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Research Article

Evidence of paucity of residential green spaces from the normalized difference vegetation index (NDVI) in Metropolitan Lagos, Nigeria

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A Biophillic city reconnects man with nature through green spaces which foster mental and physical productivity. The industrial revolution ushered in a wave of technological deterministic choices at the expense of environmental deterministic processes in the fashioning of cities. The background of this research is set in the urban residential fabric of the metropolitan city of Lagos. This study is relevant because in Lagos metropolis, residential areas have a land use zoning of 52% as opposed to 2.8% for urban open spaces. The research study aims to investigate the greenness index or NDVI of three selected residential estates each representative of the residential densities (low, medium, high) in metropolitan Lagos and its indications for the abundance or dearth of residential greenspaces. The sampling frame was gotten by multi-stage random sampling and the data collection tool used was high-resolution object-oriented imagery. The data analysis made use of geo-referencing ARCGIS and ERDAS IMAGINE software. The results show the Normalized Difference Vegetation index (NDVI) values of the residential estates are low (<0.2) thus revealing residential areas with negligible vegetation. In conclusion, the dearth of green spaces which are physical observed within the residential fabric of Lagos city on a ground truth basis have been substantiated by the results of this research. Therefore, it is important to consider actions to improve the greenness index of the city as well as ensure that peri-urban settlements which are rapidly developing in Lagos city do so in a sustainable manner based on green principles.

Keywords: biophilic city, residential estates, green spaces, city sustainability

1 Introduction

Buildings throughout history and in all regions of the world employ the healing effect of biophilia. Orr (1993) shows examples of how every building up until the Twentieth Century evinces biophilia's healing effect, although that may not be the only explanation for their success. From the onset of 20th Century, architecture abandons biophilia or uses it selectively, and even in those cases, not always successfully. Nevertheless, some buildings from the early 20th Century onward employ organic forms in a biophilic manner, and explicitly biophilic elements have been used in recent decades (Heerwagen, 2000). Evidence both from scientific sources and from traditional wisdom is giving rise to the need for a healthier environment. This principle in the built environment works through the reconnection of man with his surroundings through the application of the special geometry of nature to improve mental and physical enhancement. The resultant effect is the reduction of stress on the human mind and body, building his immunity to fight illness and to promote healing. This is seen in the greenness index of the living spaces where residents' dwell. For most of history, medicine took the environment seriously as a factor in health and healing. However, the industrial revolution brought increasing embracing of technological processes at the expense of environmental inclusion. Health care followed suite and focused largely on direct intervention via drugs, surgery, etc. This approach is now seen to have its set-backs. This is because salutogenicity a phenomenon that emphasizes healing environments has arisen in medical research. It proposes that a healing environment arises when human beings draw from the complexity of nature and conceive of themselves as in touch with their feelings and emotions. In plain terms, salutogenic environments are health inducing and improving environments. People are increasingly demanding such salutogenic environments that lower stress: living and working spaces that act to keep us

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healthy. Therefore, the introduction of green spaces into living environments as well as the preservation of green infrastructure in cityscape is necessary to achieve this order. It is hence sad to note that visibly there is a paucity of green spaces in developing cities in west Africa. Lagos is the largest city in West Africa and it is a trail blazer where several innovations are concerned. This research aims to reveal that there is a dearth of green spaces in residential metropolitan Lagos and proffers recommendations to abate this malaise.

1.1 The use of High-Resolution Satellite Imagery in Urban Open Space Research.

The classification of greyspace and greenspace units of residential private open spaces through visual interpretation and manual digitization has been done through large scale aerial photographs (Pauleit et al., 2003). The efficiency of this technique for detailed mapping, is hampered by its time-consuming and impractical nature in extracting data on private gardens (private open spaces) in medium or large size cities. Until recently, the spatial resolution of satellite sensors has been too coarse and largely low (e.g. 30 or 20 m for Landsat TM or SPOT) to be appropriate for application, given the small size of the average private garden (private open space). Image Interpretation can be defined as the art of analyzing photographs or images to extract useful information about image features and categorizing such features into meaningful classes (Image Classification). The last generation of high-resolution Earth Observation satellites, e.g. Ikonos or Quickbird, World view, provides images with a level of detail compatible with urban mapping i.e. from 4 to 2.5 m to even <1 m spatial resolution and can thus provide data at a level appropriate to garden analysis. In addition, multispectral sensors have the advantage, over color aerial photographs, of recording near infrared light which is the most sensitive spectral domain used to map vegetation canopy properties (Guyot,1990). Object-oriented techniques recognize that important meaningful information is not represented in single pixels but in image objects and their mutual relations, that is with reference to their context (Benz et al., 2004; Blaschke & Strobl, 2001). These techniques have demonstrated great potential to improve the automatic extraction of information from very high-resolution imagery (Benz et al., 2004; Laliberte et al., 2007). Software applications such as ERDAS imagine, ARCGIS, QGIS have been designed to analyze and interpret imagery data, generating classification groups such as bare land, vegetation and building structures and even process the Normalized Differentiated Vegetation Index (NDVI) of each of the selected residential estate. The NDVI, which is a combination of red and NIR reflectance measurements, is one of the most widely used vegetation indices in the world (Ramsey, Wright & McGinty, 2004, 2004) and it has been used extensively as an indicator of the state of vegetation over many spatial and temporal resolutions Abdollahi et al. (2008). It is based on the difference between the maximum absorption of radiation in the red spectral band and the maximum reflection of radiation in the near-infrared spectral bands. Values of the NDVI range between -1.0 and +1.0, but are usually positive for soil and vegetation. For bare soils alone, depending on composition and wetness, NDVI varies between 0.1 and 0.2, Glenn et al. (2008) They also reported that in remote sensing studies bare soil value scaled at 0, and 100% vegetation scaled at +1 to get fractional cover for a given pixel or area of interest in the scene. Denser and/or healthier vegetation will have higher values. NDVI values for vegetation usually offer a means of efficient and objective evaluation of phenological characteristics (Saino et al., 2004).

The index ranges from -1 to 1, with more positive values indicating greener, and thus more vegetation, in the pixel. It ranges from values -1 to +1. Very low values of NDVI (-0.1 and below) correspond to barren areas of rock, sand, or urban/built-up. Zero indicates no vegetation or water cover. Moderate values represent low density of vegetation (0.1 to 0.3), while high values indicate vegetation (0.6 to 0.8) (Takeuchi & Yasuoka, 2004).

The NDVI of each of the selected residential estate was calculated and processed to reveal the greenness index of the residential estates.

2 Materials and methods

2.1 Methods

The research employed mixed methods. Quantitative and Qualitative modes of inquiry adopted. The primary data was collected through reconnaissance surveys done in the four selected residential estates while the qualitative method which utilized the high-resolution, object-oriented satellite imagery and provided complementary data which was analyzed. The qualitative data collection was done with aid of recent satellite imagery of the selected estates after a reconnaissance survey was conducted to ascertain the coordinates of the selected residential estates. The data types and their respective sources are given in the Table below (Table 1). A noteworthy mention is given to the digital globe foundation (@digitalglobeFDN) who gave an educational imagery grant of different areas within metropolitan Lagos that covers the selected residential estates. This foundation partnered with hexagospatial.com to also provide the Erdas Imagine software for analyzing and

Table 1 Project Datasets

S/N	Segment	Data type	Source	Date of production
1	secondary data	digitized administrative map of Lagos State	LASG website	2017
2	primary data	worldview satellite imagery of 2016 with <1 m resolution	worldview	2017
3	secondary data	estates data	different LCDAS in Lagos state	2017
4	primary data	GPS coordinates of points within the study area	author's handheld GPS enabled device	2017
5	secondary data	questionnaire data	questionnaire survey	2017

Sources: LASG,2017; Digital globe foundation, 2017

Table 2 Imagery Data Information

6 images fit your filter criteria					Catalogue							Digital globe
Select	Browse image	Catalog id	Imaging bands	Space craft	Acquisition date	Total max off nadir angle (o)	Area max off nadir angle (o)	Area min sun elevation	Area max GSD (m)	Total cloud cover pct (%)	Area cloud cover pct (%)	MS Aggr
	view	10400100170D2A00	Pan-MS1-MS2	WW03	2016/01/25	22.0	22.0	57.64	0.35	0	0	N/A
	view	104001001A504500	Pan-MS1-MS2	WW03	2016/04/10	20.8	20.8	73.50	0.35	4	4	N/A
	view	103001004E6E5500	Pan-MS1-MS2	WW02	2015/12/08	26.7	26.7	55.18	0.57	0	0	N/A
	view	104001001CD61C00	Pan-MS1-MS2	WW03	2016/04/29	16.3	16.3	72.54	0.33	0	0	N/A
	view	1040010029D6CD00	Pan-MS1-MS2	WW03	2017/02/14	24.6	24.6	60.20	0.36	35	35	N/A
	view	10500100047B4C00	Pan-MS1	GE01	2016/05/21	18.4	18.4	63.90	0.45	3	3	N/A

Source: Digital globe foundation

classifying the imagery data as well as other tools such as the Greenness Index, Area analyzer and Incidence network as part of the educational grant.

The Software instrumentation used to analyze the imagery data include the following:

- ERDAS Imagine 2016: This was used in the pre-processing, processing, post-processing of the Worldview satellite imagery covering the study area.
- ArcGIS 10.2: This was used to extract the shapefile of the study area from the digitized administrative map of Lagos state and to perform various spatial analyses.
- Microsoft Office Suite (Excel, PowerPoint, Visio and Word): These were used to prepare reports, slides, and flowcharts and also to perform analysis of acquired data.
- FileZilla: This was used to download the High-resolution satellite imageries from the Digital Globe website.
- WinRAR 3.8: This was used to extract the Worldview imageries from the compressed downloaded file. The imagery datasets acquired were detailed in the Table 2.

2.2 *Satellite Imageries*

The image IDS were acquired through the application process for the education grant.

They are as follows:

- Imagery Datasets Details (Image IDs)
- 103001004E6E5500,104001001CD61C00
- 104001001A504500,10400100170D2A00
- 1040010029D6CD00,10500100047B4C00

Each area of interest (AOI) was mandated to exceed 5 km^2 per shape file, but must not exceed a total of 25 km^2 altogether. The imagery was provided courtesy Digital globe foundation as an educational grant which is the non-profit arm of the profit-making Digital Globe company. As an objective measure of overall greenness, we calculated the NDVI of the walkable neighborhood for each parcel. The NDVI is a remotely sensed spectral vegetation index derived from satellite mounted sensors and calculated in the equation below. The NDVI measures the amount of photosynthetically active light that is absorbed in each survey pixel, or its greenness, which varies with the absorption spectra of the objects in that pixel and the percentage of the pixel covered by each type of object. The index ranges from -1 to 1, with more positive values indicating greener, and thus more vegetation, in the pixel. The NDVI has a predictable linear relationship with net primary productivity – the energy accumulated by plants during photosynthesis – and has been related to bird reproductive success and morphology, and plant and animal diversity (Coops et al. 2014; Saino et al. 2004). Calculation of NDVI for giving pixel always results in a number that ranges from minus one (-1) to plus one (+1) however, no green leaves give a value close to zero. A zero means no vegetation and close to +1 (0.8 to 0.9) indicates the highest possible density of green leaves. The NDVI is the most common measurement used for measuring vegetation cover. It ranges from values -1 to +1. Very low values of NDVI (-0.1 and below) correspond to barren areas of rock, sand, or urban/built-up. Zero indicates the water cover. Moderate values represent low density of vegetation (0.1 to 0.3), while high values indicate vegetation (0.6 to 0.8) (Takeuchi & Yasuoka, 2004). The author used a dataset acquired from Worldview 2 and Worldview 3 (acquisition date between 2016-2017. The NDVI of each of the selected residential estate was calculated and processed to reveal the greenness index of each residential estate.

$$NDVI = [NIR - R]/[NIR + R] \quad (1)$$

where: NDVI – normalized difference vegetation index; NIR – near infra-red; *R* – red

When the vegetation has optimal health, it reflects more near infrared (NIR) – greenlight compared to other wavelengths but it absorbs more red and blue light. In other words, it is the process of quantifying vegetation by computing the difference between the near-infrared which vegetation strongly reflects and red light which vegetation absorbs.

3 Results and discussion

The High-resolution satellite imagery were classified using the supervised classification on the ERDAS IMAGINE 2016 software as elaborated in the research methodology. The results from the classified images show the areas where there is vegetation (greenspace) as denoted by the green areas, the red areas or yellow/gold in some cases show where there is bare land (greyspace) while the orange areas show where there are buildings. The green areas include patches of greenspaces in the residential private open spaces within the selected

Table 3 Results: normalized difference vegetation index (NDVI) (low density estates)

S/N	Name of residential estate (low density)	Normal difference vegetation index (NDVI) (mean value)
1	Parkview Estate (private)	0.068
2	Dolphin Estate (public)	0.031
3	Goshen Beach Estate (public)	0.013
4	Femi Okunnu Estate (public)	0.073

Table 4 NDVI result for Parkview Estate (private)

Minimum NDVI value	Maximum NDVI value	Median NDVI value	Mode NDVI value	Mean NDVI value	Standard deviation NDVI value
-0.1688	0.3424	0.0488	0.0349	0.0680	0.0610

Table 5 NDVI result for Dolphin Estate (public)

Minimum NDVI value	Maximum NDVI value	Median NDVI value	Mode NDVI value	Mean NDVI value	Standard deviation NDVI value
-0.0992	0.0325	0.0213	0.0213	0.0031	0.0400

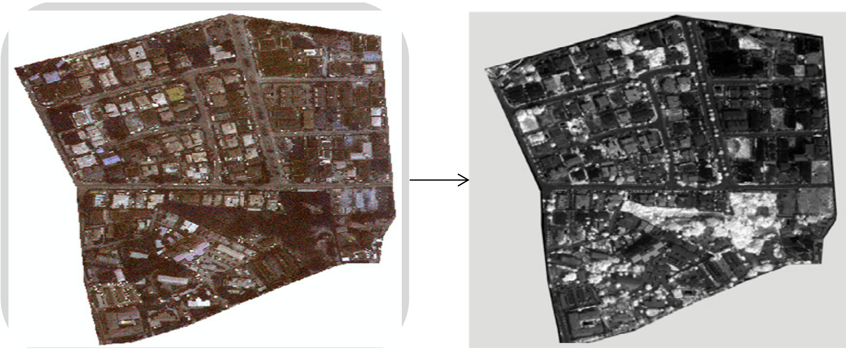

Figure 1 Imagery Classification image: Parkview Estate (private)

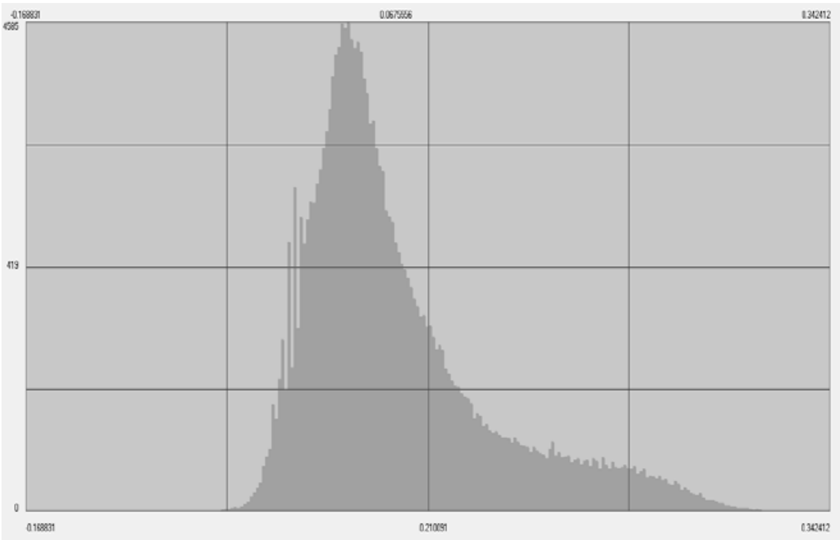

Figure 2 Histogram – (NDVI result: Parkview Estate (private)

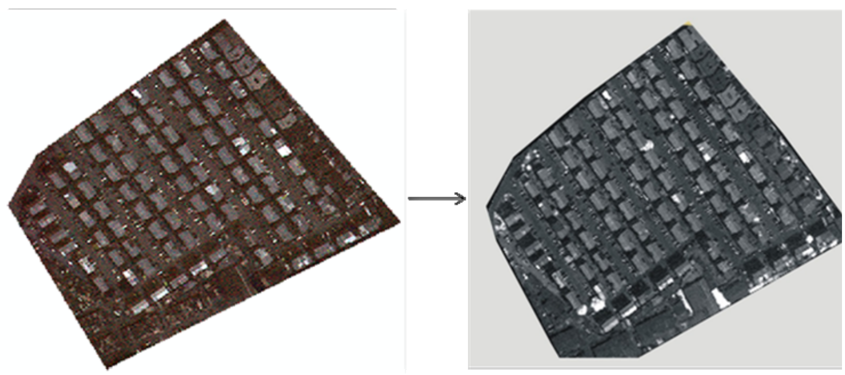

Figure 3 Imagery Classification image: Dolphin Estate (public)

residential estate as well as open land which is yet to be built upon. These are expressed in numerical signatures that show proportions of green, buildings and bare ground in the statistical table generated by the ERDAS IMAGINE software. The study reveals the Normalized Difference Vegetation Index (NDVI) in the selected residential estates. The NDVI is the most common measurement used for measuring vegetation cover. It ranges from values -1 to +1. Very low values of NDVI (-0.1 and below) correspond to barren areas of rock, sand, or urban/built-up. Zero indicates the water cover. Moderate values represent low density of vegetation (0.1 to 0.3), while high values indicate vegetation (0.6 to 0.8) (Takeuchi & Yasuoka, 2004). The NDVI was derived from the high-resolution object-oriented satellite imagery and was analyzed using the latest version of geospatial software ERDAS IMAGINE. The summary of the results and breakdown of the results are shown in the Tables 3, 4, 5, 6 and 7 below and a summary of all values in Table 8 below. Also, in Figs. 1–8, the images of the classified imageries are depicted below.

The summary of the normalized difference vegetation index (NDVI) is shown in the table 8.

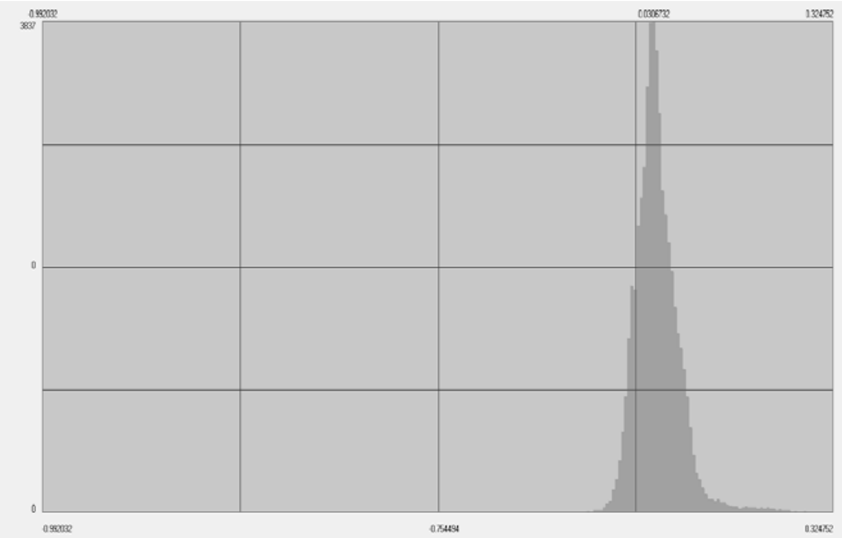

Figure 4 Histogram – (NDVI result: Dolphin Estate (public)

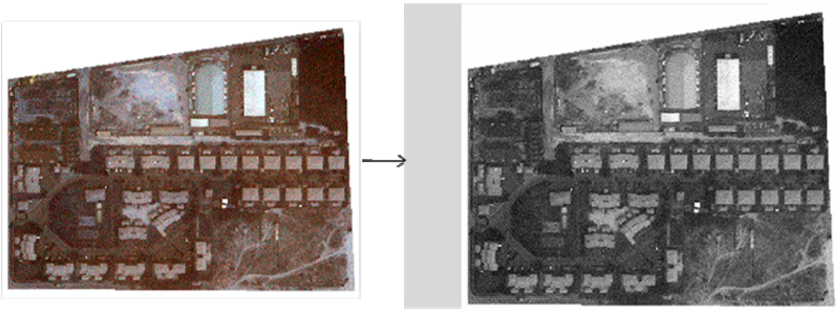

Figure 5 Imagery Classification image: Goshen Beach Estate (private)

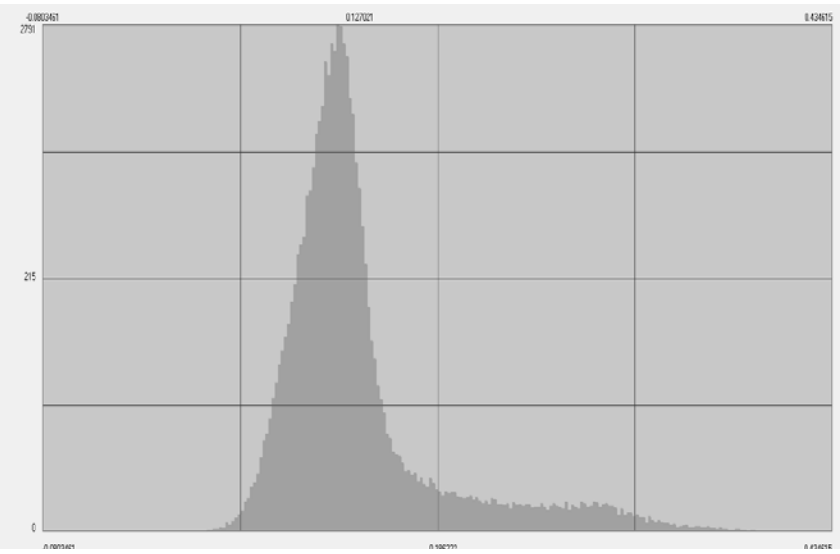

Figure 6 Histogram – (NDVI result: Goshen Beach Estate (private)

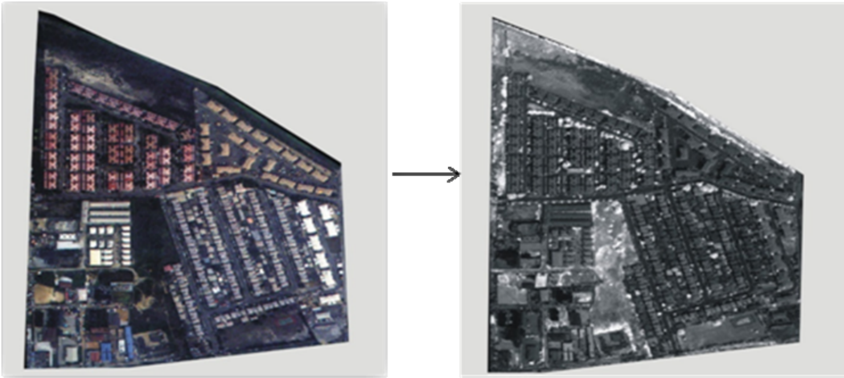

Figure 7 Imagery Classification image: Femi Okunnu Estate (public)

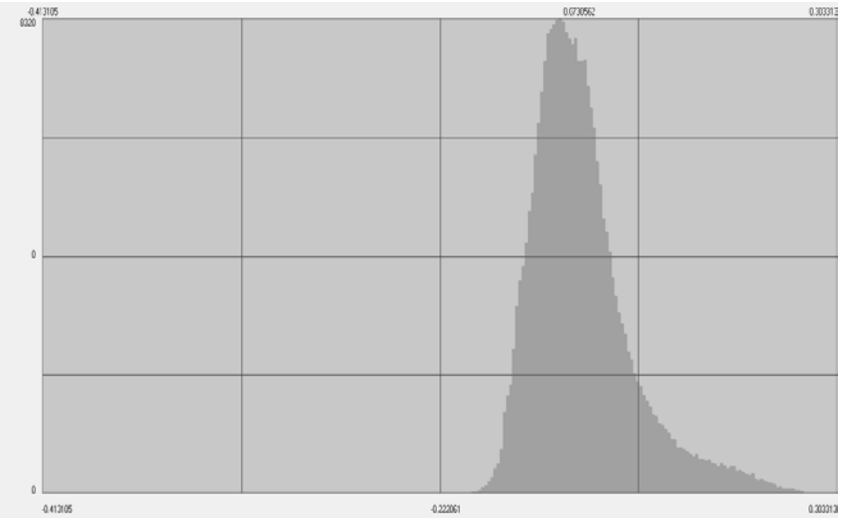

Figure 8 Histogram – (NDVI result: Femi Okunnu Estate (public)

Table 6 NDVI result for Goshen Beach Estate (private)

Minimum NDVI value	Maximum NDVI value	Median NDVI value	Mode NDVI value	Mean NDVI value	Standard deviation NDVI value
-0.0803	0.4346	0.1108	0.1107	0.0127	0.0560

Table 7 NDVI result for Femi Okunnu Estate (public)

Minimum NDVI value	Maximum NDVI value	Median NDVI value	Mode NDVI value	Mean NDVI value	Standard deviation NDVI value
-0.4131	0.3033	0.0626	0.0514	0.0730	0.0460

Table 8 Summary of the normalized difference vegetation index (NDVI) from each residential estate

NDVI result for Parkview Estate (private)

Minimum NDVI value	Maximum NDVI value	Median NDVI value	Mode NDVI value	Mean NDVI value	Standard deviation NDVI value
-0.1688	0.3424	0.0488	0.0349	0.0680	0.0610

Mean NDVI in parkview state (Private) was 0.07, Standard Deviation [SD] was 0.01 and the range was -0.16 to 0.34

NDVI result for Dolphin Estate (public)

Minimum NDVI value	Maximum NDVI value	Median NDVI value	Mode NDVI value	Mean NDVI value	Standard deviation NDVI value
-0.0992	0.0325	0.0213	0.0213	0.0031	0.0400

Mean NDVI in Dolphin Estate (Public) was 0.03, Standard Deviation [SD] was 0.04 and the range was -0.09 to 0.33

NDVI result for Goshen Beach Estate (private)

Minimum NDVI value	Maximum NDVI value	Median NDVI value	Mode NDVI value	Mean NDVI value	Standard deviation NDVI value
-0.0803	0.4346	0.1108	0.1107	0.0127	0.0560

Mean NDVI in Goshen Beach Estate (Private) was 0.01, Standard Deviation [SD] was 0.06 and the range was -0.08 to 0.43

NDVI result for Femi Okunnu Estate (public)

Minimum NDVI value	Maximum NDVI value	Median NDVI value	Mode NDVI value	Mean NDVI value	Standard deviation NDVI value
-0.4131	0.3033	0.0626	0.0514	0.0730	0.0460

Mean NDVI in Femi Okunnu Estate (Public) was 0.07, Standard Deviation [SD] was 0.04 and the range was -0.4 to 0.30

4 Conclusion

Built environment professionals; architects, landscape architects, urban designers, engineers and many others are instrumental in the creation of such environments on a local, regional and city scale. They can derive design ideas to help achieve this goal only by looking beyond mainstream conventional built environment practices, which buys into the same overly technological worldview and include the presence of living flora which is therapeutic and a key element of biophilic architecture. This would help to improve the greenscape of the residential areas. As a rapidly growing city, the mistakes that have been made in the metropolitan areas of the state can be corrected in the peri-urban areas which are also fast developing. This would forestall the rapid spiral of mass housing productions that have a dearth of green spaces and improve the greenness index of the city.

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