Analysis of high resolution satellite digital data for land use studies in the derived savanna ecosystem of Nigeria

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ABSTRACT

High-resolution satellite data can give vital information about land cover, which can lead to better interpretation and classification of land resources. This study examined the relationship between Systeme Probatoire d'Observation de la Terre (SPOT) digital data and land use types in the derived savanna ecosystem of Nigeria. The digital data of arable land, tree crops, burnt surface, riparian and settlements were analysed to establish relationships and potential of SPOT for resource discrimination and mapping. The results show that SPOT digital data are significantly different for the different land use types identified, spectral behaviour bears strong relationships with land features, and digital data are not significantly different ($P < 0.01$) within the ecosystem. Hence, the spectral behaviour from one area can be used to characterize the other within this and similar ecosystems.

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RÉSUMÉ

Ande, O. T. & Ogunkunle, A. O.: *Analyse des donneés numériques de satellite de haute résolution pour les recherches sur l'emploi de terre dans la savane dérivée de l'écosystème du Nigéria.* Les données de satellite de haute résolution pourraient donner d'information vitale au sujet de la couverture de la terre, qui pourraient mener à une meilleure interprétation et classification des resources de la terre. Cette recherche était conduite pour étudier le rapport entre les données numériques du Système Probatoire d'Observation de la Terre (SPOT) et les types d'emploi de terre dans la savane dérivée de l'écosystème du Nigéria. Les données numériques de terre arable, de cultures d'arbres, de surface brûlée, de riveraine et de habitations étaient analysées pour établir les rapports et le potentiel de SPOT pour la distinction de resource et le mappage. Les résultats montrent que les données numériques de SPOT sont considérablement différentes pour les différents types d'emploi de terre identifiés, le comportement spectral a un rapport solide avec les caractéristiques de la terre et les données numériques ne sont pas considérablement différentes (P <0.01) dans l'écosystème. Par conséquent, le comportement spectral d'une zone pourrait être utilisé à caractériser l'autre dans cet écosystème et d'autre similaire.

Introduction

Most reported relationships between land resources and spectral data in Nigeria have been from Landsat MSS, which has low spatial resolution (Fagbami, 1986a,b). The second generation high resolution remote sensing satellite (e.g. Systeme Probatoire d'Observation de la Terre (SPOT) offer possibilities for surveying resources (Agbu & Frank, 1988). The multispectral capability increases their value such that different bands are sensitive to different types of objects on the land surface. A close relationship exists between the kind of soil and nature of the parent materials, relief, climate, vegetation and age of the landform (Soil Conservation Services, 1966). Therefore, spectral characteristics of features of the earth's surface that reflect surface and subsurface conditions can be analysed such that terrain features can be predicted for similar environments from satellite imageries.

The potential of SPOT are being increasingly explored worldwide for resource mapping (Agbu, Fehrenbacher & Jansen, 1990; Korolyuk & Scherbenco, 1994; Leone *et al*., 1995) owing to its high spatial and spectral resolutions. The application of SPOT in the Nigerian environment is limited, with few applications in monitoring land use effects and terrain studies (Nichol, 1992; Akinyele, 1993). The ability of SPOT in resource mapping can bridge the gap in land information system in Nigeria. Moreover, it will be of great value in the derived savanna with variable land use types, which pose great problem to terrain mapping with satellite of low spatial resolution.

Statistical analyses of SPOT data will give room to establish or explore these techniques for terrain analysis without subjective assumptions. Hence, this study will increase the confidence of environmental scientists in using SPOT products for terrain analysis and predictions.

Materials and methods

The study areas are in the derived savanna zone of south western Nigeria. The first site lies between latitudes 7^0 28’ and 7^0 33’N and longitudes 4^0 01’ and 4^0 06’ E, with Lalupon in Oyo State as the major landmark. The second site lies between latitudes 7^0 28’ and 7^0 36’ N and longitudes 4^0 01’ and 4^0 06’ E, with Iwo in Osun State as the major landmark (Fig. 1).

The SPOT satellite images of December 1986 (Plate 1) were purchased and geo-referenced with Universal Traverse Mercator (UTM) world coordinate system, using 1:50,000 topographical maps of Nigeria re-sampled to 20 m × 20 m cell size.

The locations of the training sites were determined using Global Positioning System (GPS) 315 MAGELLAN. The locations were recorded as geographic coordinates (latitudes/ longitudes) in degrees, minutes and seconds. The GPS readings from the first site included 7^0 31' 05", 4^0 03' 23"; 7^0 31' 50", 4^0 03' 57"; 7^0 31' 32", 4^0 03'10"; 7^0 31' 10", 4^0 05' 12"; 7^0 31' 10", 4^0 03' 50"; 7^0 30’ 40", 4^0 02’ 35"; 7^0 29’ 30", 4^0 04’ 15"; 7^0 28’ 08", 4^0 03’ 45"; and 7^0 28’ 20", 4^0 03’ 15". The GPS readings from the second site were 7^0 39’ 30", 4^0 14’ 03"; 7^0 39’ 25", 4^0 13’ 35"; 7^0 38’ 44", 4^0 13’ 30"; 7^0 38’18", 4^0 12’ 40"; 7^0 37’ 50", 4^0 12’ 10"; and 7^0 37’ 11", 4^0 12’ 46"; and 7^0 37’ 20",4^0 14’ 06". The accuracy of the GPS readings was within $\pm$ 30 m.

Land use descriptions were made in 10 m × 10 m plots and the topographic positions were noted. Land cover types that were common to the sites studied included cultivated farm trees, shrubs, grasses, bare land, built-up areas or settlements, roads and rivers. Combinations of these land cover types led to specific land use classes including arable farm land, burnt areas, settlements, tree crops, and riparian. The sites were identified on the SPOT imageries and the relationship between the sites of the actual cover or use identified and their corresponding radiometric or digital values. Hence, the land features were converted to digital values. The results were subjected to ANOVA to assess the degree of variations and the effects of land use on the digital values in establishing or justifying the effectiveness of SPOT in terrain analysis in the savanna.

Results and discussion

Table 1 shows the identified land features and their corresponding radiometric or digital values. The land features common to the two sites studied are arable farmland, burnt area, tree crops, riparian, and settlements. The results of ANOVA showed that the digital values (DV) for the two sites studied were not significantly different (Table 2). Thus, the two sites could be considered as homogenous or similar.

The land use or land cover types (L) identified on the field for the ecosystem were highly significantly different ($P < 0.01$); hence, the land cover identified could be used to differentiate the scene to spectral classes. The results further showed that the band readings (B) were also highly significantly different ($P < 0.01$). This shows the sensitivity of each band to different features on the ground. The ANOVA results

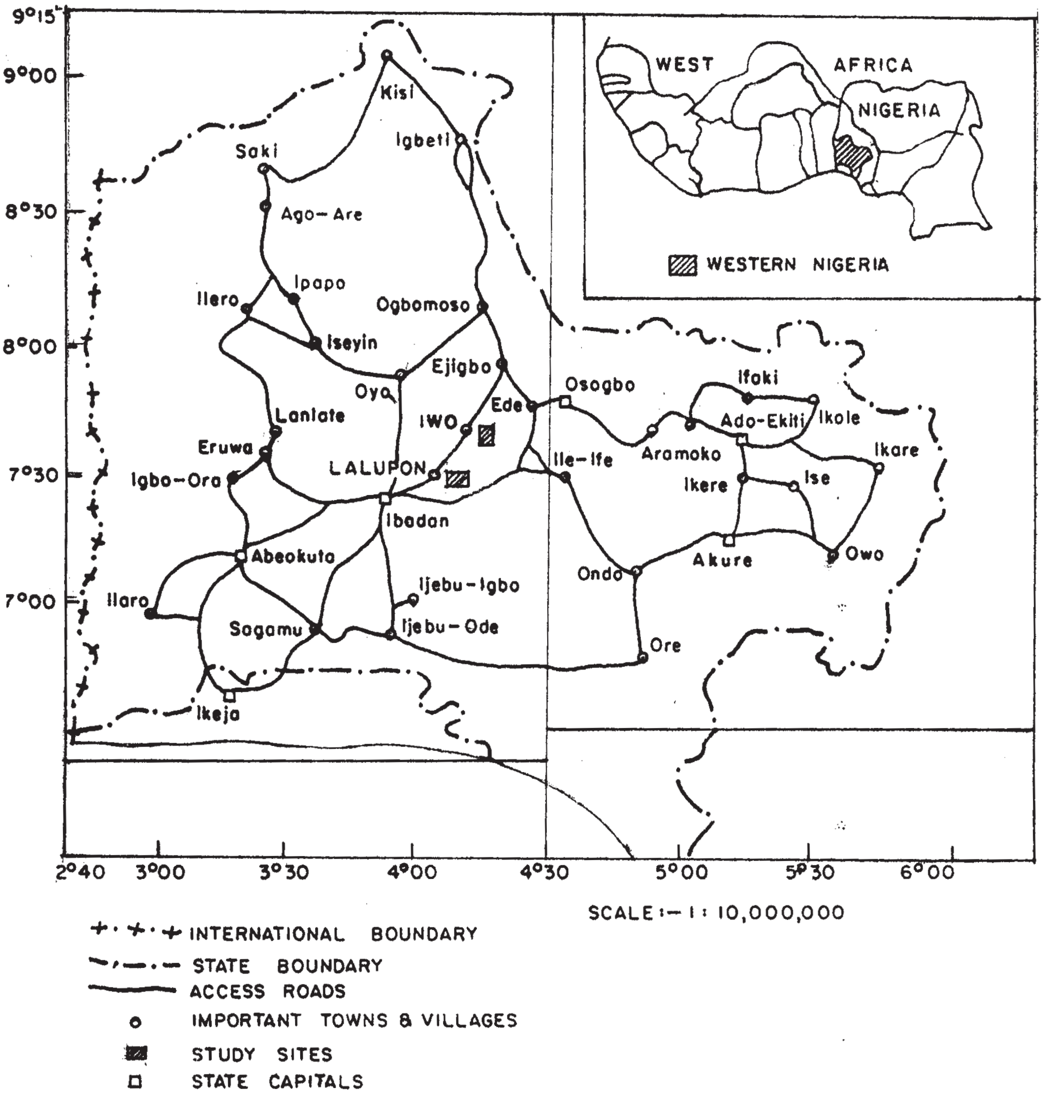

Fig. 1. Map of south western Nigeria showing the study sites.

showed that the two areas studied (A) were different from each other. This could be attributed to features which were uncommon to the areas studied. Some features such as dam and swamp at Iwo have peculiar spectral characteristics. These features were not noticed within the area studied at Lalupon. The different spectral band readings and the cover types identified (L × B) were highly significantly different ($P < 0.01$). This shows the ability of each band to separate the ground features to detail. The land use and area L×A interaction was highly significantly different ($P < 0.01$). This could also be attributed to the presence or absence of certain dominant features in the areas studied within the ecosystem. The difference between the spectral bands and the areas (B×A) was not significant. This suggests that spectral signatures of the areas are similar

Spectra behaviour	**Land use / cover**	**Land form**
Dark-red	Tree crops	Upper - midslope
Bright-red	Riparian	Valley bottom / Fringes
Very dark-gray	Burnt area	Plains / lowland
Brownish-gray	Arable farmland	Plains / lowland
Cyan	Settlements	

Plate 1. SPOT - XS: False colour composite imagery of Lalupon area.

TABLE 1

Conversion Table of the Ground Truth Data to Digital Values from the SPOT Scenes of the Study Sites

Land use (L)	*Bands* (B)	*Site1* $\bar{x}$	*SD*	*CV*	*Site 2* $\bar{x}$	*SD*	*CV*	$\bar{x}$
Arable	1	42.50	1.12		47.00	1.87		44.75
	2	30.50	1.48	1.16	38.00	2.90	2.53	34.50
	3	43.00	1.23		50.00	0.71		46.50
Burnt area	1	42.50	1.12		44.50	1.12		48.50
	2	31.25	0.83	3.42	32.25	4.82	6.36	31.75
	3	37.75	1.48		39.00	1.58		38.38
Settlement	1	53.50	3.35		53.35	1.92		53.18
	2	45.50	1.22	3.88	46.00	2.92	2.44	45.75
	3	52.00	0.83		51.50	1.12		51.75
Tree crop	1	75.00	0.83		42.20	1.12		40.48
	2	24.25	2.24	1.12	29.25	1.30	0.94	26.75
	3	57.00	0.83		50.00	1.12		53.50
Riparian	1	41.50	0.43		46.75	0.83		44.13
	2	28.50	1.12	3.42	35.00	1.22	1.28	31.75
	3	73.00	4.06		75.75	2.28		74.38

$\Sigma\bar{x}$ =44.51
CV = 4.47 %

TABLE 2

Analysis of Variance of the Ground Truth Data Converted to Digital Values from the Spot Scenes of the Study Sites

Source of variation	*df*	*ms*
DV	3	10.76^{ns}
Land use (L)	4	712.36***
Bands (B)	2	3657.35***
Area (A)	1	392.40***
L × B	8	665.74***
L × B	4	22.22*
B × A	2	10.50 ^{ns}
L × B × A	8	2.66 ^{ns}
Error	87	3.95
Total	119	

Mean = 44.51
CV = 4.47 %
Standard error of land use (L) = 0.406
Standard error of bands (B) = 0.314
Standard error of area (A) = 0.257
Standard error of L × B = 0.257
Standard error of L × A = 0.574
Standard error of B × A = 0.445

within the ecosystem. The interaction among the three factors–band, land use and area (B×L×A)–was not significantly different ($P < 0.01$). Hence, the signatures from one area can be used to characterize the others within the ecosystem. The Least Significant Difference (LSD) shows that arable land is significantly different ($P < 0.01$) from all other land use types.

Cocoa or forest is significantly different ($P < 0.01$) from riparian vegetation. This shows the ability of SPOT to recognize different tree or plant species on such terrain. Hence, the spectral signature has potential to identify land use precisely in the savanna.

The generally low coefficient of variability (CV) shows the purity of the demarcated parcels from the landscape (Table 1). The least variable in the environment is water body with 0.43 per cent, while the most variable is burnt area with 3.42-6.38 per cent. The latter could be attributed to mixture of soot, chaff and bare land, which all contribute to the spectral behaviour. The ground truth confirms that burnt areas are part of arable land being prepared for the next farming season during the time of the satellite overpass. Thus, the spectral signatures depend also on the degree to which the plant cover is burnt. Apart from this burnt area, the CV of other different parcels is between 0.43 and 3.88 per cent.

Conclusion

The following are the general and specific conclusions from the SPOT digital analysis:

1. The values recorded from digital value analysis can be used to determine homogeneity or heterogeneity of land cover in an ecosystem such that data from one site can be used to characterize the other.
2. The analysis further shows the potential of SPOT to classify the landscape in the study area to detail because of its ability to separate vegetated and non-vegetated cover; hence, it will be of great value for land use monitoring.
3. The purity of the demarcated parcels indicates that SPOT can be used for land resource survey to map their distribution precisely.
4. Therefore, in an ecosystem such as the derived savanna, the usefulness of SPOT should not be underestimated in resource mapping.

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