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SPATIOTEMPORAL ASSESSMENT OF WETLANDS AND LAND RECLAIM ACTIVITIES IN EASTERN LAGOS STATE NIGERIA

AUTHORS:
J. A. Oyedepo[1,*] and D. E. Oluyege[2]

AFFILIATIONS:
[1,2]Institute of Food Security, Environmental Resources and Agricultural Research, Federal University of Agriculture, P.M. B 2240 Abeokuta, Nigeria

***CORRESPONDING AUTHOR:**
Email: oyedepoja@unaab.edu.ng

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Abstract
This paper presents a spatiotemporal assessment of sand-filling practices and their environmental implications in eastern Lagos over a four-decade period (1984-2024). Multispectral Landsat TM images at ten-year intervals namely, 1984, 1994, 2004 and 2024 were obtained from the Sentinel hub and subjected to supervised classification to assess land area that was reclaimed over time. The classification revealed a significant shift in land cover categories; areas built-up, expanded from 6035.92 hectares in 1984 to 18002.77 hectares in 2024, while vegetation and water bodies decreased from 19351.48 to 9180.79 and from 29355.12 to 27341.49 hectares respectively. The area occupied by the sand-filled category was 508.85 in 1984, 2528.79 in 1994, 943.19 in 2004, 600.50 in 2014 and 726.95 in 2024. The cumulative area of sand-filled in forty years is 5308.28 hectares. Sand-filled areas were always converted to buildings after some years of consolidation, hence the lack of a particular trend in coverage over time. Sand filling activities are primarily driven by urbanization and infrastructure development, and they are intensified along the eastern coastline of Lagos, particularly from Victoria Island to Lekki. The ecological and environmental consequences of sand filling, include habitat loss, shoreline erosion, increased land surface temperatures (LST) and vegetation loss. The regression coefficients showed that every unit increase in the LST led to a 0.08 unit reduction in the vegetation index for 2004 and 2014, and a one unit rise in the LST led to a 0.1 unit reduction in the vegetation index value for 2024. This paper concludes with emphasis on the key role of remote sensing in monitoring sand-filling dynamics, guiding policy interventions, and promoting sustainable urban growth.

1.0 INTRODUCTION
Lagos city in Nigeria, has been experiencing population explosion due to human influx in the last four decades [1, 2]. Problems related to the population surges include difficulties in accommodating people and industries. The increasing demand for accommodation has led to a search for land spaces in any available quarter [3, 4]. Since the city is hedged in by water and wetlands, the available option for creating large accommodation spaces remains the opening of surrounding wetlands and pushing back water bodies through land reclamation and sand filling exercises [5, 6]. Thus, tremendous pressure on natural resources [7, 8] and ecosystems in Lagos have increased. Interestingly, many city dwellers seem to welcome the concept of developing estates on reclaimed land; they perceive waterfront properties as assets of great value due to scenic views, accessibility to waterways, and

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potential for high returns on building investments [9]. As such, many areas in Lagos city, including the Snake and Banana Islands and Eko Atlantic, which were created from water or swamps [10] have become the most expensive residential areas today [11].

Sand filling involves the deposition of sand to reclaim land from water bodies [12]. Sand-filling and land reclamation activities have exacerbated environment-tal degradation and habitat loss in many parts of the Lagos metropolis [13-15]. It is important to note that, weak enforcement of environmental regulations, lack of proper monitoring and inadequate land use planning are responsible for the damages recorded on the fragile environment through unauthorized sand-filling of wetlands and water bodies in Lagos [16]. Previous studies on sand-filling activities in Lagos, have focused on understanding the drivers, impacts, and management strategies associated with coastal development and urbanization [17], while others have investigated the socioeconomic factors associated with sand-filling practices [18, 19]. A handful of studies have also explored the environmental consequences of sand filling, including habitat loss, shoreline erosion [20, 21], and changes in coastal hydrology [22, 23].

It is crucial to examining the ecological implications and environmental consequences of any anthropo-genic activity [24-26] including sand filling. This is because, a good understanding of the extent, frequency, and spatial distribution of sand-filling activities is necessary for proper monitoring of land reclamation activities and development of sustainable coastal area management plans in Lagos. In the past, conventional methods have been employed in such monitoring, but have proven inadequate. They are limited in spatial coverage and temporal resolution [27]. Conversely, satellite remote sensing is another monitoring method that has proven more effective. It provides timely, and spatially explicit information on land use changes, including sand filling, at varying scales and in near real time.

In this study, remote sensing technique is useful in mapping the spatial variability of environmental parameters [28] and it has been adopted for the progressive mapping of sand-filling activities in eastern Lagos. The general objective of the study was to examine the trends and changes in sand-filling patterns over multiple years. It is believed that this research will provide a deeper understanding of the dynamics driving coastal development in Lagos and help to identify the long-standing effects of sand filling on the environment [29]. This was done with the intention of developing informed sustainable water-urban development monitoring in Nigeria.

1.1 The Study Area

Lagos State southwest Nigeria, has a territorial area of 3, 577.28 km^2, a solid landmass of 2797.72 km^2 and a water coverage consisting of lagoons and creeks of 779.56 km^2. A more recent assessment [30] revealed that mangroves, swampy areas, marshland, and water bodies, cover 400.16 km^2, 747.11 km^2, 405.26 km^2 and 711.99 km^2 respectively. The population estimate for the metro area of Lagos as of December 2023 was 15,946,000 [31]. The area is geographically bounded by latitudes of 6°23'56.03"N and 6°30'32.69"N and longitudes of 3°22'51.01"E and 3°53'19.31"E as shown in Figure 1.

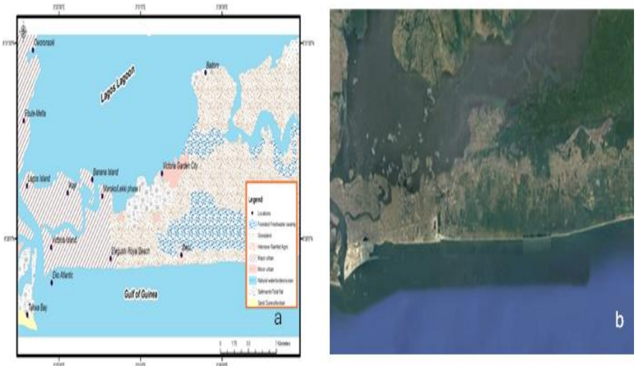

Figure 1: (a) Land use /Land cover map of the study area and (b) High resolution image showing the remaining vegetation in the study area

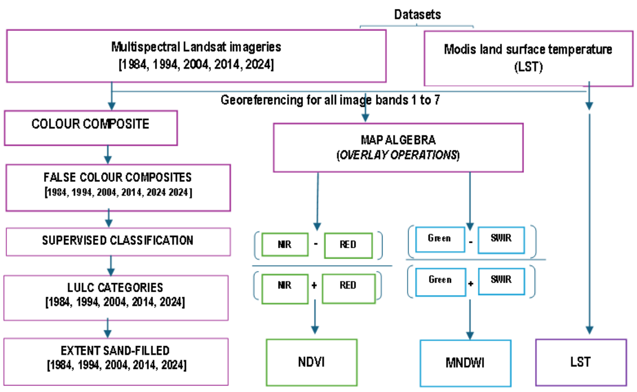

Figure 2: Workflow diagram for the study

2.0 METHODOLOGY

Pre-processed multispectral Landsat images acquired for 1984, 1994, 2004, 2014 and 2024, were downloaded from the sentinel hub. The false colour composites of the images were produced from the respective bands and subjected to supervised image classification to capture the spatiotemporal changes in land cover types and the sand-filling activities. The

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information obtained from the ground truth was used to create training sets for the supervised classification. Spectral indices such as the NDVI and the MNDWI were used to investigate the environmental consequences of the sand-filling activities. The methodology has been described in subsequent sections but can be summarised with a workflow diagram as presented in Figure 2.

2.1 Data Acquisition

Multispectral Landsat data with not more than 5% cloud cover were procured for five periods, namely, Landsat 4/5 (1984); Landsat 7 (1994); Landsat 8 and 9 (2004, 2014 and 2024). The normalised difference water index (NDWI) for 2022 and 2023, the normalised difference vegetation index (NDVI) as well as the land surface temperature (LST) for 2004, 2014, 2022 and 2024 were obtained from the Earth Observation browser of the Sentinel hub. Table 1 describes these datasets and their applications in this study.

Table 1: Dataset used, their sources and application in the study

S/N	Datasets	Description	Sources/Universal Resource Locator (URL)	Resolution/ scale	Precision	Application in the study
1	Landsat 4/5 & 7	Multispectral 7 bands	https://apps.sentinel-hub/eo-browser/	30 m	50 m	Land cover categorisation
2	Landsat 8 & 9	Multispectral 9 bands	https://apps.sentinel-hub/eo-browser/	30 m	12 m	Land cover categorisation
3	NDVI	Describes vegetation status	https://apps.sentinel-hub/eo-browser/	30 m	12 m	To check for effect of global warming on vegetation
4	MNDWI	Detects water on soil surface	https://apps.sentinel-hub/eo-browser/	30 m	12 m	To check effect of sand filling on flooding in Lagos
5	LST	Detects earth's skin temperatures	www.modis.gsfc.nasa.gov/data/dataprod/mod11.php	1 km	50 m at NADIR	To assess the effect of sand filling on local climate alterations particularly skin

2.2 Ground Checks and Satellite Data Validation

Ground truthing is important for the validation of land cover classifications. Field observations were conducted to verify the locations of sand filling, vegetation, water bodies and built-up areas. This information was useful for creating training sets for supervised classification.

2.3 Image Registration

Radiometric correction was not necessary, the image processing was performed via image registration and False Colour Composites (FCC). The images were imported into ArcGIS 10.4 software, where they were geometrically corrected into zone 31 North of the Universal Transverse Mercator (UTM) coordinate system.

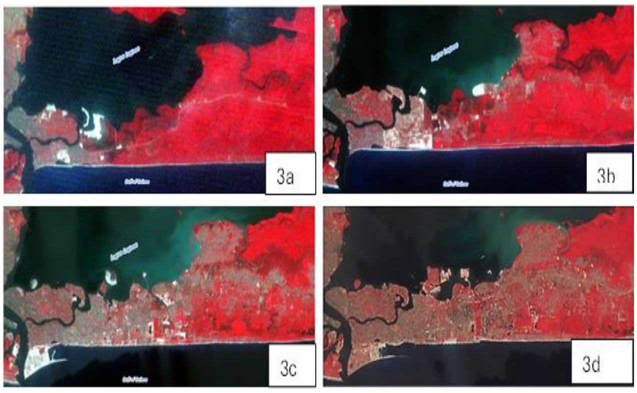

Figure 3: (a to d) FCC of the satellite images used for 1984, 2004, 2014 and 2024 respectively

2.4 False Colour Composites

The FCC for the respective years were produced by stacking bands 2, 3, 4 of Landsat 7; bands 3, 4, 5 of Landsat 8 and 9. It is the FCC that is subjected to image classification. Figure 3 shows the FCCs for 4 reference years; 1984, 2004, 2014, and 2024.

2.5 Training Set Creation

Prior to supervised image classification, machine learning is conducted to train the computer to associate specific colours on the FCC image with a particular land use /land cover category. A set of polygons (regarded as the training sets) were digitised around colours representing features (identified in the real world). The polygons were assigned as sand-filled, built-up, vegetation and water bodies. A 5% maximum likelihood was specified to instruct the computer to group any pixels with digital numbers 5% outside that of the digitised polygons.

2.5 Land Cover Classification

The FCC subjected to supervised classification using the 5% maximum likelihood method produced the land use / land cover categories [32]. Sand-filled areas were identified and quantified for their distribution and spatial extent over the years.

2.6 Spectral Indices Calculation

NDVI and NDWI are obtained from red, green, near-infrared and short-wave infrared bands of multispectral Landsat imageries in the two equations below.

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Specifically, the NDVI is derived using the following equation [33]:

$$NDVI = \frac{(IR-R)}{(IR+R)} \qquad (1)$$

Where, R is the red band and IR is the Infra-Red band. MNDWI, [34] is derived from the equation below:

$$\text{MNDWI} = \frac{(Green-SWIR)}{(Green+SWIR)} \qquad (2)$$

Where, Green is the green band, and SWIR is the short-wave infra-red band.

The LST was used to reveal the contribution of sand filling to the ambient temperature. The reflectance and albedo from bare surfaces such as sand filled areas has been shown to influence sensible heat [35, 36].

3.0 RESULTS AND DISCUSSION

Table 2 shows the land use /land cover classification of the study area.

Table 2: Land use and land cover classification of the study area

Categories	Area (Ha) in 1984	Area (Ha) in 1994	Area (Ha) in 2004	Area (Ha) in 2014	Area (Ha) in 2024
Built-up	6035.92	5164.80	11490.62	18008.89	18002.77
Sandfill	508.85	2528.79	943.19	600.50	726.95
Vegetation	19351.48	18202.31	14799.40	8729.15	9180.79
Water	29355.12	29355.12	28018.43	27913.21	27341.49
Total	55251.37	55251.01	55251.64	55251.75	55251.99

The Table indicates a significant spatial and temporal variability in the land cover classes over the forty years (1984-2024). This implies extensive anthropogenic activity within the period of assessment. The observed trend for the four land cover classes revealed that vegetation-cover steadily decreased, water bodies decreased moderately, while the built-up areas increased significantly.

The sand-filled areas are converted into built-up areas after a few years of consolidation. Hence, the difference of 218.10 hectares between the 1984, 508.85 hectares and 2024's 726.95 hectares does not reveal the cumulative size of sand-filled area over forty years which is actually is 5, 308.28 hectares. The largest sand-filled area occurred between 1990 and 1993, when the 'on-water' Maroko settlement was filled with sand [37]. The deserted sand-filled Maroko was built-up before 2004; explaining the reduction in the 2004 sand-filled area. The Eko Atlantic project commenced just before 2012. Here, the Atlantic Ocean at the Bar beach was sand-filled 1.5 kilometres seawards, explaining the 943 hectares recorded as sand-filled areas in 2014. The success of the Eko Atlantic spurred the shifting of sand-filling activities from the mangrove swamps to the Lagos Lagoon. The trend of land cover dynamics can be depicted more clearly by a chart as presented in Figure 3.

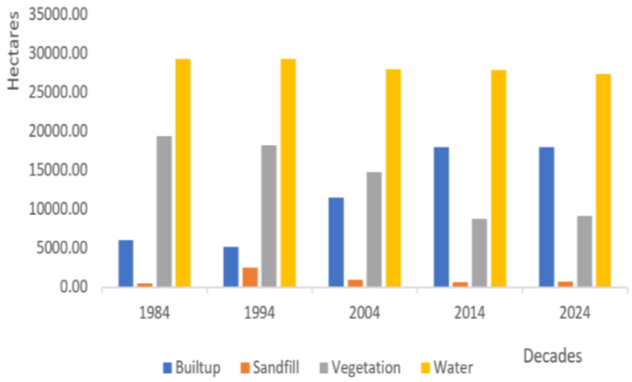

Figure 4: Chart showing different land cover categories for each decade

The spatial dimension of the city expansion in eastern Lagos could be seen in maps. The expansion of residential quarters as depicted in Figure 3, can be seen as expanding into the area once occupied by vegetation, and the area previously filled with sand was also been built-up. Despite the extension of the residential quarters into the vegetal areas, the 2024 land cover classification reveals that even portions previously sand-filled are still been further extended by more sand filling. The pattern of change in the size of the sand-filled areas namely, an initial increase and then a decrease can be seen as the conversion of the sand-filled sites into buildings after a fallow period. The maps in Figures 5(a-e) provide insights into the historical evolution of sand-filling practices and the intensity of coastal development over time.

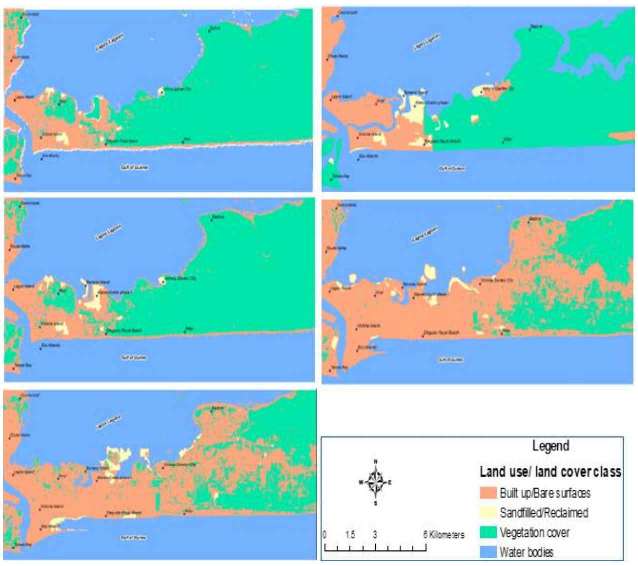

Figure 5(a - e): Land use/land cover of the study area for 1984, 1994, 2004, 2014 and 2024 showing progressive increase in the size of built-up and sand filled areas

The transition matrix in Table 3 shows the transformation of one category of land cover type to another. This

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result revealed that much of the water and vegetation had been converted to sand-filled and built-up areas respectively.

Table 3: The matrix of land cover transition over four decades

Transition	1984 - 1994 (Ha)	1994 - 2004 (Ha)	2004 - 2014 (Ha)	2014 - 2024 (Ha)
Sandfill to Built-up	0.00 Ha	755.29	938.51	474.19
Vegetation to Built-up	1491.33	4066.20	6343.56	1546.17
Vegetation to Sandfill	164.02	0.00	76.77	25.21
Water to Sandfill	708.94	0.00	328.55	467.80

The transition of sand-filled areas to built-up areas had no value because, reclaimed areas are usually given time for consolidation before building projects can commence [38]. Sand filling in the first few decades was mainly performed in Maroko and for the Banana Island on the Lagoon. The construction of physical structures did not start until approximately 10 years, when the locations were certified safe for holding buildings. This kind of transition increased from 1,491 hectares to 6,343 hectares between 1984 and 2014. However, where there are swamps and mangrove vegetation, there was sand filling first. This kind of transition was prevalent between 1984 and 1994, and was not detected between 1994 and 2004. This was probably because, Nigeria had just initiated land reclamation activities and there were more solid lands than wetlands and swamps. Similarly, the creation of islands on water also just evolved in Nigeria. The reclaimed land from water spiked between 2004 and 2014 to date as suggested by the figures (328.55 ha in 2014 and 467.80 ha in 2024) in the table. Sand filing of water bodies will likely increase in the next decades. Table 4 shows the cumulative incremental progression of the sand-filled area from decade to decade. There was a notable increase in sand-filled areas over the study period.

Table 4: Cumulative incremental progression of the sand-filled area from decade to decade

Reference year	Area Sand-filled (Ha)	% of area sand filled
1984	508.85	9.6
1994	2528.79	47.6
2004	943.19	17.8
2014	600.50	11.3
2024	726.95	13.7

From 1984 to 1994, little sand filling activity began; however, the creation of Banana Island commenced as a slight crescent, similar to the sand-filling of a portion of Victoria Island above Kuramo waters and the Maroko squatter settlements. The total land area reclaimed in the first decade was 508.85 hectares. In the second decade (1994-2004), a total of 2528.79 hectares were sand-filled because the creation of Banana Island on Lagos Lagoon was completed, the filling of the Maroko settlement was completed and even extended and then land reclamation activities shifted eastwards into the mangroves and swamps of Lekki. This was the beginning of the Lekki Peninsula which later eradicated the entire ecosystem to create the Lekki Phase 1 estate.

Figure 6 shows a panoramic representation of the spatiotemporal progression of sand filling activities over four decades in the Lagos coastal area. The analysis shows that the expansion of residential areas and need for infrastructural development projects along the coastline is primarily responsible for the sand filling of wetlands and waterbodies in Lagos. The distribution of sand-filled areas varies, with waterbodies namely, Lagos Lagoon and the Atlantic Ocean experiencing more intensive sand filling than others.

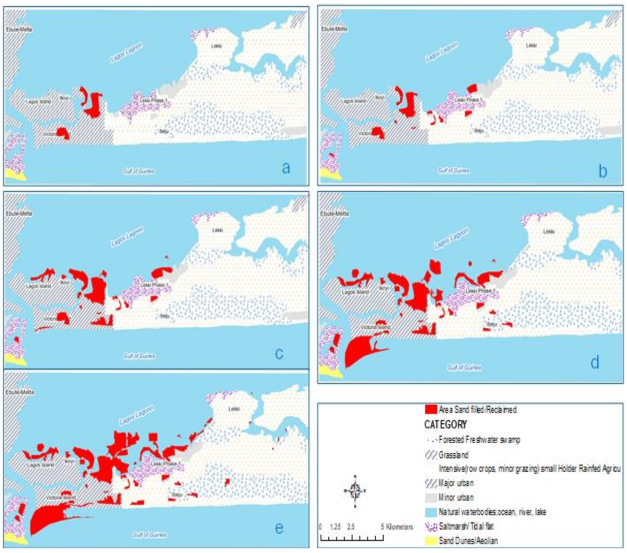

Figure 6(a to d): The progression of sand-filling activities in Lagos coastal areas from 1994 to 2024

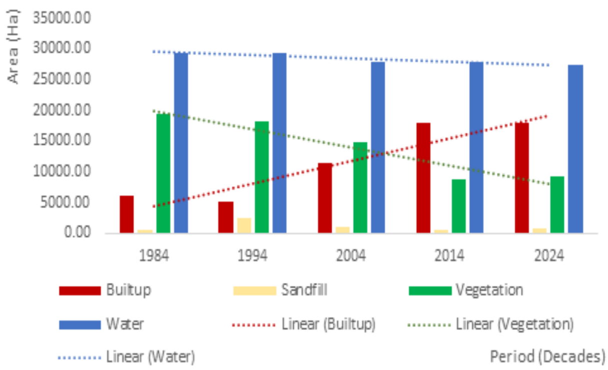

Figure 7: Trends for three land cover categories in the coastal areas of Lagos

Identification of sand-filled areas: The application of preprocessing techniques, image enhancement, and spectral index calculations facilitates the

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identification and delineation of sand-filled areas within the study area [39]. This will enable the mapping of sand-filling hotspots and the quantification of the extent of land reclaimed from water bodies through sand-filling activities.

Spatial Analysis and Visualization: GIS tools were used to delineate sand-filled areas, identify spatial patterns, and quantify changes in sand-filling distribution over time. Figure 7 shows trend for three land cover categories in the coastal areas of Lagos State.

The chart shows an upwards sloping trend for built-up areas, indicating a very rapid increase per year - a downwards sloping trend for vegetation indicates rapid loss per year. The loss of water bodies is still slow, because land reclamation activities in Lagos had just shifted from swamps to water bodies. We can calculate the yearly rate of change using the compound annual growth rate equation [40] stated as follows:

$$\mathrm{CAGR} = \left(\frac{\mathrm{X_n}}{\mathrm{X_1}}\right)^{(1/n)} - 1 \quad (3)$$

Where, X_1 is the land cover size at the beginning of the period (year 1), Xn is the size of the land cover at the end of 40 years and n is 40; the number of years during the review period. However, a simpler equation was developed in this study as stated below:

$$R_c = \frac{(\mathrm{xt_1} - \mathrm{xt_0})}{\mathrm{t_1} - \mathrm{t_0}} \quad (4)$$

Where, R_c is the rate of change per year, xt_0 is the size of the land cover category at time t_0; xt_1 is the size of land cover category at time t_1; t_0, is the base year and t_1 is the last year of review.

According to this equation, the rate of change per year of built-up areas is [(18002.77-3,017.96)/40] = 374.62 Ha per year; that of vegetation is 292.52 Ha and that of water bodies is 50.34 Ha. As explained earlier, the sand filling rate of change is difficult to estimate because of its ongoing conversion to buildings at no specific rate. The rate at which water changes to sand-filled land is likely to increase in the very near future.

Effects of sand filling on environmental and ecological integrity: These land reclamation activit-ies are not without dire consequences for the environment and natural ecosystems. As previously reported [1], sand filling in the Lagos State has resulted in environmental problems such as flooding and erosion. In some cases, water logging in many parts of the city is suspected to contribute to structural failure in Lagos [41]. The loss of vegetation namely, forested fresh water swamps has aggravated urban heat island effects and increased atmospheric carbon [42].

Figure 8 is the NDWIs of the study area for 2022(left) and 2023 (right).

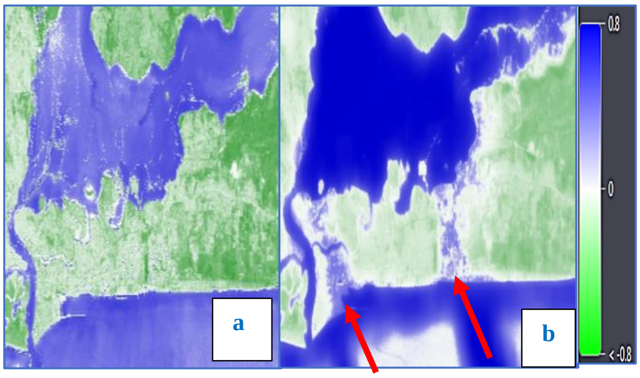

Figure 8: (a) NDWI of 2022 and (b) 2023 showing water marks in parts of Lagos

The red arrows in Figure 8(b) indicate the water reflectance in parts of Victoria Island and Lekki in 2023. The 9 km^2 area reclaimed from the ocean and sand filled areas around Kuramo waters; which is a buffer to Lagos Lagoon is probably responsible for flooding and waterlogging which has started to affect the coastline of Lagos [20, 43]. This is part of the environmental and ecological impacts of sand filling

Vegetation loss NDVI: Past studies have reported on the loss of vegetation in Lagos as a result of land clearing for residential and industrial quarters [44]. Recent NDVI of Lagos coastal areas provide good evidence of the vegetation cover loss over the years. Visual observation revealed that the populated portions on the map had very low vegetation indices. The 2020 lockdown was responsible for the greener or high NDVI values in 2022. The vegetation indices of the study area for 2014, 2019, 2022 and 2024 are presented in Figure 9.

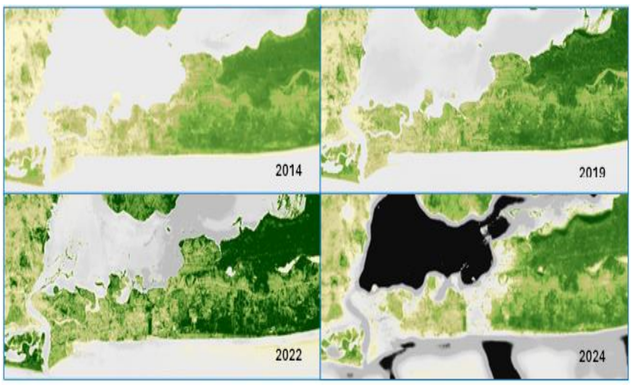

Figure 9: Vegetation indices of the study area in 2004, 2014, 2022 and 2024

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The vegetation indices obtained from specific locations in the study area reveal that the trend has been decreasing since 2004. The NDVI and LST values from 9 locations across the study area are presented in Table 5.

Table 5: The trend in the mean annual vegetation index against the mean annual land surface temperature at 9 locations

Location	NDVI 2004	NDVI 2014	NDVI 2024	LST 2004 (ºC)	LST 2014 (ºC)	LST 2024 (ºC)
Lagos Island	0.44	0.37	0.29	29.23	31.15	31.97
Victoria Island	0.02	0.00	0.08	30.15	31.73	33.93
Banana Island	-0.07	-0.18	0.04	30.15	31.73	33.93
Lekki Phase1	0.29	0.31	0.30	28.23	30.85	32.31
Eko Atlantic	0.29	0.25	0.12	29.63	32.79	33.71
VGC	0.37	0.49	0.25	29.23	31.15	31.97
Ajah	0.51	0.56	0.36	29.23	31.15	31.97
Ibeju	0.32	0.26	0.21	30.59	33.67	33.37
Maroko	0.47	0.60	0.33	26.47	27.89	31.25

For every location, a unit rise in the land surface temperature corresponds to decrease in the NDVI. The degree of association between the two indices (NDVI and LST) as ascertained by simple linear regression revealed a strong inverse relationship. Table 6 presents the statistics.

Table 6: The regression statistics of NDVI and LST across the east-coastline during different periods

Statistics	2004	2014	2024
Coefficients	-0.08	-0.08	-0.10
t Statistics	-1.64	-1.51	-6.30
Standard Error	0.05	0.05	0.02
P-value	0.145	0.17	0.00

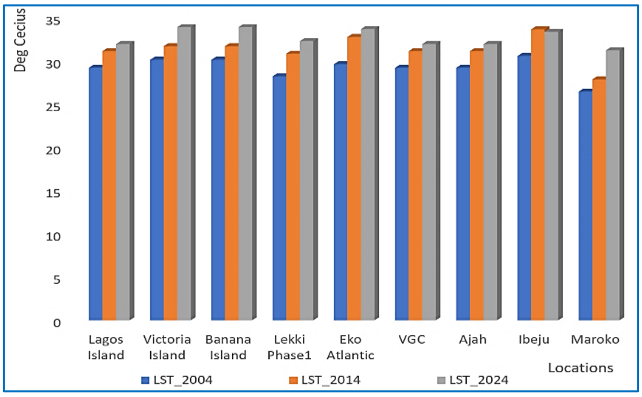

Figure 9: Trends in the LST across the study area

The coefficients show that every unit increase in LST leads to a 0.08 reduction in the vegetation index value in 2004 and 2014, by a 0.1 in 2024. The t-statistics show that the results are significant for 2004 and 2014 at 1% and at 5% for 2024. Deforestation is associated with an increase in earth surface temperatures [45]. The negative NDVI values at certain locations indicate relatively high land surface temperatures. Figure 9 illustrates that every location in the Lagos coastal area is experiencing a progressive increase in the land surface temperature on a decadal basis.

This partly provides evidence of the varying dimensions of the ecological and environmental impacts of land reclamation and sand filling activities in Lagos.

4.0 CONCLUSION AND RECOMMENDATI-ON

4.1 Conclusion

Over the four decades (1984-2024), significant variability in land cover classes has occurred; highlighting intense human activities that are evident from reduced vegetation and waterbodies, as well as the expansion of built-up areas. Despite the lack of a clear trend in cumulative sand-filled areas due to their continuing conversion into built-up zones, for example, the Maroko and Eko Atlantic project, the cumulative computation shows a substantial conversion of water and swamps to sand over 40 years. The transition matrices illustrate conversions from water and vegetation to sand-filled and built-up zones, which is indicative of shifting sand-filling dynamics. The encroachment of built-up areas into vegetated and sand-filled regions in Lagos, underscores the desperation of space for urbanization. The observed changes in LST and NDWI indicates the impacts of sand filling including; flooding and vegetation loss on the environment. Remote sensing and GIS are crucial tools, that provide insights for monitoring coastal changes and informing sustainable urban development practices.

4.2 Recommendation

To promote sustainable development in coastal areas of Lagos, while also preserving and safeguarding the ecosystem integrity in Lagos, Nigeria, it is important that:

1. Remote sensing monitoring is used for tracking sand filling and land cover changes.
2. Regulatory frameworks for sand mining activities should be strengthened.
3. government fosters community engagement that empowers locals in decision-making.
4. Eco-friendly alternatives to sand-filling and biodiversity conservation are encouraged. An example is the suspension of cities on water through pillars rather than through sand filling.

REFERENCES

[1] Auwalu, F. K., and Bello, M. “Exploring the Contemporary Challenges of Urbanization the

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Role of Sustainable Urban Development: A Study of Lagos City, Nigeria". *JCUA*, vol. 7 no. 1, pp. 175-188, 2023.

[2] Gilbert, K. M., and Shi, Y. L "Use/L Cover Changes Detection in Lagos City of Nigeria Using Remote Sensing GIS". *Adv. in Remote Sens*., vol. 12 no. 4, pp. 145-165, 2023.

[3] Akinde, J. O., and Olasunkanmi, O. O. "The Impact of Urban Growth on Slum Development in Mega City of Lagos (A Case Study of Ajegunle Lagos)". East African Scholars *J. Edu Humanit Lit*,. vol. 2 no. 4, pp. 213-222, 2019.

[4] Adedire, F. M. "Disparity in peri-urbanisation process in Lagos, Nigeria. In: Landscape architecture-processes practices towards sustainable development", Loures, L. and Ergen M. (Eds.). *Amazon* pp. 47-57, 2020.

[5] Otubu, A. K. "Quest for Housing Preservation of Wetlands in Nigeria: A Case Study of Lagos State". *IJOCLLEP*, vol. 3, pp. 146, 2021.

[6] Israel, A. O. "Loss of Wetlands in Lagos (Nigeria) and the adjacent territory: Implications for flood control". *J. Met. Clim. Sci*, vol. 19 no. 1, pp 10-21, 2021.

[7] Ubachukwu, O. A. Ubi, S. E. Esochaghi, K. P. Nwokoukwu, K. B. "Properties of eco-friendly concrete produced by partial replacement of sand with sawdust with emphasis on water-cement ratio", *Nigerian Journal of Technology*, vol. 41, no. 1: pp. 26-31, 2022.

[8] Ubachukwua O. A., Okafor, F. O., Nwokoukwua, K. B., Esochaghi, K. P. "Performance of Sand-Crushed Oyster Shells Blended Fine Aggregates in Concrete: Waste Management Perspective in Nigeria", *Nigerian Journal of Technology*, vol. 40, no. 1, pp. 13–18, 2021.

[9] Angradi, T. R., Williams, K. C., Hoffman, J. C., and Bolgrien, D. W. "Goals, beneficiaries, and indicators of waterfront revitalization in Great Lakes Areas of Concern and coastal communities". *J. Great Lakes Res.*, vol. 45 no. 5, pp. 851-863, 2019.

[10] Tata, H., and Afolabi, O. O. "Delineation of Land Reclamation Areas in Eti-Osa and Lagos Island Local Government Areas of Lagos State". *Afr. J. Land Policy Geospat. Sci.*, vol. 7, no. 1: pp. 113-125, 2024.

[11] Alabi, B. O. "Urban redevelopment as a metaphor for gentrification in the making of a mega-city: The forced displacement of Otodo Gbame/Ebute Ikate community, Lagos state. Rethinking institutions, processes and development in Africa". In: Rowman & Littlefield- Lanham, M. D. and Falola, T. (Eds.) pp. 276, 2021.

[12] Fashae, O. A., Tijani, M. N., Adekoya, A. E., Tijani, S. A., Adagbasa, E. G., and Aladejana, J. A. "Comparative Assessment of the Changing Pattern of Land cover along the Southwestern Coast of Nigeria using GIS and Remote Sensing techniques". *Scientific African*, 17, e01286, 2022

[13] Obiefuna, J., Adeaga, O., Omojola, A., Atagbaza, A., and Okolie, C. "Flood risks to urban development on a coastal barrier landscape of Lekki Peninsula in Lagos, Nigeria". *Scientific African*, 12, e00787, 2021

[14] Ekoh S. S. and Teron L. "Vulnerable spaces, unequal responses: lessons for transformative climate resilience in Lagos". *Front. Sustain. Cities* vol. 5 pp. 929121, 2023.

[15] Bako, A., and Ojolowo, S. K. "Spatial knowledge and flood preparedness in Victoria Island, Lagos, Nigeria". *Jamba*: *J. Disaster Risk Studies*, vol. 13 no. 1, pp. 1-11, 2021.

[16] Higuera R. O., O'Connor, J., Ogunwumi, T. S., Ihinegbu, C., Reimer Lynggaard, J., Sebesvari, Z. and Koli, M. "Technical Report: Lagos floods". Interconnected *Disaster Risks 2021/2022. United Nations University - Institute for Environment and Human Security* (UNU-EHS). pp. 28, 2022.

[17] Idowu, T. E., Waswa, R. M., Lasisi, K., Mubea, K., Nyadawa, M., and Kiema, J. B. K. "Towards achieving Sustainability of coastal environments: Urban Growth analysis prediction of Lagos, State Nigeria". *S. African J. of Geomatics*, vol. 9, no. 2, pp. 149-162, 2020.

[18] Fakoya, K., Oloko, A., and Harper, S. "Understanding vulnerability of urban waterfront communities to rapid development: the case of Lagos Lagoon, Nigeria". In *Blue Justice: Small-Scale Fisheries in a Sustainable Ocean Economy. Cham: Springer International Publishing.* pp. 451-467, 2022.

[19] Fatai, A. O. "Analysis of urban expansion and land cover changes in Lagos Metropolis, Nigeria". *FUTY J. Environ.*, vol. 15, no. 2, pp. 59-68, 2021.

[20] Badejo, O. T., and Akintoye, S. O. "High and low water prediction at Lagos Harbour, Nigeria". *NIJOTECH*, vol., 36, no. 3, pp. 944-952, 2017.

[21] Adegboyega, S. A., Oloukoi, J., Olajuyigbe, A. E. and Ajibade. O. E. "Evaluation of unsustainable land use/land cover change on ecosystem services in coastal area of Lagos

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state, Nigeria". *Applied Geomatics* vol., 11, pp. 97-110, 2019.

[22] Suleiman, A. A., Baderinwa, A., and Olajuyigbe, A. "Geospatial Assessment of Human-induced Land cover Changes and its Environmental Implications along the Coastal Areas of Ibeju-Lekki LGA, Lagos State, Nigeria". *J. Sust. Tech.*, vol. 11, no. 2, pp. 93-110, 2021.

[23] Okoyen, E., Raimi, M. O., Oluwatoyin, O. A., and Williams, E. A. "Governing the environmental impact of dredging: Consequences for marine biodiversity in the Niger Delta Region of Nigeria". *Insights Mining Sci. Tech.*, vol. 2, no. 3, pp. 555586., 2020.

[24] Ekeu-Wei, I. T., Azuma, K. I. and Ogunmuyiwa, F. B. B. "Assessment of environmental impact of solid waste dumpsites using remote sensing", *Nigerian Journal of Technology, vol* 37, no. 1, pp. 275-285, 2018.

[25] Osaiyuwu, R. C., and Ugbebor, J. N. "Air quality assessment of some oil facilities host communities in Rivers State". *Nigerian Journal of Technology*, vol., 38, no. 1, pp. 242-252, 2019.

[26] David, A. O., Odagbodo, O. O., Opafola, O. T., Amusan, G. M., Badejo, A. A. and, Olaniyan, O. S. "Assessment of solid waste management in Ota, Ogun State, Nigeria". *Nigerian Journal of Technology*, vol. 42, no. 2, pp. 289-295, 2023.

[27] Makinde, E. O. and Oyelade, E. O. "Land cover mapping using Sentinel-1 SAR and Landsat 8 imageries of Lagos State for 2017". *Env. Sci. and Pollution Res*., 27, no. 1, pp.66-74, 2020.

[28] Mohammed, D., Maina, M. M., Audu, I., Tudun-Wada, I. Y., and Nasir, N. K. "Remote sensing techniques in mapping spatial variability of salinity in Kano River Irrigation Project (KRIP), Nigeria". *Nigerian Journal of Technology*, vol. 40, no. 4, pp. 732-739, 2021.

[29] Alves, B., Angnuureng, D. B., Mor, P., and Almar, R. "A review on coastal erosion flooding risks best management practices in West Africa: what has been done should be done". *J. Coast. Conserv*., 24, 1-22, 2020.

[30] Enoh, M. A., Okeke, U. C., and Nkechi, B. C. "Mapping and simulating the spatial-temporal changes in the Lagos wetland ecosystem: A step-by-step approach to creating a carbon-neutral, sustainable urban city". *Ecol. Model.*, 482, 110399, 2023

[31] Macrotrends. "Lagos, Nigeria Metro Area Population 1950-2024", 2024, https://www.macrotrends.net/global-metrics/cities/22007/lagos/population

[32] Epuh, E. E., Orji, M. J., Iyoyojie, H. A. and Daramola, O. E. "Groundwater potential mapping in Ikorodu, Lagos State, Nigeria, using multi-criteria analysis and hydrogeophysics". *Nigerian Journal of Technology*, vol., 39, no. 1, pp. 278-292, 2020.

[33] Rouse, J. W., Haas, R. H., Schell, J. A., and Deering, D. W. "Monitoring vegetation systems in the Great Plains with ERTS". In *Third ERTS Symposium*. *NASA* SP-351, vol. 1, pp. 309-317, 1974.

[34] Laonamsai, J., Julphunthong, P., Saprathet, T., Kimmany, B., Ganchanasuragit, T., Chomcheawchan, P., and Tomun, N. "Utilizing NDWI, MNDWI, SAVI, WRI, and AWEI for estimating erosion and deposition in Ping River in Thailand". *Hydrology*, vol. 10, no 3: pp. 70 - 95, 2023

[35] Pramanik, S., Areendran, G., Punia, M., and Sahoo, S. "Spatio-temporal pattern of urban eco-environmental quality of Indian megacities using geo-spatial techniques". *Geocarto Int.*, vol. 37, no. 17, pp. 5067-5090, 2022

[36] Li, W., Wang, W., Yang, Y., Hou, X., and Ha, H. "Energy and vapour transfer in evaporation processes over saturated bare soil and water surface-lysimeter studies. Hydrological Processes", vol. 37, no. 6, pp. e14894, 2023.

[37] Agbola, T. and Jinadu, A. M. "Forced Eviction and Forced Relocation in Nigeria: the Experience of those evicted from Maroko in 1990". *Environment and Urbanization*, vol. 9, pp. 271, 1997.

[38] Marfo, S. A., Appah, D., Joel, O. F., and Ofori-Sarpong, G. "Sand consolidation operations, challenges and remedy". In SPE *Nigeria Annual International Conference and Exhibition* pp. SPE-178306). SPE., 2015.

[39] Pei, T., Xu, J., Liu, Y., Huang, X., Zhang, L., Dong, W. and Zhou, C. "GIScience remote sensing in natural resource environmental research: Status quo future perspectives", *Geogr Sustain.*, vol. 2, no. 3, pp. 207-215, 2021.

[40] Sumit, V. K., Kumar, M., and Rani, S. "Estimation of Compound Growth Rate using Nonlinear Growth Models for Area and Production of Cabbage and Cauliflower in Haryana". *Ann. Hortic.*, vol. 15, no. 1, pp. 13-20, 2022

[41] Tyonum, E. T. "Evaluation of the effect of climate change on building collapse in Lagos

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State". *Int. J. Adv. Academic Res.*, vol. 9, no. 11, pp. 112-123, 2023

[42] Babalola, O. S., and Akinsanola, A. A. "Change detection in land surface temperature and land use land cover over Lagos Metropolis, Nigeria". *J. Rem. Sens.GIS*, vol., 5, no. 3, pp. 1-7, 2016.

[43] Bako, A., and Ojolowo, S. K. "Spatial knowledge and flood preparedness in Victoria Island, Lagos, Nigeria", *Jamba*: *J. Disaster Risk Studies*, vol. 13 no. 1, pp. 1-11, 2021.

[44] Oyedepo, J. A., Oluyege, D. E., and Babajide, E. I. "Remote Sensing of City Extension and Vegetal Cover Changes along Lagos-Ibadan Access Strip in Nigeria". *JASEM*, vol. 25, no. 8, pp. 1371-1377, 2021

[45] Fashae, O. A., Tijani, M. N., Adekoya, A. E., Tijani, S. A., Adagbasa, E. G., and Aladejana, J. A. "Comparative Assessment of the Changing Pattern of Land cover along the Southwestern Coast of Nigeria using GIS and Remote Sensing techniques", Scientific African, e01286, 2022.

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