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Environmental Factor and Vegetaion Index of Some Digitized Farm Land (Area of Interest AOI) Using Space-Based Technology in Federal Capital Territory (FCT), Nigeria

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Abstract

FCT is endowed with enough fertile soil which is expected to be a catalyst for bountiful harvest of agricultural products. However, the major challenge is that there is growing food insecurity with a rising population highly dependent on imported foods. Monitoring environmental factor and vegetation index can provide important information for increasing food production and security in agricultural systems across the globe using GIS and remote sensing. The farmland was digitized inside the region of interest that was constructed using the high-resolution images from Maxar Secure Watch that allows us to run Map flow AI-mapping over Secure Watch imagery. Environmental factors of FCT and the vegetation index of AOI were analyzed with the aid of Arc GIS 10.8. Soil (type, pH, moisture, and productivity) was examined, and data on the climate and temperature were obtained from Tropical Applications of Meteorology using Satellite data and ground-based observations (TAMSAT) and were analyzed using the Mann-Kendall test. The results show very good change detection in NDVI and climatic factors such as, relative humidity, rainfall and temperature. Also, the soil properties, type, pH and productivity of AOI shows very promising one for Agriculture purposes which if considered by stakeholders and lawmakers will be of great advantage.

Keywords: *Environmental factor, vegetation index, space based and FCT*

1. Introduction

Agriculture is critical to the sustainability of all human activities [1]. Major difficulties such as over population and resource rivalry pose a danger to the planet's food security [2]. Agricultural productivity is closely affected by "physiography, climate, soil, and water, socioeconomic, political, institutional and organizational factors" all of which require planning and adaptation to achieve high productivity [3, 4, 5]. In Nigeria, crops are cultivated across nearly all regions by small holder farmers, sadly, they are struggling to cope with the effects of climate change, such as drought, heat waves, rising sea levels, flooding, and variations in the harmattan and rainy seasons, in addition to having insufficient data and lack of knowledge [6]. These producers lack access to these information's and expertise, which has the potential to determine if land resources are properly utilized, or being degraded or improved in quality [7, 8]. It is essential to examine the problems within the food sector from their most fundamental levels in order to embrace our own products and attain food security. The suitability of the land, the best methods to maximize yields, information about the optimum times of year to plant crops, technological exploration, and the provision of information to farmers, managers, and policymakers can all help them make well-informed decisions.

Accurate spatial information on agricultural fields is essential [9, 10]. Farmers can get precise and almost real-time information about the different soil types, the crops that are best for growing on the fields, yield forecasting, and field scale analytics using high resolution satellite data and mapping [11]. Many studies have been conducted on management, but very few on the farmlands themselves. There are not enough technical applications for the monitoring of the world's food crop fields, which is of great concern to governments worldwide, particularly Nigeria [12].

Space technologies, have demonstrated the capabilities in addressing challenges related to sustainable agriculture, be it from a stress created due to increasing demand for food, conversion of productive land to a different purpose, impacts of natural disasters or long-term impacts of a changing climate [13,14]. To effectively utilize the information on crops for improvement of the economy, there is a need to develop a state or district level information system based on available information on various crops derived from remote sensing and GIS approaches. Government can use the datasets in order to make important decisions about the policies they will adopt or how to tackle national issues regarding agriculture [15]. Farmers can utilize this knowledge to maximize land usage, choose appropriate crop types, and apply effective irrigation and fertilization procedures adapted to individual soil and environmental circumstances.

2. METHODOLOGY

2.1. Study Area

Abuja is the capital city of Nigeria located in the middle of the country. It falls within latitude 7° 25' N and 9° 20' North and longitude 5°45' and 7° 39' East respectively. The Federal Capital Territory has a land area of 8,000 square kilometers, two and halftimes the size of Lagos, the former capital of Nigeria [16]. FCT is bounded on the north by Kaduna State, on the west by Niger State, on the east and south-east by Nasarawa State, and on the south-west by Kogi State. Abuja is dotted with hills, highlands and other distinguishing features that make it a delight to behold [17,18]. Abuja has been characterized as savannah grassland of the north and the middle belt with the richness of the tropical rain forests of the south. This marriage of nature has ensured that Nigeria's capital is endowed with fertile land for agriculture and at the same time a yearly climate that is neither too hot nor too cold [19,20].

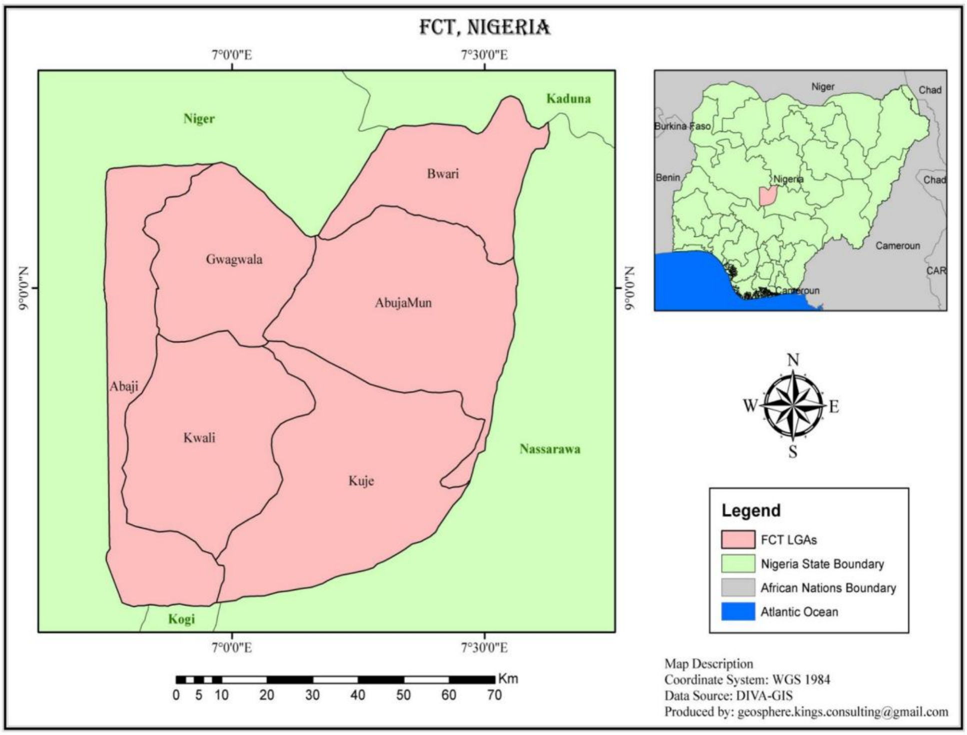

Figure 1. *Map showing the Project study area*

Table 1. *Dataset and their Source*

S/N	Source	Data Type	Spatial Resolution
1	Landsat Operational Land Imager (Oli)	Temperature, Ndvi	30 Meters
2	European Meteorology Research Programme	Rainfall	0.7 Meters
3	Fao	Soil Ph, Type And Productivity	
4	Osgof	Administrative Boundary	Shape File
6	Maxar Secure Watch	Aoi	Shape File

2.2. General Work Flow

We emphasize fine-resolution satellite image segmentation from Maxar Secure watch, which provides access to imagery base maps and various OGC services (WMS, TMS, WFS) for digitization of farmland in QGIS and NDVI for two seasons both wet and dry were analyzed for crop health status, Soil (type, pH, moisture and productivity) of the study area were analyzed and climate/temperature data was gotten from Tropical Applications of Meteorology using SATellite data and ground-based observations (TAMSAT) and was analyzed using the Mann-Kendal (Zmk) and Sen's slope estimator test at 0.05 significance level (p-value) on time series and Both qualitative and quantitative data were collected and analyze during the course of field validation.

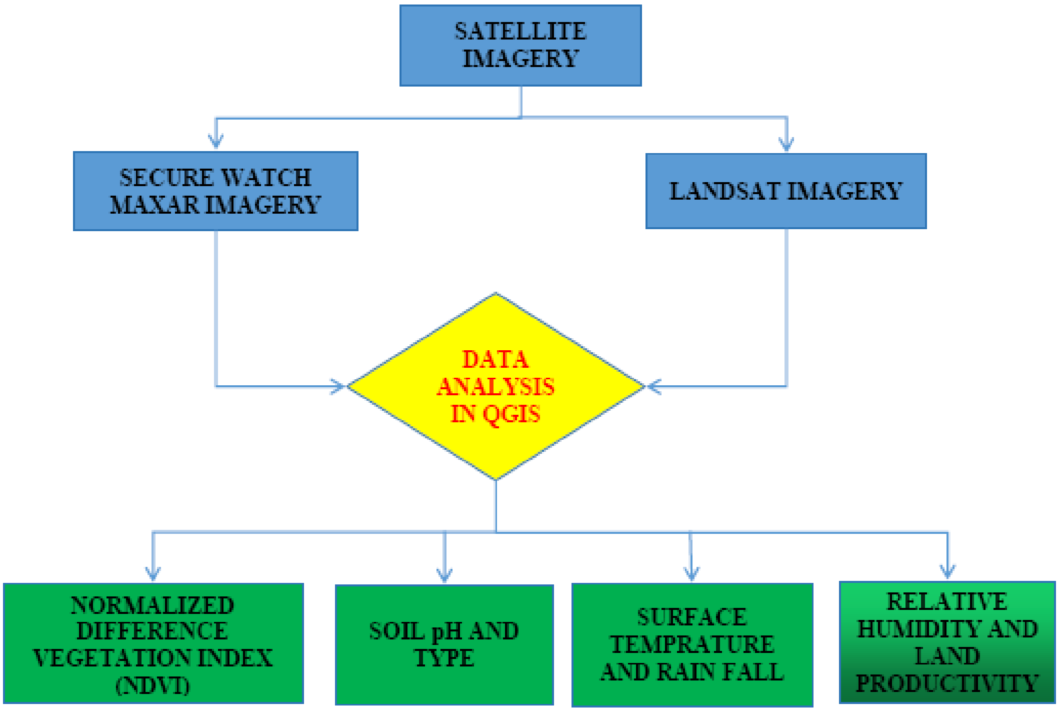

Figure 2. *Flow chart showing work flow*

3. Data Pre-Processing

Several preprocessing steps were carried out from QGIS software and Google engine before performance evaluation which include Data collection, Data cleaning, preparation, analysis and Spatial analysis.

Satellite images: Satellite images from Lands at Operational Land Imager (OLI) were downloaded and analyzed for NDVI. Measurement of vegetation index: In accordance with Talukdar et al. (2020), the Vegetation Index employing NDVI will yields good findings for describing vegetation density and condition.

Rain fall/Temperature: Rainfall/Temperature data of Abuja were downloaded and analyzed for three epoc, 2000, 2010 and 2020.

Soil properties: Soil pH and soil type were analyzed for Abuja and AOI

Soil productivity: This was done to determine the potential yields of the crop that can be produced in a particular soil or to determine the capacity of a soil to produce a certain yield of agricultural crops. We analyzed our AOI to see soils with more, moderate and stressed productivity.

4. Results and Discussion

4.1. Normalized Difference Vegetation Index

For each farm site in the six area councils of the FCT, the normalized difference vegetation index (NDVI) was employed to examine how the vegetation changed over time. It can be challenging to tell the three epochs (2000, 2010, and 2022) apart at first glance. However, the raster statistics that go along with them are also supplied below and provide quantitative proof of the reduced vegetation index. The NDVI analysis of the FCT NDVI from 2000, 2010, and 2022 were examined. For the Three epoch, NDVI indicators (NDVI minimum, maximum, mean, and standard deviation) are computed. Therefore, the quantification of vegetation change in the two periods for the era may be seen in the changes in the vegetation of the two periods (dry and rainy season). In addition to their statistics, the study site's NDVI map was created using the Arcgis 10.8 program. The two photos' maps demonstrate how the research area's vegetation distribution varies over time.

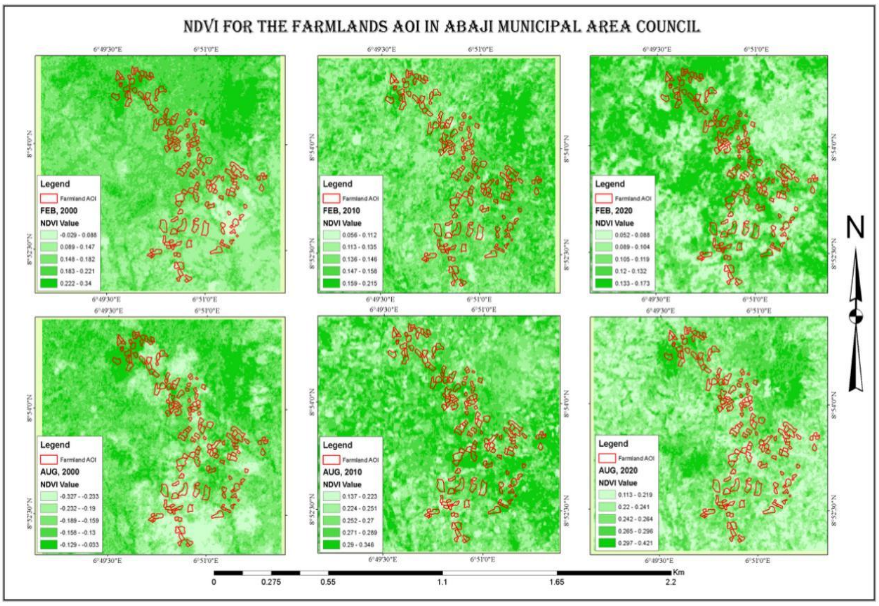

Figure 3. *NDVI OF AOI in Abaji for the year 2000, 2010 and 2020*

The NDVI values for the Abaji area indicate a significant increase in high vegetation density between 2000 and 2020, particularly in the months of August 2010. In 2000, the lowest NDVI values were observed in August, which suggests a decrease in vegetation density in that month. However, in 2010 the lowest NDVI values were observed in February and in 2020, the lowest NDVI values were observed in August, which may be attributed to the dry season in that region. Overall, the highest NDVI values were observed in August for 2 epochs, which may be linked to the rainy season and increased cultivation in the area as shown in figure 3 above and as a result of very good soil type of sandy loam and loamy soil as shown in figure 10. Also the soil pH in Abaji contribute a lot to the vegetation index (6.0 -6.3 figure 11)

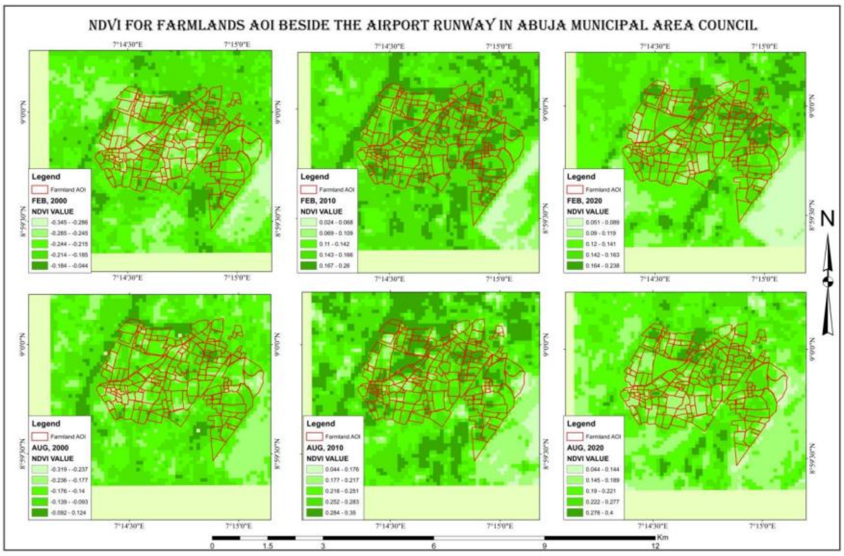

Figure 4. *NDVI of AOI beside Airport runway for the year 2000, 2010 and 2020*

The NDVI values for the AOI beside the airport runway suggest a change in vegetation density between 2000 and 2020. In 2000, the lowest NDVI values were observed in February and August, which may indicate a decrease in vegetation density in those months (figure 4). In 2010, the NDVI values were relatively low for both February and August, indicating low vegetation density in the area. However, in 2020, the NDVI values were higher compared to the previous years, particularly in August, suggesting an increase in vegetation density in that month. The low vegetation density in 2000 might be as a result of low rainfall as seen in (figure 12). These findings may have important implications for land-use management and resource allocation in the AOI beside the airport runway.

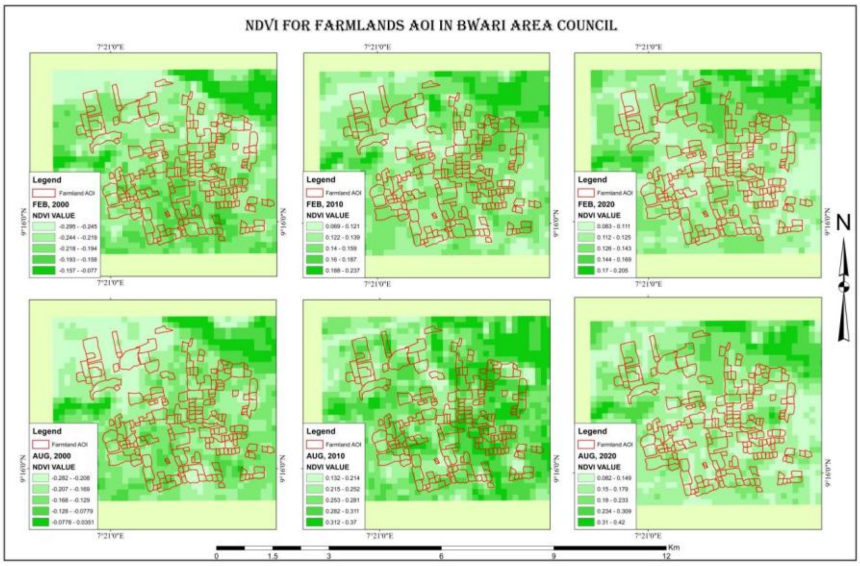

Figure 5. *NDVI of AOI in Bwari for the year 2000, 2010 and 2020*

Based on the NDVI values, it seems that there was a decrease in vegetation cover in the AOI in 2000as shown in figure 5, with negative values indicating the presence of barren land. However, in 2010 and 2020, there seems to be an increase in vegetation cover, with higher NDVI values indicating healthier vegetation. The increase in cultivated land in 2010 and growth of built-up areas in 2020 may have contributed to the changes in vegetation cover observed in the NDVI values.

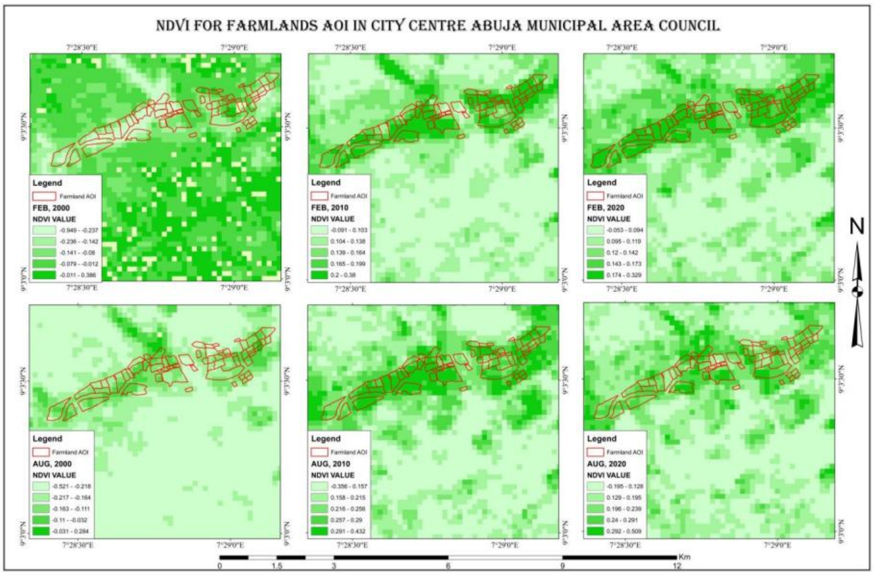

Figure 6. *NDVI of AOI in AMAC central area for the Year 2000, 2010 and 2020*

Figure 6 indicates that NDVI values in the AOI in AMAC central have changed significantly over time. In 2000, the range of NDVI values was quite large, with a minimum value of -0.949 and a maximum value of 0.386 in February, and a minimum value of -0.521 and a maximum value of 0.284 in August. This suggests that the vegetation cover was quite diverse, with some areas having very little vegetation and others having more.

In 2010, the range of NDVI values was much smaller, with a minimum value of -0.091 and a maximum value of 0.38 in February, and a minimum value of -0.356 and a maximum value of 0.432 in August. This suggests that the vegetation cover became more uniform, with a similar amount of vegetation across the AOI.

In 2020, the range of NDVI values was also relatively small, with a minimum value of -0.053 and a maximum value of 0.329 in February, and a minimum value of -0.195 and a maximum value of 0.509 in August. This suggests that the vegetation cover remained relatively uniform, with some areas having more vegetation than others, but overall a similar amount across the AOI.

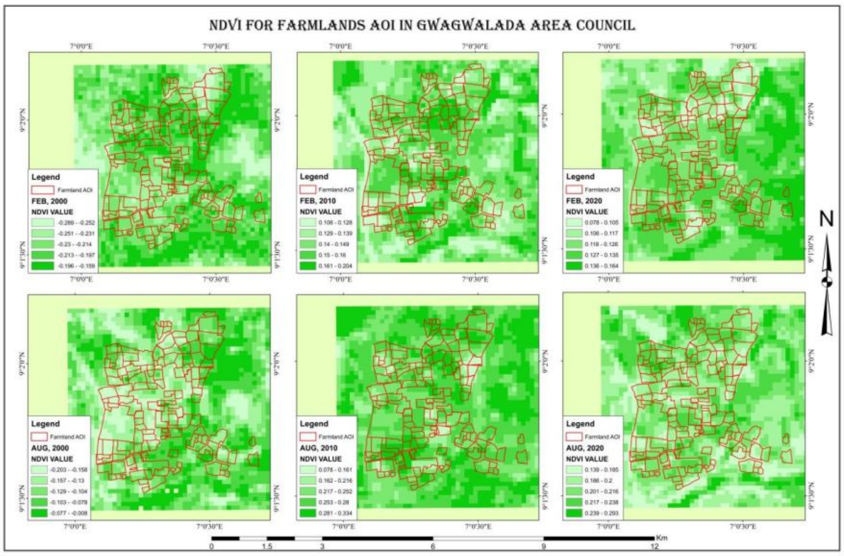

Figure 7. *NDVI of AOI in Gwagwalada for the Year 2000, 2010 and 2020*

Regarding the NDVI values, the area has generally become greener over time. In 2000, both February and August had negative NDVI values, indicating little or no vegetation. However, in 2010 and 2020, February and August had positive NDVI values, indicating the presence of vegetation. It's interesting to note that in 2010, August had a higher maximum NDVI value than February, while in 2020, February had a higher maximum NDVI value than August. This could be an indication of changes in vegetation patterns over time (figure 7).

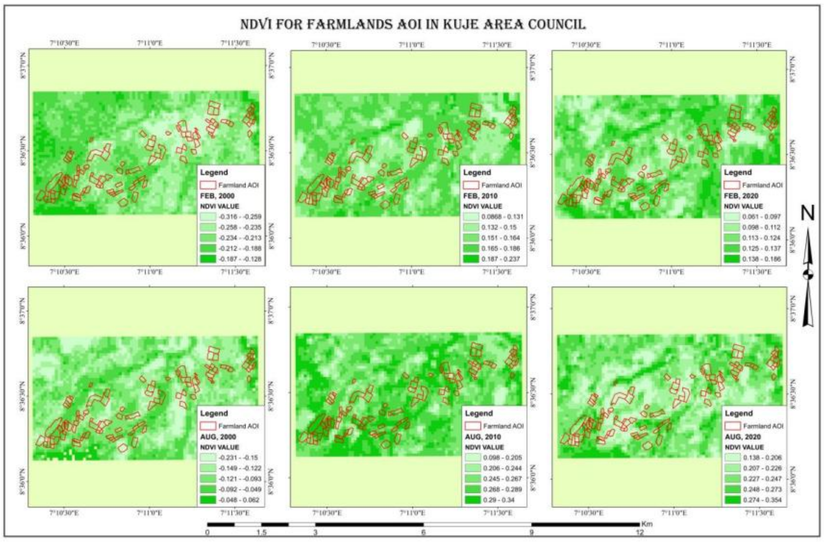

Figure 8. *NDVI of AOI in Kuje for the Year 2000, 2010 and 2020*

It appears that the NDVI values in the Kuje AOI have increased over time, with the lowest values occurring in 2000 and the highest values occurring in 2020. This suggests that there has been an increase in vegetation density in the area over the past two decades. In particular, we can see that there was a significant increase in NDVI values between 2000 and 2010, followed by a more gradual increase between 2010 and 2020. The highest NDVI values were observed in August of each year, which is consistent with the wet season in Nigeria when vegetation is typically more abundant.

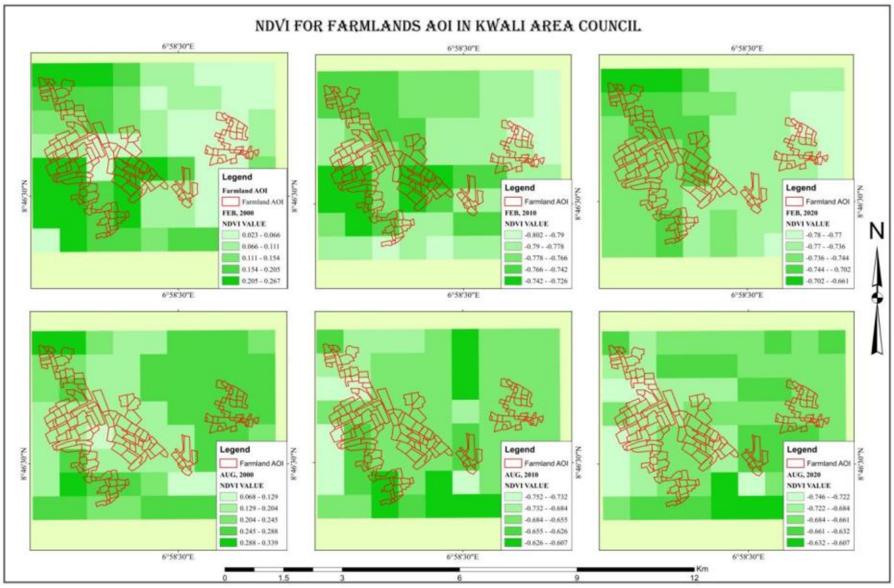

Figure 9. *NDVI of AOI in Kwali for the Year 2000, 2010 and 2020*

Looking at the results for the AOIi, we can see that there was a significant decrease in NDVI values between 2000 and 2010, and a futher decrease between 2010 and 2020. this indicates a decline in vegetation cover in the area over time, likely due to factors such as land-use change, climate change, and/or natural disturbances due to population expansion

Generally, our area of interest (AOI) in kwali shows a good vegetation ranging from (0.2 - 0.3) in both the two seasons. This might be as a result of water bodies around the AOI and very good soil type: Abaji and Bwari (Loam), Gwagwalada and AMAC (Sandy loam), Kwali and Kuje (Sandy loam and Loam) which is good in water retention. In 2020, the vegetation was reduce this might be as the result of reduced rainfall in the year as shown from the annual rainfall chart as shown in figure 21

4.2. Soil Type

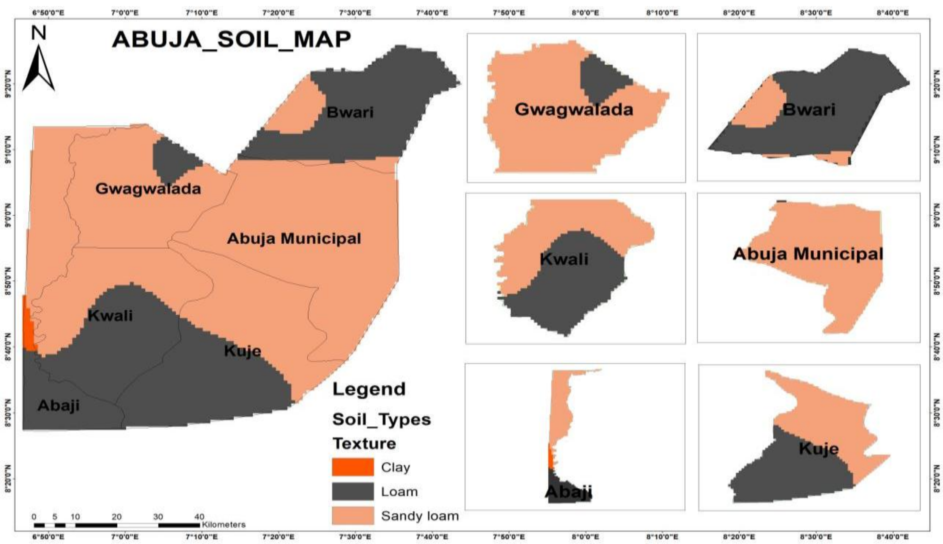

Figure 10. *Soil Map of Abuja*

FCT as stated in the study area description is located in the central region of the country. Due to the city's climatic and geological diversity, Abuja has various soil types. Despite the city being located at the fringe of a Savannah ecosystem, it underwent massive rural and urban development, which led to the change in the soil profile. The soil types in Abuja, Nigeria, are mainly Laterite (clay), Alluvial (loamy) and Colluvial (sandy) (Sunday, 2012) as shown in figure 10 below. Laterite soil is one of the main soil types in Abuja, Nigeria, and it covers about 40% of the area. The soils support good drainage and are well aerated. They are also easy to cultivate and are mostly used for growing cash crops like cocoa and rubber (Nair and Nair, 2021). While agriculture is an important part of the Nigerian economy, the different soil types in Abuja provide farmers with diverse options to choose from. It also ensures that the soil remains fertile and capable of supporting agricultural production.

4.3. Soil pH

Understanding how soil pH variations interact with crops is crucial for optimal crop development (Neina, D., 2019). The pH of the soil is between 0 and 14, with 7 being neutral. The pH of the soil has an impact on agricultural yield, and certain crops have specific pH requirements for growth**.** For instance, whereas crops like beans and alfalfa grow in a neutral to slightly alkaline range of 6.0-7.5, crops like potatoes and strawberries need acidic soil with a pH range of 4.5-5.5. The most suitable plant species for a specific soil type and location can be determined by understanding the pH range of the soil and how it interacts with crops (Fierer, 2017).

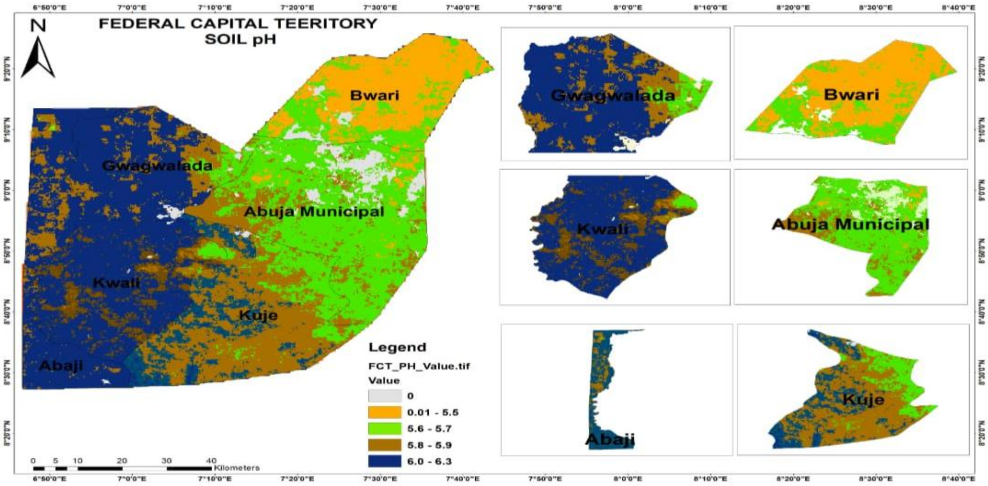

Figure 11. *Soil pH of FCT Abuja*

The pH range of the soil is very important in determining the amount of nutrients that are available in the soil (Marschner and Rengel, 2023). Within a certain pH range, plants can absorb soil nutrients. For instance, as the pH level falls below 6.0, calcium becomes less available to plants, while iron and aluminium become poisonous to plants in soils with a pH of 5.5 or below. In order to achieve effective nutrient absorption, it is crucial to maintain the soil's proper pH level for the intended crop. Because certain crops can alter the pH ranges of the soil, causing soil acidification or alkalization, crop rotation is another crucial strategy for maintaining a balance in the pH levels of the soil. Understanding how crops interact with different soil pH ranges thereby aids in enhancing soil fertility, plant growth, and crop output. The pH of the soil in Abuja ranges from 5.5 to 8.5, from mildly acidic to alkaline. Beans, tomatoes, and strawberries are among the crops that like acidic soil; in contrast, some fruits and vegetables like grapes, melons, and spinach prefer alkaline soil.

4.4. Rainfall and Temperature Analysis

4.4.1. Annual Rainfall

The rainfall variability on time series was performed annually using Mann Kendal which is a non parametric test which allows to accept the alternative hypothesis (Ha) that states the presence of a monotonic trend or reject (Ho), which states that no monotonic trend occurred. The Z-Value represents significant trend in the rainfall data while the Sen's slope estimator (m) shows a magnitude of trend. If the Zmk is greater than zero (Zmk > 0) trend is increasing, if Zmk < 0, trend is decreasing and if Z is zero, no trend occurred. The positive value of (m) indicates an upward trend on the other hand, a negative value indicates a downward trend.

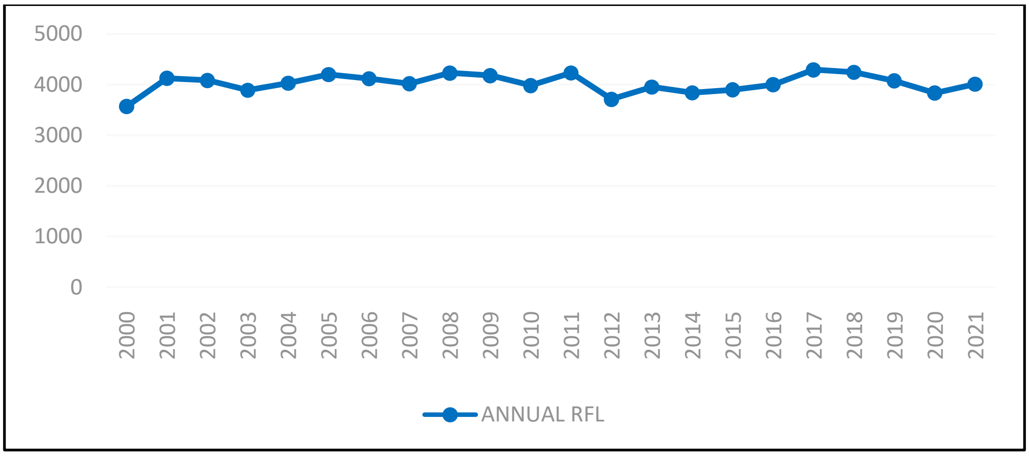

Figure 12. *Annual rainfall from 2000 -2021*

Results above were obtained from statistical trend tests and are explained annually. The results of time series and trend analysis of FCT for the period of 2000-2021 shows rainfall value in the year 2018 and 2019 to be 4292.92 mm and 4242.54 mm respectively. These years experienced higher rainfall in the time series. However, lower rainfall was experienced in 2001 and 2013 with annual rainfall values of 3566.04 mm and 3708.78 mm respectively, the temporal trend shows steady increase lately.

Abuja's surface temperature can be quite high, especially during the dry season, which usually runs from November to March, the city's surface temperatures can reach as high as 35-40 degrees Celsius (95-104 degrees Fahrenheit) during the day, with temperatures remaining relatively warm at night. This can be uncomfortable for many people, especially those who are not acclimated to the heat. In the wet season, which typically runs from April to October, brings lower surface temperatures to Abuja. The increased cloud cover and rainfall help to cool the air and surface temperatures, with daytime temperatures averaging around 28-30 degrees Celsius (82-86 degrees Fahrenheit). Nights tend to be cooler, with temperatures dropping to around 20-22 degrees Celsius (68-72 degrees Fahrenheit).

From the map below, the productivity in Kuje (figure 14) is stressed which might be as a result of continuous cultivation of the land due to soil type which very fertile as shown in figure 10 and favourable soil pH (figure 11) while AMAC shows declining with the rest showing moderate, increasing productivity and part of Bwari having no data for productivity. Additionally, the government should promote better farming practices to increase productivity and encourage the adoption of modern farming technologies.

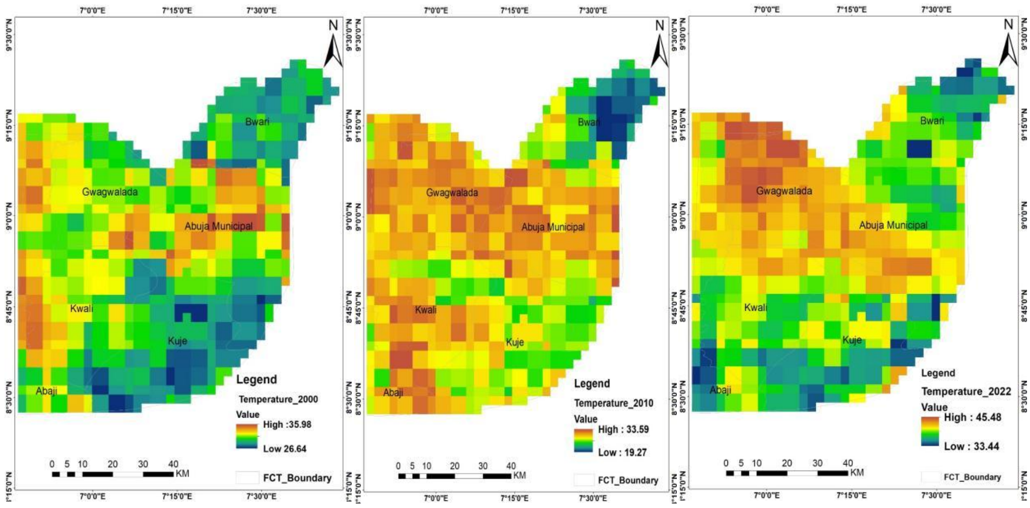

Figure 13. *FCT surface Temperature for year 2000, 2010 and 2022*

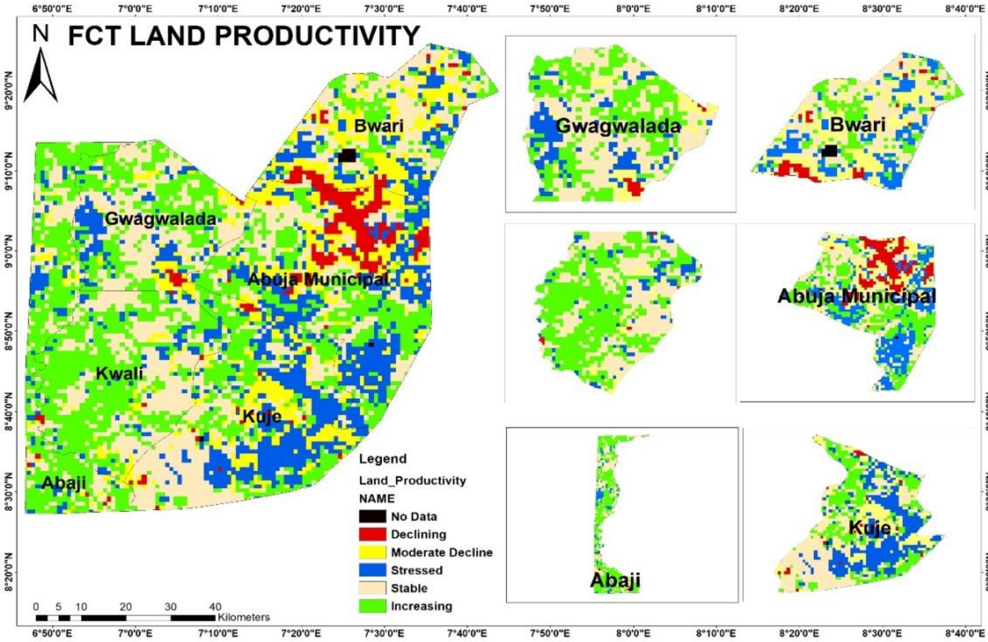

Figure 14. *Land productivity map of Abuja*

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