Land use/Land cover mapping of the Lagos Metropolis of Nigeria using 2012 SLC-off Landsat *ETM+* Satellite Images

Ugonna C. Nkwunonwo

Abstract— Recent explosions in demography and urbanization have prompted concerns for investigating the various dimensions of human environment. Of particular interest are the land use/land cover (LU/LC) themes, which have been undergoing severe modifications, due to the range of human activities. The problem with such changes, if not checked, is that the land surfaces will become vulnerable to environmental threats of all kinds, and human populations will be at the receiving end of incidental difficulties. This paper presents the result of LU/LC investigation and mapping of the metropolitan areas of Lagos, Nigeria, using 2012 SLC-off Landsat ETM+ images. While unsupervised maximum likelihood classifier (MLC) was adopted for the investigation, the gaps in the SLC-off images were filled by means of a simple heuristic approach that applies the inverse distance weighting (IDW) interpolation algorithm, available in QGIS software. The result obtained tends to show that more than half of the land areas of the Lagos metropolis have been urbanized, and this change is occurring at an alarming proportion. This rapid urban explosion can be attributed to the influx of large numbers of the human populations, who have migrated from different parts of Nigeria, and the establishment of more housing units to accommodate them. The evidence of such urban growth is often perceived in the reclamation of land from water body, and the despoliation of vegetative networks, which help maintain the balance of the ecosystem. Ultimately, such adjustments compound the impacts of climate change and intensify the frequency and severity of environmental disasters, such as flooding and drought, on human populations.

Index Terms— LU/LC, Demography, Urbanization, SLC-off Landsat image, ETM+, IDW, MLC, Climate change, Environmental disasters.

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1 INTRODUCTION

The attention given to the condition of human environment, especially land surfaces has increased in recent times, for example, [1-3]. One can only surmise, given the foregoing, that there are just few places of the earth's land area still retaining their natural landscapes. A major concern is the rate at which environmental hazards, such as flooding, is threatening many land areas, in recent times, which has been unprecedented. Historically, flooding has been the most common of all environmental hazards and accounts for more than 40% (both in losses and frequency of occurrence) of all natural disasaters worldwide [4]. As it involves water covering land areas not normally covered by water, flooding, world over has caused displacements of large numbers of human populations, destruction of farmlands and critical infrastructure, disruption of economic activities, and outbreaks of epidemics and death [5-7]. Unfortunately, such havocs resulting from flood hazards seem more critical in the developing countries (DCs), such as Nigeria, where lack of flood management measures prevails, and rapid growth in urbanization and demography has been unfavorable in respect of the availability and utilization of land resources for the range of human activities.

Apart from flooding and other land-related challenges such as, erosion, landslide, and coastal areas despoliation, one should address oneself with other issues, which are also at-tracting attention in recent times. For example, pollution, population pressure, urbanization and climate change, all of which might be likened to unusual menace that are equally precipitating ugly scenarios on the human environment. While a good guess can link these matters of environmental and land surfaces degradation to the use and disuse of the natural endowments of life, which includes biotic and abiotic factors, the frequencies at which they are occurring and the severity of their impacts have been attributed to the increasing alteration in the natural balance of the ecosystem, in particular the natural land use/land cover (LU/LC) themes [3] [8]. This knowledge that the natural endowments of life, particularly the LU/LC themes, are being threatened is widespread, and solutions to the problems have equally received considerable attention. Yet, while such disorders have continued to intensify, more attention is required to moderate the range of human activities that upset the land surfaces.

LU/LC can be conceptualized as the natural land surface themes of an area, which give rise to a range of activities human beings undertake for their survival and well-being [3]. Fundamentally, it refers to the surface and subsurface attributes of the earth, including soil, topography, surface and underground water bodies, and built-up developments. While land use and land cover are two terms that suggest the same idea, *albeit*, can be applied to refer to different contexts in the strictest sense, they are used interchangeably in the literature (for example, [9-10]), and refer to both natural and human induced scenery of an area. Since the 1970's, when the Global Environmental Change (GEC) literature championed discussions

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pertaining to land surface processes that influence climate change [11-12], many studies have focused on the modifications in LU/LC themes, due to human activities and natural environmental processes [10] [13-16]. Worthy of note among the environmental processes is climate change and variation, especially with regards to the intensity and frequency of rainfall, the impacts of which are compounded by rapid growth in urbanization and demography, to modify urban environments [17-18]. Unfortunately, as such interactions between climate change and urban components cause many urban areas to lose their natural scenery, which threatens both the stability and the functional strategies for urban development, they prompt more concerns for investigating LU/LC and for analyzing the changes that have occurred over time.

LU/LC investigations and change detection and analyses have been one of the most extensive applications of Remote Sensing and GIS technologies, directed toward understanding the changing aspects of land surface utilization in the past, present and future, vis-à-vis human activities [10]. LU/LC change analyses provide researchers with valuable information for assessing the impacts of environmental processes on land utilization, and assist in delineating the spatial relationship that exists among different urban development activities on the land surface. Such analyses, which are equally relevant to natural resources management, development designs, fund provision, socio-economic development planning, public administrations, and overall environmental management, have been possible through the availability of suitable data relating to land surfaces. Ample discussions pertaining to data requirements and the methodologies applicable to LU/LC investigations and change detection analyses are available in current literature for examples, [14-16] and [19-21]. With regards to data, remote sensing technologies through satellite and stereo-aerial photogrammetry have been very resourceful. Landsat images, resulting from Landsat missions, a popular earth resources satellite sponsored mainly by the National Aeronautics and Space Administration (NASA), have been available for more than four decades. Since the first Landsat missions in the early 1970's, the availability of Landsat data to the public at no cost through the Earth Observing System Data and Information System (EODIS) and Global Land Cover Facility [22] have been steady. But the utilization of those freely available geospatial data to investigate LU/LC has since the mid-2003 prompted significant concern. The scan line corrector (SLC) of Landsat-7 *ETM+* sensor, developed a fault in June 2003, causing remotely-sensed images to have gaps in a systematic pattern, and the affected images have since then been referred to as SLC-off images.

SLC-off images have posed significant bottlenecks to various earth-surface-related studies, especially LU/LC investigations and change detection analyses. The major limitations are the gaps that appear in a systematic wedge-like pattern outside of the 22% swath of the imagery, *albeit*, the spatial and the

spectral quality of the remaining portion of the images are not diminished [23]. Nevertheless, the utilization of the entire image for any investigation has remained inauspicious, and investigators have been challenged to devise methods of filling the gaps in order to make such images suitable for their intended purposes. As per filling the gaps, a number of methods have been proposed and are contained in current literature (for example [24-26]). The joint United States Geological Survey (USGS) and NASA Landsat team proposed a histogram-matching method that utilizes one or more SLC-off or SLC-on images to fill the gaps [24]. In Roy *et al.,* [25], information detected from MODIS was utilized to estimate reflectance for the pixels sampled in the SLC-off portion of the image. A multi-scale pigmentation methodology has also been applied to filling the gaps [26]. In Zhang *et al.,* [27], Pringle *et al.,* [28] and Van der Meer [29], some geostatistical methods, especially kriging and co-kriging, were proposed and applied. Chen *et al.,* [1] proposed and applied a neighborhood similar pixel interpolator (NSPI) methodology that estimated the values of the pixels within the SLC-off portions and utilized them to fill the gaps. Most recently, the weighted linear regression (WLR) and non-reference regularization recovery methods were proposed for restoring the degraded pixels [30]. Many software and application programs have also been developed, and the capability for filling the gaps of SLC-off landsat images have been incorporated in existing remote sensing software, such as ENVI, ERDAS IMAGINE and GRASS.

While existing methodologies for filling the gaps in SLC-off landsat images lacks standardization, and are rife with assumptions, and required advanced computing skills, they do not have wider prospects and applications. Moreover, as NASA's EODIS now offers masking data along with SLC-off images, as inputs and contribution toward solving the problem associated with unscanned pixels in landsat images, investigators are better disposed to devise suitable and more convenient means of resolving the gap-filling issue, while ensuring that the information contained in the degraded Landsat image remains intact. The usefulness of statistical tools, computing facilities and capacity that have favored gap-filling of SLC-off Landsat images, has not been beneficial to the DCs. As a result, various inauspicious alternatives are being applied in such places to study earth-surface-related matters: unfortunately such alternatives have been inadequate, and most of the results obtained through them have been imprecise. Moreover, LU/LC investigations and change detection analyses in such places, especially from year 2003 up to the present date, have been under-studied and under-implemented. Therefore, a gap has been created in the use of Landsat *ETM+* data for earth-surface-based investigations.

It is on the basis of such a background that the present study is being carried out, the aim for which is to utilize 2012

Landsat *ETM+* images, to investigate the LU/LC changes in the metropolitan areas of Lagos, Nigeria. How the investigation was carried out through a quartet of objectives is presented in this paper. First, identification of the major LU/LC themes of the study area was undertaken from existing maps, previous literature, and ground survey operations. Then, 2012 SLC-off landsat *ETM+* images, covering the Lagos metropolis of Nigeria, acquired from NASA's EODIS were processed and gap-filled. Third, by means of unsupervised maximum likelihood classifier, the pixels in the resulting gap-filled data were assigned to features: the accuracy assessment of the classification procedure was done. Finally, the results were interpreted and presented in a map, with the hope that the findings obtained, would form the bases for appropriate recommendations that would be made to the government, stake holders, data providers and the wider populations inhabiting the metropolitan areas of Lagos, Nigeria, in respect of the impacts of recurring modification of LU/LC in the area, and possible solutions. The rest of the paper focuses on a description of the study area, the methodology applied to the study, results and discussions, recommendations and conclusions.

2   STYDY AREA

Lagos, metropolis consist of sixteen local government areas (LGAs), lying within the geographical coordinate of 3.1^0 *E* to 3.4^0 *E* longitudes and 6.5^0 *N* to 6.8^0 *N* latitude, south-western Nigeria, West Africa, and forms part of what was formerly known as the capital city of Nigeria (Figure 1). The metropolis covers approximately $1100 km^2$ of low-lying coastal land, with more than sixteen million inhabitants [31], presently reputed as Nigeria's most populous city, the second largest city in Africa, and the seventh largest city in the world. Surrounded by inland water ways and the lagoons, the conurbation is known to drain two-thirds of the south-western Nigeria southwards into the Atlantic Ocean.

The vast population of Lagos metropolis is made up of local indigenes and migrants from other states of Nigeria and overseas, and has grown from twenty-five thousand and eighty three persons in 1866 [32] to its present number. The area is characterized by muddled human settlements, encroachments, overcrowding, illegal structures and slum envelopments. For want of space, many people tend to inhabit unsuitable locations, and put up houses, the adherence to local building regulations and town planning guidelines of which is uncertain [33]. From antiquity, the LU/LC themes of the Lagos metropolis has been predominantly water bodies and vegetation, with few residential areas, but since the last two decades, urban areas have spawned, resulting to insufficient space for much of the human population and their concomitant activities. Previous studies have shown that between 1984 and 2006, urban areas have grown steadily in Lagos state and have occupied much of the total land areas [34-35].

3   DATA AND METHODOLOGY

Data

The data requirements for this study and their sources are listed in table 1 below. Basically, it included of two tiles (Row/Path: 191/055 and 191/056) of Landsat *ETM+* images, of eight bands each (figures 2 and 3), along with their mask data acquired from the NASA EODIS. High resolution topographic image and GIS vector map of Lagos state acquired from the Survey department of Lagos state and Google Earth site respectively are equally included.

S/No.	DATA	SOURCES
1.	Landsat ETM+ images	NASA GLCF
2.	Topographic image of Lagos State	Google Earth
3.	GIS vector map of Lagos State	Lagos State Survey Department
4.	Landsat ETM+ mask data	NASA GLCF

Table 1: Data Requirements and their sources

Figure 1: The Study Area: The Lagos Metropolis of Nigeria
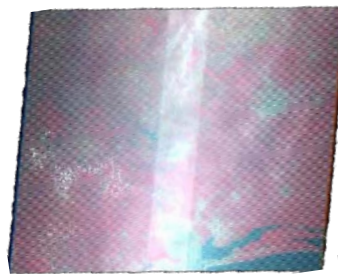
Figure 2: SLC-off Landsat 2012 image (Path/Row: 191/055). Source: NASA/EODIS

Figure 2: SLC-off Landsat 2012 image (Path/Row: 191/056). Source: NASA/EODIS

Some basic characteristics of the Landsat images relevant to their utilization for LU/LC investigations were verified. The information describing these characteristics, which broadly represent image acquisition sensors, date and times, spatial, spectral, and radiometric characteristics, as well as reference datum, are given in table 2 below.

S/No.	IMAGE FEATURE	RESULTS
1.	Date of Acquisition	6th January , 2012
2.	Sensor	ETM+
3.	Number of Bands	8 bands
4.	Path/Row	191/055 and 191/056
5.	Scene ID	LE71910552012006ASN00
6.	Map projection	UTM
7.	Datum	WGS84
8.	Ellipsoid	WGS84
9.	UTM_Zone	31
10.	Grid cell size pan-chromatic	15.00
11.	Grid cell size reflec-tive	30.00
12.	Grid cell size thermal	30.00
13.	Orientation	North up
14.	Data type	L1T
15.	Elevation source	GLS2000
16.	Output format	GEOTIFF
17.	Ephemeris type	Definitive
18.	Spacecraft	LANDSAT_7
19.	Resampling option	Cubic convolution
20.	Scan gap interpola-tion	2.0

Table 2: Landsat ETM+ image history, with sensor and orbital characteristics. Source: NASA/EODIS.

Gap-filling of Landsat ETM+ data

A simple heuristic approach that follows a step-by-step procedure was applied to fill the gap in the degraded Landsat ETM+ images. Basically, it applied an inverse distance weighting (IDW) interpolation algorithm available in QGIS software, using the mask files acquired along with the degraded images. First, the bands 1-8 orthorectified Landsat-7 SLC-off images and their corresponding masks files of tile 191_055 were individually mosaicked with those of tiles and 191_056, to obtain a more accurate seamless spatial extent covering the Lagos metropolis. Small sizes of each mosaicked bands covering the Lagos metropolis were subset, to enable faster gap filling, as larger images would require more computer time. The same procedure was equally applied to the individual masks files. Each subset mosaicked mask file was then applied to the corresponding subset SLC-off images, to fill its gaps. The process is repeated for the eight bands, each time combining subset mosaicked mask file and its corresponding subset mosaicked SLC-off images. The gap-filled images are then layer-stacked to enhance them spatially and spectrally. Figure 4 shows the result of the operation – a gap-filled subset image of

Lagos metropolis displayed as bands 4, 3, 2 combinations. Comparing this image with that of figure 5, which is the sub-set SLC-off image of the same displayed equally as bands 4, 3, 2, it is clear the gaps have been filled.
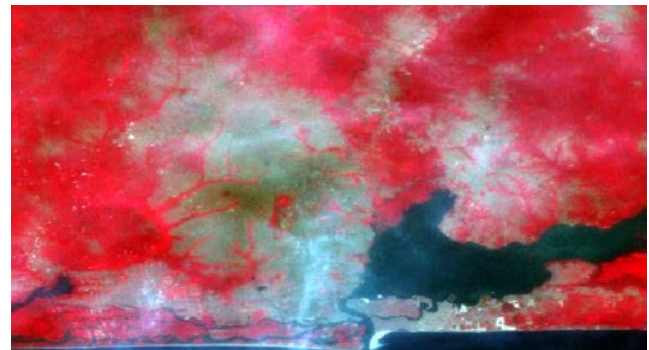
Figure 4: Gap filled mosaicked and subset image

Figure 5: Mosaicked and subset SLC-off image

Image Classification

By layer-stacking all the gap-filled bands, the panchromatic band enhanced the new image to 15 m spatial resolution. With this added quality, the new image lent itself easily for effective feature identification, detection and extraction. Unsupervised maximum likelihood classifier was applied to extract features and to group pixels into different LU/LC themes. Four LU/LC themes were extracted, which included; residential area, water body, vegetation and industrial areas, consistent with Anderson et al., [36] classification scheme. For investigating the LU/LC themes, the sizes of the grouped pixels representing the themes detected on the image are given in table 3.

S/No.	LU/LC Themes	• Year 2012 (Sq Km)
1.	Industrial	• 3676638
2.	Residential	• 4641841
3.	Vegetation	• 5071511
4.	Water Body	• 1904893
	Total	• **15294883**

Table 3: Classified amounts of LU/LC themes in Lagos Metropolis

While image processing and classification was carried out in ERDAS IMAGINE 2011, field verification and accuracy assessments were carried out, to verify and validate the classification results. The overall accuracy was estimated at 80.47%. Tables 4 and 5 show the accuracy totals and the *kappa* statistics respectively of the error analysis.

Class Name	Refer-ence To-tals	Clas-si-fied To-tals	Number Cor-rect	Pro-ducers Accu-racy (%)	Users Accu-racy (%)
Unclas-sified	0	0	0		
Class 1	27	26	25	92.59	96.15
Class 2	87	85	80	91.95	94.12
Class 3	63	60	38	60.32	63.33
Class 4	79	85	63	79.75	74.12
Totals	**256**	**256**	**206**		
Overall Classification Accuracy =			**80.47%**		

Table 4: Accuracy assessment Accuracy Totals

Class Name	Kappa
Unclassified	0.0000
Industrial	0.9570
Residential	0.9109
Vegetation	0.5136
Water body	0.6257
Overall Kappa Statistics = 0.7273	

Table 5: Accuracy Assessment: Kappa (K^) STATISTICS

GIS mapping

The final raster layers, resulting from the LU/LC investigation, were fine-tuned and symbolized using various GIS tools. ESRI ArcGIS 10.1 software was applied to create a map representing the 2012 LU/LC themes of the Lagos metropolis of Nigeria in a way that the results can be easily understood by end users. Although not shown in figure 6, GIS incorporates map features, such as north arrows, legend, marginal information, scale bar, title, grids and graticles, to bring out the aesthetics of mapped features.
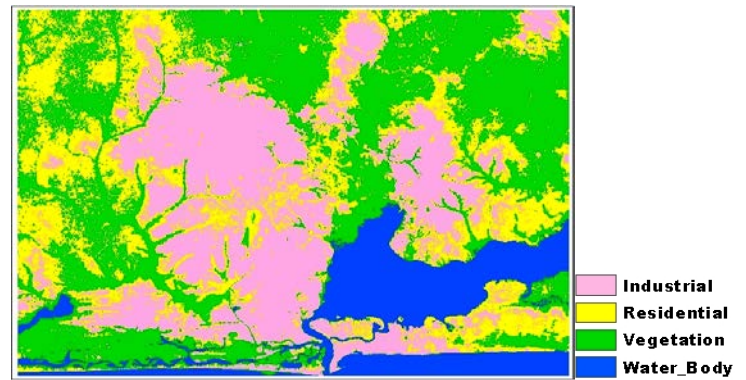

Figure 3: 2012 Land Use / Land Cover map of Lagos metropolis

4 RESULT AND DISCUSSION

Four major LU/LC themes were identified in the metropolitan areas of Lagos, Nigeria, and they include; water body, vegetation, residential, and industrial areas. From the classification, the total area of vegetation and water body measures 5071511 km^2 and 1904893 km^2 respectively, while those of residential and industrial areas were found to be 4,128.2km^2 and 4641841km^2 respectively. The result tends to show that urban areas, that is, residential and industrial areas account for more than 54% of the whole Lagos metropolis. While the metropolis accounts for more than three quarters of the entire Lagos state, the urban areas within the metropolis account for more than half of the total area. This reveals an unimaginable urban growth in the area in recent times, as more human populations have migrated to the Lagos metropolis, resulting to population pressure and urban explosion.

The evidence of such urban growth is often perceived in the reclamation of land from water body, and the despoliation of vegetative networks, which help maintain the balance of the ecosystem. Ultimately, such adjustments compound climate change and increase the frequency and severity of environmental disaster, such as flooding and drought, on human populations.

5 CONCLUSION

LU/LC comprises mainly of natural and man-made features on the land surfaces that define an area, and forms the basis of human activities. Unfortunately, human activities in recent times are modifying the natural LU/LC themes, and causing the land surfaces to lose the natural quality. While the affected land surfaces become susceptible to all forms of environmental and ecological threats, human populations are at the receiving ends of incidental difficulties. Investigating LU/LC has been useful for understanding the dynamics of human environments, while utilizing freely available Landsat images. In recent times, earth-surface-related investigations Landsat im-

ages have experienced bottlenecks due to SLC-off problem associated with Landsat *ETM+* images. While various methodologies proposed to overcome such limitations have been rife with assumptions, and statistical tools, they lack standardization, global applications, and have been unsuitable for use in many DCs. The present study has investigated and mapped the 2012 LU/LC of Lagos metropolis, Nigeria, using the SLC-off Landsat *ETM+* images. The degraded Landsat images were corrected by means of a simple heuristic approach that applies the IDW interpolation algorithm, available in QGIS software. Unsupervised MLC was adopted for image classification. The result obtained reveals the areas investigated to be undergoing rapid urbanization. While the result forms a basis for recommending urban development planning and land management strategies for the local and state government of the Lagos metropolis, Nigeria, the results will serve as data for future study on the urban flood risk mitigation of the area.

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