Exploiting Landsat ETM to Validate the Potentials of Nigeriasat-1 in Vegetation Mapping of Southwestern Nigeria

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Abstract

Mapping and monitoring rainforest vegetation through remotely sensed images involve various considerations, processes and techniques. Satellite imageries are known for their differences in spectral, spatial, radioactive and temporal characteristics and thus are suitable for different mapping purposes. Achieving these purposes involves various considerations, processes and techniques. For rainforest vegetation assessment, it is important to identify discernible spectral characteristics of satellite imageries and therefore develop a preliminary vegetation classification for mapping vegetation cover. It is based on these that this paper demonstrated the potential of NigeriaSat-1 in assessing rainforest vegetation of the Southwestern Nigeria using Landsat ETM as a means of validation. In this study, the spectral classes of the NigeriaSat-1 and Landsat ETM were translated into the land use land cover classes in the image processing. The findings revealed that of the total area of about 9,700km^2, NigeriaSat-1 and Landsat ETM captured 68.0% and 56.4% respectively for rainforest vegetation. Using the accuracy values generated from the two images, the results of Landsat ETM was subsequently used to establish the potentials of NigeriaSat-1 in the assessment of rainforest cover. For vegetation representation in this study, the NigeriaSat-1 data produced better and consistent producer and user's accuracies of 98.41% and 96.88% respectively as compared to the Landsat ETM image with producer and user's accuracies of 80.28% and 98.28% respectively.

Keywords: *Rainforest, vegetation, image classification, NigeriaSat-1, Landsat ETM*

1. INTRODUCTION

The advancement in remote sensing technology has continued to increase the scopes of research scientist's choices of earth observation imageries (Xie et al., 2008). Imageries are suitable for different purposes because each image is characterised with specific and unique spectral, spatial, radiometric and temporal properties based on its mission and objectives (Xie et al., 2008). The use of imageries saves time as it has capabilities to provide much information on large scale earth surfaces within a short time (Rhyma *et al.*, 2016). Presently, the increasing numbers of earth observation satellites and their possibility of measuring changes in the earth's resources have substantially become more practical in monitoring different changes at the regional and global scales, and also for future references (Billingsley, 1984). The use of certain and relevant satellite data will depend on the spatial and temporal scales of vegetation covers and researchers' interest. Assessing and monitoring the state of the earth surface is a key requirement for global change research (National Research Council, 1999; Lambin et al., 2001; Jung et al., 2006). Mapping natural resources such as vegetation for potential benefits is an important technical task that can form a base for all living beings and essential role in impacting environment positively (Xiao et al., 2004). Therefore, detailed understanding of the environments (both natural and man-made) through quantifying vegetation cover from local to global scales over a period of time require proper vegetation mapping to obtain critical and valuable information. All over the world, efforts have been made by researchers and scientists in assessing forestry and vegetation cover from different scales using remote sensing imagery. Remote sensing technology has been recently considered the best means of acquiring the data for assessing vegetation cover changes particularly over large areas since other methods are too expensive, time consuming, and as well characterized with date deficiencies (Langley et al., 2001; Nordberg and Evertson, 2003; Xie et al., 2008).

For about 40 years now, Nigeria's forests including the conservation areas have continued to shrink, especially in the north, where uncontrolled commercial exploitation of privately owned forests began in the late nineteenth century (Ayeni 2013). The forest system in Nigeria fall into three major categories of vegetation this include the mangrove and freshwater forest, the tropical rainforest and the drier forest (Akinbami, et al., 2003; Salami and Balogun et al., 2006; Ayeni 2013). The mangrove/freshwater and tropical rainforest is a characteristic the southern humid zone while the drier forest covers the middle and north regions. Although, these forests have greatly reduced due to various human activities such as logging and agricultural encroachment nevertheless they have played important roles in providing habitat for wildlife as well as purifying the environment. Presently, the rate of deforestation is now estimated at about 3.5% per annum translating to a loss of 3,500–4,000 km^2 of forest land per year while current level of demand for forest products outstrips the sustainable level of supply (Ayeni 2013). In the future, if adequate management and conservation measures are not put in place, this situation is expected to deteriorate further (Ayeni, 2013).

It should be noted that generating spatial representations through remotely sensed data and appropriate techniques to extract detail information on forest degradation is quite essential in monitoring and managing forest (Ayeni 2013). Although, there are challenges facing geo-spatial database in Nigeria which has remained big factor in forest resources and management. For instance, rainforest monitoring using remotely sensed data had been hindered by the problem of poor funding in the recent past and still the one of serious problem facing research in geo-spatial data usage (Ayeni 2013). In September 27, 2003 and August 17, 2011 National Space Research and Development Agency (NASRDA) successfully launched NigeriaSat-1 and NigeriaSat-X respectively. These two satellites have a combination of characteristics with great potentials for forestry monitoring. NigeriaSat-1 has a resolution of 32m and 3 spectral bands namely; Green: 0.52 – 0.62µm, Red: 0.63 – 0.69 µm, and NIR: 0.76 – 0.9 µm. It is one of the Disaster Monitoring Constellation (DMC) satellite and has a swath width of 600km and a revisit cycle of 3 – 5days (NASRDA 2003). It also has spectral resolution comparable to spot XS and spatial resolution comparable to Landsat TM (Salami and Balogun et al., 2006). On the hand, NigeriaSat-X is based on the SSTL-100 platform and features a 22-meter multispectral imaging system with a 600-km swath (NASRDA 2011). Nevertheless, access to these satellites data is a serious issue that needs to be addressed between NASRDA management and relevant Nigeria scientists/researchers (Ayeni 2013). It is against this backdrop that this current study aims to demonstrate the potential of NigeriaSat-1 in the assessment of part of rainforest vegetation of SW Nigeria using Landsat ETM as a means of validation.

1.1 The Study Area

The study area cut across three (3) states in Southwestern Nigeria - Ogun, Oyo and Osun and geographically located between Longitude 3°0'51.821" and 4°12'24.415" E, and between Latitude 6°54'28.043" E and 7°34'2.875" N (Figure 1). It covered an area about 9727.44 km^2 and fall within the tropical rainforest Nigeria.

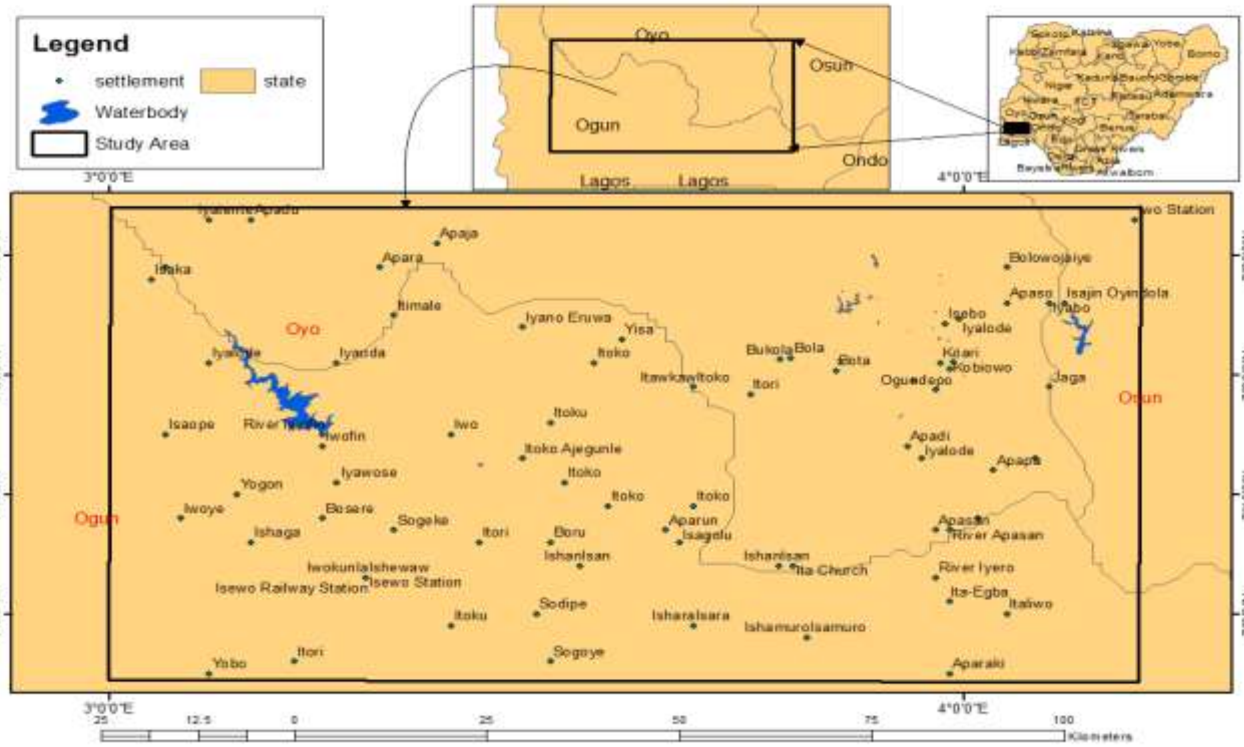

Figure 1: Study area

The area is characterised with an average annual rainfall of about 1350mm and its annual temperatures range between 21°C and 29 °C with high humidity depending on the vegetation latitudinal location. Two seasons dominate the area and they are under the influence of the South-Westerly wind which brings rain and the North-Easterly Trade winds which brings harmattan (Barbour et al., 1982). The tropical forest originally covered this part of Nigeria. However, due to continuous forest exploitation for many decades, its original vegetation has been seriously induced with patches of woodland and reduced in size compared to what it used to be in the 1960s (Ayeni, 2012; Ayeni et al., 2015; Ayeni et al., 2016).

2. MATERIALS AND METHODS

2.1 Data Acquisition

In this study, one-time Landsat ETM of January 2011 image was used for the validation of potential NigeriaSat-1 for LULC assessment (Table 1)

Table 1: Satellite data used and their characteristics

Parameter	Landsat ETM	NigeriaSat-1
Date acquired	January, 2010	January, 2010
Spatial resolution (m)	30	32
Sensor	Enhanced Thematic Mapper	Imager
Spectral resolution	8 Bands in the visible, near IR, mid IR and thermal IR	3-Bands • Green (0.52-0.62 µm) • Red (0.63-0.69 µm) • NIR (0.76-0.90 µm)
Dynamic range (bits)	8	8
Repeated cycle (days)	I6	3-5 (DMC satellites)
Swath width (km)	185	600
Satellite vehicle	Delta-7920-10C	Kosmos-3M
Year launched	15-Apr-99	September 27th 2004
Orbit altitude (km)	705	675

NigeriaSat-1 of the study area for 2011 was acquired from NARSDA, Abuja while the Landsat image of the study area for 2011 was acquired from GLOVIS portal (http://glovis.usgs.gov/). The images which covered part of Southwestern Nigeria were processed and classified for the purpose of this study's aim. To minimize the effect of seasonal variation, the two images were acquired in the same dry season.

Image Processing and Analysis

The satellites images were opened directly within the ENVI 5.3 classic: Files>Open External Files>Landsat ETM / NigeriaSat-1>Landsat ETM / NigeriaSat-1 GeoTiff with Metadata. Then, the imageries were prepared for pre-processing. Although, the two imageries used for this study had already been orthorectified by the providers according to their standards and their reported root mean square (RMS) errors for the positional accuracy were less than 50m, nevertheless, the two imageries were geo-referenced to same coordinates system using the first order polynomial equations so as to remove the errors related to rotation and scaling (Salami, 2000; Saadi and Abolfazi, 2003) as follows:

$$X = a_0+a_1x+a_2y \quad (1)$$

$$Y = b_0+b_1x+b_2y \quad (2)$$

Where:

"x" and "y" are the coordinates of point in the first coordinate system and "X" and "Y" are the new coordinates in the new coordinate system. It was ensured that the Root Mean Square Error (RMSE) was less than 0.5 in each case while the first mapping was done with 95% level of confidence under the Gaussian hypothesis.

ETM scan line error was corrected using radiometric adjustment algorithm to match the "SLC-on" scene data to the "SLC-off" scene and subsequently implementing ENVI software to apply the selected adjustment algorithm to provide replacement values for the pixels in the SLC-off scene scan gaps and create a gap-filled output product (Gonzalez and Wintz, 1987; Quinlan 1993; Storey et al., 2005). After which the imagery was calibrated using both radiance and local histogram matching method.

Specifically, this paper focuses on the validation of the Nigeria Sat-1 and Landsat satellite data. The imageries processing was done using ENVI ver. 5.3 and based on standard procedures as stated in Armston *et al*., Tucker *et al*., de Vries *et al*., Chander *et al*., Ayeni *et als* (Ayeni et al., 2015; Ayeni et al., 2016;Armston et al., 2002; Tucker et al., 2004; de Vries et al., 2007;Chander et al., 2009). Thereafter and according to the standard operational procedures of SLATS, the imageries were corrected geometrically and radiometrically (Pringle et al., 2009). Geometric correction was done using the of Armston *et al*., (2002) method as part of resampling the images while local calibrations were done using radiometric correction of de Vries et al., (2007). Calibration was the next step taken. Although, there is an automatic Calibration tool in ENVI. Calibration tools embedded in ENVI software was used for atmospheric correction according to Chander *et al*., (2009). We therefore choose to convert the digital numbers of Landsat ETM to reflectance values -Basic Tools>Pre-processing>Calibration Utilities>Landsat Calibration. After a careful assessment, the composite Landsat ETM image was generated by fusing three reflectance bands for ETM images- bands 7 (infrared), band 5 (green) and band 3 (red) together (Figure 2). The NigeriaSat-1 image were already in their natural states of Bands3 (Blue), 2 (green) and 1 (red) and was already calibrated with a false composite as acquired (Figure 3). For enhancement procedure, 2% linear enhancement was applied to the imagery before the bands were fused together for error corrections and for clarity.

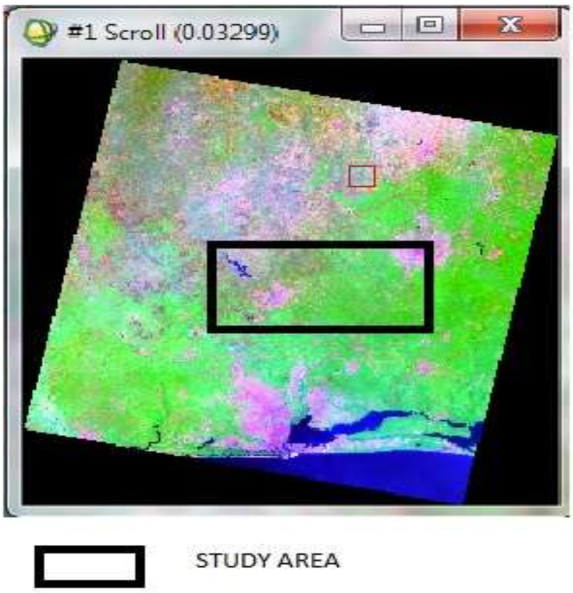

Fig 2: Landsat ETM False composite image

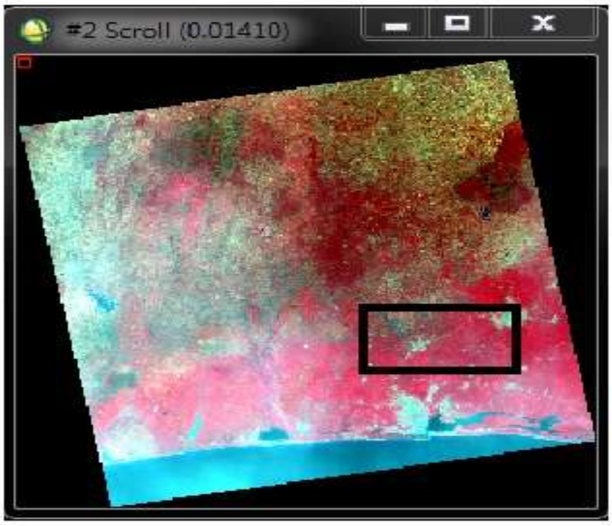

Fig 3: NigeriaSat1False composite image

2.2 Image classification

The LULC features were classified and interpreted using the elements of image color, association site, size, tone, variation and patterns as well as the local knowledge of the environment. The common processing methods and prevailing classification accuracy assessments related to land cover mapping as stated by Anderson *et al*., (1979)and Xie et al., (2008) were adopted for this study (Table 2).

Table 2: The Classification Scheme adopted

	LC Classes	Description
1	Built-up	Built-up forms the fully or partially developed areas covered with buildings and structures as well as intensive human anthropogenic in-print. The fully developed area includes residential, industrial, commercial, strip development along highways, and institutional complexes while the partially developed areas comprises the less intensive usage and are mostly sited around the outskirt of towns particularly areas where gradual developmental processes is in progress
2	Vegetation	Vegetation include forested area, wetlands covered with aquatic plants mostly mangrove and raffia palms as well as marshy areas mostly with ferns, shrubs and short mangroves. It also includes contiguous areas used for growing crops of various kinds and are apparently cultivated during the growing season, rain fed and irrigated cultivation, including fallow plots, cultivated land mixed with some bushes, trees and rural homesteads but dominated by farmland.
3	Open land	This include following areas cover mainly transitional areas, mixed barren land, bare surfaces, fire scar; open spaces influenced by human influence.
4	Waterbody	Water body include the areas cover mainly with water: lagoon, rivers, creeks and ponds. The ponds are water-bodies in depression, but mostly connected to other water bodies through seasonal streams.

Based on realistic hierarchical scheme using previous maps and additional information from literature as well as the authors' peculiar knowledge of the study area; the characteristics of twenty (20) training sites were captured with GPS across the selected area during previous visits. Thereafter, the images of the study area were visually assessed comparatively on-screen and subsequently identified, classified, enumerated and delineated into respective classes. Subsequently, maximum likelihood supervised classification of the imageries was done using head up on screen supervised classification.

The identified sites were used to generate regions of interest (ROI) for the acquired images which were later used to derive four classes each from both images vis-à-vis Built-up, open space, vegetation, and waterbody. The resulting land use maps were converted to shape files and imported into the ArcGIS environment. The results of the classifications from the two data were then compared if classified features were well captured particularly from NigeriaSat-1. This comparison and field knowledge of the study area were therefore used to establish the aim of this study with reference to vegetation coverage of the study area.

3. RESULTS AND DISCUSSION

3.1 LULC classifications of NigeriaSat-1 and Landsat ETM

Built-up, open space, vegetation, and waterbody covered 335.5km^2, 2,754.8km^2, 6,621.4km^2 and 24.7km^2 respectively on classified NigeriaSat-1. On Landsat ETM, built-up, open space, vegetation, and waterbody covered 223.4km^2, 3,989.9km^2, 5,480.1km^2 and 28.5km^2 respectively (Figures 4 & 5).

Table 3: NigeriaSat-1 and Landsat ETM LC classifications

Classes	NigeriaSat-1		Landsat ETM image		Difference (Km^2)
	Km^2	**%**	**Km^2**	**%**	
Built up	335.5	3.4	223.4	2.3	112.2
Open space	2,754.8	28.3	3,989.9	41.0	1,235.1
Vegetation	6,621.4	68.0	5,480.1	56.4	1,141.2
Waterbody	24.7	0.3	28.5	0.3	3.8
Total	**9,736.4**	**100.0**	**9,721.9**	**100.0**	**14.5**

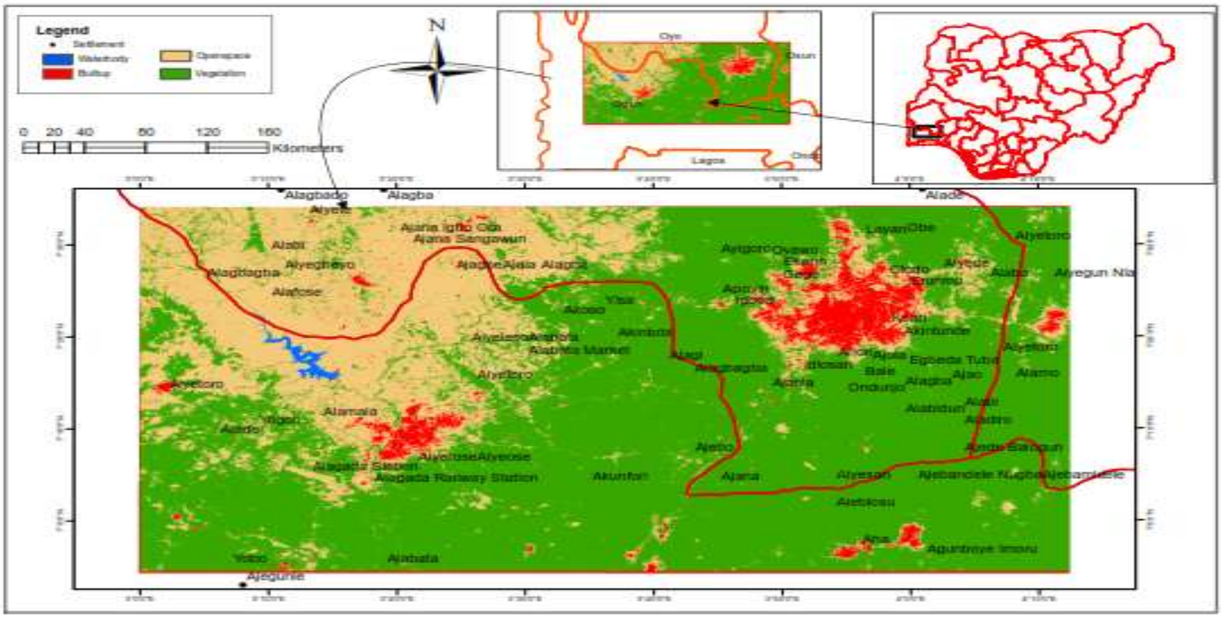

Fig 4: Classified NigeriaSat-1

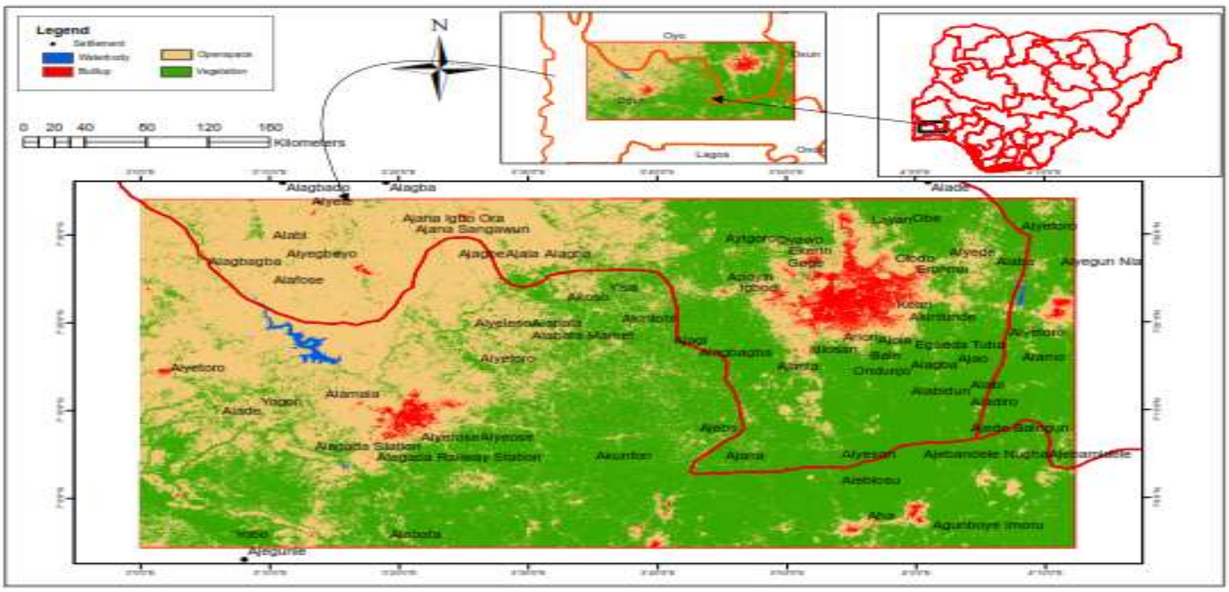

Fig 5: Classified Landsat ETM

In summary, land cover classification of the two imageries is comparable despite the differences in the spatial resolutions of the images. Vegetation which comprises cultivation and forest occupied the largest area in the two images. The findings revealed that out of the total area of about 9,700km^2**,** NigeriaSat-1 and Landsat ETM captured 68.0% and 56.4% respectively for vegetal cover. This is followed by open space with 28.3% and 41.0% in order of NigeriaSat-1 and Landsat ETM. The built-up occupied 3.4% and 2.3% for NigeriaSat-1 and Landsat ETM respectively while waterbody occupied the least comparable size of 0.3% for each.

Major differences were recorded for the two images which indicate wide disparities in open space and vegetation for the differences of 1,235.1km^2 and 1,141.2km^2 respectively. Also, the dry season signifies the period when cultivation harvest is at peak therefore part of the cultivation might have been captured as either vegetation in NigeriaSat-1 or as open space in Landsat image. Nonetheless, there is a higher level of agreement between the NigeriaSat-1and Landsat ETM images with respect to waterbodies which recorded a difference of 3.8km^2.

3.2 Accuracy assessment on NigeriaSat-1 and Landsat and Imageries

For validity of these results, the classifications were subjected to accuracy assessment using appropriate standard. To validate the classification done on NigeriaSat-1and Landsat, 250 points were randomly sampled and collated from Google earth 2015 for confusion or error matrix. The error of omission and commission were determined before the determination of the overall accuracy and kappa accuracy.as presented in Tables 1 and 2. Table 4 shows the summary of errors and accuracy for NigeriaSat-1. The average producers and user's accuracy were 92.33 percent and 91.780 percent respectively. This shows an error in producer accuracy since user's accuracy is less than user accuracy. Also, overall accuracy is 0.920, and kappa accuracy is 0.893 represent a well classified image (Cohen, 1968).

Table 4: Confusions matrix for Land-use Classification accuracy for NigeriaSat

Land-use Classes	Open Space	Vegetation	Built Up	Waterbody	Total	Commission	User's Accuracy
Open Space	57	1	4	10	72	20.83	79.17
Vegetation	1	62	0	1	64	1.56	96.88
Built Up	0	0	60	3	63	4.76	95.24
Waterbody	0	0	0	51	51	1.96	98.04
total	58	63	64	65	250		
Omission	1.72	1.59	7.69	20.31			
Producer's Accuracy	98.28	98.41	92.31	78.13			
Overall Accuracy	0.920						
Kappa Accuracy	0.893						

Table 5 shows the summary of accuracy assessment from the Landsat (2011) satellite imagery. The average producers and user's accuracy were 92.91 percent and 93.50 percent respectively. This shows that the referenced point is well represented compared to the classified points. The overall accuracy is 0.928, and kappa accuracy is 0.904 represent a well classified image (Cohen, 1968; Congalton, 1991).

Table 5: Confusions matrix for Land-use Classification accuracy for Landsat

Land-use Classes	Open Space	Vegetation	Built Up	Waterbody	total	Commission	User Accuracy
Open Space	62	1	0	2	65	4.62	96.88
Vegetation	1	57	7	6	71	19.72	98.28
Built Up	1	0	59	0	60	1.67	89.39
Waterbody	0	0	0	54	54	0.00	87.10
Total	64	58	66	62	250		
Omission	3.13	1.72	10.61	12.90			
Producer's Accuracy	95.38	80.28	98.33	100.00			
Overall Accuracy	0.928						
Kappa Accuracy	0.904						

Since the focus of this study is on vegetal cover and based accuracy assessment on each image under the same classification processes, the results of the classification revealed that NigeriaSat-1 performed better in capturing built-up and vegetation when compared to other two classes. Table 4 summarizes the results of accuracy assessment generated from the two images on the four-land use. The overall user and producer accuracies of individual classes were consistently high for the two images. The accuracies for NigeriaSat-1 and Landsat ETM, were 66.5%, 81.2% and 82.8% respectively. The Kappa statistics were 0.87, 0.97 and 0.89 respectively. The user and producer accuracies of individual classes ranged between 78.13% and 98.41% for NigeriaSat-1 while ranged between 87.10% and 100.00% for Landsat ETMETM.

For instance, the producer and the user accuracies for rainforest vegetation on NigeriaSat-1 are 98.41%.and 96.88% respectively. These indicate that more than 95% of the vegetal cover in NigeriaSat-1 was accurately classified compared to 80.28% and 98.28% obtained on Landsat ETM for the producer and user accuracies. Other three classes vis-à-vis built-up, open space, and waterbody had a relatively inconsistencies in the producer and user accuracies. Therefore, built-up, open space, and waterbody are not accurately defined in the two images compared to vegetal cover.

The images characteristics might have been responsible for these differences as noted by (Chen and Stow, 2002) as the spatial resolution of images usually have impact on the levels of accuracies and outcome. For instance, NigeriaSat-1 has spatial resolution of 32 metres while Landsat ETM has a spatial resolution of 30metres. It was also noted that the spectral characteristics of the landcover types could be responsible for the differences (Cushnie, 1987). For instance, built-up and open space may be similar and captured as same class. Due to the high resolution of NigeriaSat-1, its image classification outcome had higher correlation with Landsat ETM. This implies that, NigeriaSat-1 is as good as Landsat ETM in monitoring vegetation. This finding revealed a comparable result with the findings of Salami and Balogun (2004) where they obtained similar results for the vegetation mapping of some parts of southern Nigeria using the NigeriaSat-1 and Landsat ETM. The study also corroborates the work of Salami and Balogun (2006) carried out in on the assessment of the NigeriaSat-1 image of December 2003 in comparison with ASTER image of January 12, 2002 and of the Landsat ETM image of January 8, 2001 for ecosystem monitoring in the mangrove belt of Nigeria. The spatial and spectral characteristics variations in the assessed features make a differentiation of such study possible. The fundamental differences in the characterisation of the images used for this study have proved that vegetation assessment and characterization varied from one image to the other (Adesina and Amamoo, 1994; Ojo and Adesina, 2010).

4. CONCLUSION

This study was conducted with the intention to validate the potentials of NigeriaSat-1 with Landsat ETM for LULC studies in part of Rainforest vegetation of South Western Nigeria. The use of the NigeriaSat-1imagery has been demonstrated in this study to have proximate potential in vegetation assessment and monitoring with its relative outcome which is relatively similar with that of Landsat ETM. The higher spatial resolution of NigeriaSat-1 has more influence to depict features on the earth surface more accurately when compared with Landsat ETM. The findings of the study revealed that the images obtained from the NigeriaSat-1 have relative outcome based on producerand user's accuracies as well as classification outcome. In conclusion, the study revealed that the output from NigeriaSat-1 and Landsat ETM the images slightly varied due to their capacity to capture LULC data particularly vegetal cover and the variation is attributed to the differences in their spatial resolution and spectral potentials of features.

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