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Assessing the interrelationship between LST, NDVI, NDBI and land cover change in Amuwo-Odofin, Lagos Nigeria

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ABSTRACT

Climate change is undoubtedly one of the greatest existential threats to humans. This threat is continuously being aggravated by continuous urbanization which leads to the rapid change of land cover profoundly affecting biodiversity and ecosystem function as well as local and regional climate. This study assesses the variation of land surface temperature (LST), normalized difference vegetation index (NDVI) and normalized difference built-up index (NDBI), and the relationship with land cover change in Amuwo-Odofin Local Government Area of Lagos State, Nigeria. Multi-date Landsat imageries for years 2002 and 2019 were classified using the parallelepiped technique into five land cover classes – vegetation, bare land, built-up area, water body and wetland. The spectral indices (NDVI and NDBI) were computed and the LST was determined using a single-channel algorithm. In the findings, there was a negative correlation between LST and NDVI, and between NDVI and NDBI. The distribution of the LST, NDVI and NDBI varied correspondingly in accordance with changes in land cover.

1. Introduction

In recent times, there has been renewed interest in understanding the dynamics of land cover change and its relationship with several environmental parameters. Some of these key environmental parameters that have received the attention of researchers include the land surface temperature (LST), normalized difference vegetation index (NDVI), and normalized difference built-up index (NDBI) (Guha et al., 2020; Al-Faisal et al., 2021). These three parameters (LST, NDVI and NDBI) are integral in the study and monitoring of land cover change (Alademomi et al., 2020; Abir and Saha, 2021). However, very few studies have investigated the link between LST, NDVI, NDBI and land cover change, and more studies are required to explore their interrelationship. Environmental parameters of relevance to human population and sustainability within an environment are mainly climatic factors which are easily influenced by land cover practices and the same holds for the reverse (Xiong et al., 2012).

LST is one of the key environmental parameters that is affected by changes in land cover. For many fields, measuring LST is significant, including climate variability and change, urban heat island impact, land/atmosphere feedback, fire monitoring, mapping and detection of land cover and change, geological studies, crop management and water management (Jaber, 2019). According to Weixin et al. (2011), the key causes of land surface temperature variations that are correlated with vegetation density are changes in vegetation. This was also corroborated by Fathizad et al. (2017). Although it is known that vegetation cover has a moderating effect on LST, vegetation types can vary in their ability to reduce the temperature of the surface.

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A spectral index for detecting long-term differences in vegetation coverage and its status is the Normalized Difference Vegetation Index (NDVI) (Fathizad et al., 2017). With values ranging from -1 to +1, NDVI shows the condition and abundance of the green vegetation cover and biomass. Another interesting spectral index is the Normalized Difference Built-up Index (NDBI), which gives information on the extent of urbanization in a region as well as the land cover change. Similar to other spectral indices, the NDBI value ranges from -1 to +1 with higher values indicating presence of more impervious surface and vice versa. NDBI like other spectral indices which quantitively represent land cover type have been used widely in LST-land cover studies. NDBI plays an important role in urban areas where most of the human population are concentrated (Xiong et al., 2012).

This study is focused on the assessment of the interrelationship between LST, NDVI, NDBI and land cover change using multispectral Landsat imageries for 2002 and 2019. The objectives are: (i) supervised image classification of the Landsat imageries; (ii) calculation of the spectral indices: NDVI and NDBI; (iii) determination of the LST using the Landsat thermal bands and a single channel algorithm (iv) assessment of the correlation between LST, NDVI and NDBI, and the relationship with land cover changes. The findings of this study contribute to the body of knowledge on land cover change dynamics, and global and environmental change.

2. Methods

2.1. Study area

The study area is Amuwo Odofin local government area (LGA) in Lagos State, Nigeria (shown in Figure 1). The LGA covers an area of about 173km² and is located within the metropolitan area of Lagos. According to the 2006 Nigerian population census, Amuwo Odofin LGA had a population of over 524,971 and this figure was expected to rise to 766,111 in 2018 and over a million in 2021 (Annual Abstract of Statistics, 2019). Two air masses influence the climate of the area: the tropical maritime and tropical continental air masses. The former is wet and originates from the Atlantic Ocean, while the latter originates from the Sahara Desert and is warm, dry and dusty. The two main seasons recognized in the region are: the dry season (between November and March) and the rainy season (between April and October), with a brief break in the middle of August. Amuwo Odofin is divided into two distinct geographical spheres of riverine areas and upland. The area is richly blessed with mangroves and varieties of coastal wetlands. Tropical swamp forests are the dominant type of vegetation; fresh waters and mangrove swamp forests and dry lowland rain forest (FEPA, 1997).

2.2. Datasets

The Landsat imageries for this study were downloaded from the United States Geological Survey (USGS) Earth Explorer website (https://earthexplorer.usgs.gov/). Table 1 shows the imagery characteristics.

Table 1. Characteristics of the Landsat imageries

Dataset	Resolution	Date of Acquisition (DD-MM-YYYY)	Acquisition Time (GMT)
Landsat 7 ETM+	30m	28-12-2002	9:51:41
Landsat 8 OLI		01-01-2019	10:02:48

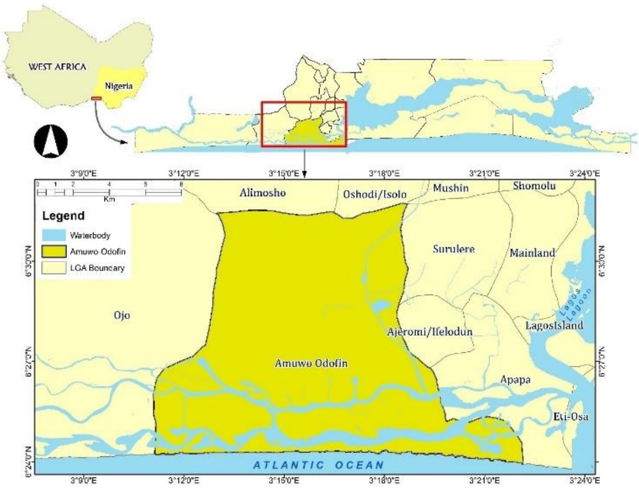

Figure 1. Map showing the location of Amuwo-Odofin LGA

2.3. Image pre-processing and enhancement

The Landsat imageries were combined into false color composites within the ENVI 5.2 software environment using the following band combinations: 5-4-3 for Landsat 8 OLI and 4-3-2 for Landsat 7 ETM+. Thereafter, the Gram-Schmidt spectral sharpening algorithm was used to pansharpen the image composites using the panchromatic band. This improved the spatial resolution from 30m to 15m thereby enhancing interpretation.

2.4. Land Cover, NDVI, NDBI and LST

Using the parallelepiped supervised classification algorithm, the Landsat imageries were classified into 5 information classes – vegetation, bare land, built-up area, water body and wetland. The theoretical background of the parallelepiped algorithm is already well explained in the extant literature (e.g., Obiefuna et al., 2021). Landsat Level 2 products were ordered and downloaded from the USGS Earth Resources Observation and Science (EROS) Centre Earth Science Processing Architecture (ESPA) on-demand interface. The ESPA is an incubation environment that provides users with an on-demand interface to process and customise Landsat science products. The NDVI is computed as the difference between the near-infrared (NIR) and red (RED) spectral reflectance bands divided by their sum. The NDBI is calculated as a ratio between the shortwave infrared (SWIR) and near infrared (NIR) values in traditional fashion.

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (1)$$

$$NDBI = \frac{SWIR-NIR}{SWIR+NIR} \quad (2)$$

Where;
Red = Band 4 (Landsat 8 OLI) or Band 3 (Landsat 7 ETM+)
NIR = Band 5 (Landsat 8 OLI) or Band 4 (Landsat 7 ETM+)

SWIR = Band 6 (Landsat 8 OLI) or Band 5 (Landsat 7 ETM+)

The LST was computed using the single channel algorithm. The theoretical basis and equations behind the single channel algorithm are already well explained elsewhere and only a brief explanation is provided here Landsat ETM Band 6_1, and TIRS Band 10 were used for the retrieval. This basically involved the following steps: (i) conversion of Digital Number (DN) to Spectral Radiance; (ii) conversion of Spectral Radiance to Top-of-Atmosphere Brightness Temperature; and (iii) conversion of Brightness Temperature to LST.

3. Results

This section presents the results of the different processing and analysis carried out in this study. These include the Land cover, LST, NDVI, and NDBI maps, and analysis of the interrelationships. Figures 2 and 3 present the land cover, NDVI, LST and NDBI maps respectively.

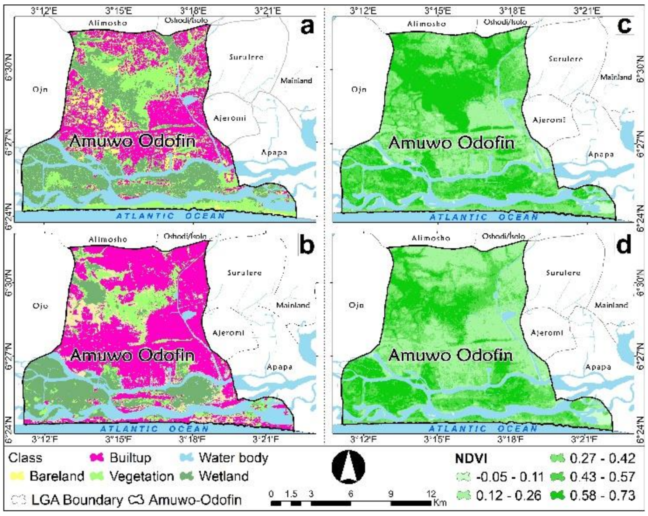

Figure 2. Land cover – (a) 2002 (b) 2019, and NDVI – (c) 2002 (d) 2019

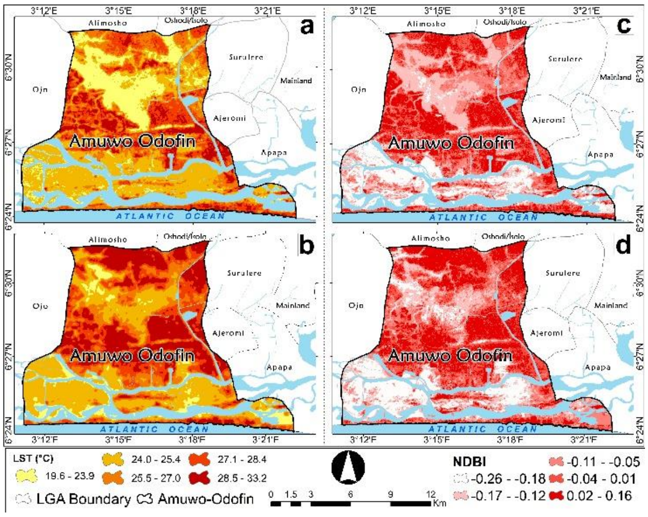

Figure 3. LST – (a) 2002 (b) 2019, and NDBI – (c) 2002 (d) 2019

Table 2 presents the coverage area of the land cover classes, while Tables 3 and 4 present the descriptive statistics of the LST, NDVI and NDBI for the different land cover classes. Table 5 presents the coefficient of correlation (r) between the LST, NDVI and NDBI.

Table 2. Coverage area of land cover classes

Land cover	Area -- 2002		Area -- 2019	
	km^2	%	km^2	%
Bare land	15.12	8.73	20	11.55
Built-up area	46.78	27	81.09	46.81
Mixed vegetation	44.93	25.94	18.88	10.9
Water body	23.82	13.75	22.73	13.12
Wetland	42.58	24.58	30.53	17.63
Total	173.23	100	173.23	100

Table 3. Descriptive statistics of LST, NDVI and NDBI per land cover class - 2002

Land cover		Bare land	Built-up area	Vegetation	Wetland
	Count	16783	51970	49908	47208
LST	Min	22.84	23.69	23.12	22.84
	Max	34.20	34.98	30.49	28.92
	Mean	28.94	28.21	26.03	24.88
NDVI	Min	0.06	0.04	0.00	0.03
	Max	0.49	0.60	0.64	0.64
	Mean	0.26	0.28	0.42	0.46
NDBI	Min	-0.07	-0.25	-0.46	-0.47
	Max	0.75	0.26	0.23	0.22
	Mean	0.15	0.05	-0.10	-0.26

Table 4. Descriptive statistics of LST, NDVI and NDBI per land cover class - 2019

Land cover		Bare land	Built-up area	Vegetation	Wetland
	Count	22100	89862	21007	33841
LST	Min	21.93	20.12	19.64	21.65
	Max	33.17	33.15	29.14	28.99
	Mean	26.32	28.08	24.77	24.27
NDVI	Min	0.04	0.05	0.06	0.21
	Max	0.72	0.61	0.73	0.73
	Mean	0.44	0.27	0.53	0.58
NDBI	Min	-0.23	-0.18	-0.25	-0.26
	Max	0.13	0.16	0.07	0.00
	Mean	-0.08	0.001	-0.14	-0.19

Table 5. Coefficient of correlation (r) between LST, NDVI, and NDBI

	LST 2002	LST 2019	NDVI 2002	NDVI 2019	NDBI 2002	NDBI 2019
LST 2002	1.00	0.81	-0.19	-0.26	0.86	0.69
LST 2019	0.81	1.00	-0.09	-0.37	0.83	0.86
NDVI 2002	-0.19	-0.09	1.00	0.79	-0.14	-0.29
NDVI 2019	-0.26	-0.37	0.79	1.00	-0.26	-0.63
NDBI 2002	0.86	0.83	-0.14	-0.26	1.00	0.80
NDBI 2019	0.69	0.86	-0.29	-0.63	0.80	1.00

4. Discussion

The observed increase in built-up area is in tandem with the findings of Obiefuna et al. (2018), Babalola and Akinsanola (2016), and Abiodun et al. (2005). All these studies examined the land cover changes in Lagos metropolis. The decline in wetland is also corroborated by Obiefuna et al. (2018) and Ajibola et al. (2012). Ajibola et al. (2012), posited that the loss of wetlands in Lagos metropolis is as a result of human activities which include incessant sand filling and conversion of wetland environment to economic uses (through construction) and perennial flooding which is a common and regular occurrence in the metropolis. Other studies have also reported vegetation decline in Lagos (e.g., Abiodun et al., 2005; Obiefuna et al., 2018; Babalola and Akinsanola, 2016). The slight decrease in the waterbody area could be as a result of the expansion of the residential areas causing the inland water body to decline. Also, as earlier identified, another possible reason for decrease in water body could be the land reclamation projects within the study area.

The effect of these changes manifested in the distribution of LST, NDVI and NDBI. The spatial pattern of the LST was similar to built-up areas. This validates the known premonitions that built-up areas are major contributors to increase in LST. This relationship has been corroborated by several authors including Nse et al. (2020) and Obiefuna et al. (2021). According to Obiefuna et al. (2021), the main driver of land cover change is built-up area or urban development which had grown by over 770% since 1984 and as a result caused an increase in the mean LST over Lagos from 28.60°C in 1984 to 30.76°C in 2019. The low mean LST in the vegetated and wetland areas suggests relatively a higher rate of evapotranspiration and favoring of latent exchange between surface and atmosphere as compared with impervious surface like built-up and bare land areas (Alademomi et al., 2020).

The NDBI results exhibited similar trend as LST and this is backed by the strong positive correlation between the indices for all the years: 2002 ($r = 0.86$), and 2019 ($r = 0.86$). The low NDVI observed over bare land and built-up area and high values seen over mixed vegetation and wetland is a common trend which has been reported by different NDVI-land cover studies (e.g., Alademomi et al., 2020).

5. Conclusion

The interrelationship between LST, NDVI and NDBI within Amuwo Odofin LGA of Lagos State has been examined in this study in relation to the prominent land cover. The study observed that the pattern and values of the three parameters varied correspondingly in accordance to changes in land cover. The built-up area had the most significant change and as such, the LST increased consistently throughout the study period. Consequently, it can be concluded that increase in the built-up area is the major driver of LST, NDBI and NDVI with an observed relationship that NDBI and LST values increase with increase in built-up areas. Conversely, it was observed that there exists an inversely proportional relationship between NDVI and LST, and between NDVI and NDBI.

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