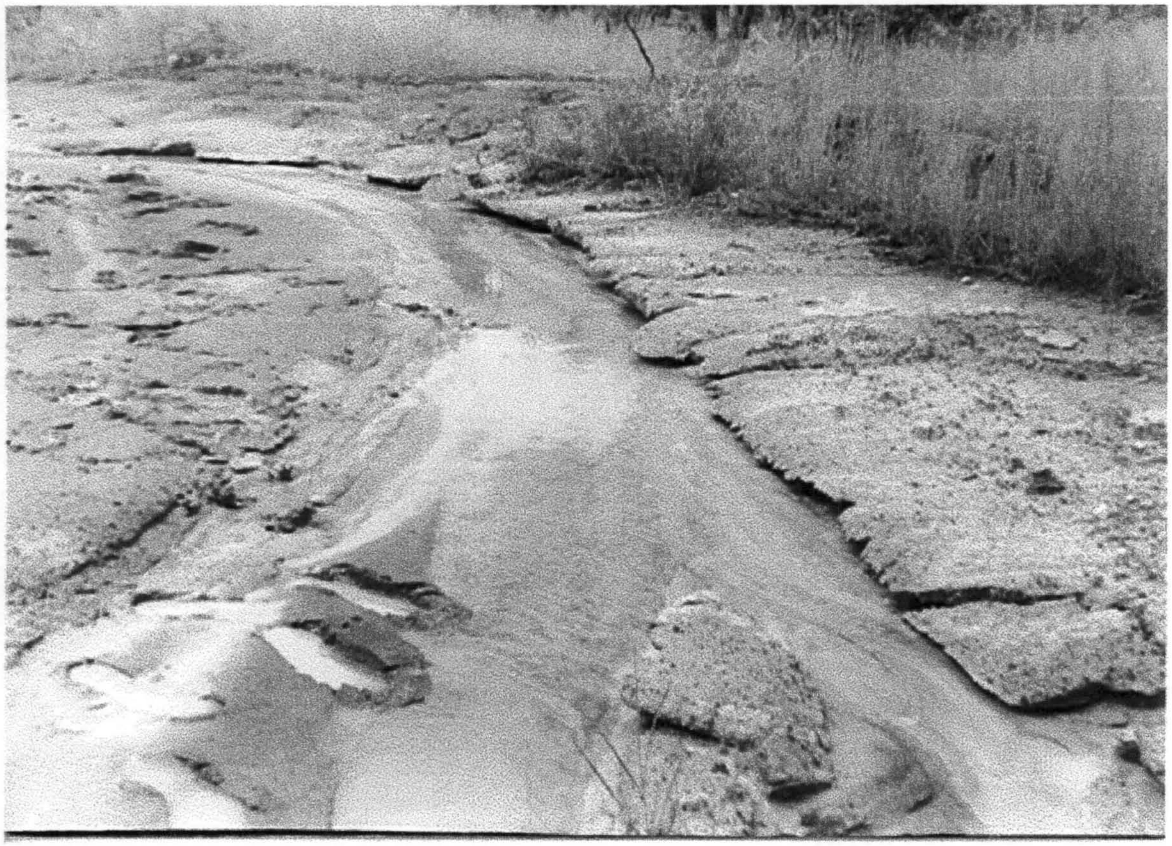
S/No	Factor of Degradation	% Contributed	Type of degradation
1	Shifting Cultivation (Rain fed Agriculture)	15	Sheet Wash and Gullying
2	Irrigation Along River Courses	9	Gullying
3	Grazing	15	Sheet Wash and Gullying
4	Rainfall (Water Erosion)	17	riling, sheet wash and Gullying
5	Bush fires (Uncontrolled)	10	riling, sheet wash and Gullying
6	Bush Burning (Controlled)	2	riling, sheet wash and Gullying
7	Settlements	10	Sheet Wash and Gullying
8	Track Construction	7	Sheet Wash and Gullying
9	Feeder Roads	9	Sheet Wash and Gullying
10	Games	5	rilling, sheet wash
	Total	**100**	

Plate 4.3

Bush fire, a factor of land degradation.

Borgu Sector of the Park used to extent to the areas covering the entire lake and the neighbouring settlements of Doro–Malale, Leshibe, Luma, Shagunu and other Pressure for the release of more land for agricultural activities led government to reduce the size of the Park. An enabling Decree No 46 of 1999 was promulgated to that effect. This led to the release of the buffer zones to enhance peaceful co-existence as it was called. This meant that the natives could use such areas for cultivation and animal grazing. These activities, however, increased the level of land degradation within the Park.

Plate 4.4



Development of gullies on tract/road network within the Park.

Degree of Present Degradation due to Water Erosion:

Slight: in deep soils (rooting depth more than 50 cm) part of the topsoil removed with shallow rills.

Moderate: in deep soils: all top soil removed and shallow rills created with moderately deep gullies

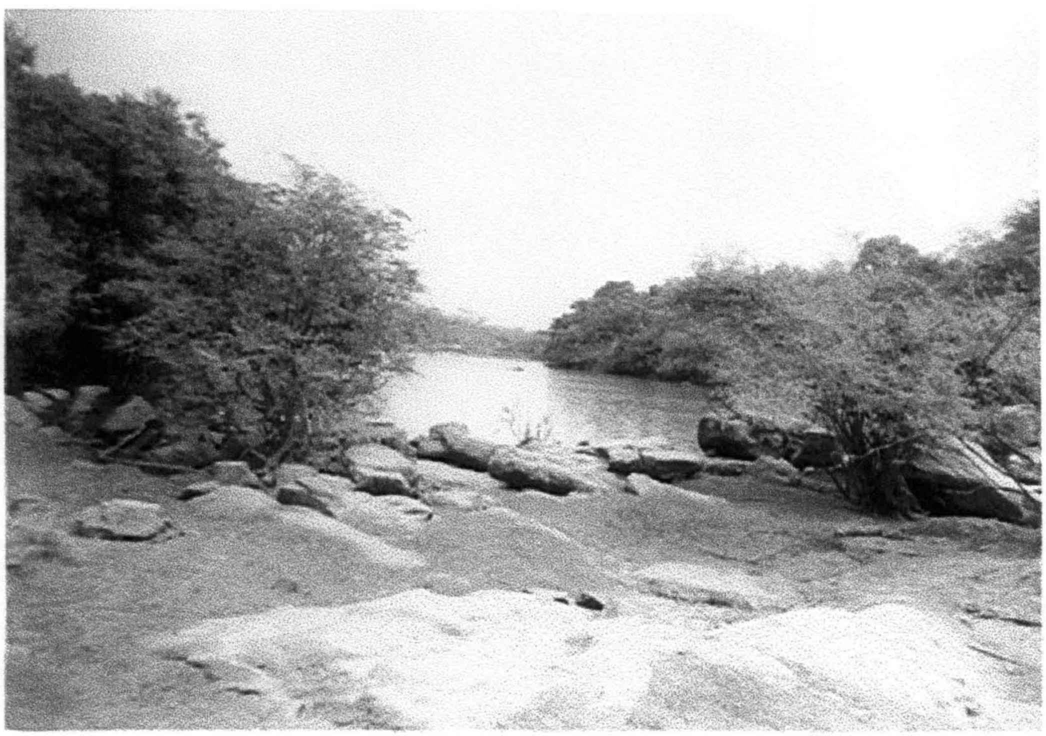
Severe: in deep soils all topsoil and part of subsoil removed, and/or with moderately deep gullies. In shallow soils: all topsoil removed: lithic or leptic phases or with exposed hardpan.

Table 4.2: Extent of Water Erosion

S/No	Item	%	Remark
1	Severe Water Erosion	11	Evidence of gullies
2	Moderate Water Erosion	17	Evidence of rills
3	Light Water Erosion	21	Evidence of rills
4	Vegetation Cover	50	Tree with high canopies
	TOTAL	100	

Plate 4.5 shows the river bed exposed by water erosion.

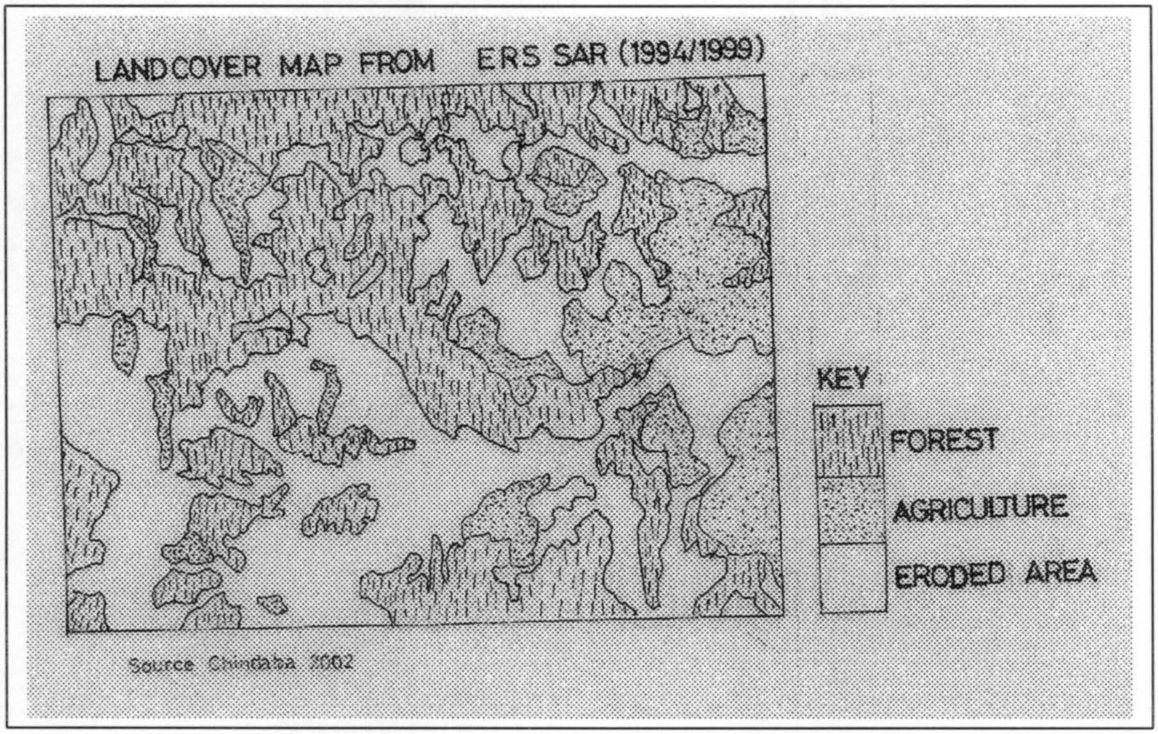
Plate 4.5



Land Degradation by Water.

Figure 4.1 shows the classification on the land cover and a manifestation of 47% of the area degraded by water erosion and human activities.

Figure 4.1: Land cover map from ERS-SAR (1994/1999)



Source: Chindaba 2002

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the discussion on the summary of the project and also highlights the conclusion which of course, was based on the findings of the researcher. Recommendations were also made on the investigations on land degradation to those in authorities of government, Non-governmental Organisations, private individuals conservationists and environmentalists

5.2 SUMMARY OF FINDINGS

The researcher's aim has been to show the contributions of satellite remote sensing to the study of land degradation in the National Park. KLNP environment is experiencing a dramatic increase in precipitation, rapid changes in agriculture, and grazing activities by the neighbouring communities, and other needs that make increasing demand on the land. Any organisation concerned with management of natural resources such as wildlife must have access to a precise up-to-date inventory. At present, the basic source documents are topographical maps. Unfortunately, their accuracy depend on not only their scales but also dates of publication and constant review. Up-to-date inventories will provide decision-makers with effective and efficient means of management. Furthermore, instant retrieval through computerized management technique is possible since observation data enable fast inventory of the topography.

The increasing rainfall is attributed to climate change with its major elements as global warming , as a result the depletion of the Ozone layer. The differential warming of the poles and the equator by the sun results in hot

- The application of image enhancement and transformation techniques.

Extensive and intensive research activities involving, for example, the establishment of spectral response of local terrain features and ensure optimum utilization of remote sensing techniques. To reduce duplication of efforts and to benefit from lost sharing effects, bilateral and regional cooperative arrangements should be made so as to establish and utilize remote sensing facilities.

Aerial survey capability should be acquired to ensure the ability to obtain aerial photographs of any needed territory at a minimal cost, with least foreign currency expenditure and taking advantage of any available odd weather conditions. This will reduce the usual delays in executing development projects, which arise from the often prolonged process of contractual arrangements. After making the necessary investigations to determine prospects of continuity and compatibility of existing or immediate future, satellite systems in both data processing and reception, appropriate ground receiving and processing stations should be established.

Developing countries such as Nigeria should also improve their national communication networks with a view to streamlining the dissemination process for data and information derived from remote sensing applications to ensure prompt supply of data to the user communities. In addition, they should diversify, strengthens, and intensity any existing contacts with the appropriate scientific communities of industrialized nations operating remote sensing systems on both bilateral and multilateral bases. Where no such contacts currently exist, they should be promptly established.

Industrialized nations operating remote sensing systems should endeavour to consult developing countries at the planning and design stages

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