Accuracy assessment of nigeriasat-x and landsat images for landuse/landcover analyses in enugu state,Nigeria

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ABSTRACT
This study aimed at assessing the difference in Landuse characterization, relative accuracy of feature definitions and the usage of spatial data with NigeriaSat-X and Landsat ETM images. Images from the two satellites over Enugu taken concurrently were analysed. The result supports the knowledge that each image has certain relative advantage over the other. For instance, while NigeriaSat-X images have shown to be very efficient in the analysis of information within the visible portion of the electromagnetic spectrum. Information from Landsat ETM images was rather weak at both portions (Visible and NIR) of the Electromagnetic Spectrum. The study also showed that NigeriaSat-X images have higher level of reliability accuracy of (76.03 %) than Landsat ETM (70.74%). The reasons for this may be the intrinsic characteristics of the images. Another reason of course, is that spectral characteristics among the different land cover types (e.g. built-up, bare rock) could be similar. Finally, the images differ in their ability to reveal Landuse characteristics and differences in spatial resolution may not be a challenge to accuracy but interpretation and explanation of the obtained information which majorly depends on the subject of interest.

I. INTRODUCTION

Satellite technology is used to collect data of the whole world as well as the planets and almost all of their orbiting moons are continuously assessed and imaged. It is from this point that many countries, are using produced images which are collected by remote sensing devices for inventory, assessment, monitoring and management of resources from local to global scale.With the availability of remotely sensed data from different sensors of various platforms and wide range of spatiotemporal, radiometric and spectral resolutions has made remote sensing as, perhaps, the best source of data for large scale applications and study (Mellese and Wang, 2007).

The use of remotely-sensed data in natural resources mapping and as source of input data for environmental processes modeling has become popular in recent years. The collected data are used for map production of the earth’s surface, seafloor topography, natural resources and urban infrastructure. This is why remotely sensed data is crucial to environmentalists who are eager in monitoring natural resources to ensure environmental sustainability by providing support to present and for future generation.

Satellite sensors are widely used in environmental applications and natural resources management. These sensors provide data in a wide range of spatial and temporal resolutions, radiometry, and band numbers. It also provides distinct advantage of consistency of data, synoptic coverage, global reach, cost effectiveness (per unit area), repeatability, precision, and accuracy. Environmental monitoring mostly requires satellite images frequent coverage of the same region. This can be maximized by using data from multiple sensors. However, since data from these sensors are acquired in multiple resolution (spatial, spectral, radiometric), and in varying conditions, they need to be harmonized and synthesized before being used (Thenkabail et al., 2004). With the continuous technology advances and societal needs, remote sensing of urban areas has increasingly become a new arena of geospatial technology and has applications in all socioeconomic sectors (Weng and Quattrochi, 2006).

With increasing capacity to rapidly generate maps of large areas, planners in the rural and urban areas are getting more empowered to address issues associated with Landuse analysis such as land misuse and various forms of incursion into properties and trespassing (Ojo and Adesina, 2010). The combination of vegetal cover, built up areas, rock outcrop, water body, bare ground and so on makes up the landscape. These Landscape surfaces exhibits a unique radiative, thermal, moisture, and aerodynamic properties, and relates to their surrounding site environment to create the spatial complexity of ecological systems (Oke 1982). To understand the dynamics of patterns and processes and their interactions in heterogeneous rural and urban environment, one must be able to quantify accurately the spatial pattern of the Landuse and its temporal changes (Wu et al. 2000).

Remote sensing technology has been widely applied in urban land use, land cover classification and change detection. However, it is rare that the classification accuracy of greater than 80% can be achieved by using per-pixel classification (so called “hard classification”) algorithms (Mather 1999). Mather in 1999 went further saying that the low accuracy of land use/cover (LU/LC) classification in urban areas is largely attributed to the mixed pixel problem, where several types of LU/LC are contained in one pixel. The mixed pixel problem is resulted from the fact that the scale of observation (i.e., pixel resolution) fails to correspond to the spatial characteristics of the target (Mellese and Wang, 2007). In order to avoid this mixed pixel problem, Wang in 1990 stated that the “soft”/fuzzy approach of LU/LC classifications should be applied, in which each pixel is assigned a class membership of each LU/LC type rather than a single label.

The link between spatial resolution and classification accuracy, however, is sometimes weak (Jensen, 2005). In heterogeneous areas, such as residential areas, it has been shown that classification accuracies may improve even as spatial resolution decreases (Cushnie, 1987). Some of the most commonly used remote sensing data sets for mapping Landuse and Landcover are those from Landsat, MODIS (Moderate Resolution Imaging Spectrometer), JERS-1 (Japanese Earth Resources Satellite), ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), SPOT (Système Probatoire d'Observation de la Terre), IRS (Indian Remote Sensing), and in recent times are the NigeriaSat- 1, NigeriaSat-X and NigeriaSat-2 satellites, BilSat, AlSat and many more. This study is aimed at assessing and evaluating the capabilities of two satellite imageries of medium resolution sensors which includes NigeriaSat-X and Landsat ETM for Landuse/Landcover studies. The result revealed its specific potentials, merits and limitations for environmental studies.

II. STUDY AREA

Enugu State is one of the states of the southeastern zone of Nigeria, which was created in 1991 with its capital at Enugu City. Enugu state is located within latitude 6^0.00’N and 7^0.00’N and longitude 7^0.00’E and 7^0.45’E. The capital is called the Coal City because of the discovery of coal in commercial quantity in 1909. It has a population of 3, 267,837 as at 2006 and an estimated population of over 3.8 million people as at 2012 (NPC, 2006). Some of the important towns in the State are Enugu Urban, Oji, Udi and Nsukka Urban.

The state shares borders with Abia State and Imo State to the south, Ebonyi State to the east, Benue State to the northeast, Kogi State to the northwest and Anambra State to the west. Enugu Urban which is the study area is made up of Enugu East, Enugu North, and Enugu South local government areas. The geological formation present in this area is mainly sedimentary rocks.

The study area falls within the humid tropical rain forest belt of Southeastern Nigeria. It has two seasons, the raining season and the dry season. The rainy season is characterized by heavy thunderstorms which last from April to October with the South Westerly moisture accompanied by air mass moving northwards. The turbulent runoff result in leaching, sheet erosion and eventually gullies (Enete and Okwu 2013). The mean temperature varies from about 20.30ºC to about 32.16ºC in the dry season and rainy season respectively, (Enete and Okwu, 2013).

During the dry season the humidity is lower than in the rainy season. Temperature is most often high during the day and low during the night. This results in high evaporation rate during the day. Harmattan which occurs between the months of November and February is always accompanied by poor visibility mostly at night and early in the morning. The rivers and streams which flow from the Udi hills dissect the study area into several sections. Thus there are rivers such as Ekulu, Idaw, Asata and Nyaba Rivers which separates Enugu South from Nkanu East. These rivers have many tributaries; the study area is generally marked by low land. The elevations are between 182.88m and 219.45 m above the sea level.

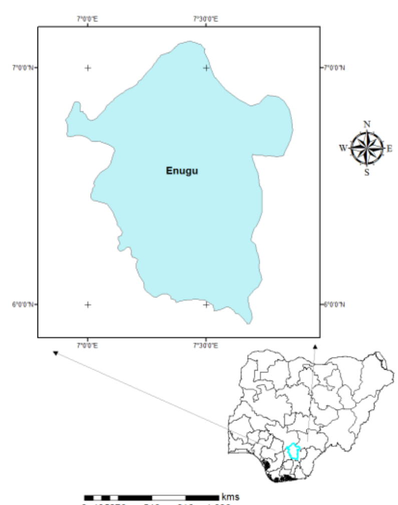

Figure 1: Study Area Map

III. DATA ACQUISITION AND DATA SOURCES

Primary data sources and secondary data sources were used for this study. The primary data source includes the coordinates of the sample sites with the use of handheld Global Positioning System (GPS) receiver and some photographs which were acquired with a digital camera during the field survey. Secondary data used were Landsat ETM and NigeriaSat-X covering the study area. Table1 shows key characteristics of the data used for the study.

Images were obtained from the National Space Research and Development Agency (NASRDA), Global Land Cover Facility (GLCF) an Earth Science Data Interface. The topographic map covering the study area was collected from the Office of the Surveyor General of the Federation. In addition, the software used to accomplish the set objectives of the study includes ILWIS 3.1, ArcGIS 10.1, Microsoft word and Microsoft excel.

A. Fieldwork and Primary Data Collection

A rapid made up of Landsat ETM and Nigeriasat-X imageries integrated with settlement and road maps was generated in preparation and to guide for the field work. The main purpose of the field work was to validate the accuracy extent of the satellite imageries and to identify major infrastructures. This was conducted using a Garmin GPSMap 76CSX handheld GPS to obtain three dimensional dataset (Altitude, Latitude and Longitude) of coordinates of some major landmarks and specified infrastructures in the study area. Also, Sony Nex-3 Digital Cameras, printed copies of satellite imageries, and base maps were used as the field tools to guide the team during the field work. The GPS coordinates and photographs of major infrastructures were acquired and plotted on the rapid maps.

B. Pixel Re-sampling

This involves the harmonization of the images acquired to ensure that they conform to the same spatial resolution (pixel size). The spatial resolution of multispectral images from Landsat ETM is 30m while that of NigeriaSat-X is 22m. The Landsat ETM image was re-sampled to 22m so that information on the Landsat ETM image can be compared to the NigeriaSat-X image of 22m resolution. Furthermore, this is done to maintain balance and also to reduce the error margin during comparison

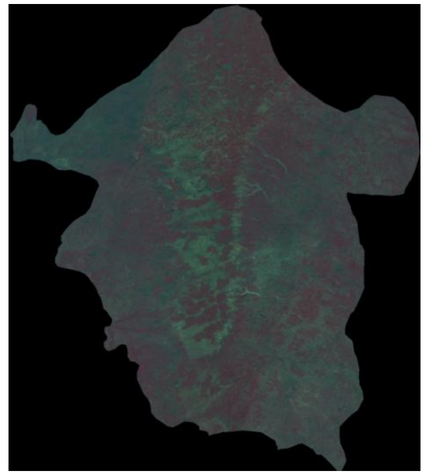

Figure 2: Landsat Image of Enugu

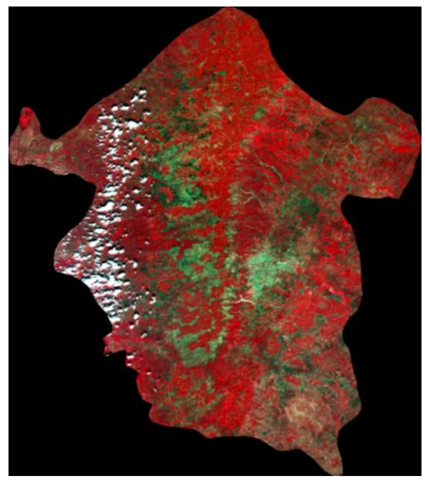

Figure 3: NigeriaSat-X Image of Enugu

IV. METHODOLOGY

This section of the study describes the procedure used for the image processing, analysis and other criteria used in the accuracy assessment of both images in order to arrive at a conclusive decision on the performance of the images used in the research.

A. Image Processing

The Landsat imageries were extracted scene by scene and later mosaic to form the extent of the Area of Interest (AOI). For the purpose of landuse/cover assessment, a common window covering the same geographical coordinates of the study area was extracted from the scene of the images obtained. This made the band Near-infrared, Red and Green (RGB) colour combination. For Landsat data, Band 4 was assigned Near-Infrared plane, Band 3 to Red and Band 2 to Green plane. The band combination then consisted of Near-infrared, Red and Green (RGB-432) colour combination. For NigeriaSat-X data set, colour combination, Band 1 was assigned to Near-infrared plane, Band 2 to Red plane and Band 3 to Green plane. This puts the band combination Near-infrared, Red and Green (RGB-123). Geometric errors were corrected using ground control points (GCP). The process of georeferencing in this study started with the identification of existing features on the image data, which can be clearly recognized on the printed base and topographical maps of the study area and whose geographical locations were clearly defined. The intersection of the highways and other road network, stream intersections and other spot heights were used as ground control points (GCP). The latitude and longitude of the GCPs of clearly seen features obtained in the base map were used to register the coordinates of the image data used for the study. The georeferencing of both imageries (Landsat ETM and the NigeriaSat-X) was done to the Universal Transverse Mercator (UTM) projection of WGS 84 coordinate system, zone 32N and the box classifier re-sampling method was used to correct the data geometrically. The original shape of Enugu state was extracted from the classified imageries through the masking process in the ArcGIS environment using the shapefile of Enugu state which is obtainable in NASRDA.

B. Land Use/Cover Classification Scheme

Based on the knowledge of the study area, reconnaissance survey and additional information from previous studies in the study area, a classification scheme was developed after Anderson *et al.*, (1976). The scheme gives a broad classification where each of the land use/ land cover was identified by a class. There are five identified classes used for the study area and it was well defined on the Landsat ETM and NigeriaSat-X images respectively.

C. Landuse/Landcover Analysis

The Landuse/Landcover (LU/LC) analysis was done through the classification of the satellite images using the supervised classification method. The basic knowledge of visual image interpretation which takes into account tones/colours, patterns, shape, size, and texture of the imageries and also digital image processing were used to identify homogeneous groups of pixels, which represent various land use classes already defined. This process is commonly referred to as “training’’ sites because the spectral characteristics of those known areas are used to “train’’ the classification algorithm for eventual land use/ cover mapping of the remaining parts of the images (Ojo and Adesina 2010).

A map of the study area (Enugu) was produced and used as a guide to identify features both on ground and also on the image data. The geographical locations of the identified features on the ground were clearly defined. These were used as training samples for supervised classification of the remotely sensed images. The five categories of land uses/ land covers that were clearly identified during ground Truthing were Built-up, Vegetation, Water body, Bare soil and Rock outcrop. Locations of major infrastructures were tracked with the GPS to facilitate confirmation of the field information onto the satellite images.

D. Classification

In this study, the satellite images were classified using supervised classification method. The combined process of visual image interpretation of tones/colours, patterns, shape, size, and texture of the imageries and digital image processing were used to identify homogeneous groups of pixels, which represent various land use classes of interest (Ojo and Adesina, 2010). The study engaged in ground truthing of the three Local Government Area of the study area. These are Enugu town, Nsukka town and 9th-mile environs in Enugu State. Before the ground Truthing, maps of the study area was printed to serve as guide to locate and identify features both on ground and on the image data. The geographical locations of the identified features on the ground were clearly defined and GPS coordinates of some major infrastructures were taken. All these were considered used as training samples for supervised classification of the remotely sensed imageries. Five categories of land uses and land covers were clearly identified during ground Truthing. These are water body, bare soil, built-up areas, Rock outcrop and Vegetation. The processed images were subject to band correlation analysis to assess the nature and strength of the relationship among the bands in the imageries.

V. RESULT

A. Land Use/Cover Accuracy Assessment

The accuracy assessment for Landsat ETM are: Overall Accuracy 93.44%, Average Accuracy 90.66%, Reliability Accuracy 70.74%. The result of NigeriaSat-X accuracies are: Overall Accuracy 96.92 %, Average Accuracy 96.91 %, Average Reliability 76.03 %. The result shows that Landsat ETM has lower value for accuracies than NigeriaSat-X. Table 3 and 4 refers.

Different reasons are responsible for this outcome. One main reason has to do with the intrinsic characteristics of the images. For instance Landsat has a spatial resolution of 30metres while NigeriaSat-X has 22 meters which simply implies that the imageries of NigeriaSat-X is slightly of higher resolution than Landsat. Chen, et al., (2002) has shown that these can variously have effect on the levels of accuracies obtained from the images. Another reason is that, spectral characteristics among the different land cover types (Built-up, Rock Outcrop) are similar, while spectral variation within the same land cover type or even within the same image might be high (Cushine, 1987). The figure 3 and 4 shows the classified images of Landsat ETM and NigeriaSat-X. This also displays the Landuse/Landcover types in Enugu state.

The tables 3 and 4 below contain summaries of the results of the accuracy assessment generated from the two images based on the five land use/cover classes. The overall, average as well as reliability accuracies of individual classes were computed in ILWIS environment for the two imageries.

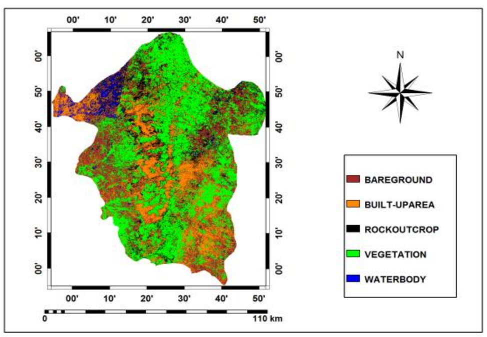

Figure 4: Classified Image of the Landsat ETM of Enugu State

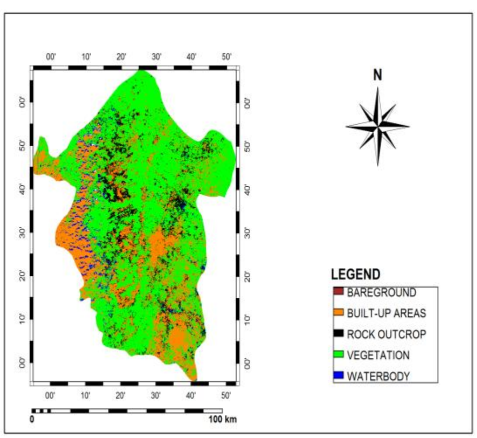

Figure 5: Classified Image of the NigeriaSat – X of Enugu State

__B__. __Land Use/Cover Characterization of the Study__

The table 5 shows that the area covered in hectares, by the five Landuse classes' namely built-up areas, bare soil, vegetation, rock outcrop and water body. On the Landsat ETM, "built-up area'' covered 143,906.5 hectares which represented 19% of the total area of land under study. Rock outcrop covered 88830.17 hectares (11%); vegetation covers 320,061 hectares (41%); bare soil covers 197041.4 hectares (26%) and water body covers 20,390.72 hectares which represents (3%). On NigeriaSat-X, built-up area covered an area of 222634.8 hectares which represents 29% of the total land area; rock outcrop covers 63284.7 hectares (8%); vegetation covers 447749.1 hectares (59%); bare soil covers 7188.1 hectares (1%) and water body covers 24548.4 hectares (3%).

From the table 5, it can be seen that the percentage of bare soil has greatly reduced over time due to a significant increase in Built- up areas from 19% to 29% between the years 2000 to 2012 which is attributed to urbanization and human activities. The Rock Outcrops has also reduced slightly by 3%, this reduction can either be due to the vegetation cover or human activities such as quarrying. Water body on the other has remained almost the same in both images at 3%. The vegetation cover increased from 41% to 59% due to the season of acquisition of the images. The Landsat image was during the dry season while the NigeriaSat-X was during the offset of the rainy season. The histogram on figure 5 shows the Landuse comparison of different land cover types between Landsat ETM and NigeriaSat-X.

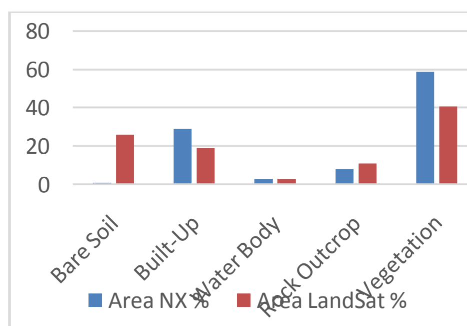

Figure 6: Land Use/Cover Comparison Chart

VI. DISCUSSION

The application of remote sensing to any Landuse/Landcover studies is basically the attributes of the Landuse types in the area of interest (AOI). Ojo and Adesina in 2010 stated that when information about Landuse/Landuse studies is available for over a long period of time, it allows for monitoring Landuse dynamics. This is also very vital for environmental studies and developmental planning.

The differences in spectral and spatial characteristics of features made it possible to differentiate the Landuse types. Based on the results of the classification of the NigeriaSat-X and Landsat images in this research, there is little difference in the Landuse/ Landcover (LU/LC) types because of the spectral and spatial characteristics. With NigeriaSat-X having a higher resolution of 22m, it is expected to capture more information than Landsat ETM of resolution 30m. Again with respect to Landuse recognition, some Landuse types like vegetation, built up area, water body were more efficiently identified by the NigeriaSat-X compared to Landsat ETM.

For the accuracy, there are different factors that affect the accuracy of LULC classification but the two most significant are the spectral registration and spectral characteristics of the images.

Chen and Stow (2002) showed that the spatial registration of images affects the levels of accuracy in images. Another is the spectral characteristic among different types (rock outcrop and built up) are similar, while spectral variation within the same Landcover type or even with the same image might be high (Cushine, 1987).

VII. CONCLUSION

This study was conducted with the intention of assessing the difference in Landuse characterization, relative accuracy of feature definitions and the usage of spatial data with NigeriaSat-X and Landsat ETM images. The result of the study supports the knowledge that each image has certain relative advantage over the other. For instance, while NigeriaSat-X images has shown to be very efficient in the analysis of information within the visible portion of the electromagnetic spectrum. Information from Landsat ETM images was rather weak at both portions (Visible and NIR) of the Electromagnetic Spectrum. The study also showed that NigeriaSat-X images have higher level of reliability accuracy of (76.03 %) than Landsat ETM (70.74%). The reasons for this may be the intrinsic characteristics of the images. Another reason of course, is that spectral characteristics among the different land cover types (e.g. built-up, bare rock) could be similar. Finally, the images differ in their ability to reveal Landuse characteristics and differences in spatial resolution may not be a challenge to accuracy but interpretation and explanation of the obtained information which majorly depends on the subject of interest.

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Table 1:

Image Name	Data Source Type	Sources	Sensor Type	Acquisition Date	Resolution	Spectral Range (um)	Area Coverage (km)
Topographic map	Secondary	OSGOF	-	1967	-	-	-
Landsat	Secondary	GLCF	ETM	2000	30m	0.45 – 0.90	185km by 185km
NigeriaSat-X	Secondary	NASRDA	Imager	2012	22m	0.52– 0.82	600km by 600 km

Table 2: Land Use /Cover Classification

LANDUSE/LANDCOVER CATEGORIES	DESCRIPTION OF THE LANDUSE/LANDCOVER
Built up Area	Buildings, Roads etc
Bare Soil	Bare ground, Open Surface
Vegetation	Shrubs, farmland, cropland, Agro forest, riparian forest, advanced bush re-growth, gardens and parks etc.
Water Body	Dam, rivers, streams, Lakes
Rock Outcrop	Rocks, Ridges, Quarry sites etc.

Table 3: Accuracy Assessment Landsat ETM Image

Class	Bare soil	Built Up Areas	Rock Outcrop	Vegetation	Water Body	Accuracy
Bare soil	264	0	0	0	0	1.00
Built up Areas	885	91538	1642	1971	36	0.95
Rock Outcrop	4	138	8138	131	228	0.94
Vegetation	4	478	1	74778	13	0.99
Water body	0	1	7	35	962	0.96
Reliability	0.23	0.99	0.83	0.97	0.78	

Average Accuracy = 90.80 %, Average Reliability = 70.74 %, Overall Accuracy = 93.44 %.

Table 4: Accuracy Assessment of NigeriaSat – X Image

Landuse/Landcover Categories	NigeriaSat-X (2012) (Hectare)	Area %	Landsat ETM (2000) (Hectare)	Area %
Bare soil	7188.1	1%	197041.4	26%
Built up Area	222634.8	29%	143906.5	19%
Waterbody	24548.4	3%	20390.72	3%
Rock Outcrop	63284.7	8%	88830.17	11%
Vegetation	447749.1	59%	320061.0	41%

Average Accuracy = 96.91 %, Average Reliability =76.03 %, Overall Accuracy = 96.92 %.