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ASSESSING THE IMPACT OF CLIMATE CHANGE ON THE BUILT ENVIRONMENT IN KADUNA METROPOLIS AND ENVIRONS

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ABSTRACT
The Kaduna's tropical climate for the last twenty years with its uniform characteristics of high temperature, humidity and precipitation witnessed an unprecedented widespread weather variability resulting to an extended dry spell and rising temperature. The study was conducted in Kaduna metropolis and environs using integrated dynamic model technique with the aim to ascertain the impact of climate change on the environment. Data were compiled from various land use map and historical climate and weather data (rainfall, ambient air temperature, heat weave, wind speed, direction, cloud cover and relative humidity) from the Country Planning department and Nigeria Meteorological Department respectively. The finding indicated that higher temperatures intensified urban heat island, especially during dry season (February to April). Decades rainfall revealed an upward trend of 408mm while temperature shows to increase by 0.1996^{o}C. The average evaporation was found to be 163 cm yr−1 (±9%) and likewise relative humidity was found to increase by 66.5%. The rain fall regime in the metropolis is highly variable and its seasonality change is another good indicator of climate change which revealed some fluctuation in rainfall seasonality in the metropolis resulting to flooding. Also, the monthly evaporations and relative humidity have seasonal variability indicating an important relationship between evaporation, relative humidity and seasonal changes in the environment. Conclusively, there is no doubt that the human populations, infrastructure and ecology of cities are at risk from the impacts of climate change as flooding is more frequent and intense rainfalls leading to stream and riverine flooding and overwhelming of urban drainage systems. However, tools are becoming available for addressing some of the worst effects. For example, appropriate building design and climate sensitive planning, avoidance of high-risk areas through more stringent development control, incorporation of climate change allowances in engineering standards applied to flood defences.

Keywords: Precipitation, Variability, Climate change, Meso-scale and High risk

INTRODUCTION
Climate change effect has been pronounced in melting of the ice around the world with glaciers and ice sheets are largely, slow moving assemblages covered about 10% of the world (Akan *et al.* 2013). The potential impacts of climate change include increases in global ambier temperatures, subsidence of coastal lands and thermal expansion of ocean waters (Sutherland, 2004). Presently increasing attention is being paid to the potential impacts of climate change on urban environments. Due to changes in climatic conditions, flood disasters become one of most severe problems in most areas. In particular, low-lying areas, which are strongly affected by flooding or by active processes of shoreline erosion and sedimentation, pose the most serious consequences for communities. Functions and values of most areas have been degraded, and public safety and economy has been impacted. These problems could be increase precipitation with poorly planned development in natural hazard-prone areas and potential scenarios of climate change, increae precipitation and relative sea level rise (Szlafsztein, 2006). The effects of climate change/precipitation upon vulnerable communities, and infrastructure would range from serious to catastrophic. Inundation and loss of land could result in (United Nations Development Programme (UNDP), 2003; Darwin *et al.* 2001).

At present, roughly 50 per cent of the world's population live in cities, but this figure is expected to rise to more than 60 per cent over the next 30 years (Mills, 2006). Climate change will increase the frequency and intensity of heavy rainfall events, thereby increasing the risk of urban flooding. While addressing infrastructure issues is a necessary component of reducing urban flood risk, individual homeowners can have a significant role in reducing risk through protecting their own homes and reducing their contributions of storm water to municipal sanitary sewers and storm water management systems. However, the barriers of low public awareness will have to be overcome to effectively engage homeowners in urban flood risk reduction. Some cities have been working to improve homeowner knowledge and risk-reducing behaviour through education and financial assistance programs in the advance world.

According to the Intergovernmental Panel on Climate Change (IPCC), even the best-case scenarios indicate that change in precipitation would have a wide range of impacts on the environments and infrastructure. Effects are likely to include erosion, and plain flooding, soils, and a loss of habitats for fish, birds, and other wildlife and plants. The IPCC notes that as much as 33% of l land and habitats are likely to be lost in the next hundred years if the level of precipitation continues to rise at its present rate (Akan *et al.* 2013).

Urban flooding occurs in urban areas, where the impacts of extreme rainfall are exacerbated by high concentrations of impervious surface, infrastructure, buildings, property and people. Urban flooding can have serious implications for both buildings and infrastructure, as extreme flows of water during heavy rainfall events can damage both overland and underground stormwater management infrastructure and road pavements. Flooding has also become the greatest reasons for the numerous gully erosion problems because of concentration and discharge to many unsafe areas. These are mainly due to poor road designs, numerous public and private building springing up and exposing land surface in many built up areas.

Climatologists are already beginning to detect and attribute

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changes in extreme events to human influences on the global climate system (Zwiers & Zhang, 2003). For example, the risk of a heat wave like that experienced across Europe in 2003 is thought to have doubled due to historic greenhouse gas emissions (Stott *et al*. 2004). The risk of other extremes such as intense precipitation (Groisman *et al*. 1999), destructive tropical cyclones and flooding (Milly *et al*. 2002) is also expected to increase and these changes will, in turn, have both direct and indirect impacts on the ecological resources of urban communities (Wilby & Perry, 2006). Not surprisingly, managing existing weather- related risks has become a key activity as evidenced by, for example, the growing number of urban heat health warning systems, or measures for countering excessive temperatures in urban centres through improved planning and building design (Shimoda, 2003).

Anticipated consequences of climate change for cities include fewer periods of extreme winter cold; increased frequency of air and water pollution episodes; rising sea levels and increased risk of storm surge; and changes in the timing, frequency and severity of urban flooding associated with Climate change and its effects on temperature, precipitation, storm patterns, sea level rise, and other environmental processes have important implications for the construction, maintenance, and operation of buildings and infrastructure. Recognizing this, the increase in flooding Kaduna metropolis in 2017and the recent flood incidence in the nation as a whole that the study was undertaken and it seeks to consider climate change and flood vulnerability ascertain the risk of flood vulnerability on the metropolis. It is likewise important for the various state agencies and people to prepare for the impacts of climate change on state operations and facilities and also to account for these impacts when conducting environmental reviews under the Kaduna Environmental Protection Authority (KEPA).

MATERIALS AND METHODS

Study Area

The study area falls within the north eastern region of Nigeria precisely the metropolis of Kaduna State (Fig 1). Kaduna is one of the largest states of Nigeria and occupies about 36,917 square kilometres. The State has an estimated population of 760,084 people in 2019 (World Urbanisation Prospects: United Nations, Department of Economic and Social Affairs, Population Division (2014) using an annual population change of +2.94%/year. The metropolis drainage pattern is dendrites in nature empting water into river Kaduna. (Fig .2)

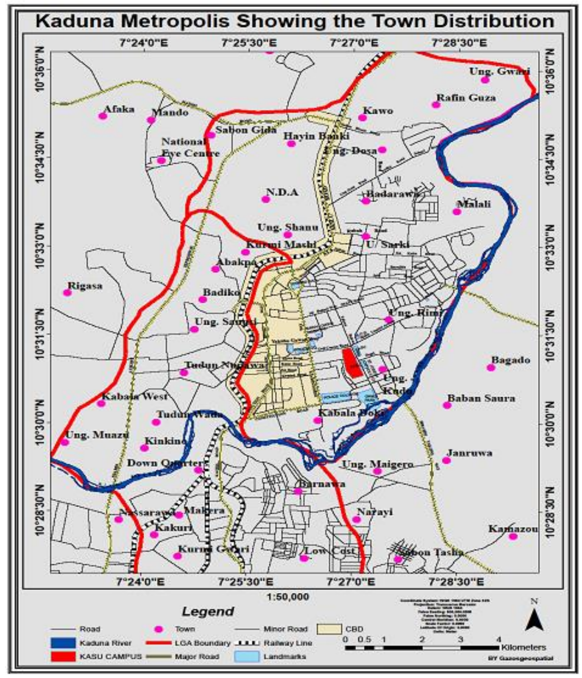

Figure 1: Area located in Kaduna Metropolis

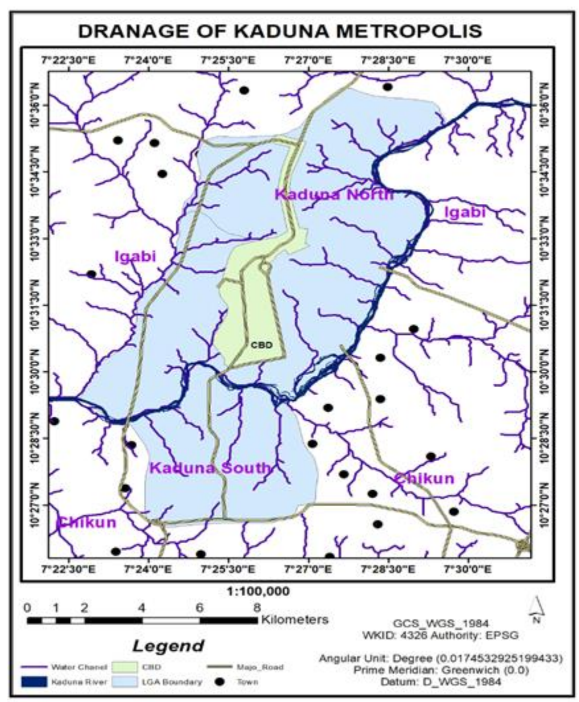

Figure 2 Drainage Pattern of Kaduna Metropolis

Lithology Study of Kaduna Metropolis

Lithology is the study of the general physical characteristics of roc ks (the geology and geomorphology of rocks of the earth surface). Geology is the scientific study of the origin and history of rocks

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and soil of which the earth is made up of while; geomorphology is the study of the physical features of the surface of the earth and their relation to its geological structures. The geology and geomorphology of Kaduna metropolis and the entire adjoining landmass, lies within Basement Complex in the northern part of Nigeria. The rocks of the area are mostly Precambarian in age and have been subjected to several phases of deformation, the latest being the Pan African Orogeny.

The vegetation

The vegetation of the area is of the northern Guinea Savanna type, characterized by patches of woodland, herbs and grasses with few widely scattered deciduous trees, although continuous cultivation, bush burning and grazing activities have greatly modified the natural vegetation cover and composition. The area is drained by a network of rivers, the drainage pattern is dendritic and the streams are all subject to seasonal water level fluctuations

METHODOLOGY /MODELING STAGES

Step 1 Collection of meteorological data

This involve the compilation of historical climate and weather data (rainfall,, ambient air temperature, heat weave, wind speed, direction, cloud cover and relative humidity) from 1986 to 2018.

Step 2 Data transformation and Modelling parameterization

The emission rate from various sources will be expressed as area source using 1km*1km grid according to the sub-district of the study area.

Step 2: Modelling Approach

Integrated dynamic and mesoscale modeling was employed using various databases. The inventory import step reads the raw emissions data, screens, processes, and converts the data to the intermediate inventory file. The combined output from this step will creates model-ready files to produce meteorological conditions spatially and temporally.

Step 4. Data analysis

Descriptive statistical approach was used to quantify the agreement between the predicted/simulated (P) values and observed (O) data of the modelling system.

Step 5 Sensitivity Analysis

This approach is used to evaluate the various weather variables considering influences on the environment, (soil, residential and Infrastructure).

RESULTS

CLIMATE VARIABILITY AND MODELING

Flood prediction or forecasting is the use of real-time precipitation data in rainfall-runoff model to predict flow rates or water levels in given timeline and depend onsize of watershed (Qin. *et al.* 2008). As state by Qin. *et al.* 2008. Artificial Neural Networks (ANN) modelling is popular method in self-adaptive technique for prediction and forecasting of flood's modelling field including water resources, areas and environmental science. ANN has ability to determine which model inputs are critical and parameter measurement (Seibert. 1999). In addition, multivariate nonlinear nonparametric statiscal method is one of the ANN modeling (Qin *et al.* 2008). Many methods can be applied in predicting flood such as CMAQ, ANN, NNARX, Adaptive Neuro- Fuzzy Inference System (ANFIS) and Support Vector Machine (SVM) (Areerachakul, and Junsawang., 2014, Mandal, Saha, & Banerjee, 2005., Remesan. *et al.* 2008). In this study, a combination of CMQQ, ANN and integrated modeling were applied.

Climate change occurs when changes in Earth's climate system result in new weather patterns that last for at least a few decades, and this variability has been recorded in the study area between the period of 1986 to 2018, as 2019 data can only be capture at the end of the session for complete data. The climate variability results are as follow:

Evaporation Variation

Meteorological data were collected from 1986 to 2018. Evaporation was estimated using both vapor flux and energy budget methods. The results were placed into a long-term context using 33 years of temperature and rainfall data collected in the study area. Evaporation also was estimated from this long-term data using an empirical formula relating evaporation to clear sky solar radiation and air temperature. Evaporation estimates for the various months period ranged from 144 to 175 cm yr−1, with an average of 163 cm yr−1 (±9%). Monthly values ranged from 9.2 to 18.5 cm, with the highest value observed between 1986 and 2015 (Fig 3). While relative stability in evaporation was recorded in 2016 (Fig 4.) with an increased between 2017 and 2018, corresponding with the maximum in measured net radiation over a 33-yr period (1986–2018) Figure 4

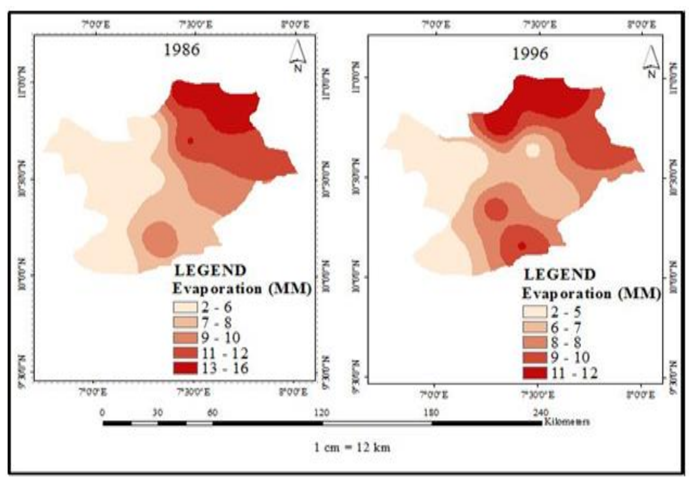

Figure 3: Long term annual mean Evaporation from 1986-1996

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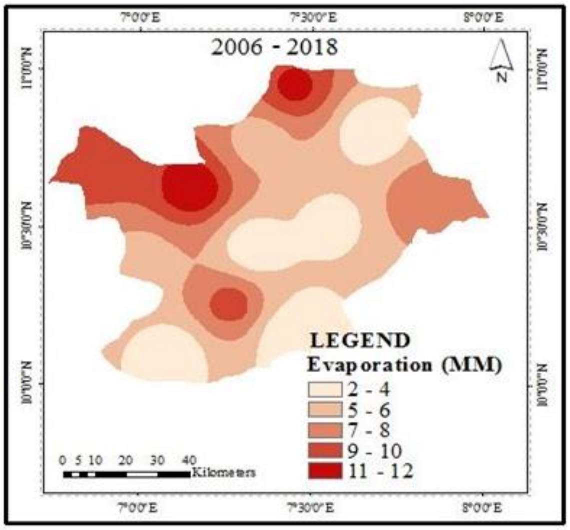

Figure 4: Long term annual mean Evaporation from 2006 to 2018.

Pressure Variation
From the pressure variation maps (Fig 5 & 6), it can be deduce that the pressure is relatively average in a large part of Kaduna and its environs. The difference in pressure within Kaduna is relatively uniform ranging from 41 – 45 (Fig 5 & 6).

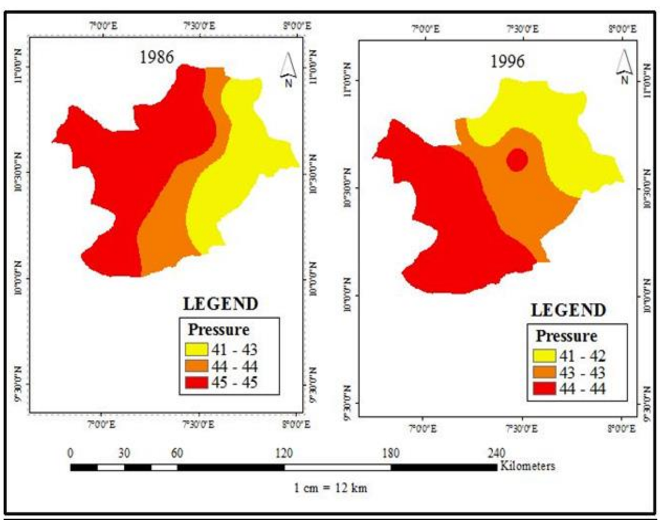

Figure 5: Annual mean Pressure from 1986-1996

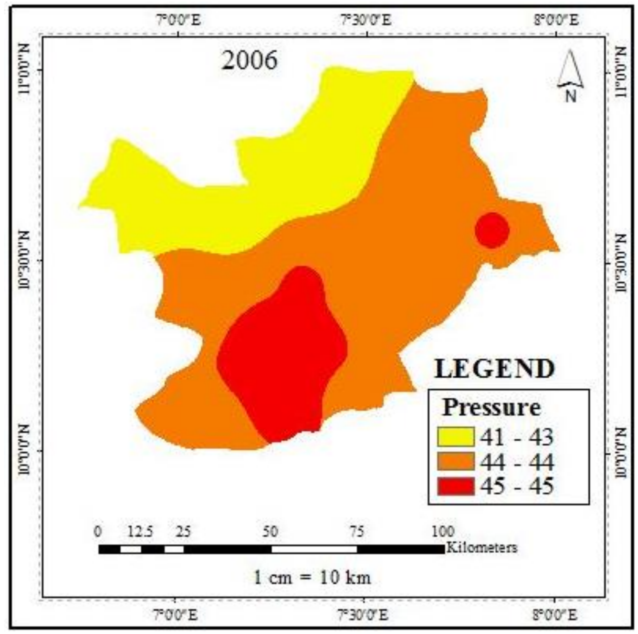

Figure 6: Annual mean Pressure from of 2006 -2018

Rainfall Variation
Rainfall is one of the most important fundamental parameters of climate as it determines the environmental condition of a particular region. The amount of rainfall received in an area is an important factor in determining the amount of water available; therefore, global climate changes may influence long-term rainfall patterns impacting the availability of water, along with the danger of increasing occurrences of droughts and floods .
The results revealed that the mean annual rainfall of the study area was recorded to increase between 227mm and 319mm in 1986 and 1996 (Fig 7), while in 1996 to 2005, the rainfall was found to likewise increased from 319mm to 332mm with a slide dropped by 96mm . However the linear trend line equation and the second order polynomial showed an increase in rainfall in recent decades, was above the long-term mean from the 1986 to 2005. Decades rainfall revealed an upward trend in the last one and the half decades (2006-2018) to an average increased to 408mm (Fig 8).

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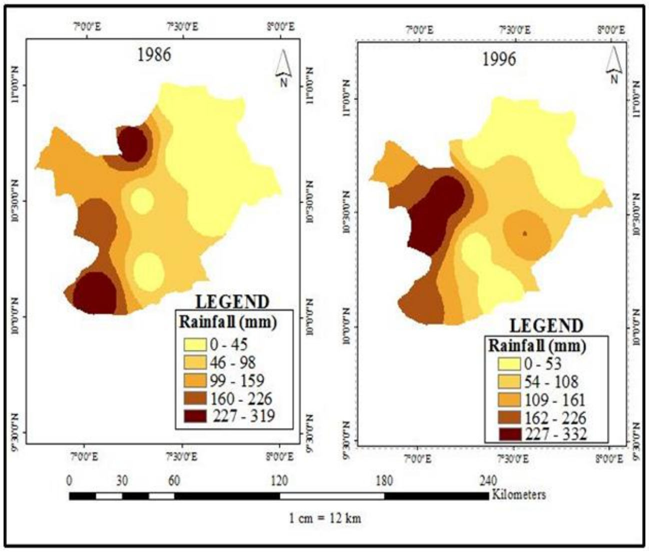

Figure 7: Annual mean Rainfall variation from 1986- 1996.

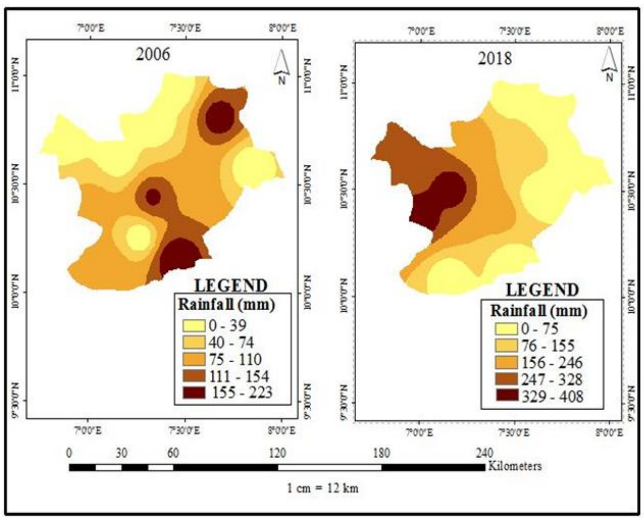

Figure 8: Annual mean Rainfall variation from 2006- 2018

Relative Humidity Variation

The annual mean relative humidity in Kaduna metropolis was observed to have slide increased from 1986-1996 after every two years (Fig 9). The scenario changed in 2006-2018 where relative humidity increased dramatically (Fig 10). The lowest annual mean relative humidity of 43.5% was observed in the first decade 1986-1996 while the later decades recorded the highest value of relative humidity (66.5%).

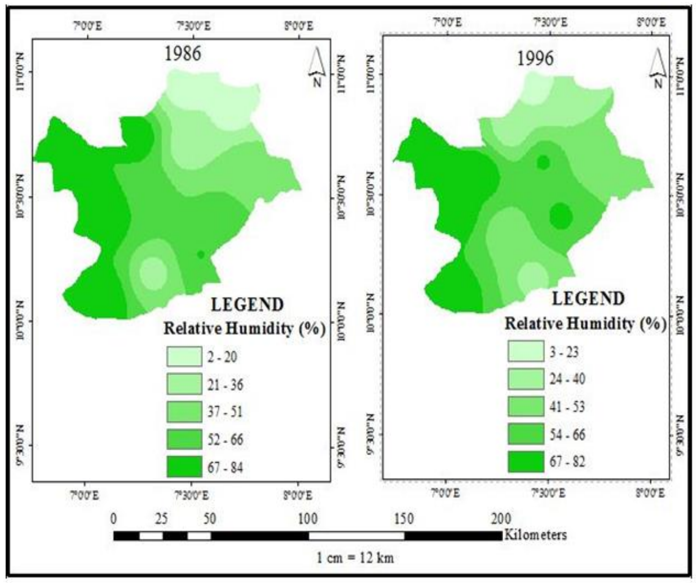

Figure 9: Captured Relative Humidity from 1986- 1996

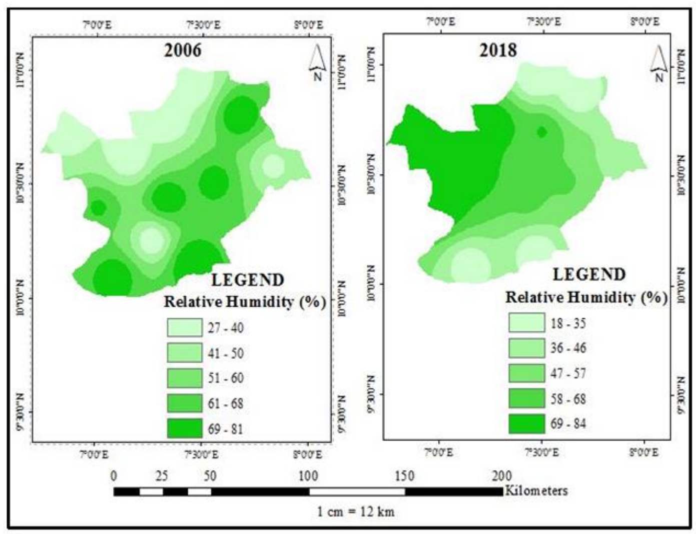

Figure 10: Captured Relative Humidity from 2006- 2018.

Temperature Changes

Temperature shows the hotness or coldness of the atmosphere on some chosen scale. Temperature is a very important factor in determining the weather because it influences other elements of the weather. In this study, The researcher attempt to determine the rate of change of temperature over a span of thirty three years (1986 – 2018) in Kaduna metropolis. Figure 11 show temperature anomalies, or changes, not absolute temperature. They depict how much the various parts of Kaduna metropolis have warmed or cooled as the years go by.

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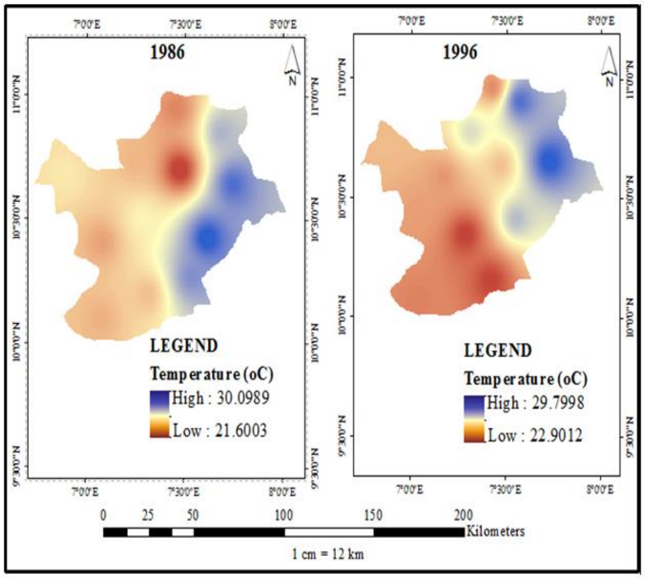

Figure 11: Captured Temperature from 1986- 1996.

The finding revealed that the highest average temperature occured in 1986 was 30.10^{o}C and the lowest average temperature for the same year was 21.60 ^{o}C (Fig 11), again, the highest levels of temperature was experienced in the eastern part of kaduna. In 1996, there was a reduction by 0.30^{o}C in the highest average temperature while there was an increase by 1.30^{o}C in the lowest average temperature in the area.

Thirteen years period of 2006 to2018 also shows a decrease in both the highest and lowest average temperature of the area by 0.1002^{o}C and 0.701^{o}C respectively (Fig 12). However, in 2018, the highest average temperature was observed to have increased by 0.1996^{o}C while the lowest average temperature is seen to have also increased by 0.0007^{o}C.

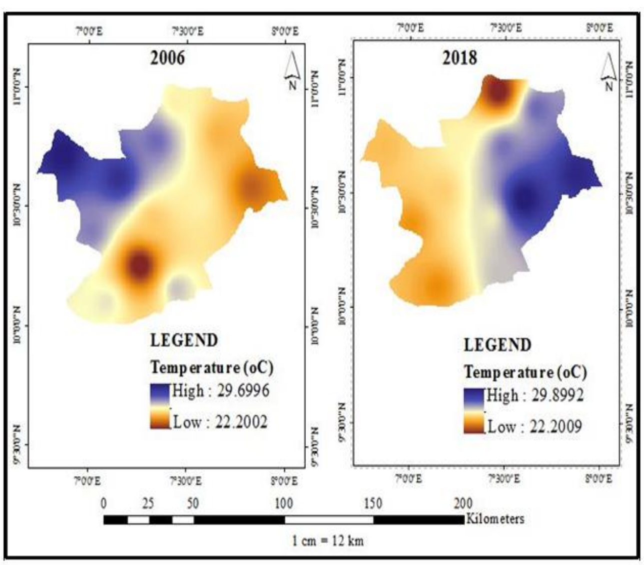

Figure 12: Captured Temperature from 2006- 2018.

DISCUSSION

Evaporation Variation Result Outcomes

Under a changing climate, an increase in the frequency of flood, extreme rainfall, high temperatures, wind events is expected and the metropolis can expect an exacerbation of the environmental impacts associated with these events. Based on the various meteorological elements observed in Kaduna Metropolis, the monthly evaporations have seasonal variability indicating an important relationship between evaporation and seasonal changes in the environment. Therefore the major climate factor that accounted for the annual daily and hourly evaporations increase was the rising net radiation and air temperature, wind velocity, and air humidity and the study is similar to the finding of Easterly *et al.* (2007). This has show the effects of climate change in Kaduna Metropolis, as well as to provide insights for studies on the variation trends of terrestrial evaporation. The finding revealed that the highest average temperature occured in 1986 was 30.10^{o}C and the lowest average temperature for the same year was 21.60 ^{o}C, again, the highest levels of temperature was experienced in the eastern part of kaduna. In 1996, there was a reduction by 0.30^{o}C in the highest average temperature while there was an increase by 1.30^{o}C in the lowest average temperature in the area which is related to jaiyeoba (2002) study in realeted to temperature and precipitation sensitivity.
The rainfall variation result of the second order polynomial revealed more positive across the entire decade, confirming that the climate is getting wetter in recent years. The entire period moving averages, the rain fall regime in the area is highly variable in the area and the rainfall seasonality change is another good indicator of climate change which the result revealed some fluctuation in rainfall seasonality in the metropolis resulting to flooding as was observed by Cinso *et al*. (2014). The impact of climate change on the Kaduna metropolis environment revealed that the metropolis does have some few streams or rivers and areas in the state capital that have frequent history of river flood are River Kaduna.. Based on the model, the situation at the Kaduna river show the lowest return period has a probability of 50% of occurrence at 318.1 cms discharge. Likewise, the return period of 50 have a flood impact of 74828.5 cms but with a probability of 2% occurrence. The mean instantaneous flow is 5254.93 cms and has a return period of 1 year. Most of the watersheds around these areas are contributing to the flow at River Kaduna via their drainages. The rainfall model established trend and recurrence interval to monthly values and rainfall values were derived for each return year and using the rainfall data for a gauge station to assess the impact of rainfall on the watersheds were likewise employed and the rainfall of 2, 5, 10 and 50 years the return period have a probability of 50%, 20%, 1% and 2% chances of occurrence respectively

Conclusion and Recommendations

There is no doubt that the human populations, infrastructure and ecology of cities are at risk from the impacts of climate change as flooding is more frequent and intense rainfalls leading to stream and riverine flooding and overwhelming of urban drainage systems. During rainfall of higher intensity flash flood occur along some of the channels as the flood varies with the intensity, amount, duration, antecedent precipitation and resulting soil moisture. This challenge was as result of the rain fall regime in the area which is highly variable and the seasonality change is another good indicator of climate change which the result revealed some fluctuation in rainfall seasonality resulting to flooding. Further, the annual daily and hourly evaporations increase was the rising net radiation and air temperature, wind velocity, and air humidity.

There should be adaptive strategies for building design. Building flexibility into design to allow for the unexpected makes investment decisions robust to most possible changes in climate conditions. This may include no-regret strategies that bring benefits even in the absence of future climate change, e.g. strengthening tile fixtures securely to a roof to avoid wind damage. Preparing buildings for the predicted hazards which may include: increasing temperatures, coastal storm surges and inundation, flooding, tropical cyclones and intensified downpours.

Flood Risk assessment in the metropolis flood risk is further needed to ascertain the performance of the urban drainage system, which responds to highly localized effects such as blocked culverts or overwhelming of the hydraulic capacity of sewers .

The Metropolis should have an urban forestry that is a total cover and distribution of all vegetation in cities and suburbs are important in making cities more liveable, and play key roles in making urban regions more economically and ecologically sustainable. This will reduce the amount of runoff resulting to flooding.

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