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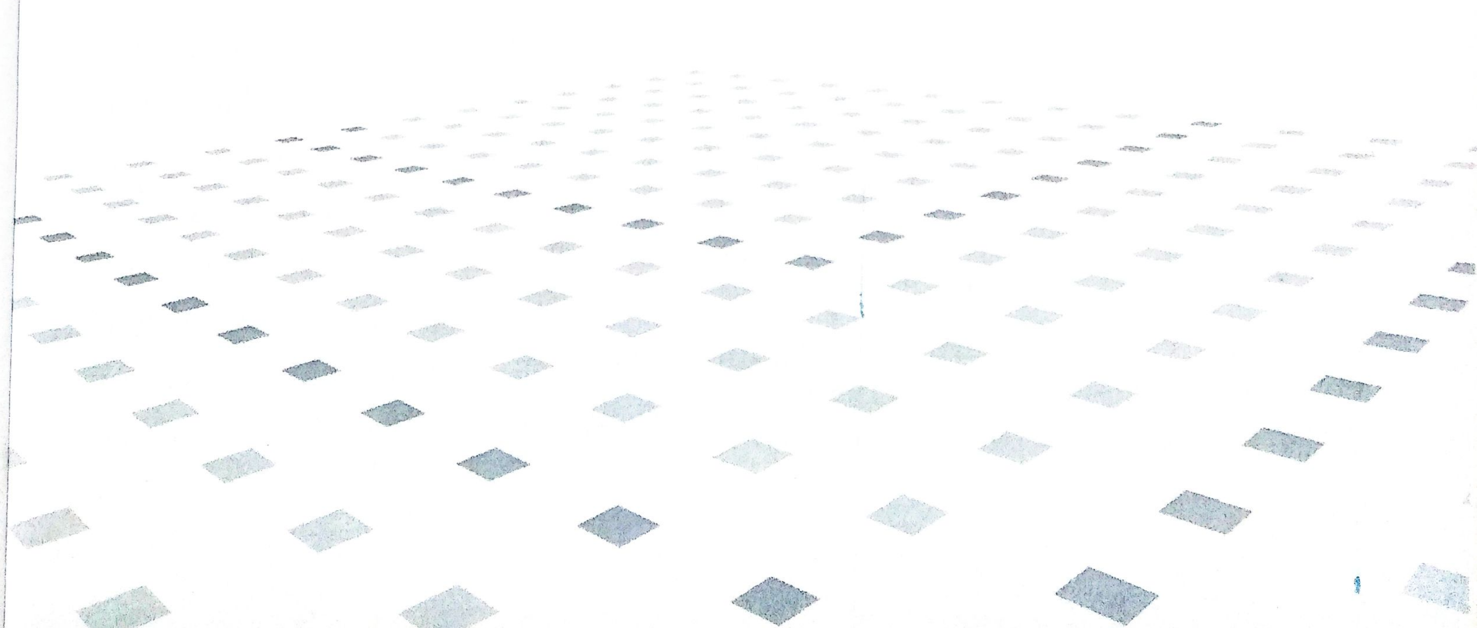
ASSESSING THE **EXISTENCE** OF THE **ATMOSPHERIC URBAN HEAT ISLAND** OVER **KANO METROPOLIS, NIGERIA**



Assessing the Existence of the Atmospheric Urban Heat Island over Kano Metropolis, Nigeria.

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Abstract -The Urban Heat Island (UHI) effect is a phenomenon of higher atmospheric and surface temperatures occurring in urban areas than in surrounding rural areas happening majorly as a result of urbanisation and industrialisation. This study investigated the occurrence of Atmospheric UHI in Kano metropolis. Data utilised in this study includes; temperature records for the period of 1980 – 2015 for the urban city centre and 1985 - 2015 for the sub-urban city centre sourced from the Nigerian Meteorological Agency (NIMET) and Department of Geography, Bayero University, Kano respectively. The Linear trend analysis was used in analysing the trends of temperature distribution in the study area and the combination chart was used in comparing the temperature data of the urban and sub-urban city centres. Results obtained showed that temperature distributions has been on the increase for both the urban and sub-urban city centres, with that of the urban city centre being faster than that of the sub-urban centres. The urban city centre exhibit higher atmospheric temperature compared to its sub-urban counterpart thus, indicating the presence of Atmospheric UHI in Kano metropolis. The study concluded that the UHI exists in Kano metropolis and is more concentrated in the urban city centre. The study recommended massive afforestation programmes, adoption of green and cool roofing technologies, and accommodation of green areas and open spaces into cities physical plans due to their cooling potentials as some of the ways of adapting and mitigating to the impacts of UHI

Keywords: Atmosphere, Heat Island, Urbanization, Temperature, Metropolis

1. Introduction

One of the environmental consequence and implication of urbanisation and industrialisation is the Urban Heat Island (UHI) effect, which is a phenomenon of higher atmospheric and surface temperatures occurring in urban areas than in surrounding rural areas ([1] [2]). UHI intensifies urban air pollution, changes rainfall pattern in and around urban centres, and alters the composition of biodiversity [3], and it also supports global warming [4]. In urban areas, the warmer air when compared to the cooler air in nearby sub-urban and rural areas defines the Atmospheric UHI. This Heat Island is further divided into two different types, namely; Canopy layer UHI and Boundary layer UHI. The former type of UHI exist in the layer of air where people live, usually extending from the ground to below the tops of vegetation and roofs while the latter type begins from the level of roof tops, extending upward to the point where urban landscapes no longer affect the atmosphere. This region typically extends not higher than 1.5km from the surface [5].

Schmidlin[6] conducted a study titled Urban Heat Island at Toledo, Ohio in which 31 years of temperature data were studied for Toledo. In this study, an electronic remote reading thermometer was used with a thermograph that was maintained as a back-up system and was used infrequently when personnel unavailable to read thermometers on weekends prior to 1983 [6]. This study utilised two stations; one downtown and one at a rural site (airport). The study revealed the annual temperature was 2°C warmer at the urban site than the rural site. The Heat Island was most intense during the summer months and least evident during winter and spring [6].

In the work of Alghamdi and Moore (2014) which attempted to analyse and compare trends in extreme temperature in Riyadh city, Kingdom of Saudi Arabia, time series of thirteen extreme temperature indices for the period 1985 – 2010 were utilised to analyse and compare temporal trends at two weather stations in Riyadh city, Saudi Arabia. Although both stations were situated in Riyadh, they were presumed to represent relatively urban and rural locations. Riyadh Air base (old station) was presumed as the Urban station and it is located within the first urban limit at a distance of 150m from the city edge and within the urban affected area, whereas King Khalid Airport (new station) was presumed as the rural station and is approximately 20km northeast of Riyadh Air base (old station) beyond the secon urban limit and is remote from urbanisation (Alghamdi and Moore, 2014). Th RClimdex Software was used to administer quality control as well as to deter missing data and errors to the data series. For the trend detection and compariso analysis, techniques employed included the non-parametric Kendall-tau test whic was used to detect and assess the statistical significance of the linear trends, and th least square method which was used to estimate the slope of the linear trends. Th results of the trend analysis indicated warming of the local air for the city. Significant increasing trends were found in annual average maximum and minimum temperatures, maximum of minimum temperature, warm nights, and warm days for the urban and rural station. Significant decreasing trends were detected in the number of cool nights and cool days at both stations (Alghamdi and Moore, 2014). Comparison of the trends suggests that in general the station closer to the city centre warmed at a slower rate than the rural station. Significant differences were found in a lot of the extreme temperature indices, suggesting that Urbanisation and other factors may have had effects on the rate of warming at the urban station [7].

This study, therefore investigate the occurrence as well as the existence of the Atmospheric UHI in Kano Metropolis, Nigeria.

2. Study Area

The study domain is Kano Metropolis in Kano State, Nigeria, located between latitudes 11°55′N and 12°3′N and longitudes 8°27′E to 8°36′E with an elevation of 472m above sea level. The estimated area of Kano metropolis increased from 122.7km^2 in 1962 to 154.6km^2 in 1981, an increase of about 25% based on the average expansion rate of 2km^2 per annum [8]. Since then, Kano Metropolis has witnessed rapid growth covering 196.4km^2 in 1986, and 337.9km^2 in 2005. The Metropolis was projected to cover about 499km^2 in 2015 [9]. Kano metropolis is a conurbation of eight Local Government Areas around the main city which includes; Dala, Fagge, Kano Municipal, Nassarawa, Tarauni, Kumbotso, Gwale and Ungogo. Kano metropolis registered a population of approximately 10 million people in the year 2006 National Population Census [10]. The city is the trade nerve center of West Africa and a major industrial center of Northern Nigeria. Figure 1 shows the administrative boundary of Kano state and the Kano metropolis. The state is bordered by Jigawa State in the north-east, Katsina State in the north-west, Bauchi in the south-east and Kaduna State is on the south-west boundary.

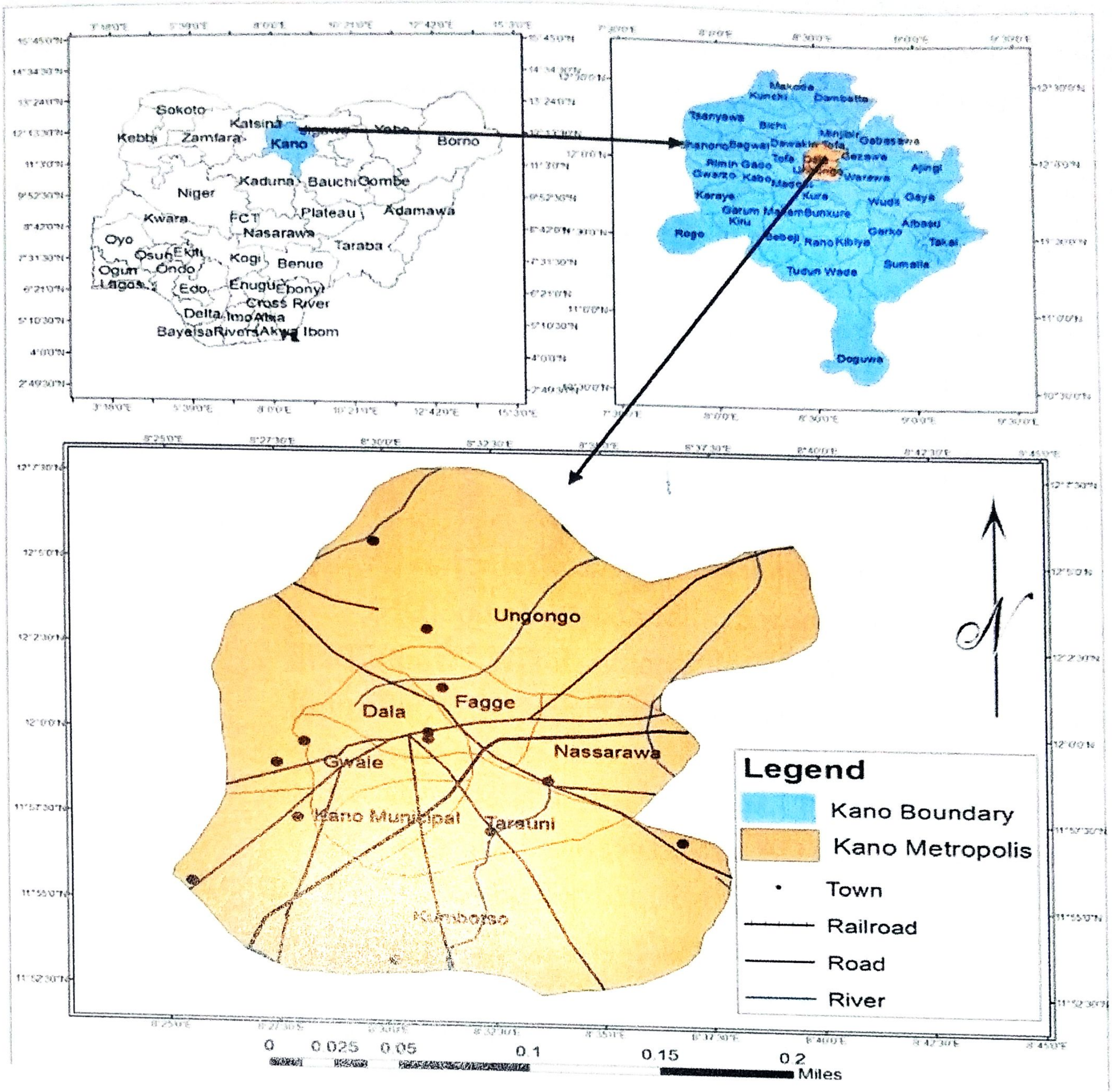

Figure 1: The Study Area (Kano Metropolis, Kano State, Nigeria)

Source:Hexagon Geospatial Technology Limited (2017).

3. Methodology

The investigation of the Surface UHI in the study area was carried out using Earth Resource Development Assessment System (ERDAS) Imaging 14 application software. Land Surface Temperature (LST) Maps for the years 1986, 1998, 2006, and 2016 were estimated using Model Maker in ERDAS Imaging 14 software.

In doing these, thermal bands of Landsat 5, 7 and 8 for the years 1986, 1998, 2006 and 2016 were inputted into ERDAS working environment, and the tabular information for gain and bias obtained from the Landsat meta-data file were also inputted.

The Digital Numbers (DN) values for each image were converted to Lλ radiance, and radiance was also converted to reflectance. Emissivity was als estimated from reflectance, and subsequently the emissivity corrected surfac temperature was also derived and this served as part of atmospheric correction.

The formula for estimating the Land Surface Temperature (LST) was then inputted and the final output was the LST map for each of the selected years. The temperature image was then exported as image (IMG) file and imported into ArcGIS 10.1 software and was re-classified.

Thus equations utilised include;

Lλ = Gain x DND + Bias (1)

Where: Lλ = the normalised atmospheric reflectance at a particular wavelength,
DN = Digital numbers of the Landsat images.

Lλ= Grescale × Qcal + Brescale (2)

Where: Lλ = Spectral radiance at the sensor's aperture [W/(m2srμm)], Qcal = Quantised calibrated pixel value (DN),
Grescale = Band-specific rescalinggainfactor [W/2srμm))/DN],
Brescale = Band-specific rescaling bias factor (m[W/(m2srμm)]

Pλ =ESUN λ cosΘs π Lλd2(3)

Where; ρλ = Planetary TOA reflectance (unitless),
π = Mathematical constant approximately equal to 3.14159 (unitless),
Lλ = Spectral radiance at the sensor's aperture [W/(m2srμm)],
d = Earth-sun distance (astronomical units),
ESUN λ = Mean exo-atmospheric solar irradiance [W/m2iam)],
Θs = Solar zenith angle (degrees)

*KK*2

LST = *KK* 1+ *EE*+1) (*LLLL* (4)

Where: LST =Land Surface Temperature (Kelvin),
K1 = Calibration constant 1
K2 = Calibration constant 2 (Kelvin),
W/(m2srμm)],
Lλ = Spectral radiance at the sensor's aperture [W/(m2srμm)],
E = Emissivity corrected reflectance,
In = Natural Logarithm

4. Results and Discussion

Figure 2 presents the mean monthly temperature distribution trend over the urban city centre. The months of March, April, May and June had the highest temperature distributions in the last 36 years, while the months of December and January had the lowest temperature distributions. The month of April has the highest temperature distribution and it is followed by the month of May. The implication of this is that, the UHI phenomenon in Kano metropolis tends to exercise more of its effects in the hottest months of the year namely, April and May.

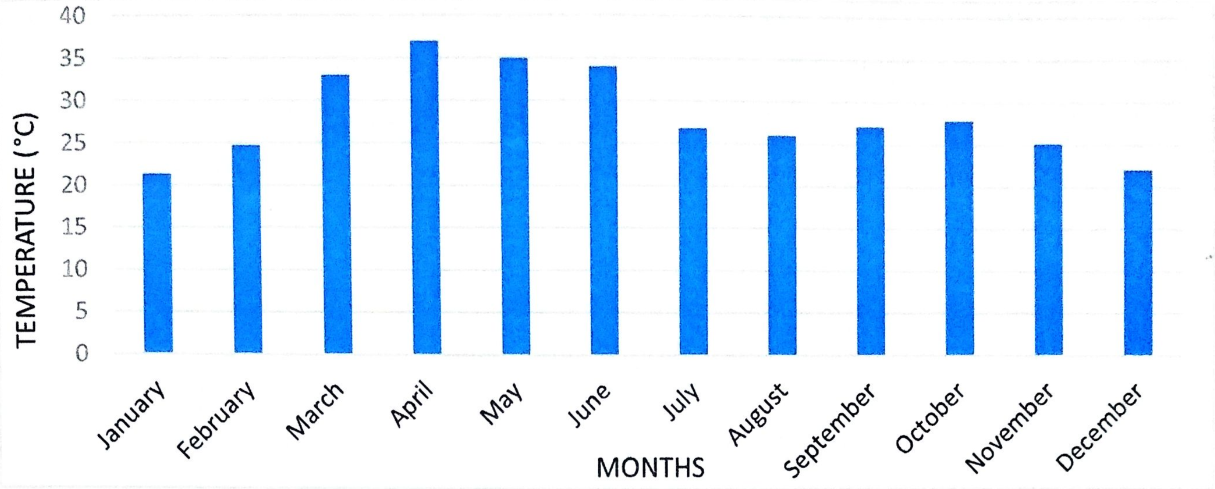

Figure 2: Mean Monthly Temperature Distribution Trend over the urban city centre of Kano Metropolis (1980 to 2015)

Figure 3 shows the mean annual temperature trend over the urban city centre. The trend equation showed an increasing trend with an annual increase of 0.054°C per year. This implies that over the last 36 years, the annual mean temperature of the urban city centre of Kano Metropolis has increased by 1.944°C.

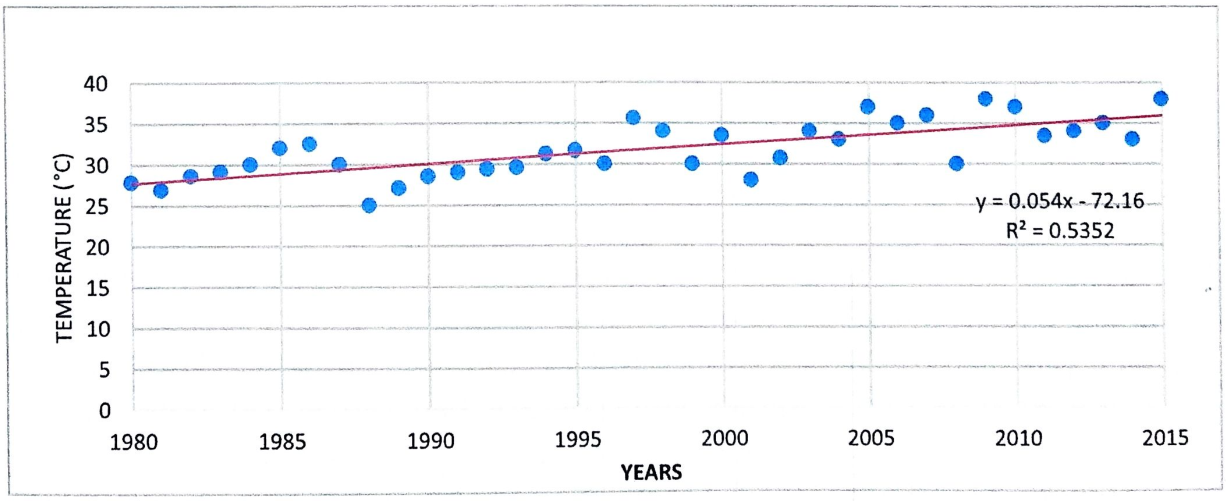

Figure 3: Mean Annual Temperature Trend over the urban city centre of Kano Metropolis (1980 to 2015)

Figure 4 presents the trend of annual temperature deviation from overall mea in the urban city centre of Kano Metropolis.It was observed that the annu deviation from overall annual mean temperature shows decreasing trends durin the years of 1980 to 1983, 1987 to 1993, 2000, 2001, 2008, 2011, 2012 and 2014. A other years have shown increasing temperature trends. In short, there are 1 different years showing increasing temperature trends compared to 17 differen years showing decreasing trends. Thus, the overall implication is that, the temperature of the urban city centre of Kano Metropolis is steadily increasing a justified by the results from Figure 3 which indicates that temperature in the urban city centre of Kano metropolis has increased in the last 36 years by 1.944°C.

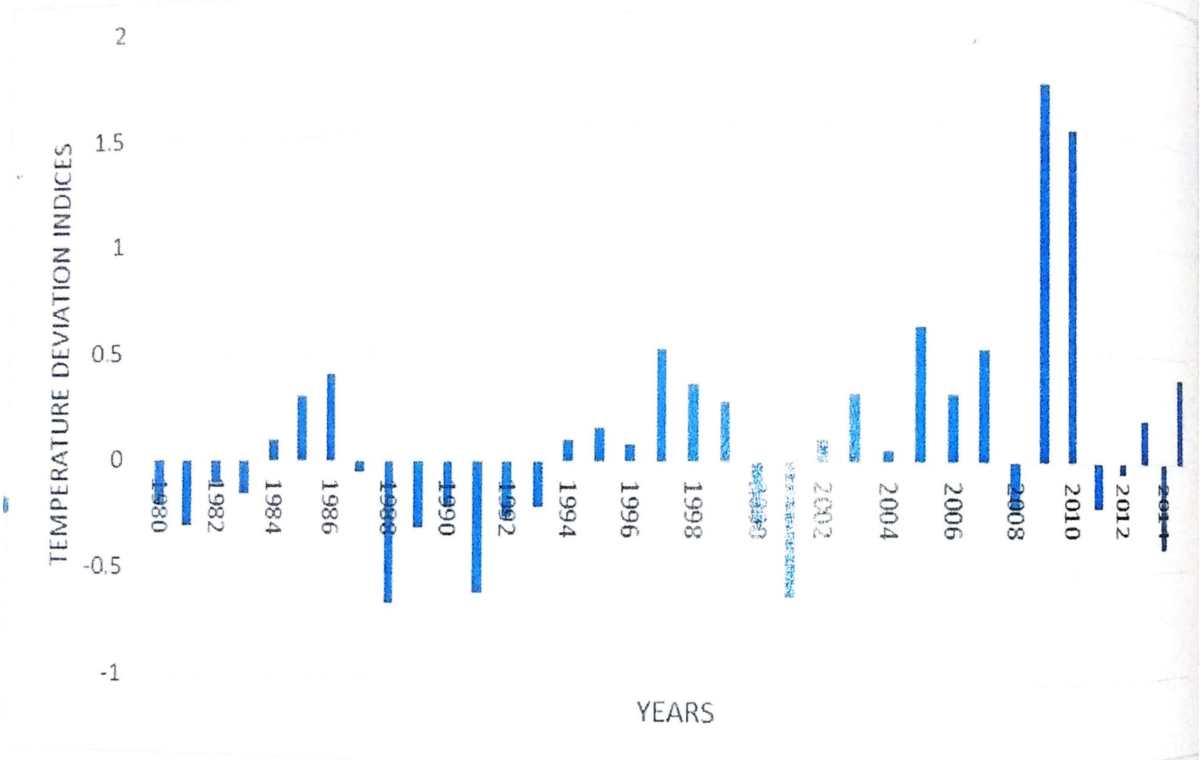

Figure 4: Trend of Annual Temperature Deviation from Overall Mean in the urban city centre of Kano metropolis (1980 to 2015)

Figure 5 depicts the mean monthly temperature distribution trend over the sul urban city centre. As obtained in the urban city centre, the months of March, Apri May and June had the highest temperature distributions during the last 31 year while the months of December and January had the lowest temperatu distributions. The month of April had the highest temperature distribution and it followed by the month of May. The implication is that the UHI comparison betwee the urban and sub-urban centres of Kano metropolis is better reflected during th hottest summer months of the year, namely April and May.

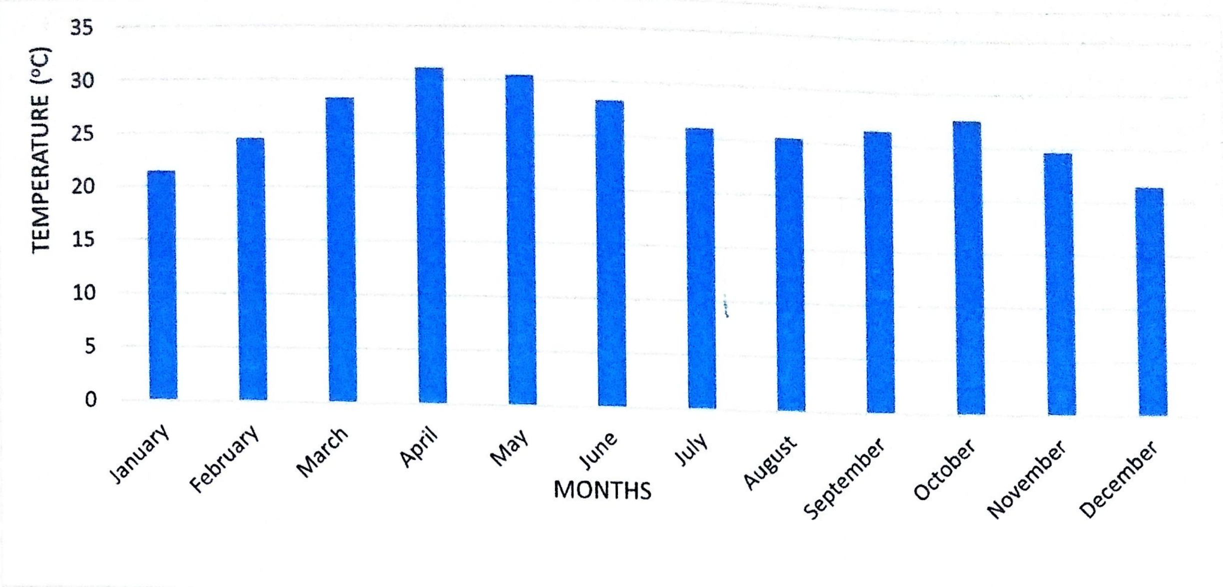

Figure 5: Mean Monthly Temperature Trend over the sub-urban city centre of Kano Metropolis (1985 to 2015)

Figure 6 is the mean annual temperature trend over the sub-urban city centre of Kano Metropolis. The trend equation indicated an increasing trend with an annual increase of 0.021°C per year. This implies that over the last 31 years, the annual mean temperature of the sub-urban city centre of Kano metropolis increased by 0.651°C, and this increment is less than the increment of the urban city centre of Kano metropolis by 1.293°C. In other words, the temperature of the urban city centre of Kano Metropolis has increased beyond that of the sub-urban Kano by 1.293°C.

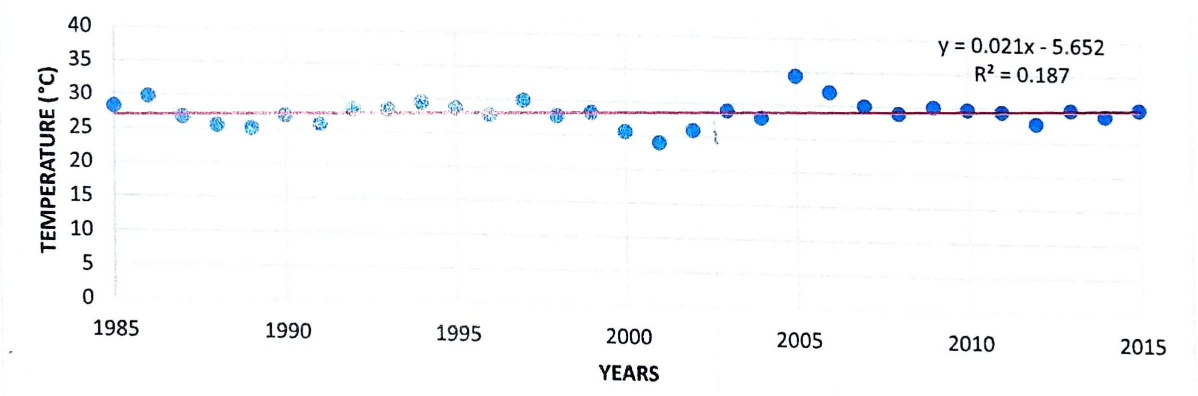

Figure 6: Mean Annual Temperature Trend over the sub-urban city centre of Kano Metropolis (1985 to 2015)

Figure 7 illustrates the trend of annual temperature deviation from overall mean in the sub-urban city centre of Kano Metropolis. It was observed that the annual deviation from overall annual mean temperature shows decreasing trends during the years of 1985, 1987 to 1989, 1991 to 1996, 1999 to 2002, 2004, 2006, 2007, 2010 to 2012, 2014 and 2015. All other years have indicated increasing temperature trends. In short, there are 23 different years with decreasing temperature trends and seven different years with increasing trends. Though, the results from Figure 6 has shown that the temperature of the sub-urban city centre of Kano metropolis increased over the last 30 years by 0.651°C which is quite appreciable increment, the overall implication of results as shown in Figure 7 is that the sub-urban city centre of Kano Metropolis does not quickly had increment in temperature as compared to the urban city centre. In other words, the temperature in the urban city centre of Kano Metropolis increases faster than that of its sub-urban counterpart.

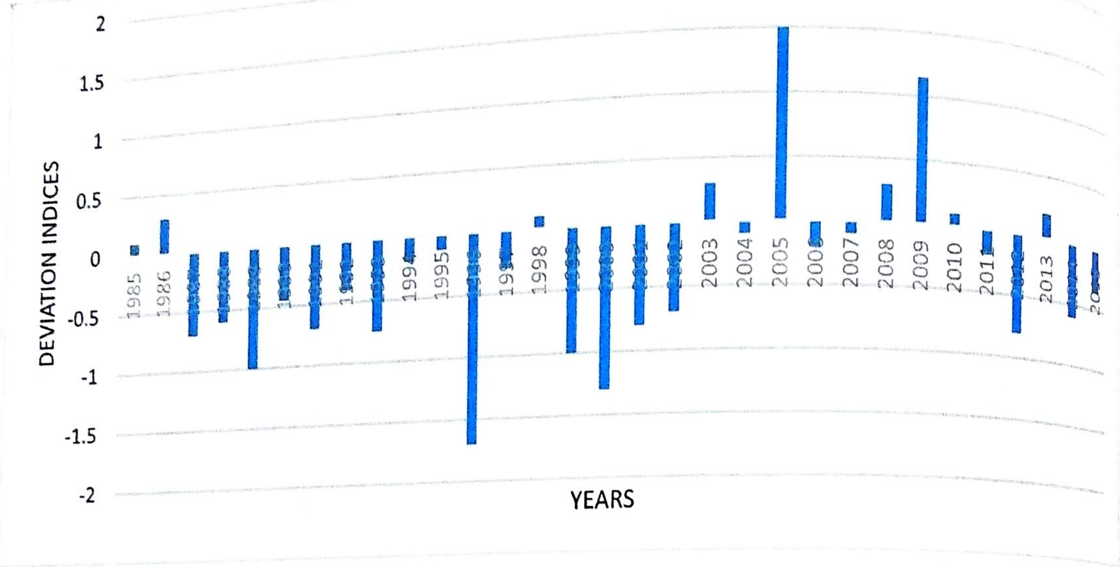

Figure 7: Trend of Annual Temperature Deviation from Overall mean in the sub-urban city centre of Kano Metropolis (1985 to 2015)

Figure 8 depicts a comparison of the mean annual temperatures of the urban city centre as well as that of the sub-urban city centre of Kano Metropolis from the year 1980 to 2015, although data was only available for the sub-urban city centre as from 1985 to 2015, thus, comparative interpretations were made for both centres (urban and sub-urban) based on the period of 1985 to 2015 (31 years). The comparison showed that for most of the years considered in this study, the urban city centre of Kano Metropolis had always being higher in atmospheric temperature than its sub-urban counterpart. Specifically, the urban atmospheric temperature was higher than that of the sub-urban in 26 different years out of the 31 years (1985 to 2015) under consideration, and these are the years of 1985 to 1987, 1989, 1991 to 1996, 1998 to 2004 and 2006 to 2015. The sub-urban city centre had higher temperature values than the urban city centre in only three years out of the 31 years under consideration in this study, and these are the years of 1990, 1997 and 2005. Additionally, both the urban and sub-urban city centres were at par having the same value of mean annual temperature in the year 1988.

The implication of higher temperature distribution in the urban city centre of Kano Metropolis both in frequency and amount is greater than its sub-urban counterpart. The atmospheric temperatures are rising more quickly and more often as compared to the sub-urban city centre. This fact is further corroborated by the results from Figure 3 which showed that the urban city centre of Kano metropolis has a mean annual increasing trend of 0.054°C per year and that its temperature has increased by 1.944°C in the past 36 years. Also, Figure 6 indicated that the sub-urban city centre of Kano metropolis has a mean annual increasing trend of 0.021°C per year and that its temperature increased by 0.651°C in the past 31 years. These results specify a temperature difference of 1.293°C between the urban city centre and its sub-urban counterpart. It gives strong indication that the atmosphere of the urban city centre is warmer than that of the sub-urban city centre, and this defines the occurrence of the Atmospheric UHI phenomenon in the atmosphere of urban Kano Metropolis.

Furthermore, Figure 8 further indicates that in recent times (2006 to 2015), the atmospheric temperature trend in the urban city centre of Kano Metropolis has been consistently higher than that of its sub-urban counterpart, thus showing that the Atmospheric UHI phenomenon is currently waxing stronger and becoming more concentrated in the atmosphere of the urban city centre than it used to before this study period.

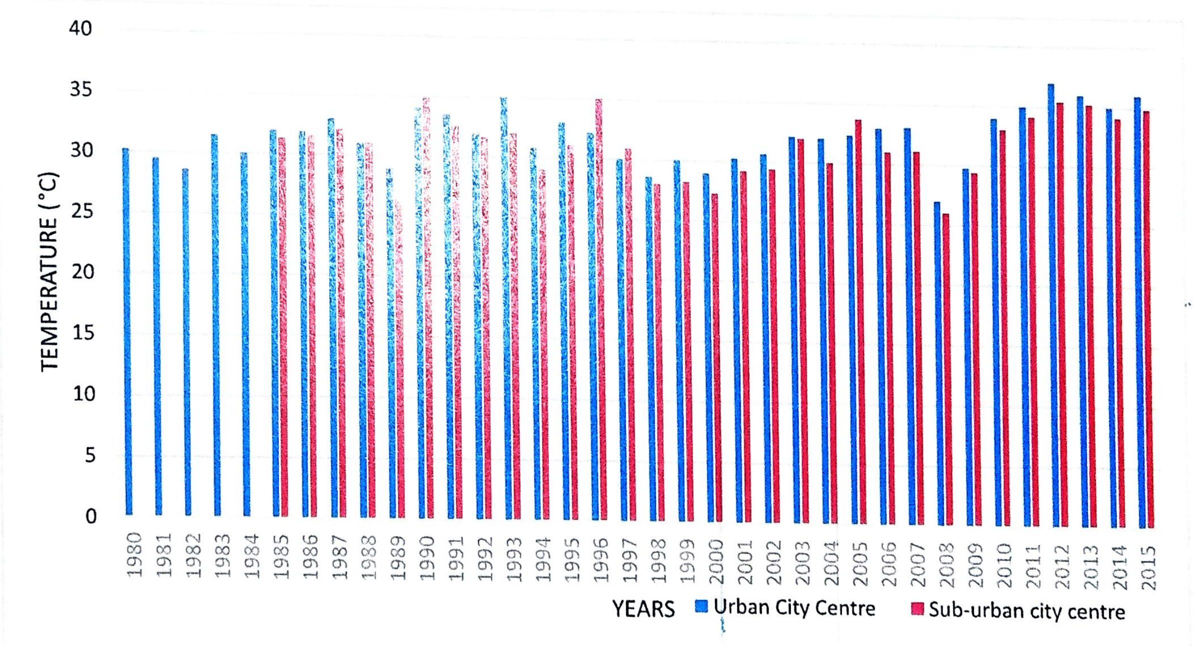

Figure 8: Comparison between the Mean Annual Temperatures of the urban city centre and the sub-urban city centre (1985 to 2015)

Figure 9 further simplify Figure 8 in other to establish a clearer comparison between the atmospheric temperatures of the urban city centre to that of the sub-urban city centre. Figure 9 shows overall total mean of all the annual averages (1985 - 2015) for both the urban and sub-urban city centres. The results indicated an overall total mean of 32.61°C for the urban city centre under the 31 years (1985 - 2015) andthe sub-urban city centre with the overall total mean of 31.32°C. This, indicates a difference of 1.29°C. In other words, the urban city centre is 1.29°C warmer than the sub-urban city centre and this revelation is further validated by the findings of [11], which concluded and generalised that average ambient temperature in urban systems is generally 1 - 3°C higher than the surrounding sub-urban environment. The bottom line is that based on the findings from this study, the Atmospheric UHI exists in the atmosphere of Kano Metropolis.

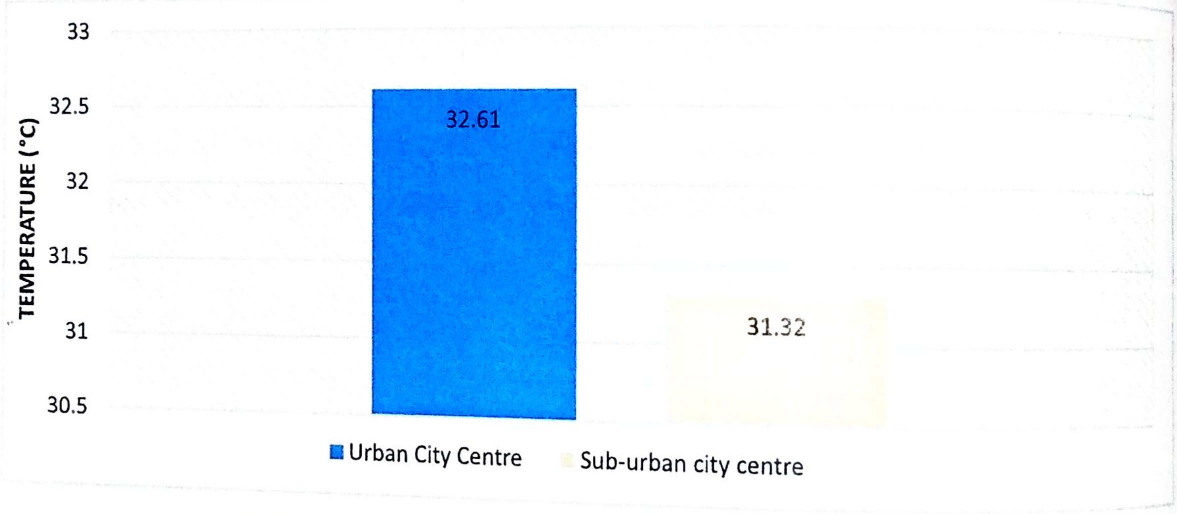

Figure 9: Overall Total Mean of All Annual Averages for the Urban and Sub-urban City Centres (1985 – 2015)

5. Conclusion and Recommendations

The Mean Monthly Atmospheric temperature distribution of the urban and sub-urban city centre of Kano Metropolis have a similar pattern of distribution, with the months of March, April, May and June exhibiting the highest values while the months of December and January had the lowest values. Other months fall in between the two extremes. In other words, the UHI impact is felt most in the hottest months of March, April, May and June.

In addition, the Mean Annual Atmospheric temperature distribution of both the urban and sub-urban city centre of Kano Metropolis show an increasing trend, although, that of the urban centre had a faster increasing trend than its sub-urban counterpart. Further comparisons between the atmospheric temperatures of both centers indicated that the urban city centre is warmer than its sub-urban counterpart, thus, confirming the existence of the Atmospheric Urban Heat Island in Kano Metropolis.

It is therefore recommended thatthere is an urgent need for communities to embark on massive afforestation programmes and campaigns in order to establish green lands which will provide cooling effects to the surfaces and atmospheres of these Heat Islands, Technologies such as the green and cool roofing technologies should be accommodated into building designs since they have high albedo and low heat absorbance, Further scientific researches and investigations which will result into rich innovations that will bring about adaptive and mitigating measures to UHI impacts need to be conducted and implemented urgently and the establishment of more synoptic weather stations to generate data that will be useful in the monitoring of vital phenomena such as the UHI.

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SUBSISTENCE FARMERS' ADAPTATION STRATEGIES TO CLIMATE CHANGE IN NIGER STATE, NIGERIA

Subsistence Farmers' Adaptation Strategies t Climate Change in Niger State, Nigeria

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Abstract - Climate change and variability have far reaching implications on agric production, particularly on the livelihood of subsistence farmers in developing co whose vulnerability is aggravated by multiple stresses. Adaptation has been identified key to sustaining agriculture, reducing the vulnerability of subsistence farmers and en the survival of their livelihoods in a changing climate. This study examines the adap strategies by subsistence farmers in Niger State to climate change. Focused G Discussions (FGDs) were conducted in 18 selected farming communities, across the agricultural zones in the state. This is to ascertain the adaptation strategies employed communities, the effectiveness of the strategies and the limitations in adapting. The shows that adaptation measures common to all communities are increased domestica cattle, early planting, planting early maturing crop varieties, swapping to the cultiva crops with higher profit turn over, cultivating crops tolerant to low soil nutrient, culti crops tolerant to drought, and digging of wells and bore holes to cope with the dep water resources. Measures such as irrigation, involvement in off-farm jobs, introduct new crops, bush fallowing, migration and establishment of new farmsteads do not widespread application. Increased food crop yield, increased income from farming act and sustenance of cattle during the dry season are identified as accruable benefi adaptation strategies. Identified constraints are ownership of land in small holdings, poverty, non-availability, inaccessibility, scarcity and expensive costs of tractors and inorganic fertilizer, and high cost of agro-chemicals. The study recommends the strengthening of capacities of farming communities to adapt by way of greater logistic support and technical aids.

Keywords: Adaptation, Subsistence, Farmers, Climate Change, Variability

1. Introduction

Climate change is unequivocally accepted as a reality [1] and the world community faces many risks from it [2]. Particularly, the inevitable changes in climate patterns undermine the services provided by ecosystems; thereby threatening peoples' livelihoods[3]. The agricultural sector in Sub-Saharan Africa is especially vulnerable to climate change because the region already endures high temperature and low rainfall [4]. Smallholder and subsistence farmers are particularly complex, diverse and risk-prone, because their farmlands which are generally small and most often held under traditional or informal tenure are in marginal or risk-prone environments [5]. Since their livelihoods depend on the use of natural resources, they are likely to bear the brunt of adverse impacts, and the extent to which these impacts are felt depends in large part on the extent of adaptation in response to climate change[6].

Rain-fed crop production characterized by low input and low output, is the basis of subsistence farming in most parts of Niger State and accounts for more than 95% of the land area cultivated annually. However, in all the communities surveyed by the researchers in the three agricultural zones, the participants unanimously agreed that they have progressively witnessed changing climatic trends which have resulted in environmental changes. The communities highlighted major consequences of the changing climate which make adaptation very imperative if the livelihoods and economic fortunes of the subsistence farmers who rely solely on agriculture must be sustained.

Globally, traditional farmers and indigenous local communities employ traditional knowledge, expertise, skills and practices in adapting to ensure food and livelihood security in diverse ecosystems ([7][8][9]). Adaptation has been defined as the modification in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities [10] Particularly, African farmers have developed several adaptation strategies for coping with the current global climate variability, although such strategies may be insufficient for projected future changes in climate[11]. This stu therefore aims to examine adaptation strategies at the subsistence farmers' level Niger State.

2. Study Area

Niger state is situated in the North-central Geo-political zone of Nigeria. It located approximately between latitudes 8°20′N and 11°30′N, and longitude 3°30′ and 7°20′E (Figure 2.1).

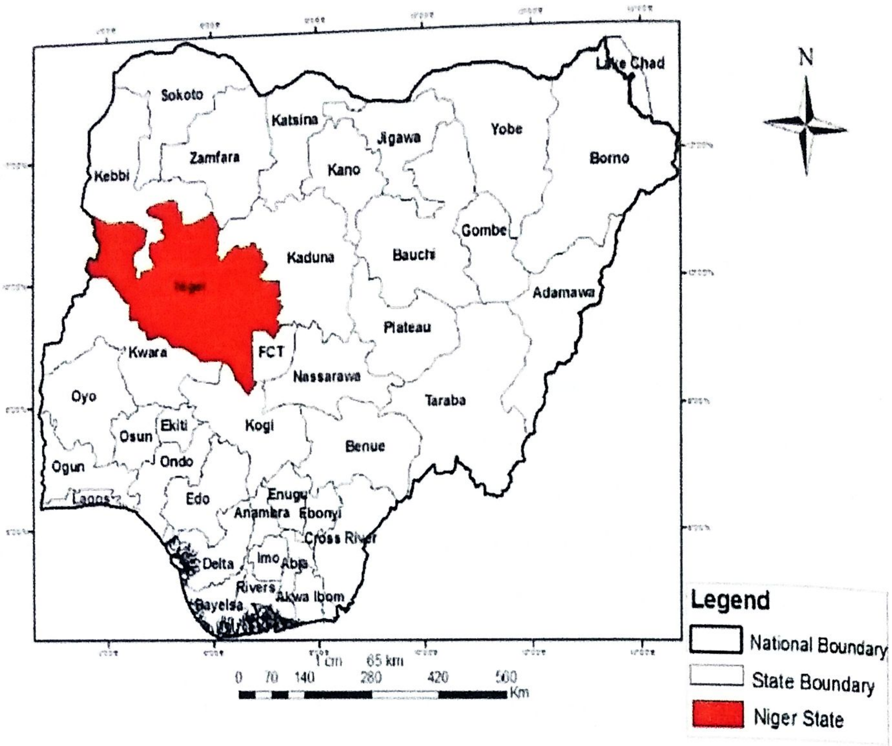

Figure 2.1 Nigeria Showing Niger State

Currently Niger State covers a total land area of about 76,363 sq. km (about 9 percent of Nigeria's total land area and the largest in size) and an estimated 80% of its land area suitable for agriculture. State experiences a distinct dry season (which lasts from October – March) and a wet season (which lasts from April – October). Annual rainfall in the state varies from an average of 1,200 mm in the northern part to about 1,600 mm in the southern part. The rainy season lasts for an average of 150 days in the Northern parts and about 210 days in the southern parts of the State. Mean maximum temperature remains high throughout the year, hovering about 32°C, particularly between March and June, while the minimum temperatures usually occur between December and January when most parts of the State come under the influence of the Tropical Continental air mass (Harmattan).

Agriculturally, Niger State is divided into three agricultural zones; Zones 1, 2 and 3. The zones are identified by the most dominant crops grown, even though most crops are grown all over the state. Agricultural Zone 1 is called rice and tuber zone, because rice is predominantly grown in large quantities across the local governments in the zone, and tuber zone because of the widespread cultivation of cassava in commercial quantities across the zone. Agricultural Zone 2 is called tuber zone because of the large scale cultivation of yam tubers in the zone. Agricultural Zone 3 is called cereal zone as it largely produces cereal crops especially millet, sorghum, and maize.

3. Methodology

The study primarily employed Focused Group Discussions (FGD) as its data source. The FGD is a qualitative method targeted at obtaining in-depth information on concepts, perceptions and ideas from a group. The FGD provided opportunities for group members to discuss the subject matter freely among themselves, with guidance from the facilitator. The FGD data was used to elucidate information on the actual climatic changes and variations witnessed by all surveyed communities, the impacts these impacts have had on the communities, the adaptation strategies that are being adopted by the communities to reduce vulnerability to observed changes as well as and the major constraints in adapting.

The FGDs were conducted with subsistence farmers in nine randomly selected local government areas (LGAs) of Niger State; three (3) from each agricultural zone, cutting across different climatic zones, tribes and cultures. The local governments are Gbako, Lapai and Mokwa for Zone 1, Gurara, Rafi and Shiroro for Zone 2; and Kontagora Magama and Wushishi for Zone 3. From each of the nine selected LGAs, two farming communities were randomly chosen. The selected communities are Muwo, Wuya Kede, Gbadafu, and Somazhiko, Duma and Takuti for Zone 1. For Zone 2, the selected communities include Shakwatu, Lashi, Gawu Babangida, Bonu, Tegina and Ungwar Batwu. Selected Communities in Zone 3 include Raba, Salka, Maito, Mailehe, Masuga and Kampanin Kiriya. Between 15 and 30 participants (drawn from the aged, middle-aged, youths and women) made up the focus group for each community.

4. Results and Discussions

4.1. Adaptation Strategies in Niger State

Results show that farmers across the three agricultural zones in Niger State have employed several adaptation measures to the observed climate related changes in land, water, atmosphere and vegetation.

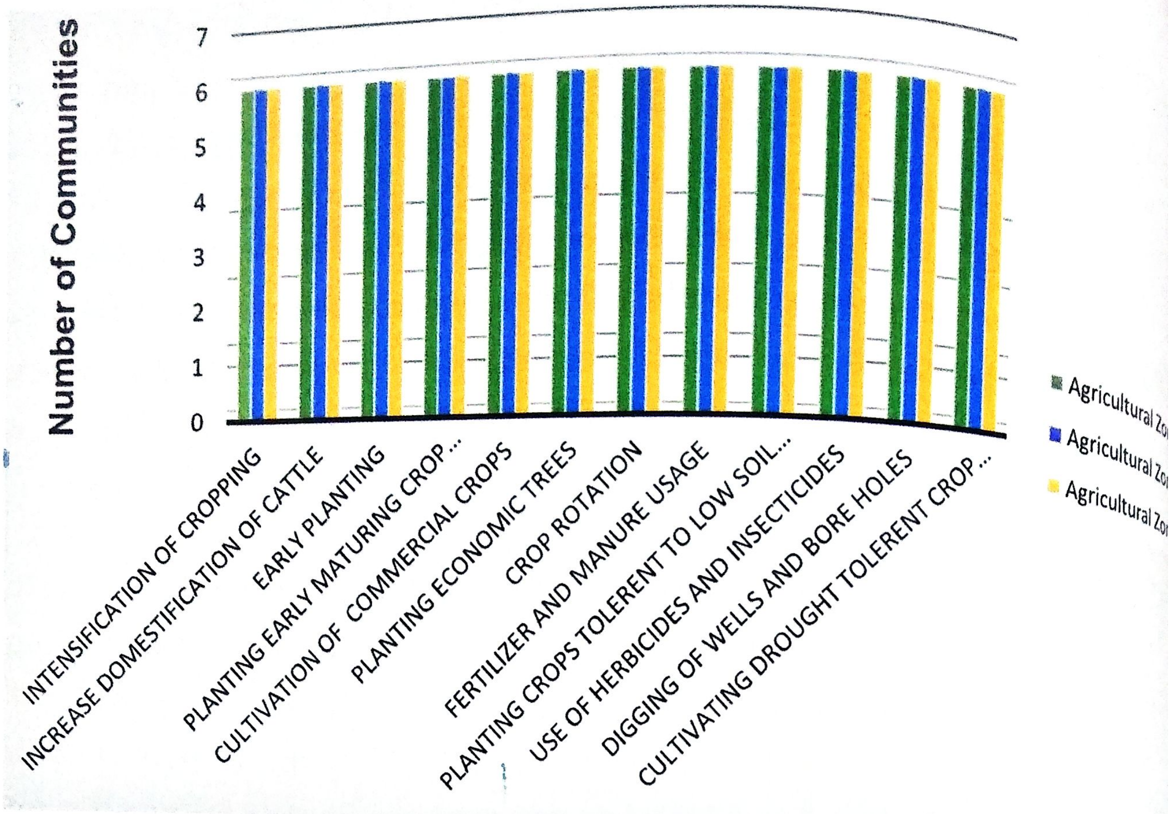

Figure 4.1 Adaptation Measures Common to all surveyed communities

Results show that farmers in all three zones have employed several adaptati measures to the observed climate related changes in land, water, atmosphere a vegetation. Figure 4.1 shows twelve (12) adaptation strategies that are common to the 18 communities across the three agricultural zones. The strategies were adopt at individual levels; as there were no communal adaptation or mitigation measur in all the surveyed communities. The strategies are increased domestication cattle, early planting, planting early maturing crop varieties, swapping to t cultivation of crops with higher profit turn over, and planting of economic tree Others are crop rotation, fertilizer and manure usage, cultivating crops tolerant low soil nutrient, cultivating crops tolerant to drought, use of herbicides ar insecticides and digging of wells and bore holes to cope with the depleting wat resources. The study however reveals some slight differences in some of the adaptation measures.

4.1.1 Introduction of New Crops/Crop Varieties

Subsistence farmers in all communities surveyed pointed out that they do n necessarily have to totally substitute all crop types traditionally cultivated in th communities. This is because there are no alternative crops that can thrive wel under the prevailing climatic conditions of the communities. However, they hav introduced a few more suitable crops to supplement the existing ones and adopte varieties of the traditional crops that more adapted to the changing weather and climate.

In Agricultural Zone 1 *Glycine max* (soy or soya bean) often referred to as "wonder crop", was introduced in only two communities, while vegetables and spices were introduced in only one community. Wuya Kede is the only community in the Zone that has intensified upland crop cultivation as an adaptation to augment the dwindling livelihood from fishing. The community also adopted dry season irrigation, cultivating *Allium cepa* (onion), *Hibiscus esculentus* (Okro), *Amaranthus spinach*, *Lycopersicon esculentum* (tomato) and *Capsicum sp* (pepper). All communities in the zone introduced *Manihot palmata* (bitter variety cassava) and intensified its cultivation and legumes but reduced the cultivation of white yam because of decreasing yield. The legumes cultivated in commercial quantities in all upland communities in the zone are *Arachis hypogaea* (groundnut), *Vigna unguiculata* (cowpea or beans), and *Cucumis melo* (melon or egusi). The communities grow cassava, melon, beans (cowpea) and early maturing groundnut in commercial quantities because of their economic values, very short maturation periods, and ability do well in less fertile soils and little moisture, without fertilizer application. In addition farmers in two communities mentioned that although flood plains are prone to seasonal floods, insufficiency of arable land now compels them to cultivate such plains, since they possess fertile alluvial soils and often support high yield. As an adaptation, they often postpone the cultivation of rice till after the seasonal floods; planting early maturing varieties. The floodplain-dependent communities have intensified the cultivation of traditional crops like *Saccharum officinamum* (sugar cane) and rice in commercial quantities due to their higher turnover while non-floodplain dependent communities have introduced *Manihot esculentum* or edible cassava and upland variety of rice which is tolerant to lower soil moisture in commercial quantities.

In Agricultural Zone 2, soya bean was introduced in all communities. Agricultural Zone 2 adapts by changing to more tolerant, higher yielding yam varieties. With the exception of Tegina community, all other surveyed communities in Agricultural Zone 2 gradually replaced traditional varieties of *Dioscorea rotundata* (white yam) such as Suba, Leleyi, Gbaguso, Shakata, Suru, Gbazheboyi, Kpako, Amana, Efei, and Giwa whose yields were deteriorating due to changing climate and soil nutrient depletion. They introduced more tolerant varieties less susceptible to adverse conditions and have higher yields such as Sule, Lagos, Kwasu, Coach, Paper, Laushi, Nyangbazhi and Dindinya etc. Altering crop varieties, substituting plant types, cultivars and hybrids, with those with higher drought or heat tolerance possess potential to increase farm efficiency in the light of changing temperature and varieties of the traditional crops that more adapted to the changing weather and climate.

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More food crops were introduced in Zone 3 than the other zones. All communities in the zone introduced crops like *Pennisetum typhodes* (late maturing millet), Okro, tomato, *Solanum melongena* (garden egg or eggplant), rice (early maturing variety), soy or soya bean), *Ipomoea batata* (Sweet potato), *Hibiscus sabdarif* (sorrel, roselle), *Anacardium occidentale* (Cashew), while increasing white yam and cowpea. Decrease in cultivation of yam was attributed to reduced rainfall and poor soil fertility which result in dwindling yam yields, while decrease in cowpea production was attributed to the increased incidence of insects and diseases which tend to defy all available insecticides.

4.1.2 Increased Domestication of Cattle

All the communities visited are of the view that in recent times, they have intensified the rearing of these domestic animals (birds, sheep and goats) and introduced domestic cattle rearing, as a means of diversifying their livelihoods and complementing income from crop production and for generation of animal dung (farm-yard manure). This strategy has been identified by[13]. The reason advanced by the communities for the intensified rearing of animals is that that complement income from crop production. In addition, the animal dung from stalls or pens provides organic fertilizer; which is believed to be better, stronger and more lasting than the inorganic ones. The use of farm-yard manure is particularly beneficial to one community in Zone 2 which lays much more emphasis on the use of animal manure; especially poultry because it is stronger and lasts much longer than inorganic manure.

In spite of the enormous benefits of cattle rearing, the communities do not totally substitute cropping with livestock because it is (particularly cattle) expensive to purchase, difficult to rear and cannot be entirely relied upon. Moreover, the safety of the animals against invasion by thieves and cattle rustlers is often not guaranteed. In recent time, most communities in the state have been under frequent attack by cattle rustlers who have parted away with thousands of cattle. Furthermore, the discussions reveal that large scale animal production by the farmers is hampered by the difficulty in providing animal feeds during dry season and the prevalence of animal diseases during the raining season. Consequently two communities in Zone 2 left their cattle in custody of nomadic Fulani herdsmen because of the diminishing pasture (grazing) land and the difficulty of providing feed for domesticated animals.

Hence, the prediction by ([14][13]) that global livestock production will be hampered by changes in the availability of fodder and pastures, changes in areas from rangelands to unproductive shrub lands, and increased diseases and mortality of livestock is already evidenced across the state.

4.1.3 Intensification of Cultivation

All surveyed communities have intensified cropping and increased the cultivation of crops that that can considerably withstand drought and those that are more tolerant to low soil fertility in response to the comparative lower yield occasioned by decreasing rainfall and depleting soil fertility respectively. Two communities in Zone 1pointed out that although flood plains are prone to floods, insufficiency of arable land now makes them take the risk of cultivating such plains, because the plains possess fertile alluvial soils and often support high yield. In coping with the annual flood episodes, some farmers delay the cultivation of rice in the flood plains till after the flooding periods, often planting short duration varieties of rice which matures within three months. However, these varieties often have lower yields and normally fail in years of early rainfall cessation.

4.1.4 Use of Herbicides and Insecticides

In all the communities visited in the 3 zones, farmers have all adopted the use of insecticides of and herbicides especially those containing paraquat dichloride and related chemicals. The beneficial effects of herbicides as highlighted by the communities include effective control of some fast growing/emerging weed species, ease of labour, and improvement soil fertility in the short run. Also, the chemicals sometimes kill pests and reptiles and leads to improved crop yield. These findings are in agreement with the assertion by[12] that altering the intensity of agro-allied chemicals, capital and labour inputs could reduce the risks in farm production in the light of climate change. However, farmers in all the communities have noted that frequent application of chemicals increase crop production costs and reduce farmers' incomes.

4.1.5 Early Land Preparation

Another adaptation measure identified by most communities is early land preparations, especially the making of yam heaps. Early operations or preparations such as these are done as adaptation measures to cope with early rainfall cessation and late onset to pave the way for early planting at rainfall onset. Particularly, the study revealed that making of new yam heaps against the next planting season traditionally used to commence September/October but now commences in August due to the uncertainty of rainfall cessation. Gbagyi speaking farming communities now take advantage of the new heaps to plant la maturing (dry season) melon to boost their livelihood.

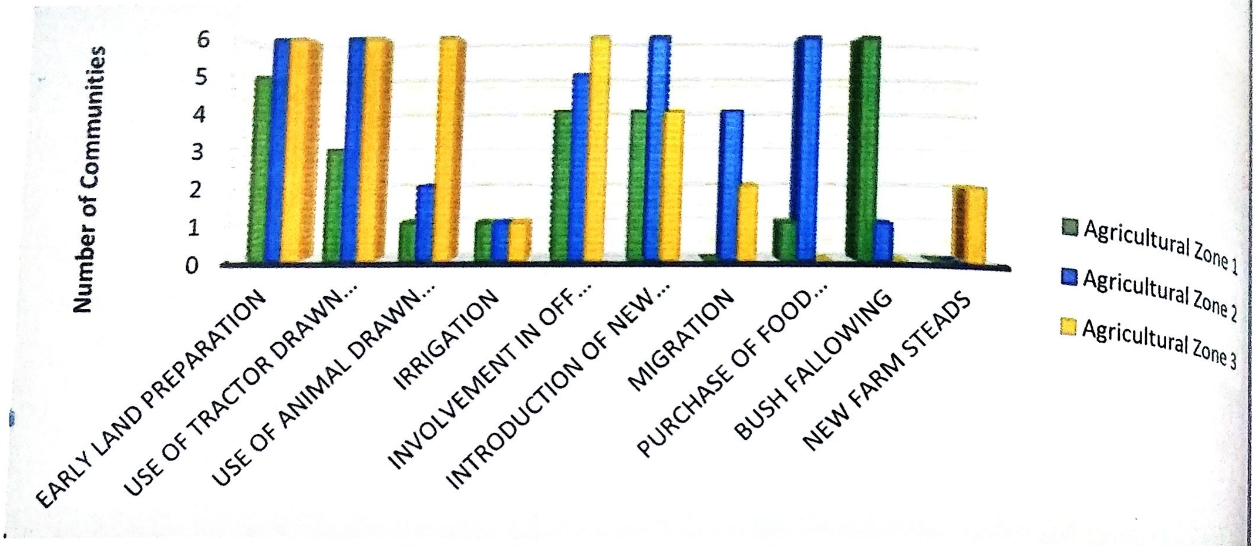

Figure 4.2 Other Adaptation Measures

Figure 4.2 shows other adaptation measures employed but not in all surveyed communities. The measures are early land preparation, use of tractor drawn implements, use of animal drawn implements, irrigation, and involvement in off-farm jobs. Others are introduction of new crops/varieties, purchase of food processing machines, bush fallowing, migration and establishment of new farmsteads.

4.1.6. Use of Farm Mechanization

The intensification of agricultural activities across the three zones is often facilitated with the use of farm mechanization. In Zone 1 only one community (Muwo) representing 5.6% of the surveyed communities uses both tractor-drawn and oxen drawn farm implements and possess some modern food processing machines. Two communities (Gbadafu and Takuti) or 11.1% of the surveyed communities use tractor drawn farm implements if available, while the rest hardly have access to tractors and therefore entirely rely on manual labour for soil tillage.

In agricultural Zone 2, all the communities use tractor-drawn farm implements when available but only two communities depend heavily on animal-drawn farm implements since tractors are hard to access, while the stony nature of land in another community hinders the use of animal drawn farm implements. In agricultural Zone 3 all communities use tractor-drawn farm implements when available but rely very heavily on animal drawn implements which are readily available and affordable.

4.1.7. Bush Fallowing, Migration and Establishment of New Farmsteads

Migration by individuals or relocation of settlements have been discussed in various studies as a potential adaptive response option to climate change[15]. Figure 4.2 shows that the responses on adapting agricultural practices to climate change by practicing bush fallowing, permanent migration and the establishment of new farmsteads differed across the three agricultural zones. All the six communities in Zone 1 representing 33.33% of the communities surveyed still practice the traditional bush fallowing system. However, the fallow period has been considerably shortened from about 10-15 years in the past to a maximum of three years duration at present. They are however more often than not constrained by access to land due to land tenure system. Only a community in Zone 2 representing 5.6 % of the entire communities practice bush fallowing but the practice has ceased in all communities in Zone 3; the reason being that the rising population of the households exerts much pressure on the already insufficient available land which falls short of the demand for annual cultivation. All communities therefore adopt crop rotation as a major means of soil nutrient replenishment.

On permanent migration, four communities in Zone 2 representing 22.2% of the communities adopt permanent migration as an adaptation strategy. The communities migrate to other locations they consider to be more favourable and possess more fertile lands. Migration by individuals or relocation of settlements have been discussed in various studies as a potential adaptive response option to climate change[15]. Particularly, the Gbagyis in Zone 2 whose major livelihood is derived from yam cultivation have more readiness to permanently migrate to new locations they consider more favourable for yam cultivation in terms of fertilizer and agro-meteorological requirements. Only a community in Zone 3 (5.6 %) adopt permanent migration as adaptation strategy. However, all communities in Zone 1 are strictly sedentary, unwilling to migrate because they do not want to break ancestral family ties and are afraid of uncertainties in new locations. They therefore consider migration as undesirable adaptation.

In addition, as an adaptation to insufficiency of land, two communities (11.1%) in Zone 3 (Salka and Raba) resulted to establishing new farms (sabon-gonna in vernacular) far away from their communities where they construct farm steads during the growing season and sometimes stay a week or more on the farm before returning home, similar to[16].

4.1.8. Irrigation

Irrigation has been identified as an adaptation strategy that not only enhances the productivity of labour and land[17] but also leads to higher incomes and wages, and lower food prices[18]. However, the practice is not widespread in the state. Only three (11.7%) of the 18 communities surveyed practice irrigation. In Zone 1 it is practiced only in Wuya Kede on small scale. Here, some farmers take advantage of the perennial River Kaduna to cultivate vegetables during the dry season. In Zone 2 it is employed only in Gawu Babangida mostly by non-indigent migrant Hausa farmers (locally called Chinrani). In Zone 3 Maito community and its neighbouring villages, practice irrigation basically during the dry season as a way of adaptation since the commissioning of Tungan Kawo Dam (Wushishi) constructed by Niger River Basin Development Authority in 1982. The community has enjoyed tremendous benefits from the irrigation scheme, as it now cultivates rice twice a year. For other communities several reasons were highlighted for non-adoption of irrigation. The reasons range from the notion that irrigation has not been part of the communities' cultural practices traditionally (specifically in Zone 1) to the non-availability of perennial rivers and the absence of irrigation dams and facilities in most of the communities. Masuga Community in Zone 3 noted that the irrigation scheme which used to sustain the community during the dry season has now failed, because the erstwhile perennial stream used for that purpose now dries up during the dry season.

4.1.9 Off Farm Jobs

Except for two communities, the youths in all communities in Zone 1 now involve in off farm jobs such as tailoring, bricklaying, furniture making, auto-mechanics, and carpentry. Women, in addition to the traditional livelihood activities such as food harvesting, food processing and trading in food commodities now trade in provisions, engage in making soap and body cream, and own large farmlands mostly cultivated using hired labour, but often supplemented with their own labour. For Zone 2, five out of the six communities representing 27.8% of the entire surveyed communities now engage in similar off farm activities.

4.2. Effectiveness and Perceived Benefits of Adaptation

In responding to the question of the beneficial effects of adaptation, all the communities expressed some satisfaction with the employed adaptation strategies; since the measures have brought noticeable improvements. The communities specifically expressed that intensification of cultivation, early planting, use of fertilizer, and use of herbicides have resulted in increased food crop yield, increased income from farming activities, and provided more opportunities for those engaged in food processing and traders of food stuff. In addition, farmers in two communities mentioned that although flood plains are prone to floods, insufficiency of arable land now makes them take the risk of cultivating such plains, because the plains possess fertile alluvial soils and often support high yield. Furthermore, all six communities in Zone 2 noted that planting of legumes specifically for feeding animals has helped sustained the animals during the dry season, when pasture is virtually absent. As rightly noted by [19], these adaptation measures in these communities could be said to have significantly reduced the negative impacts from changes in climatic.

The beneficial effects of herbicides as highlighted by the communities are that herbicides effectively control some stubborn weeds, reduce farm labour, increase soil fertility and sometimes kill pests and reptiles, while use of insecticides now leads to improved beans yield. Thus, altering the intensity of chemicals capital and labour inputs has the potential to reduce the risks in farm production in the light of climate change [12]. By and large, these adaptation measures have the potentials to significantly contribute to reductions in negative impacts from changes in climatic conditions as well as other changing socioeconomic conditions [19] in those communities. However, for countries located in tropical regions, the potential benefits of low-cost adaptation measures such as changes in planting dates, crop mixes, and cultivars are not expected to be sufficient to offset the significant climate change damages[20].

4.3. Constraints in Adaptation

From all the communities surveyed however, notable problems arising from some adaptation strategies were expressed. A major problem expressed by all communities is that early planting is often hampered by the prolonged dry spell at the beginning of the rainy season which often leads to the decay of planted seeds especially yam (before or after germination), withering, dying of young crop seedlings and stunting of plants growth. These often lead to crop failure and consequently necessitating re-planting of failed crops. Secondly, that the use of tractors weakens the soil and contributes to rapid soil nutrient depletion or exhaustion. Also, in most communities, there is a difficulty in providing animal feeds during dry season as well as the prevalence of animal diseases during the rainy season. This consequently hampers large scale animal rearing. This is supported by the prediction that livestock production will suffer due to changes in the availability of fodder and pastures[14], deteriorated rangeland quality, and increased d and mortality of livestock and/or forced sales[13]. In addition to these problems community observed that lack of proper enlightenment on the appropriate and application of herbicide sometimes results in the destruction of the cultivated crops alongside the weeds. Furthermore, in Zone 2, five of the communities revealed that continuous overturning of the soil with the use of trac during ploughing as well as use of herbicides in the long run weaken the soil introduce *Striga Hamontica* and leafy weeds (*such as Chromolaena odorata, Agera conyzoides and Hyptis suoveolens*). The leafy plants are believed to grow faster than gr increase the population of termites, and lead to rapid soil nutrient depletion a [illegible]osion. Masuga Community in Zone 3 lamented that the irrigation scheme wh used to sustain the community during the dry season has now failed, because the erstwhile perennial stream used for that purpose now dries up during the dry season

In all the communities, it was pointed out that there are major constraints militating against successful adaptation. Intensification of cropping and bush fallowing are hampered by ownership of land in small holdings; which necessitates leasing of farmlands from those who have adequate lands (often paid for by using farm produce), triggers communal clashes or farmers–nomads clashes, and discourages farm mechanization. Another implication is that this has mostly happened through conversion of forest and grasslands and shortening of fallows[18]. Therefore, Agricultural intensification and/or expansion into marginal lands can cause crop failure, exacerbate environmental degradation [21] and reduce biodiversity[22].

5. Conclusion

There is a dire need for the capacities of farming communities to adapt to climate change to be strengthened if the gains from adaptation must be sustained and maximized. This calls for support such as amenities, infrastructures, training and technical aid, sensitization and useful information, monetary donations, credit facilities, modern efficient storage facilities, modern efficient, affordable but non-sophisticated farm machinery etc. to farming communities.

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