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Assessment of Multi-band Capabilities in the Detection of Built-up Areas in Northwestern Nigeria

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Abstract: Corrected and uncorrected SPOT XS imageries are used to achieve comparative assessment of built-up areas land use and land cover classes in Northwestern Nigeria. The built-up environment showed on both imageries. The PAVM was used to determine the ability of the data sets to produce similar results over the area. Results indicate a low PAVM value for the tertiary level urban land use and land cover classes except the commercial areas. Vacant lands, industrial areas and open spaces showed zero values. The results have implications on the planning of urban and natural resources development in the ecologically fragile region of Northwestern Nigeria.

Key words: Multi-band, built-up area, land use, land cover, imagery, multispectral

INTRODUCTION

Land Cover (LC) and Land Use (LU) are two key elements that describe the terrestrial environment in natural and anthropogenic contexts, respectively. LC may be of natural origin (e.g., forest, rivers and other open water bodies or bare soil or rock) or it may be created by LU (e.g., building, roads and water reservoir). LC is characterized by the biophysical features of the terrestrial environment. LU on the other hand refers to the manner in which the people use these biophysical resources. It is the employment of LC and management strategy used on a specific type by human agents or land managers (Baulies and Szejwach, 1997; Cihlar and Jansen, 2001). LU may also describe the intent with which particular LC was formed. The issues involved in environmental problems and management, in Nigeria as elsewhere, especially those which relate to changes in LU over time, is making LU and LC to be of increasing concern (Meyer and Turner, 1994; Omara-Ojungu, 1993; Vos and Opdam, 1993).

To acquire improved resource information for use in stressed environments (Adeniyi and Omojola, 1988), recommended the application of remote sensing techniques. The tool is capable of minimizing bias and subjectivity in resource information gathering. In fact, any area where remote sensing is less developed that area is often characterized by paucity of resource information and knowledge (Njoku, 1992). The net impact of this scenario is retarded growth and development in the affected region. This is the situation in less developed and developing countries, especially in sub-Saharan Africa. Most parts of Nigeria shares this description. Even as series of decisions and innovations are regularly introduced into resource planning and development programs, little success is achieved. Reason is because current, accurate data, which can be integrated into resource management decisions, are lacking. There are also the crucial problems of obtaining and analyzing data acquired through remote sensing for sustainable resource management.

Remote sensing technique is presently being applied by resource developers for the detection, inventory and management of environmental resources and problems. This study describes the application of remotely sensed data in the mapping of built-up areas LU and LC compared to others of Northwestern Nigeria. It involves a multi-band assessment of SPOT imaging system in a fragile, ecologically unstable and stressed region. Adeniyi (1988) and Adeniyi and Omojola (1988) successfully applied this technique to resource studies and inventory in parts of the study area. In this study, SPOT XS 1 with hybrid of bands, XS 1, XS 3 and Vegetative Index (VI). is applied to investigate and quantitatively detect and map built –up areas LU and LC in Northwestern Nigeria using The static nature of built-up areas LU and LC features as shown in the band XS 1 and combination of bands XS 1, XS 3 and VI are mapped. The relative significance and capabilities of each band and band combination in mapping the LU and LC information are assessed.

This study was based on two assumptions, namely:

- Built-up areas LU and LC features differ in spectral reflectance and

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- Band XS 1 and generated bands XS 1, XS 3 and VI vary in their capabilities to capture the spectral reflectance of built-up terrain features.

The original band XS 1 and selected band hybrids XS 1, XS 3 and VI of the SPOT imaging system are used to generate information on the built-up areas LU and LC. Quantitative assessment and comparison of the datasets are carried out, in order to empirically identify which of the two is better for mapping the characteristics of the built-up areas LU and LC characterizations of the area. The built-up areas represent the area of intensive use with much of the land covered by physical structures. These comprise the towns, villages, industrial and commercial areas and institutions. In the imageries this is represented by Sokoto Township, the close-settled area, the numerous villages and small compounds scattered over the study area as well as the Uthman Dan Fodio University, the industrial and central market complexes. The built-up areas are notably complex in cover and use.

Study area: The study area is stressed by climate and ecological events and so prone to myriads of environmental hazards. This makes environmental information imperative.

The study area in Northwestern Nigeria is 35,784 ha. It lies approximately between latitude 12°56′ north and longitude 5°9′ east, latitude 13°6′ north and longitude 5°20′ east. and latitude 13°9 north and longitude 5°11′ east.

The region is characterized by semi-arid and arid climates. Rainfall which is the most critical element of climate shows a marked seasonal variation. The wet season is characterized by high spatial and temporal variation (Nnaji, 1998; Nnaji, 1999). Annual rainfall varies from about 700 mm in Sokoto to about 1090 mm around Junta, southeast of Gusau. (Table 1). Nnaji (1999) explains the cause of the higher cumulative rainfall variability over the area in terms of the climate forcing agents controlling the entire region.

The temperature as shown in Table 1 is high and sufficient to allow plant growth but rainfall insufficiency impose limitation on the viability of rainfed agriculture. Vegetation is a mixture of Sudan and Sahel savanna and consists of continuous grass cover and mixed savanna woodland and fire resistant trees. As a result of human interference and persistent annual bush burning, the grass has given way to drought resistant trees with crooked trunks (Brinckman and de Leeuw, 1975; Udo, 1970; Areola, 1983). The Date Palm (*Hyphaene thebaica*), Baobab (*Adanonia digitate*), locust bean, shear butter (*Butyrosperum*) are common economic trees. Elsewhere only very impoverished secondary vegetation survives.

Soil profiles show sandy topsoil and clayey subsoil in which concretions are common. If the vegetal cover is removed through farming or grazing, the topsoil is readily washed off by rain. Fadama soils provide more fertile farmlands (except where drainage is poor) and, are very close to water sources for dry season irrigation. Irrigation drainage schemes are designed to control soil moisture in order to facilitate maximum exploitation of soil in the fadamas and elsewhere.

The economy of the area is dominated by subsistence and semi-mechanized farming and herding. Farming is based on multiple crops which depend on the duration of rainfall, moisture retained in the soil and the sensitivity of certain crops to planting dates. The Fadama and other low-lying areas are liable to seasonal flooding and so retain moisture for dry season farming. The floodplains and Fadamas are cultivated by peasants who rely on natural irrigation by floodwater at the commencement and end of the rainy season. According to Oguntoyinbo (Oguntoyinbo, 1983), crop failures are common under these climatic conditions.

The Hausa engage in arable farming, while the Fulani are pastoralists. Uncontrolled roaming of the herds is largely responsible for the erosion and increased decertification. The nomadic Fulani move from one location to the other as dictated by availability of water and pasture. The outcome is over-concentration of livestock and overgrazing of the already degraded environment.

Thus, the choice of this region for the study is predicated on two issues, namely; availability of the remotely-sensed data. Secondly, the apparent need for current and relevant information on built-up areas so as to attempt to tackle the numerous environmental problems of the region especially those which relate to human population and settlement.

Table 1: Mean (min. and max.) temperature in some stations in Northwestern Nigeria

	Mean minimum temperature in centigrade			Mean maximum temperature in centigrade			
Station	Lowest recorded	Average	Highest recorded	Lowest recorded	Average	Highest recorded	Duration of measurement
Sokoto	20.6 (1961)	21.0	22.6 (1973)	33.4 (1955)	34.9	37.4 (1970)	1951-1980
Katsina	17.0 (1961)	18.9	20.2 (1980)	32.1 (1961)	33.6	34.8 (1973)	1951-1980
Gusau	18.4 (1965)	19.3	20.2 (1972)	32.8 (1961)	33.5	34.0 (1969)	

Source: Adapted from Adeniyi (1989)

MATERIALS AND METHODS

The original band XS 1 and selected band hybrids XS 1, XS 3 and VI of the SPOT imaging system are used to generate information on the built-up areas LU and LC. Quantitative assessment and comparison of the datasets are carried out, in order to empirically identify which of the two is better for mapping the characteristics of the built-up areas LU and LC characterizations of the area. The built-up areas represent the area of intensive use with much of the land covered by physical structures. These comprise the towns, villages, industrial and commercial areas and institutions. In the imageries this is represented by Sokoto Township, the close-settled area, the numerous villages and small compounds scattered over the study area as well as the Uthman Dan Fodio University, the industrial and central market complexes. The built-up areas are notably complex in cover and use.

This study involves quantitative, comparative assessment of the SPOT imageries from band 1 and generated imageries from the combination of bands 1,3 and VI for built-up areas LU and LC mapping. It is carried out through the manual image analysis technique of preprocessed SPOT multi-spectral (XS) imageries and steps involved are shown in Fig. 1. The choice of band 1 and hybrids of band 1, 3 and VI of the SPOT imagery is as a result of availability of the datasets for the period required.

The main data are the uncorrected XS SPOT of bands 1 from the blue portion of the electromagnetic spectrum and the corrected XS SPOT from the blue band 1, red band 3 and the VI. The imageries were acquired at the scale of 1:1, 000, 000. The data were cloud-free and of high quality, having been acquired simultaneously during the dry season. There were no marginal information concerning azimuth, sun elevation and flight line on the imageries.

The Nigerian topographical map series Sokoto sheets 10 SE and 10 SW at the scale of 1:50, 000 were used as base map for orientation and geometric registration of the

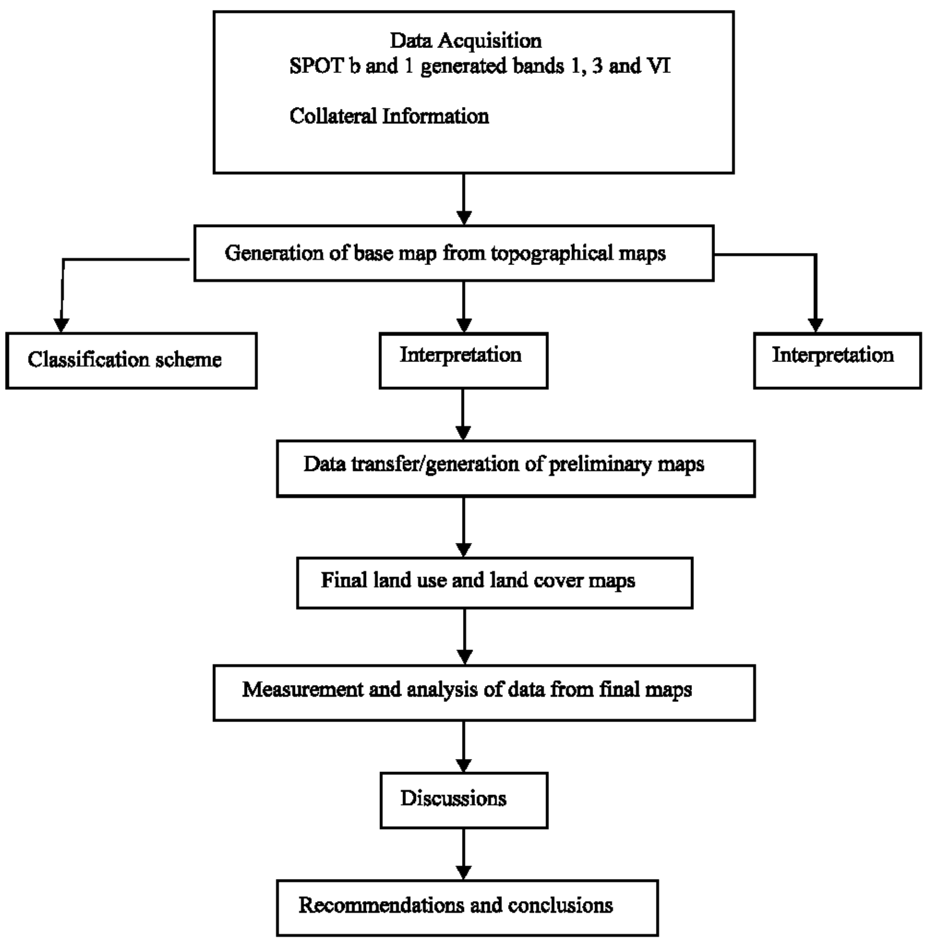
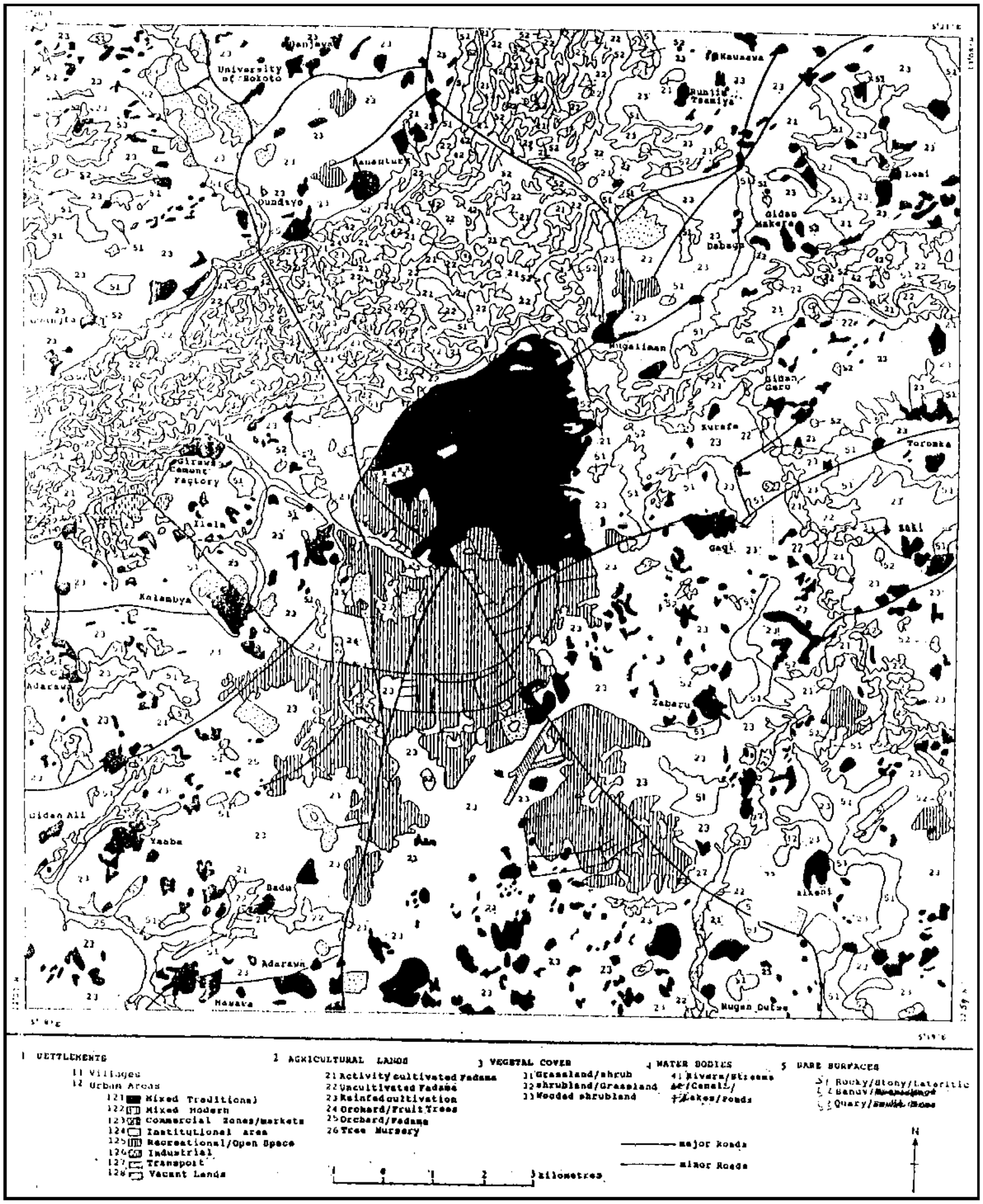
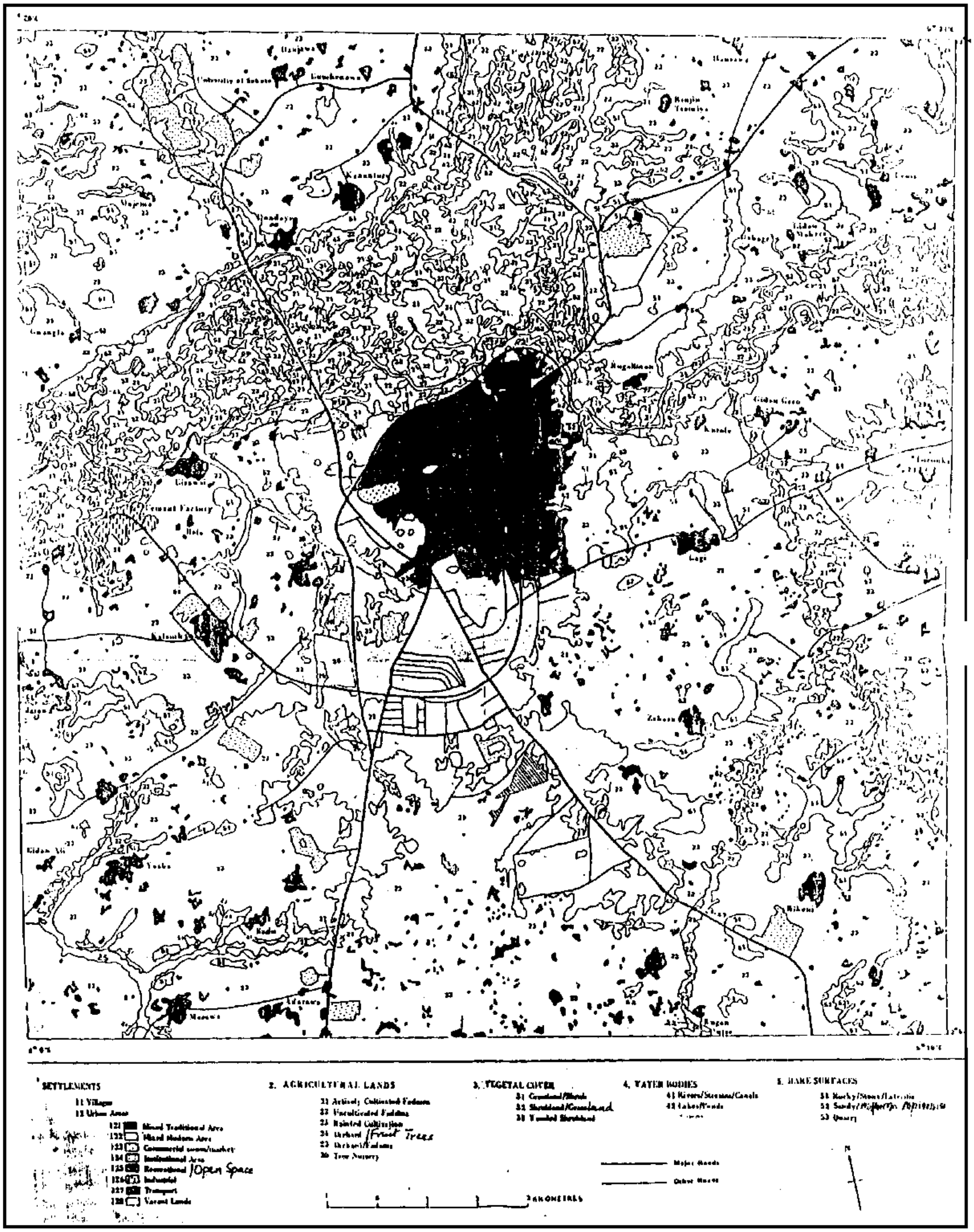


Fig. 1: The research procedure



Source: XS 1, 3 and VI SPOT imagery

Fig. 2: XS 1 SPOT land use and land cover map of Sokoto environs



Source: XS 1 SPOT imagery

Fig. 3: Generated SPOT XS1, 3 and VI land use and land cover map of sokoto environs

imageries during interpretation. A built-up areas classification scheme developed as none existed prior to the study for the region is on Table 2. The scheme arranged the built-up features and areas into classes based on their appearance on the imageries. It was developed to be pertinent to the study and compatible with those for other LU and LC classes already in use in the region, numerically coded and collapsible in nature. The classification also considered the purpose of the study, the scale and resolution of the datasets as well as the peculiarities of the region being studied. Area calculations of polygons of the different LU were based on squared graph paper of 2 mm squared cells. Results obtained are shown in Table 3.

Visual analysis of the imageries were achieved using PROCOM-2, while TAMRON ZOOM lens designed to magnify imageries were adjusted to provide required focal length and magnification for the desired mapping scale. The features were then registered on the transparent tracing paper placed on the base map. The grant projector was used to adjust the scale and size of the maps presented in this study report. The 2 mm squared graph paper was also used for the calculations, while the light table was used for map preparations.

The maps generated from the uncorrected SPOT XS 1 imagery is shown in Fig. 2, while the one generated from the hybrid of SPOT XS 1, 3 and VI is shown in Fig. 3.

RESULTS AND DISCUSSION

Details of the findings and results of the capability assessment are shown in Table 3 and 4 for hybrid imagery XS 1, 3 and VI and XS 1, respectively.

The comparison of Table 2 and 3 indicate similarities and differences between the built-up areas covered by the data sets in ha. If the figures are similar, then there are no differences in the ability of the two imageries to detect and map the LU and LC. The reasons for the inherent dissimilarity include:

- One data set is corrected while the other is not.
- There is the inability of the LU and LC class to be easily identified and delineated, on one imagery than on the other, due to their appearance on the imageries.
- The lack of some physical cover basis for boundary delineation of the built-up area LU and LC class.
- The inaccuracies of the interpretation equipment and measuring standards used and the incidence of human error.

Table 2: Land use and Land cover classification scheme for all classes

1.Built-up areas
11 Villages,
12 Urban Areas,
121 Mixed Traditional Areas,
122 Mixed Modern Areas,
123 Commercial Areas,
124 Industrial Areas.
125 Open Spaces/Recreational Areas,
126 Institutional Areas,
127 Transportation,
128 Vacant Lands.
2.Agricultural lands
21 Actively Cultivated Fadama,
22 Uncultivated Fadama,
23 Rainfed Agricultural Lands,
24 Orchard/Fruit Trees,
25 Orchard/Fadama,
26 Tree Nursery
3.Vegetal cover
31 Grassland/Shrub,
32 Shrub/Grassland,
33 Wooded Shrubland.
4.Water bodies
41 Rivers/Streams/Canals,
42 Lakes/Ponds.
5.Bare surfaces
51 Rocky/Lateritic Surfaces,
52 Sandy Surfaces,
53 Quarries.

Table 3: Built-up areas land use and land cover data from spot XS generated band 1, 3 and VI

Code description	Areas (ha)
1 Settlement (Built-up areas)	6, 294.1
11 Villages	1, 328.1
12 Urban areas	4,966.0
121 Mixed traditional areas	861.3
122 Mixed modern areas	4,145.9
123 Commercial areas	380.0
124 Institutional areas	59.3
125 Open spaces/recreational areas	46.0
126 Industrial areas	66.8
127 Transportation areas	1, 680.0
128 Vacant lands	78.0

Table 4: Built-up areas land use and land cover data from spot XS band 1

Code description	Area (ha)
1 Settlement (Built-up areas)	6,747.6
11 Villages	1,306.0
12 Urban areas	5,441.6
121 Mixed traditional areas	1,372.3
122 Mixed modern areas	4,011.0
123 Commercial areas	29.8
124 Institutional areas	251.0
125 Open spaces/recreational areas	40.0
126 Industrial areas	78.6
127 Transportation areas	61.2
128 Vacant lands	81.2

Simple percentages are used to show the differences and similarities in the use of XS 1 and generated XS 1, 3 and VI. The simple percentage represents the relative amount of the built-up areas LU

Table 5: Built-up areas land use and land cover data in percentages and the percentage absolute variation of mapping values

	Generated XS 1, 3 and VI		SPOT XS 1		
Code Description	Study area%	Intra class %	Study area %	Intra class %	PAVM
1 Settlement (Built up areas)	17.6	(100)	18.80	(100)	3.3
11 Villages	3.7	21.1	3.60	19.4	1.4
12 Urban areas	13.9	78.9	15.20	80.6	4.5
121 Mixed traditional areas	2.4	13.7	3.80	20.3	22.6
122 Mixed modern area	11.6	65.9	11.20	59.4	1.8
123 Commercial areas	1.1	6.0	0.08	0.4	86.4
124 Institutional areas	1.0	5.7	0.70	3.7	30.0
125 Open spaces/recreational areas	0.1	0.7	0.10	0.6	0.0
126 Industrial areas	0.2	1.1	0.20	1.2	0.0
127 Transportation areas	4.7	26.7	0.20	0.9	91.8
128 Vacant lands	0.2	1.2	0.20	1.2	0.0

and LC as a percentage of the entire area. The percentages of the intra class classification are also shown. These are the percentages of the LU and LC class within its primary and secondary levels. These simple percentages were used to highlight the differences and similarities between the relative amounts of the built-up area LU and LC classes. The strength of their differences and similarities are displayed by Adeniyi (1988) and Adeniyi and Omojda (1988), using the Percentage Absolute Variation of Mapping (PAVM) within the study area. The PAVM is expressed as:

$$\text{PAVM}=\frac{|G-B|}{|G+B|}\times\frac{100}{1}$$

Where, G = generated SPOT XS bands 1, 3 and VI generated map percentage of the LU and LC class and B = SPOT XS band 1 generated map percentage of the LU and LC, while $|G - B|$ = Absolute differences in the values of G and B.

The values of PAVM range from 0 to 100%. A zero value implies that no differences exist between the datasets in mapping the LU and LC classes. The value of one hundred implies that the LU and LC class identified using one dataset was not possible on the other.

The values for generated imagery and band 1 datasets are presented alongside the simple percentages in Table 5. Considering the major built-up areas LU and LC classes; the mapping was identical with less than 9% PAVM value.

The tertiary level built-up areas LU and LC classes also showed absolute similarity in open space, vacant land and industrial area and fair similarity in mixed modern area. On the other hand, transportation and commercial areas showed unusual high values of PAVM implying dissimilarity in the ability of the image data to map the LU and LC information.

CONCLUSIONS

The quantitative capability assessment and evaluation of corrected SPOT XS bands 1, 3 and VI and the uncorrected SPOT XS band 1 showed that the built-up areas LU and LC classes developed for this study can be mapped at the scale of 1:50,000 chosen for the study area.

The built-up areas LU and LC class was largely identified and delineated. This is because typical contextual, physical environmental features, which contrasted with the surroundings, characterize these classes. The built-up areas classes which do not possess these attributes were identified and mapped after a field check for ground truth. The imageries differential sensitivity to the spectral signatures of the built-up LU and LC classes, especially by their colors, posed a problem to proper identification and delineation. In some cases, different built–up features are rendered in the same colors and were identified taking into consideration other image interpretation elements. Most of the features in the built-up areas showed well on the two datasets. This is expected, given the improved spatial resolution of the SPOT imaging system.

The PAVM data was used to show the ability of the two datasets to produce similar built-up areas LU and LC results over the study area.

The tertiary level built-up areas LU and LC classes showed a low PAVM except commercial areas, while vacant lands, industrial areas and open space showed zero values.

From the details presented, no area of the region is strictly characterized by a single, uniform built-up areas LU system. The people have adopted multiple built-up LU systems. Even within the urban and rural areas, there are pockets of different built-up areas LU and LC types. This scattered and irregular built-up areas LU pattern and the lack of any real spatial specialization in LU may be an obstacle to result-oriented planning efforts.

For meaningful results to be achieved planning control and guided use of land must be introduced and enforced. Land use control is necessary so as not to frustrate modern innovations and management techniques, but also to ensure that each area is devoted to the type of built-up activity to which it is ecologically suited. It is also to ensure that land is protected from wasteful exploitation and damage.

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