INTERNATIONAL JOURNAL OF RESEARCH AND SCIENTIFIC INNOVATION (IJRSI)
ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue IV April 2026

Assessment of the Impact of Climate Change on Potential Agricultural Lands in UYO, Nigeria

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DOI: https://doi.org/10.51244/IJRSI.2026.1304000055

Received: 04 February 2026; 09 February 2026; Published: 29 April 2026

ABSTRACT

Climate change is a global menace affecting environment and socioeconomic activities around the world. Its effects significantly altered hydrological and environmental activities causing severe damage to farmlands, leading to rise in sea levels, drought and dry spell. This study was carried out in Uyo to assess the impact of climate change on the agricultural lands within the area. The essence was to investigate the economic impact on the farmers.

ArcGIS technology was adapted to carry out imagery of the area under investigation using Landsat 8 satellite data. The parameters analyzed include temperature, precipitation and soil characteristics within a ten-year period (2012-2022). Soil analysis was carried out to ascertain its vulnerability to climatic elements. The OLi band 4 (red) and band 5 (Near infra-red) were used in the Normalized Difference Vegetation Index (NDVI) computation, while band 10 is employed for estimation of the brightness of the temperature.

The NDVI values ranged between 0 (low) and 1 (high), and showed a decline from 0.46 in 2017 to 0.34 in 2021. The year 2012 witnessed the driest period while 2016 was the wettest year, vegetated areas have reduced within the study period due to urban expansion and environmental degradation. From the result of the study, climate change influenced temperature which ranged from 26^0C to 32^0C leading to wide temperature and precipitation variation affecting soil health, thus reducing crop growth and food production.

This research will provide useful information for formulating long term agricultural policies for the region and the state at large.

Keywords: Climate change, Agricultural land, land suitability, Land use/ land cover. UYO.

INTRODUCTION

Climate change is a global menace with its attendant effects on the environment, economic and social lives of the people. It plays a significant role in the variability of weather patterns that leads to obvious deviation in weather conditions and in most cases result in extreme events. Its impacts are on individuals, regions and nations. Agriculture is one of the most affected activities by climate change carried out by man that influences human sustainability. According to FAO (2019), agriculture assists food production, livestock and the fibre industries. Studies done by FAO (2017) and Udoumoh *et al.,* (2020) evaluated the effects of climate change on the world agricultural landscapes temporally and spatially.

Agriculture is arguably one of the most important human activities enabling human existence. Temporal studies have also been done on land evaluation focusing on critical agricultural products such as wheat, rice, and corn within the framework of the predicted. solution to this problem is not on the near future, however, studies carried out in several regions are adopting strategies based on local policies and regional features (Alonge, 2018; Abatzoglou and Brown, 2011,Ujoh *et al*., 2019; Kamruzzaman *et al*., 2020). In developed countries of the world like the United States of America, it is reported that the impacts of climate change is extreme and it is costing the nation an estimated sum of $150 billion each year and over the past 15 years (2005-2019), there have been 156 separate billion-dollar weather or climate disasters in the U.S that have cost a combined $1.16 trillion in damages (Ebbs,2023). A joint effort between U.S. Geological Survey (USGS),U.S. Army Corps of Engineers (USACE), Bureau of Reclamation and National Oceanic and Atmospheric Administration (NOAA) working together to explore various ways to mitigate the effects of climate change on water resources by tackling, anticipating, and responding to activities relating to climate change. Water is another one of the natural resources most affected by climate change, whether that flowing above the earth surface or the ones flowing below the earth surface. Its major tool is temperature variation leading to change in the state vis:- solid, liquid and gaseous states. These states are not equally distributed on earth as a result, the artificial concentration of any of these states of water often constitute nuisance especially near human habitations, industrial areas and livestock banes. Therefore, water has become the medium by which climate change expresses itself thus influencing human livelihood in particular and the Earth's ecosystems in general. According to (Meshasha *et al*.,2014) the consequences of this phenomenon is the rise in average temperature variation resulting in precipitation leading to distorted rainfall distribution and upsurge in soil moisture, groundwater and surface water pollution resulting in deterioration of water quality. Recently, the impact of climate change on agriculture is frequently assessed using Geographic Information System (GIS) based models (Dabi and Khanna 2018).The physical properties of the land determine its capacity to meet human needs, and appropriate human land-use decisions are imperative to achieve optimal agricultural productivity of land while ensuring the sustainability of ecosystems. Geographical patterns of bio-physical constraints and potential capacity of the land for cultivation of specific crops can aid in planning the sustainable use of land resources, especially in the face of future impacts of climate change (Abd-Elmabod *et al*., 2020). Land evaluation has been used to classify land suitability for agriculture, determine sustainable land management approaches, and make predictions of land performance over time based on the specific type of uses. Thus, land suitability evaluation can contribute towards strategic land-use decisions that are biophysically and economically viable, while mitigating the negative effects of climate change on agricultural productivity (Yitbarek *et al*., 2013).

The agricultural sector in Uyo, Akwa Ibom State, Nigeria, faces significant risks due to changes in precipitation, temperature, and wind patterns. These climatic variations exert pressure on farmers who rely heavily on rain-fed agriculture as well as for their livelihoods but lack the resources to effectively respond to climate shocks (Alonge and Ituen, 2009). The exploration of the impacts of climate change on potential agricultural land in Uyo and emphasizes becomes urgent for adapting strategies to safeguard food production and sustainable development. The effects of climate change are associated with increases in temperature (T) and extreme weather events such as heavy rainfall, droughts, frosts, storms, and rising sea levels in coastal areas. These effects may also increase the threats to soil such as soil erosion, soil compaction, reduced soil fertility and lowered agricultural productivity, ultimately deteriorating food security and environmental sustainability (Lal *et al*., 2011).

These climate-related risks raise major concerns regarding the future role of soils as a sustainable resource for food production. Climate change can affect soil functions directly and indirectly. The direct effects of climate change on soil functions include soil process changes in organic carbon transformations and nutrient cycling through altered moisture and increased soil erosion rates due to an increased frequency of high-intensity rainfall events. Climate change and soil management can change the ability of the soil to perform its functions. However, for the sake of simplicity to achieve set goals (Ostle *et al*., 2009) recommended changes in approach. The indirect effects of climate change on soil functions include those that are induced by climate change adaptation options. Agricultural management can mitigate climate change effects, for example, through increased soil organic carbon (SOC), sequestration also known as regenerative agriculture (Haddaway *et al*., 2019). Uyo, a region situated in Southern Nigeria, exemplifies the intersection of these challenges. Agriculture serves as a primary source of income and sustenance for the local population, making it a backbone of economic stability and food security (Etim and Anwana, 2014).

However, like many regions around the world, it is experiencing the effects of a changing climate, including rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events. The impact of climate change on potential agricultural land suitability in Uyo is a critical concern for the region's food production, livelihoods, and overall economic stability (Udoumoh, *et al*.,2020). Variations in temperature and precipitation can influence soil quality, affect the yield of certain crops and disruption of traditional planting seasons (Arora, 2019). These changes have the potential to reshape the agricultural landscape, posing challenges that demand innovative solutions. Policy makers, agricultural practitioners, and local communities need actionable insights to develop adaptive strategies that can mitigate the adverse effects of climate change on agriculture. In the light of these challenges and opportunities, this study aims to assess the impact of climate change on potential agricultural land suitability in the area. By employing climate modeling, land suitability analysis, and historical agricultural data, this research seeks to provide a comprehensive and region-specific perspective on the evolving dynamics of agricultural land use in the face of a changing climate. Ultimately, the findings aim to inform policy makers and practitioners that promote sustainable agriculture and food security in Uyo and beyond.

MATERIALS AND METHODS

Study Area

Uyo as seen in Figure 1 is the capital city of Akwa Ibom State which is located in the South – South region of Nigeria .Its present status plays a significant role as it serves as the largest metropolitan city in the State thereby experiencing rapid rural-urban population migration and expansion in terms of infrastructural development. This expansion in land use is creating a negative impact on the natural vegetation and reducing agricultural productivity, hence affecting local food security negatively contributing to hunger and poverty in the area (Etim and Ndaeyo, 2020). Uyo covers between latitude 5°5’2.288” N and 4°52’32.477” N and longitude 7°47’25.785” E and 8°0’54.393” E. Uyo is the largest developed Local Government Area of Akwa Ibom State with an estimated population of 1,393,453 and a total land area of 8412km^2 (Udoumoh *et al.*, 2020) . Uyo is centrally located and shares boundary with nine other Local Government Areas namely; Abak, Mkpat Enin, Etinan, Nsit Ibom, Ibesikpo-Asutan, Uruan, Itu, Ibiono Ibom and Ikono. It enjoys humid climate due to its closed proximity to the Atlantic Ocean. It is within the tropical rain forest with an average temperature ranging from 26^{o}C to 32^{o}C, with the driest period experience between December and February and the wettest period experienced between July and August each year respectively. The average sunshine culminates to 1450 hours annually.

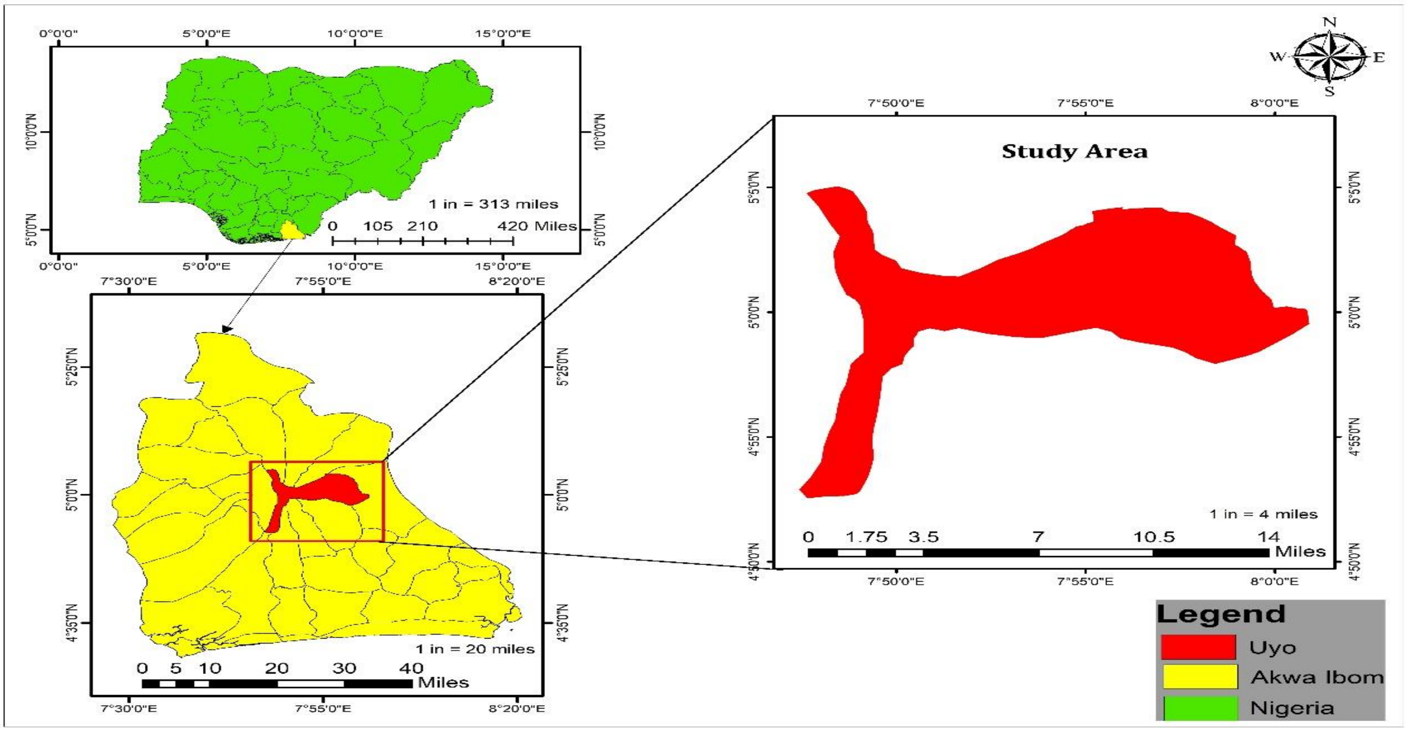

Figure 1: Map of Akwa Ibom State showing the study area in the context of Nigeria

Source; Digitalized by Advanced Space Technology Applications Laboratory, 2024

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue IV April 2026

METHODOLOGY

The methodology adopted in this study involves series of stages vis;-(1) acquisition of data, (2) data processing which includes image preprocessing, subset of multispectral and (3) data analysis LANDSAT 8 (Ifeanyi-Obi et al.,2013), because of its global acceptability and in dependability. Operational Line Imager Satellite data was used for this study to generate Normalized Difference Vegetation Index (NDVI) Map. Landsat 8 maps of Uyo LGA for the years 2013, 2016, 2019, 2022 were studied. The land use and land cover were generated from the 2022 satellite imagery using ArcGIS 10.89 software. The four-land use and land cover types identified from this Landsat image are; (1) built-up area, (2) water bodies (3) vegetated areas and (4) bare land.

The Normalized Difference Vegetation Index (NDVI) which is essential to identify different land cover types of the study area using Band 5 and Band 4. The NDVI value ranges between -1.0 to +1.0. and is computed on per-pixel basis as the normalized difference amid the near infrared band (0.85 µm - 0.88µm) and red band (0.64 µm - 0.67µm) of the images using the expression given in Equ. (1).

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

Where,

NIR is a pixel's near infrared band value and RED is the same pixel's red band value. NDVI = float (Band 5 – Band 4) / (Band 5 + Band 4)

The technologies of Geographical Information System (GIS) and Remote Sensing (RS) were adopted for this research to gather satellite data. ArcGIS software was used for data analysis, visualization and spatial modeling.

Climatic Data

A historical climate data for Uyo which involves including temperature, precipitation, relative, humidity and wind speed readings were used. These data were sourced from the Nigerian Meteorological Agency (NIMET). Soil data including soil type, soil texture, pH and organic matter was done according to Jimenez *et al*.,(2006).

Land Suitability Analysis (LSA)

Land suitability analysis is more than just a (GIS) based procedure, it is often used to locate the most suitable location for a project (AbdelRahman *et al.*, 2022). According to a study conducted by Joerin *et al*., (2012), land suitability analysis is one of the significant contributions of ArcGIS. The ArcGIS programme was used for analyzing the scope of the study area to determine the suitability of the land for agricultural practice. Data obtained from these are soil type, electrical conductivity, erosion potential, temperature and soil moisture for spatial analysis that could enhance land suitability analysis.

Land Cover Classification was done using the remote sensing imagery to determine the current land use and land cover within the study area.

Built Area: These areas are usually located within the limits of the city and are characterized by the substitution of the natural land cover with the artificial structures. It is often impervious surfaces such as roads buildings and pavement.

Bare land: These are naturally occurring soils with no vegetation cover and are not submerged in water. Vegetated areas on the other hand include cultivated and managed crop lands, orchards, plantation, forest, shrubs land, grasslands and sparse vegetation areas lying within the capital city. Finally, water bodies are rivers, streams, lakes, ponds, swamps, bogs and marshes mixed up with water.

Laboratories Analysis

Soil parameters

The soil texture analysis was determined using the hydrometer method according to (Jimenez *et al.,* 2006).

Soil pH plays an important role in the life of the plant as it serves as an appropriate indicator to investigate its suitability for plant growth. This soil parameter was measured in a 1:1 soil-water ratio by using a glass electrode (H19017 Microprocessor) pH meter (Gee and Bauder, 1986). The soil electrical conductivity indicates the ability of the soil to conduct or attenuate electrical current of the soil. This was determined using a conductivity meter as used by (USDA,2011).The soil moisture content was carried out through gravimetric or volumetric methods (Blake and Hartge,1986).The soil texture is a classification method for determining soil classes based on their physical texture, with reference to its particles size less than two millimeters in diameter, including sand, silt and clay. In this study the hydrometer method was adopted (Jimenez et al.,2006).

RESULTS AND DISCUSSION

Climate change plays a significant role in agriculture through the impact it has on the vegetation of the area. Common consequences are drastic reduction on agricultural activities and global food insecurity. One index used to observe this is the application of Normalized Difference Vegetation Index, where its values ranged between 0 and1.A value from 0 to 0.5 indicates that the vegetation of the area is not healthy while and from 0.51 to 1 the value indicates that the vegetation is healthy. NDVI is often used to monitor the health and the productivity of an agricultural land and the total ecosystem of the region. Figure 2 (a and b) shows the NDVI obtained for Uyo Local Government Area by expressing the NDVI values obtained in terms of percentage of land under vegetation, bare land, built-up areas and that covered by water bodies. It captured a period of ten years from 2013 to 2022. The map 2013 showed rich vegetated area with NDVI value of 0.46 having less built-up areas compared to maps 2016, 2019 and 2022.The map 2022 of the local government on figure 2a indicated a greater portion of the area being continuously loss to built-up area and NDVI value of 0.34. Map 2019 shows that more areas were open to negative impacts of climatic conditions like rainfall which could lead to the damaging forces of erosion. The normalized vegetation difference index mask was applied when NDVI values are greater than 0.60 indicating a healthy vegetation in 2013. NDVI responds to climatic variations and other factors such as soil type and vegetation cover. The temperature projection shows a decrease in temperature in the study area from year 2013, but later witnessed increase in other years up to year 2022.

The yearly record shows a significant mean annual rise in temperature due to climate change Between 2013 and 2022, the average monthly temperature in Uyo ranged from 25^0C and 32^0C with the hottest months being December to March. However the influence of climate change has caused higher and more frequent intensity of heat waves during the period. This change in climatic variables will affect crop growth in the study area. Figure 3 shows the yearly behaviour of NDVI of the study period, with year 2013 experiencing the highest and year 2019 experiencing the lowest.

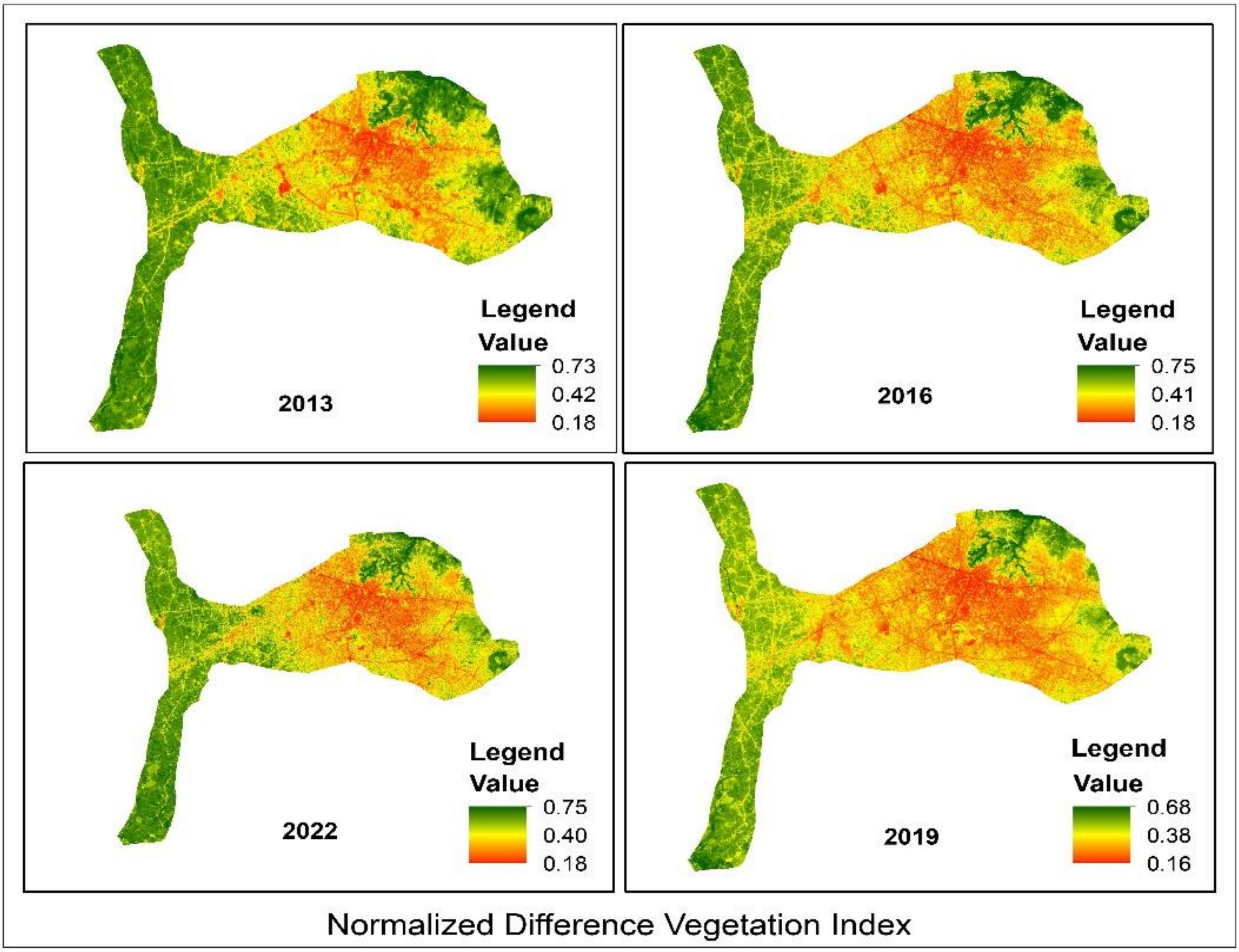

Figure 2a: Showing Normalized Difference Vegetation Index from years 2013 to 2019

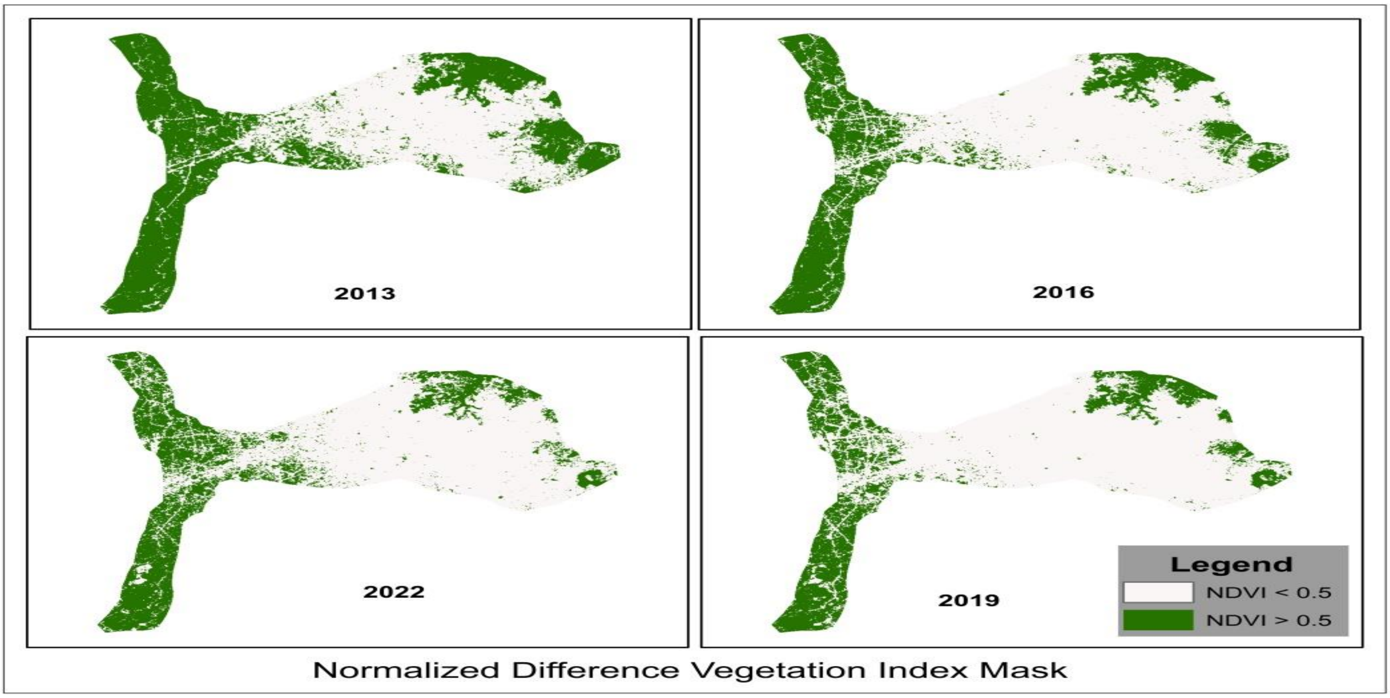

Figure 2b:Normalized Difference Vegetation index Mask 2013 to 2012

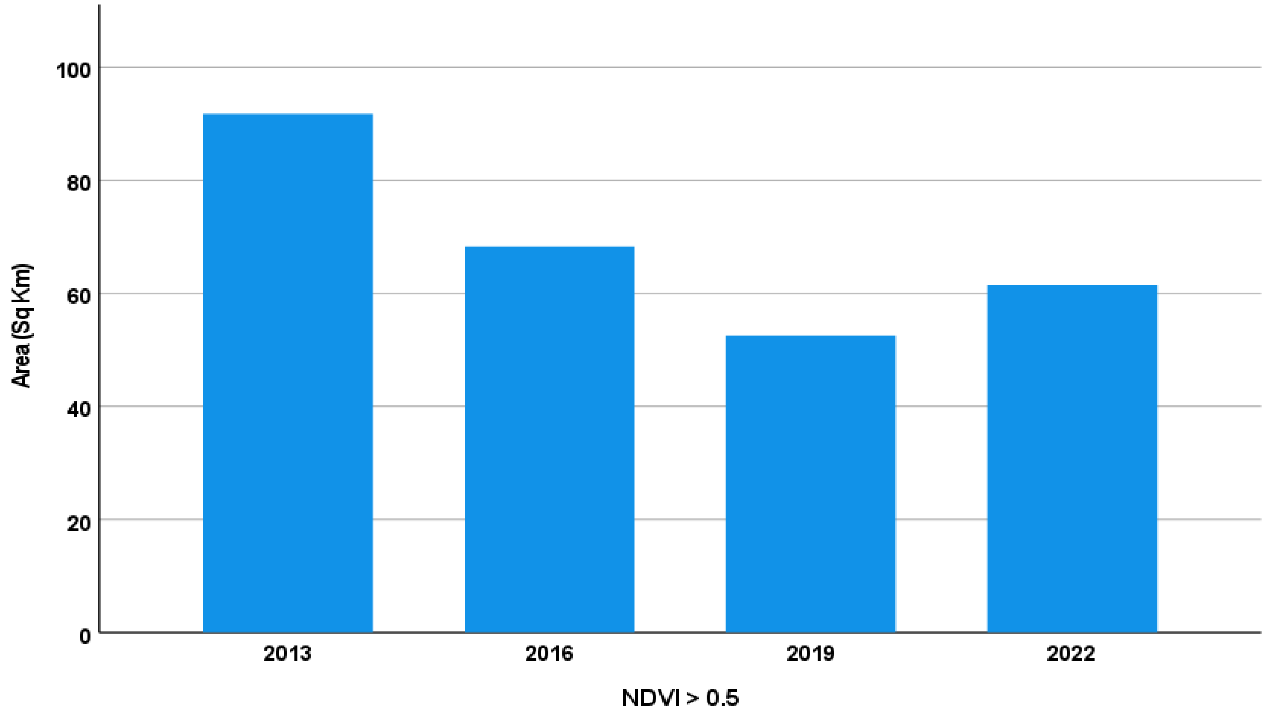

Figure 3. Yearly NDVI Chart of Uyo from year between 2013 to 2022

Changes in rainfall and temperature pattern were assessed by comparing the current climate variation (2013–2022). Figure 4 shows the fluctuation in temperature in the study area within the recorded years. This aligns with global warming patterns that contribute to more frequent heat waves and temperature extremes in the region. Between 2012 and 2022 Uyo experienced several extreme weather events influenced by rising temperatures and changing precipitation patterns. The yearly record shows that the mean annual temperature varied considerably with maximum temperature ranging from a lower temperature of 26ºC to a higher temperature of 36.5ºC as witnessed in year 2012. These dry periods resulted to bodily discomfort and health risks especially for vulnerable populations. Areas with high vegetation index has low land surface temperature while areas with low vegetation index has high land surface temperature. This change in climatic variables will affect the climatic suitability of crop growth in the study area.

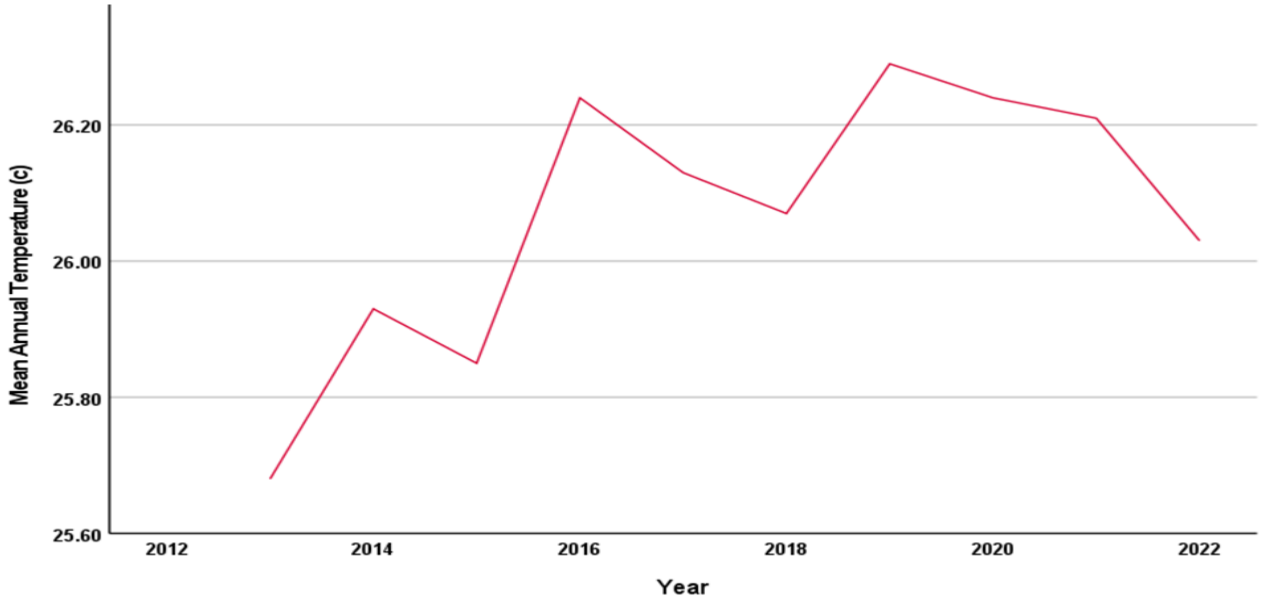

Figure 4. Mean annual temperature of Uyo between year 2012 and 2022

Precipitation

Climate change, though a global phenomenon does not have uniform effects in all the regions. Some region may experience increase in air temperature while others are suffering from increased desertification hence affecting the socio-economic lives of its inhabitants. Figure 5 shows the precipitation pattern in Uyo between year 2012 and 2022. It is apparent from the result that precipitation affects vegetation coverage on land as well as the greenness of the study area to a larger extent. It was also observed that there is always less precipitation at the beginning of the year in at least the first three months in the study area from the year 2013 to 2022. Within the period of observation, it was reported of Uyo experiencing heavy rainfall and constant flooding as there have been increased in rainfall localized flooding. This trend indicates that the region is becoming wetter over time. The driest period was recorded in year 2012 while the period May-July and August-October recorded the highest rainfall, while February-April and November-January had the lowest rainfall. Besides, the area experienced high humidity which shows high positive correlation with rainfall. Relative humidity in the region can be associated with precipitation occurrence in the region. The graph shows a yearly precipitation change for Uyo a linear climate change trend. The rainfall pattern affects socio-economic activities in the area as well as the land use and land suitability for various purposes.

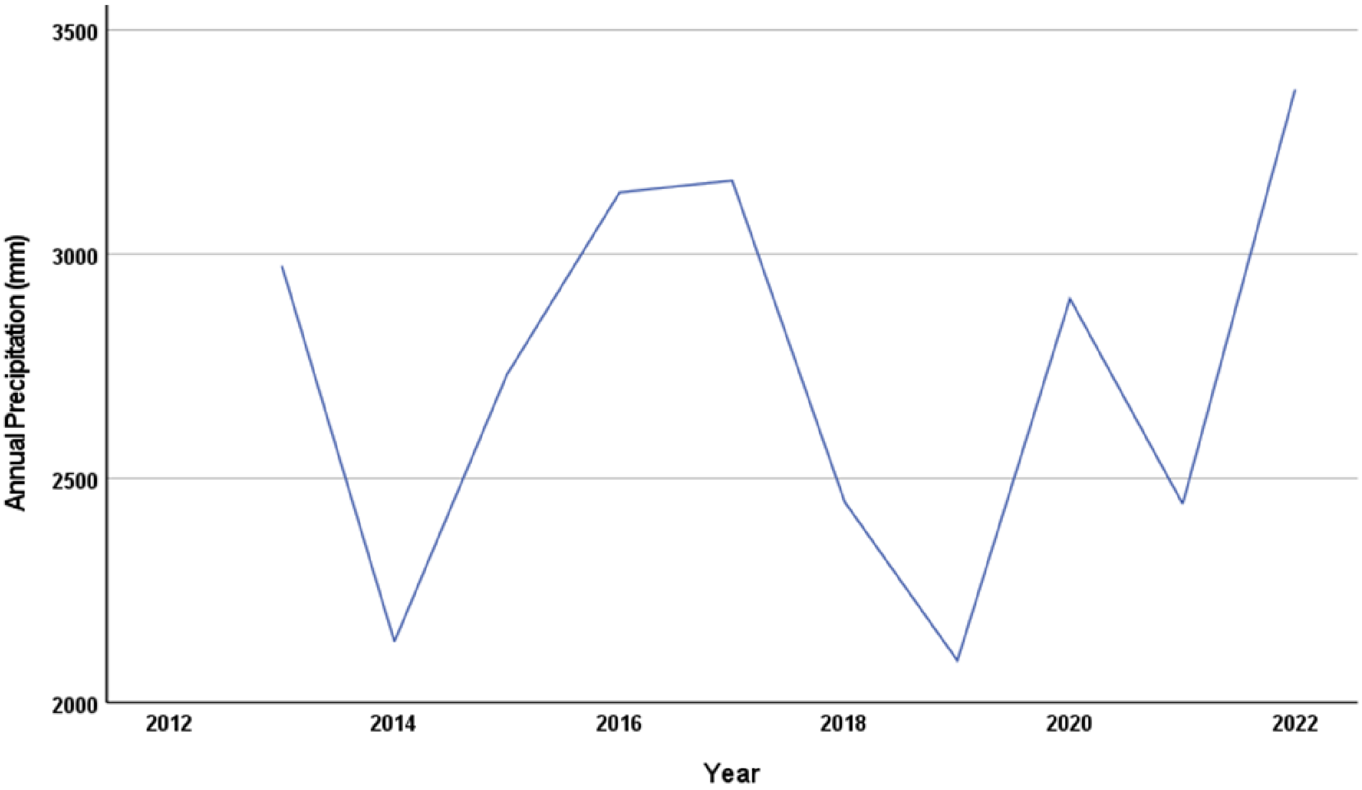

Figure 5. Mean annual precipitation of Uyo

Land Use and Land Cover

Figure 6 shows the land use and land cover of Uyo Local Government Area. Under this study, the total land mass of Uyo LGA is 18,712 ha with land suitability less than 60% . The built up area is 9,849ha (52.6.%), and bare land accounts for 938 ha (5.0%), vegetation accounts 7,909 ha (42.3%) and water bodies accounts for 16ha (0.1%) as shown in Table 1.The application of Normalized Difference Vegetation Index (NDVI) analyses showed different land cover types of the study area using Band5 and Band4. NDVI measures the greenness of and the density of the vegetation captured in the satellite image and helps to scout for exact geo-locations within the area under investigation. It value ranges between -1.0 and +1.0. and is computed on per-pixel basis as the normalized difference amidst the near infrared band(0.85μm-0.88μm) and red band(0.64μm-0.67μm)of the images using the formula according to (Iroh, 2020). This method allows field monitoring of the greenness of the study area thereby tracking changes in the field throughout the season.

The advantage of this is the ability to refer to the historical data of the field for a period of past ten years thus enabling field monitoring both past use and current vegetation as shown in Figure 6. A thorough analysis of the maps helps to locate negative development within the field and notify automatically area under stress through satellite imagery over time, essentially allowing for best decisions based on the maps and data as shown in Table 1. This served as a preferred tool for tracking the health of crops on the field and general vegetation remotely whose failure exposes the soil to elements of weathering and erosion. Figure 6 shows a clear view of the area to ascertain the suitability for various infrastructural development, agriculture and soil conservation. This period between 2012 and 2022 has witness changes in land use and land suitability especially in urban development. This in turn has led to drastic reduction in agricultural land. Being one of the fastest growing city in Nigeria, Uyo has witness increased built-up areas significantly reflecting urban infrastructural development and increased housing demand. Despite this development within the area, scattered farmland remains a significant land use, occupying less than 22.7% of the area. However, this surge in urban development is posing a big challenge to agricultural development and land suitability for farming. On the other hand, the infrastructural development comes with environmental challenges like flooding and erosion majorly as a result of poor urban planning and development.

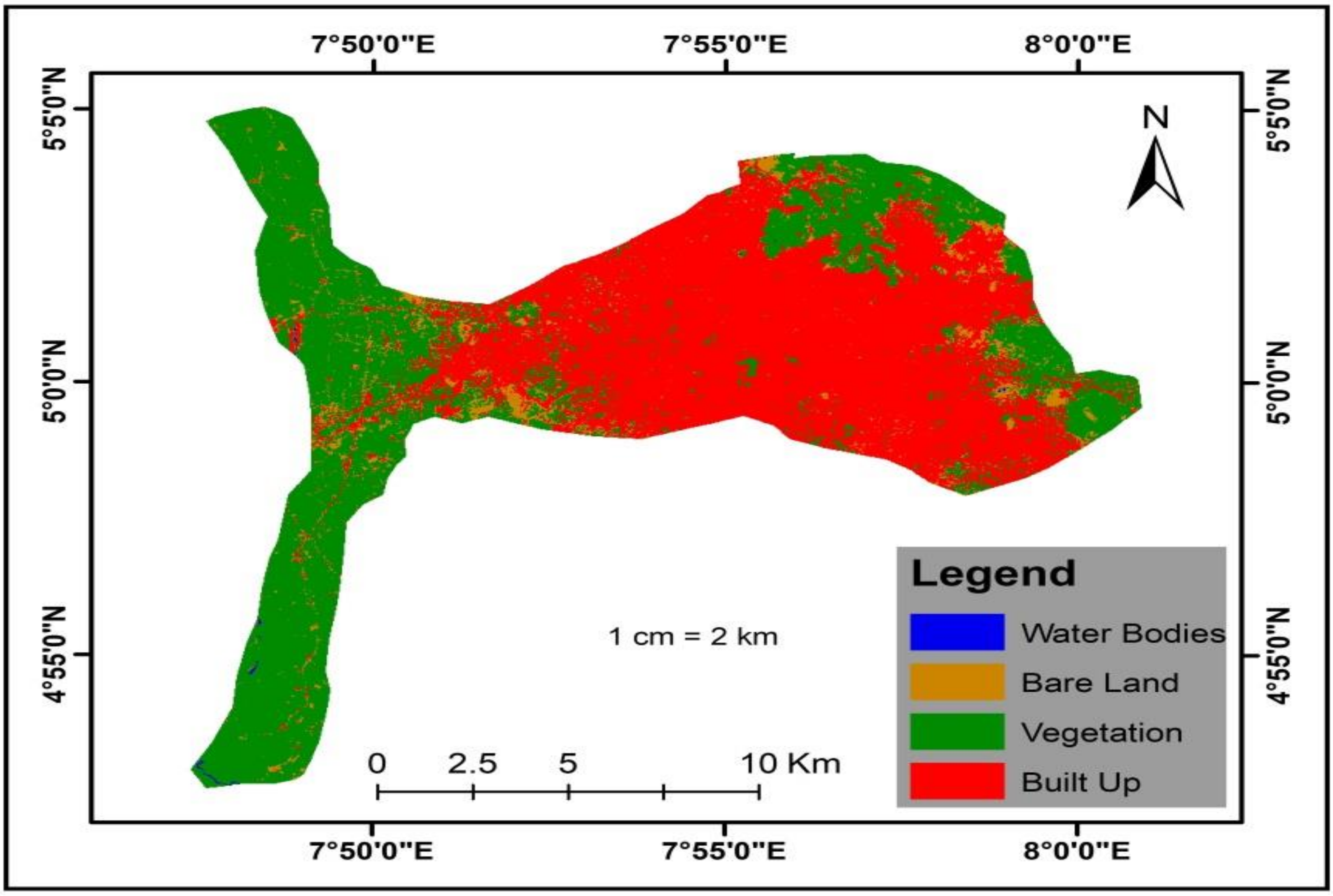

Figure 6: **Land Use and Land Cover Map of Uyo**

Table 1. Trend of land use and land cover in Uyo

LULC Table		
Type	Area (km^2)	Area (%)
Built up	98.49	52.63
Bare land	9.38	5.01
Vegetation	79.09	42.27
Water bodies	0.16	0.09

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue IV April 2026

Soil

Table 2 shows soil analysis in four selected areas within the city to evaluate their suitability for agricultural activities. The parameters analyzed included textural class, pH, electrical conductivity and moisture content. The soil generally indicated loamy soil. These soil parameters are very important to plant growth and crop yield, as soil water retention and nutrient availability is dominantly influenced by these parameters. Aeration and root penetration are also influenced by these parameters. The soil pH was dominantly alkaline with only point 3 showing weak acidic soil. This soil factor indicates nutrient availability and high salinity levels in the soil (Chen et al., 2015). This level of EC indicates high osmotic pressure around the root of the crops, which in turn influence nutrient uptake and overall plant health. Therefore, the soil EC under investigation as shown in Table 2 indicates poor suitability for plant growth. The soil parameters in the study area indicate that the clay, silt and sand content in the soil are agriculturally suitable for crop growth.

Table 2: Soil Analysis in selected Areas in Uyo

Parameters	1	2	3	4
Temperature	30.1	28.3	30.0	29.2
Textual class	LS	LS	LS	LS
Sand%	43.3	49.1	51.4	49.8
Clay%	37.8	34.9	30.1	33.4
Silt%	18.9	16.0	18.5	16.8
p^H	7.5	7.23	6.75	7.38
Electrical conductivity(us/cm)	102.7	89.7	79.3	83.4
Moisture content, %	12.7	15.3	11.9	11.5
Erosion potential	NA	NA	NA	NA

Future Scenarios

Changes in rainfall and temperature pattern were assessed by comparing the future scenario (2013-2030) and current climate. The mean temperature in 2013 was 25.6°C and may increase to 26.4°C in 2030. The map in Figure 2b and data in Table 2 illustrates the predicted changes in temperature. The autoregressive integrated moving average (ARIMA) modeler used in this study is projecting a higher temperature increase in the study area shown in Figure 7. This change in climatic variables will affect the climatic suitability of crops growth in the study area in the future years to come.

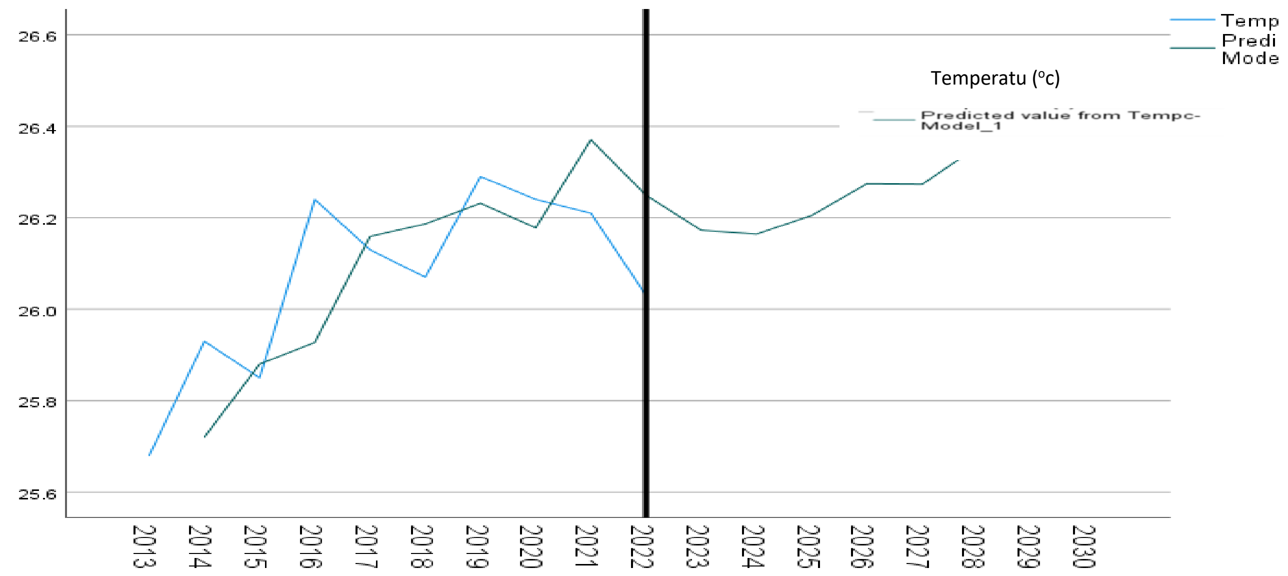

Figure 7: Future Projected temperature of Uyo

According to ARIMA modeler used in the study area as shown in Figure 8,there shall be a projected declined annual precipitation in the study area. However, this decline shall be associated with an increase in minimum mean and maximum temperature, it could lead to plant's higher evapotranspiration rate, which would trigger heat stress and water deficit in the soil.

Figure 8: Future Projected Precipitation

CONCLUSION

This research was carried out to assess the impact of climate change on farmlands on Uyo to determine the influence of climate change on climatic parameters and soil characteristics as they influence agricultural practices in the area. The results showed that different soil parameters played significant roles in the health of the vegetation of the area. Parameters like soil pH and electrical conductivity played important role in soil binding forces hence resisting its erodibility. On the other hand climatic characteristics like temperature variation and precipitation influence its erosivity. Furthermore, built-up areas have significantly reduced the total area of land allocated to agriculture which in turn may affect the food supply in the area. The important aspect of this study brings to light that the continuous yearly of the climatic forces on the soil will damage farmlands permanently if unchecked. It is therefore recommended that efforts should be put in place to mitigate the dangers posed by continuous exposure of farmland in Uyo to both natural and anthropogenic activities.

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