MAPPING COVER SAND ENCROACHMENT IN NORTHERN NIGERIA, USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

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Abstract

An area in semi-arid region of the northern Nigeria, particularly in Sokoto State has been mapped to show the extent of cover sand encroachment. Landsat MSS and aerial photographs have been used for feature identification and extraction of data. The imageries have also been used for monitoring land use/cover changes by visual interpretation and for spectral classification via digital processing. The suitability of the generated images for topographic, geomorphologic, topsoil, vegetation and drainage pattern recognition increased in terms of quality, using principal component (PC) analysis. The data obtained have been processed and integrated using ILWIS-GIS. The result showed that, there was an increase in active cover sand from 1,942 hectares in 1976 to 13,594 hectares in 1986. The sand cover accumulation in the main landscapes of the study area in 1986, were as follows: Plateau: 3,301 hectares (3.4%); Piedmont: 9,516 hectares (9.8%); Valley: 388 hectares (0.4%). The orientation of the landscape patterns (mostly parallel to the dominant wind direction) and the sandy textures of the soil mantle suggest an aeolian origin of the cover sand. The dry season wind "Harmattan", blowing across the Sahara desert from the northeastern region, is the principal age

1. Introduction

Sand cover encroachment leads to land and ecological degradation and the eventual environmental destruction. This is one of the most serious environmental and socio-economic problems facing the world today. This situation is most noticeable within the arid, semi-arid and sub-humid zones of the world. About 35% of the world's land surface is currently at risk and more than 20 million hectares are reduced annually to near or complete uselessness (UNESCO, 1980).

The climate of a region has much effect on sand deposition. Where the climate is dry and windy much sand is carried along the directional movement of that wind. In West Africa, the rainfall gradient from the desert to dense forest results from the alternating and antagonistic relationship of two main air masses. One is the continental trade wind, dry and cool at the beginning but gradually turning warm, which, travels north to south and then northeast to southwest. The other is the monsoon, which is humid and cooler, originating in the Atlantic Ocean and moving from southwest to northeast.

The 3.2% annual population increase in the study area-Sokoto State, like most Sudan and Sahel areas is one of the highest in the world (World Bank, 1985). It has some corresponding consequences on the increase in urbanization, cultivation and further remobilization of the already stabilized ancient dunes. Increasing sand accumulation, decrease in livestock farming and perennial grasses and increase in salinity in the valley areas are frightening indication of desertification caused by wind blown cover sands. The study area is located within the semi-arid region of the northwestern part of Nigeria, particularly in Sokoto State. The area is bounded within latitudes 13° to 13°10'N, and longitudes 5° to 5° 30'E (Fig 1).

The cover sand accumulation in the three main landscapes of the area in 1986 shows increase in all of them when compared to the imageries of 1976. The orientation of the landscape patterns, which are mostly parallel with the wind direction (NE-SW) of the study area and the sandy textures of the soil mantle suggest that the sand is of an aeolian origin. Hence, the northeastern blowing dry wind (Harmattan) is the principal agent responsible for sand cover formation and encroachment.

The study addressed such a possibly wind-constructed or reworked sand cover formation island in the northwestern part of Nigeria in order to map cover sand encroachment. The aim of this study is to produce results that will help planners and engineers on ways to plan and construct infrastructure for checking and controlling cover sand encroachment that may lead to desertification.

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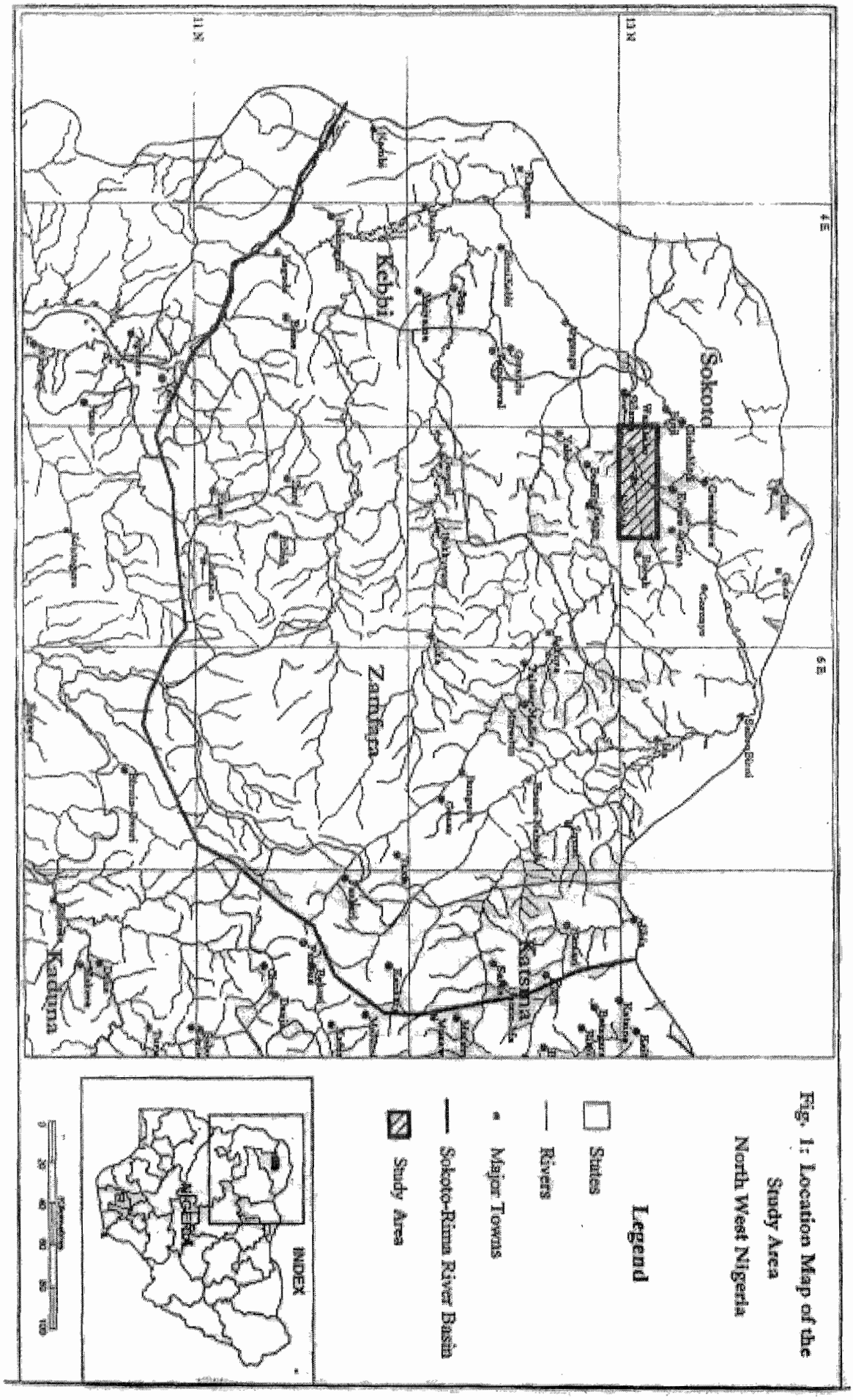

Fig. 1: Location Map of the Study Area North West Nigeria

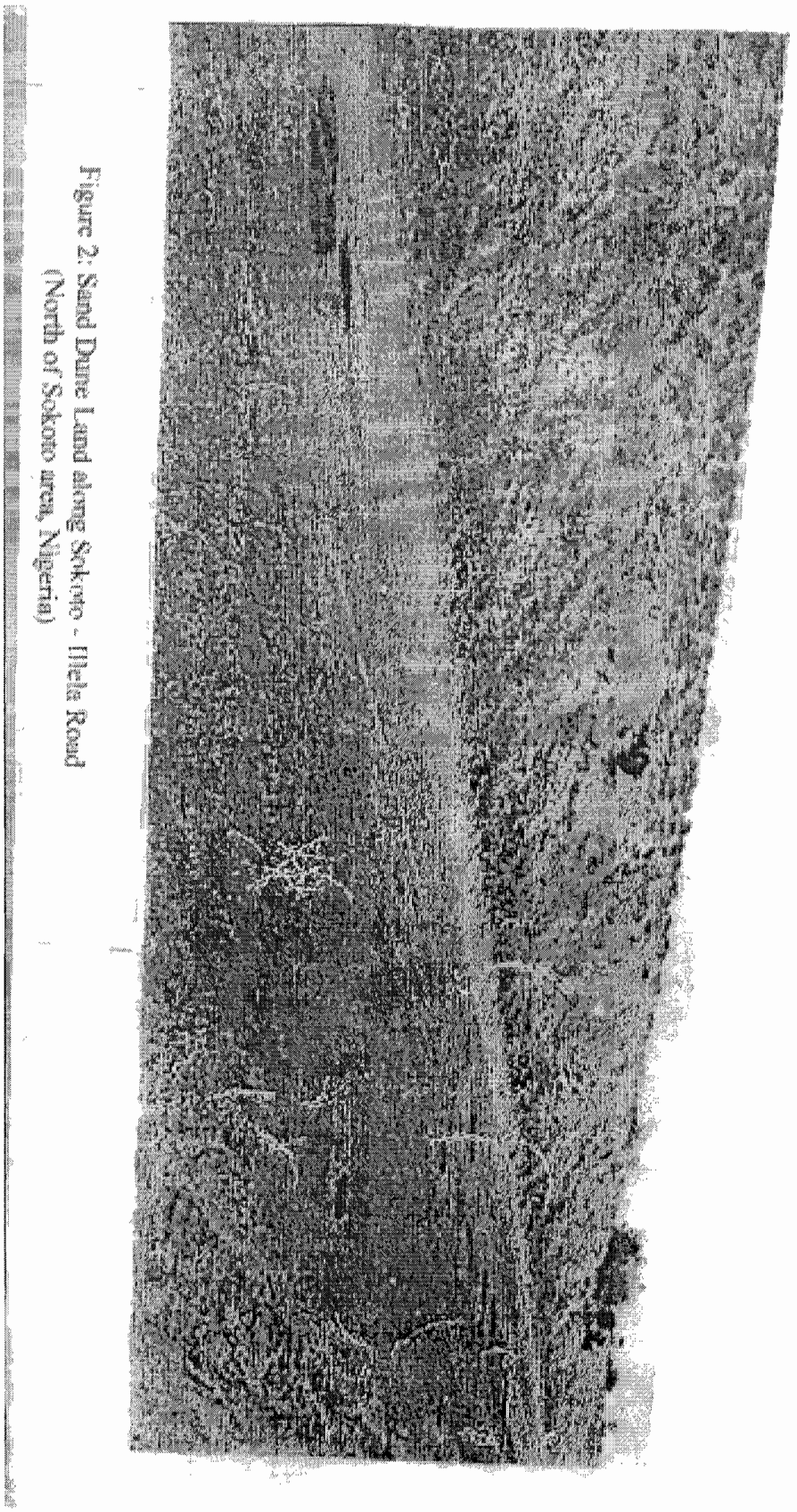

Figure 2: Sand Dune Land along Sokoto - Illela Road
(North of Sokoto area, Nigeria)

2. Methodology

Aerial photographs (1:25,000 for 1977) and landsat MSS (1:250,000 for 1976 and 1986) of the study area were interpreted. The aerial photographs were interpreted using geopedologic approach (Zinck, 1988). The interpretation resulted into soil and landuse/cover maps. In combination of geopedologic maps with the topographic map, the fieldwork was planned and executed (Ohamobi, 1993) using the tentative geopedologic map that was produced. Two major operations were carried out, using landsat MSS imageries: Image (digital) processing and the Visual interpretation.

A supervised classification was carried out using the landsat MSS data set of February (dry season) 1976 and February (dry season) 1986. To compare the reflectance characteristics of the images, we have to standardize the reflectance through normalization and scaling operations to eliminate the atmospheric changes. The intention of this analysis is to monitor sand accumulation and the extent it reached between 1976 and 1986 in the study area.

False color composite for landsat MSS data of February 1976 and 1986 and the vegetation index for the two periods were prepared. Principal Component (PC) among the other enhancement techniques was attempted. The PC1 was chosen for the vegetation index because it presented a clearer and better result for determining the underlying statistical dimensionality of image data set.

Visual interpretation of the images was also carried out for the determination of the main physiographic and land use/cover units. The physiography and the spatial distribution of main land use/cover types were delineated in order to verify the various features on the landsat imagery and determine the present state of the study area, for the purpose of monitoring. The fieldwork exercise was conducted for generating a soil map at a scale and quality compatible with the study, and also to carry out an assessment of land degradation parameter with emphasis on sand encroachment mapping. Soil samples were collected from representative soil units during the fieldwork. The post-field work involved the digitization of the soil map and other data input into the computer using GIS facilities of Integrated Land and Watershed Information System (ILWIS). Analysis and the creation of tables on land degradation characteristic (physical and chemical) were also done. Finally, cover sand encroachment maps was produced based on the analysis that was made.

3. Results and Discussion

The sand dune and shifts are mainly caused by the dry season wind blowing across the Sahara desert from the northeast (Harmattan). The use of remote sensing and GIS in carrying out a supervised classification of the data set of February (dry season) 1976 and February (dry season) 1986, made it easy to discriminate active sand from inactive sand of Sokoto sand cover, the original soil of the area. It is noticed that active sand surfaces have higher reflectances than inactive sand surfaces. The lower reflectance is as a result of substantial vegetation cover on inactive sand (Table 3a).

The use of the principal component analysis in this study is to reduce the number of unwanted images or variables that was needed for the study. The climatic and population growth analyses were obtained and integrated into the remotely sensed data for final mapping of the sand cover encroachment.

(*a*) Climatic Analysis

The aim of this analysis is to attempt to examine the rainfall variability between 1951 and 1979. Having collected the annual rainfall data of Sokoto area for the period 1951 to 1979, the data was analyzed using lotus program. The Sudano-Sahehian drought, which occurred within 1963 to 1974, is clearly shown in the analysis. The annual rainfall is 703 mm for 28 years with an annual average of 57 mm. The driest period fell within 1968-1974 drought period with only 31 mm as average, while the wettest year had only 81 mm about 2.5 times more than the driest period (Mohammed, 1993). The variation in rainfall from year to year has an adverse effect on soil, vegetation and animal life. This resulted in the consistent decrease in vegetation and increase in the drought resistant species in the study area. The mean monthly rainfall and temperature data of Sokoto area is shown in Table 1. Newhall computation program was used to assess the moisture control section of an average representative soil in the area in different dates, thus monitoring aridity.

(b) Population Growth

Since mid 1970's studies in Sudano-Sahelian area, have shown that population growth is in excess of 3% in over half of the region in Africa (Grainger, 1983). The concept of land degradation is relative in connection with human activities. Population growth has a dynamic influence on land use change, which involves increase in urbanization, cultivation, overgrazing etc. with a corresponding impact on the environment.

The population analysis is to examine the population growth trend in Sokoto State, its implication and consequences on resources. The population data were collected from the Nigerian population commission for 1963 to 1991, and were analyzed in order to obtain the rate of population increase in the area (Tables 2a and 2b). The population of Sokoto increased at the rate of 3.2% between 1963 and 1983. The geometric growth in the population of Sokoto Town could be attributed to its growing importance not only as the seat of government but also because of the increasing employment opportunity in the newly established industries to accommodate the rural urban influx of 9%. The ballooning demand

Table 1: Mean Annual Rainfall and Temperature Data of Sokoto Area

Months	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct	Nov.	Dec.
Mean Rainfall 1951--'79(mm)	0.1	0	0.8	9	39	98	179	231	120	25	0.6	0
Mean Temp. ^0C	23.9	27.2	29.7	32.3	32.2	29.3	27.4	26.2	26.9	28.3	26.1	24.4

Table 2a: Population of Sokoto State, Nigeria

No	Year	Population	Growth Rate %
1	1963	4.538.788	-
2	1973	5.991.200	3.2
3	1983	7.908.384	3.2
4	1991	8.605.542	1.1

Table 2a: Population of Sokoto town

No	Year	Population	Growth Rate %
1	1963	89.817	-
2	1973	131.431	4.6
3	1983	173.046	4.6
4	1991	269.525	9

Table 3a: Sand Accumulation From 1976 - 1986

Cover Sand	Area Covered (ha)	% Coverage	Year
Active sand	1,942	2	1976
Active sand	13,594	14	1986

Table 3b: Sand Accumulation in Main Landscapes In 1986

	Area Covered (ha)	% Coverage
Plateau affected	3,301	3.4
Piedmont affected	9,516	9.8
Valley affected	388	0.4

for resources that this growth represents is inevitably responsible for resource abuse both in the short and long run. While consumption is increasing geometrically, production has decreased. Consumption therefore, will continue to escalate at the cost of overexploitation of land resources leading to deforestation, over cultivation and overgrazing etc., leading to soil degradation and hence sand deposition on the surface of land.

(c) Land Use/Cover Changes

Land use/cover changes are of prime importance in assessing land degradation as a result of sand encroachment. This is because it indicates increases in cultivation to growth in population with the resultant consequences of the two conflicts. The supervised classifications have been found useful in estimating cultivated areas scattered across the study area. Combination of visual interpretation and supervised classification, eliminating the two limitations of both approaches presents a more reliable result in the monitoring of land use/cover of the area.

(d) Sand Encroachment

The threat posed by increase in sand migration in recent decades in the areas bordering the Sahel in Nigeria creates the biggest concern than any other parameters causing land degradation. This sand encroachment is because of sand accumulation with its potential to invade farmlands and other human activities (Fig. 2) and this is attributed to probably the southward movement of the Sahara desert as a result of the north easterly winds (locally called Harmattan) blowing across it. This is therefore, the principal agent responsible for sand dune formation and shift.

During the analysis and monitoring of sand accumulation and its extent, remote sensing was found useful in the study because of its ability to discriminate active sand from inactive sand (Figs. 3a

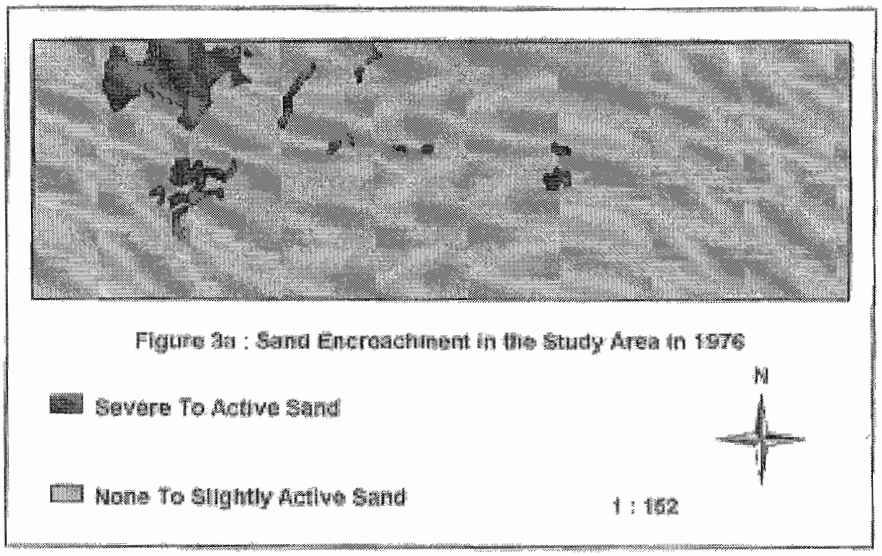

Figure 3a : Sand Encroachment in the Study Area in 1976

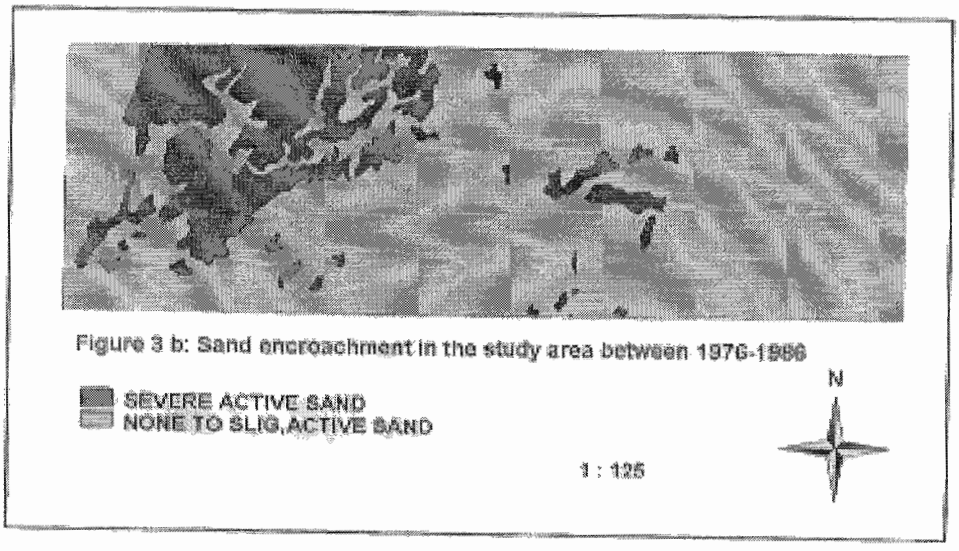

Figure 3 b: Sand encroachment in the study area between 1976-1986

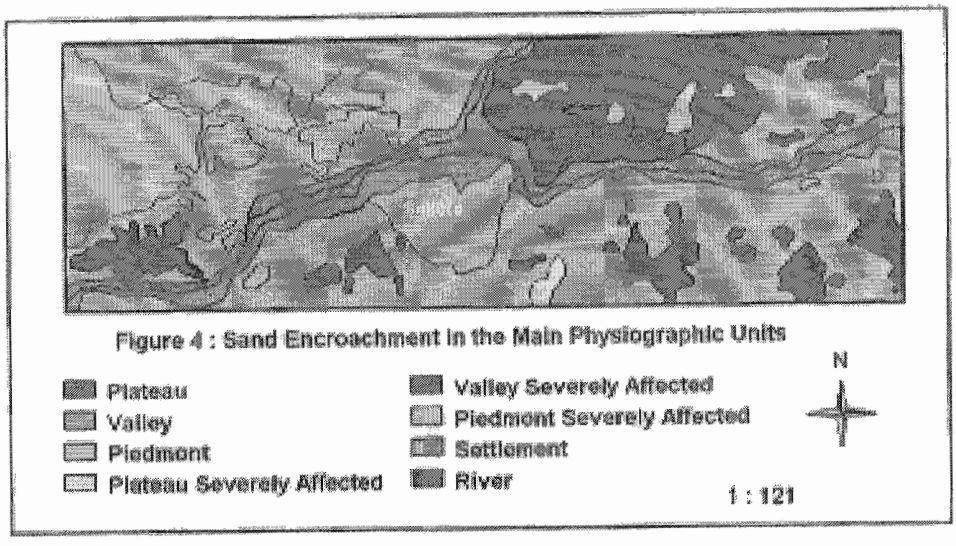

Figure 4 : Sand Encroachment in the Main Physiographic Units

FIG 5.0 Landuse Landcover of SOKOTO MSS Supervised
Source: Landsat MSS 1996