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Geospatial Assessment of Climatic Variability and Aridity in Katsina State, Nigeria

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Abstract:- This study assessed rainfall, temperature and evapotranspiration variability in Katsina state using satellite based Rainfall (mm) and evapotranspiration (mm/months) downloaded from TAMSAT (Tropical Applications of Meteorology using Satellite data and ground-based observations) and temperature data was obtained from the Climate Research Unit (cru.uea.ac.uk) for a time period of 33 years (1983 - 2016). The data were analyzed for the occurrences of aridity, abrupt changes in evapotranspiration, temperature and rainfall values over Katsina State while the spatio-temporal pattern of the meteorological variables were also investigated. Results indicated that there have been statistically significant increases in rate of evapotranspiration and temperature while there appeared to be a reduction in the amount of rainfall in Katsina state. Analyses of the spatial distribution further suggest a sequence of steady decrease in rainfall from the southern Katsina state towards the Northern part of the state and alternate increase in evapotranspiration due to temperature rise. The Northern part of Katsina falls within the arid region (0.26) which covers a landmass of 6080.9 km^2 (25%) while the Southern Katsina is in the semi-arid zone (0.49) and covers land area of 4191.682 km^2 (17%). The result showed that aridity increased during the last decade (2000 - 2016) and it is encroaching towards the Southern part of Katsina.

Keywords:- *Aridity, Risk zone, Remote Sensing, TAMSAT.*

I. INTRODUCTION

The world is faced with challenges in all three dimensions of sustainable development; economic, social and environment (UNEP, 2013). Climate Change affects the environment and the knowledge of climate variability over the period of instrumental records and beyond on different temporal and spatial scale is important to understand the nature of different climate systems and their impact on the environment and society (Oguntunde *et al.*, 2012).

The climate of any location in the world can be defined majorly by two meteorological parameters which are the annual and seasonal changes in temperature and precipitation and both varies based on regions (IPCC, 2007). Global environmental issues experienced is primarily due to anthropogenic and natural factors such as varied land surface, evapotranspiration and climate cycle which affect climate in different ways (Snyder *et al*., 2004). Climate change cannot solely cause desertification state, but it may modify the critical thresholds, so that the system can no longer maintain its equilibrium (Williams & Balling, 1996) and it also accelerates degradation of the sub-humid and dry land thus, intensifies drought condition and makes the natural environment more vulnerable (Abdulkadir *et al*., 2013).

Climate change and variability present a global challenge, but it is the less developed regions, such as Africa, where the population is most vulnerable (UNDESA, 2013). In Nigeria, the major environmental problem faced in the Northern Region particularly the Sudano-Sahelian belt is aridity, and it is in response to climate change, rainfall variability and repeated drought, which is mainly an indication of intense environmental degradation due to anthropogenic and natural processes (Abdulkadir *et al*., 2013). Globally, researches have confirmed increasing rate of desertification (Zhao *et al*., 2005; Huang and Siegert, 2006; Susana and Kelley, 2006; Sonia *et al*., 2007; Sivakumar, 2007; Hanafi and Jauffret, 2008; Abdulkadir *et al.*, 2013).

Existing literature indicates increasing trend toward aridity in recent times (Dregne and Chou, 1992; Nicholson, 2003; Hanafi and Jauffret, 2008; López et al., 2008; Gaughan and Waylen, 2012). Lázaro et al. (2001) mentioned that in order to understand the behaviour of ecosystems in semi-arid areas, rainfall must be analyzed over time. Intra- and inter-seasonal rainfall variability are imperative in studying moisture efficiency or moisture quality in the semi-arid areas of the Sudano-Sahelian belt of Nigeria (Usman 2000). Adefolalu (1986) studied the rainfall trends for periods of 1911 to 1980 over 28 meteorological stations with 40 years moving average showing appearance of declining rainfall. Eludoyin *et al*., (2009) studied monthly rainfall distribution in Nigeria between 1985 and 1994 and observed fluctuations in most months. mapping aridity so as to address the problem. This paper aims to use geospatial technique to examine the spatial and temporal variability of aridity in Katsina state, Nigeria, through analysis of temperature, evapotranspiration and precipitation trends during the 33-year period (1983–2016).

A. Problems of the Statement

In the time past, aridity has been monitored using primitive method of monitoring i.e. interview, questionnaires, and traces of historical background, which is not really reliable and cannot provide accurate description of aridity of an area at a given scale. Earlier researches were based on investigating changes using traditional descriptive statistics and relationship. This study use geospatial technique to examine the spatial and temporal variability of aridity in Katsina state, Nigeria, through analysis of temperature, evapotranspiration and precipitation trends during the 33-year period of 1983–2016. Geospatial techniques, will give an insight into specific management actions that will minimize the progressive ecological degradation and enhance food security in the state and the country at large.

B. Justification

The fundamental analytical function of a GIS based statistics in spatial analyst tools include Kriging, Inverse distance weighted (IDW), Covariance etc. are commonly used during the geological data analysis process for mapping, monitoring and modelling of aridity. However, Remote Sensing and Geographical Information System (GIS) can provide a platform that is capable of integrating climatic parameters with other relevant data or associated features, which will help measuring, monitoring and

C. The Objectives of the Study are

- Examine the temporal trend of Rainfall, Evapotranspiration and Temperature over a period of thirty three years (1983-2016);
- Examine the spatial variation of climatic variables over Katsina state from year 1983 to 2016;
- Examine the anomaly of rainfall, temperature and evapotranspiration from year 1983 to 2016;
- Determination of aridity index of Katsina state for four decades.

II. STUDY AREA

A. Study Location

Katsina State is located within latitude 11^0 7' and 13^0 22' N and longitude 6^0 52' and 9^0 2' E (Figure 1). The state stretches across three ecological zones, namely Sahel savanna to the north, Sudan savanna at the central region and Guinea savanna to the south (Abaje, 2007; Tukur *et al.*, 2013). It has a total land mass area of 24,192 km^2, a population of 5,792,578 and a population density of 140 persons per square kilometer (NPC, 2006).

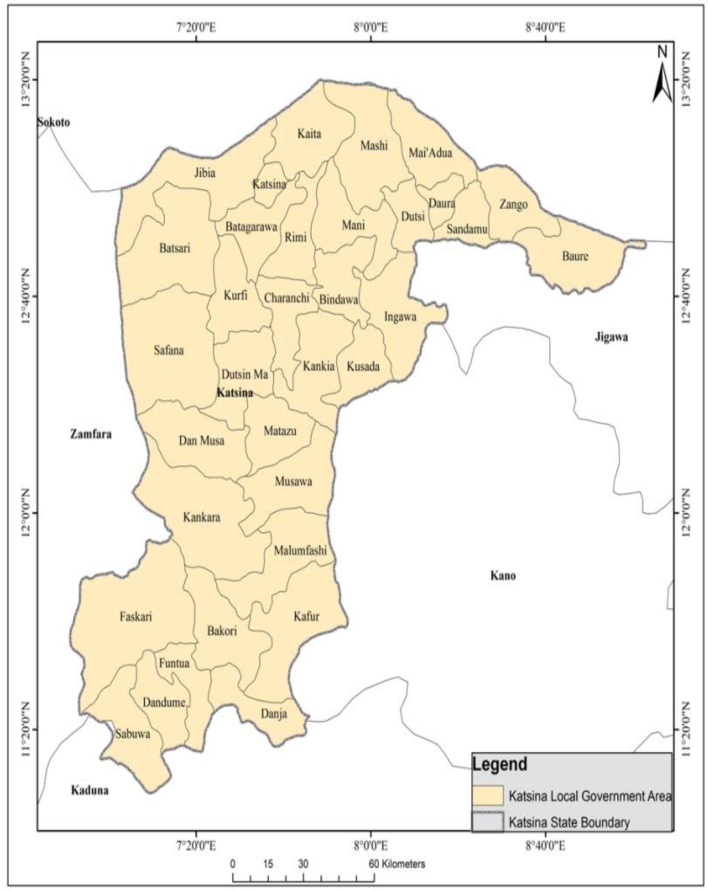

Fig 1:- Study Area Map

B. Climate and Weather

The climate of Katsina State as classified by Koppen climate is the tropical wet and dry type (tropical continental climate) and rainfalls occur mostly between the month of May and September and attains the peak in August (Abaje *et. al.*, 2012) while the dry season starts from October to April with very low humidity coupled with increased temperature. There is also a transition between the wet and dry season which is the harmattan period and it is caused by the prevalence of the North Easterly trade wind from the Sahara.

III. METHODOLOGY

In this study, the meteorological data used in the analysis concern monthly values of air temperature evapotranspiration and precipitation which spans for 33 years (1983 to 2016).

The precipitation data was downloaded from the Tropical Applications of Meteorology using SATellite data and ground-based observations Figure 2 (TAMSAT) website: https://www.tamsat.org.uk/. The TAMSAT is a satellite and ground based derived data which has a spatial resolution of 0.0375° uses archived Meteosat thermal infrared imagery, calibrated against rain gauge records collated from numerous

African agencies. The Temperature and evapotranspiration data obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) website: http://apps.ecmwf.int/datasets with a spatial resolution of 0.1°.

The meteorological data was sub-set to Katsina and resampled to the same resolution of 1km using the resample tool in ArcGIS 10.5. The annual mean data was estimated using the Cell statistics tool in ArcGIS while the zonal statistic tool was used to extract the mean value of temperature, evapotranspiration and Rainfall. The anomaly was calculated by subtracting the data for a particular year from the long term mean using the cell calculator. The excel spread sheet was used to plot the graphs and show the temporal trend for temperature, evapotranspiration and Rainfall.

The United Nations Environmental Programme (UNEP) ‘defined an aridity index (AI) by the ratio of the annual precipitation and potential evapotranspiration (PET) totals’. To estimate the UNEP aridity index (United Nations Environment Program UNEP 1997), the expression is showed in the equation below. The result for aridity Index was categorized into different classes according to the degree of severity (Table 1) ranging from Cold region to dry land area.

$AI = \frac{\mathrm{P}}{\mathrm{PET}}$ Equation……………………………………..(1)

Where AI is the Aridity Index, P is the Annual Precipitation and PET is the annual potential evapotranspiration and must be expressed in the same unit as annual precipitation, e.g., in millimeters.

Class	Aridity Index
Cold	> 0.65
Humid	>0.65
Dry Sub-Humid	0.50-0.65
Semi-arid	0.20-0.50
Arid	0.05-0.2
Hyper Arid	<0.05
Dry-land	<0.65
Susceptible dry lands	0.05-0.65

Table 1:- Categories of Aridity Index based on UNEP (2007)

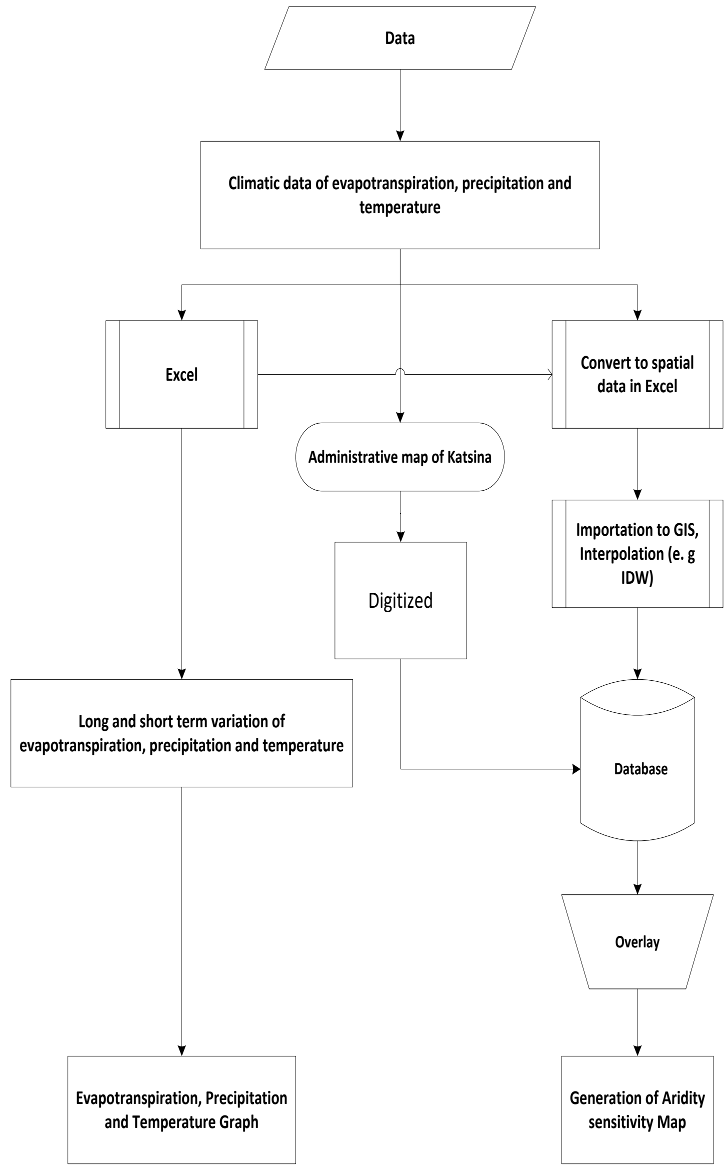

Fig 2:- Methodology flowcharts

IV. RESULTS AND DISCUSSION

Figure 3 shows the long term mean annual temperature distribution over Kastina state. Sabuwa, Dandume, Danja, and part of Faskari, Bakori and Kafur, all in the south, have temperature values ranging from 25.7^{0}C to 26^{0}C. Dan Musa, Musawa, Matazu, Dutsin Ma, Kankia, and some parts of Faskari, Malumfashi, Safana, Kankia and tiny parts of Kurfi, Charanchi, Kusada and Bakori have temperatures between 26.01^{0}C and 26.52^{0}C. Batagarawa, Bindaawa, Ingawa, Kusada, Kurfi, and Jibia have a temperature that ranges of 26.53 ℃ to 27℃. The Northern part of the state shows a temperature range of27.01 ℃ to 27.5 ℃. This shows a gradual increase in temperature as you move up north Katsina.

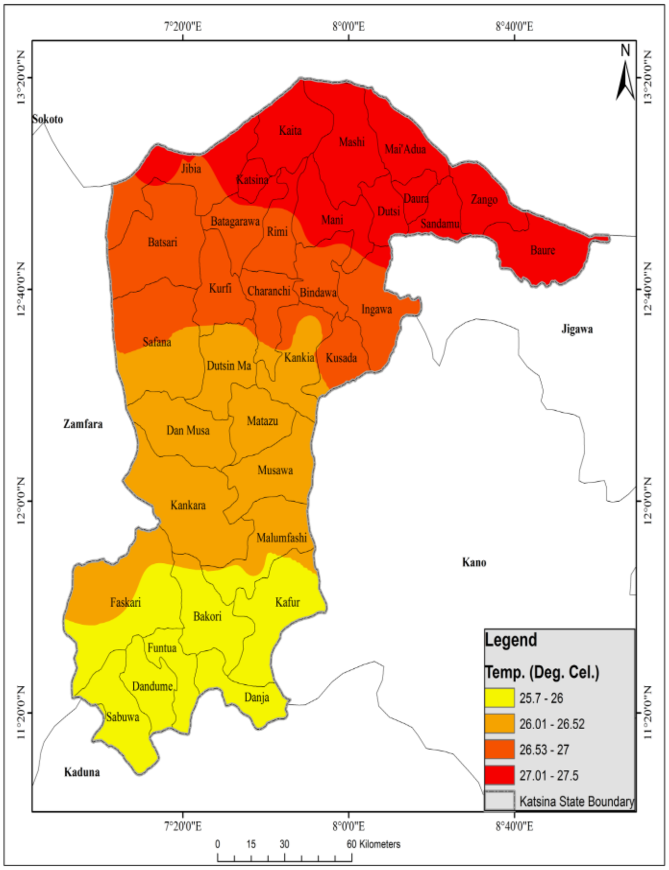

Fig 3:- Long Term Mean Annual Temperature Map

The trend of temperature in the state shows a gradual increase in mean temperature from a mean value of 26.5℃ to 28.4℃ from 1983 to 2016. The mean annual temperature reached a peak value of 28.34℃ in 2011 and a minimum value of 25.64℃ in 1993. The temporal distribution of temperature in the state shows a steadily increasing temperature in Katsina from 26.5℃ in 1983 to 26.67℃ in 2016. The fluctuations in the annual distribution can be accounted for by the natural variability in climate, which is driven by climate change *(Kiunsi and Meadows, 2006)*. Rapid urbanization and a variety of ecological, cultural and socio-economic factors can also be critical contributors to the temperature increase. The temperature trends in the state are characteristic of its aridity zoning *(Sawa et al, 2015)*. Differences in solar insolation received at different parts of the states in conjunction with the prevalent socio cultural activities, architectural designs and industrial activities could be critical factors in the increase in temperature of the state. The highest and lowest temperatures recorded in the northern part of the state were 29.6℃ and 26.1℃ while the south recorded 27℃ and22.1℃, respectively. The trend shows a prominent rise from 2011 to 2016 *(Figure 4 and 5)*.

The rising temperature of the state *(Ogolo EO, 2011)* plays a significant role in the ecosystems dynamics; longer drying season, increase in the rate of evaporation, water deficit, and variation in the hydrological cycles. An increasing risk of heat waves, measles, meningitis and other heat related diseases could be spurred on. Higher temperatures results in a high rate of evaporation of soil and water bodies in the area, which in turn lead to aridity in extreme Katsina north.

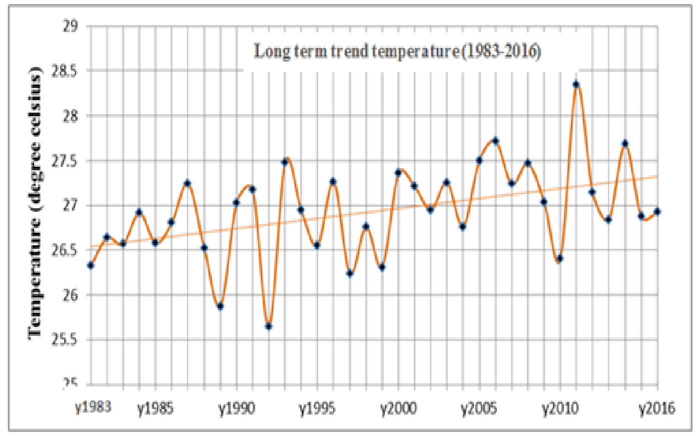

Fig 4:- Temperature Trend of Katsina State over 1983 – 1986

The anomaly graph shows in Figure 5 normal mean annual temperature at the start of the study period. An above normal temperature anomaly of 0.3 was first recorded in 1986 and was followed by a fluctuating pattern of temperature increase and decrease. The anomaly shows a rise in temperature, with 2011 recording the highest temperature anomaly of 1.41.

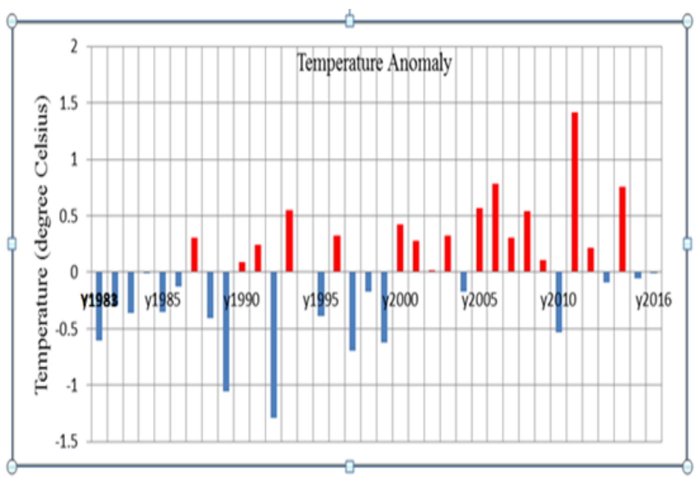

Fig 5:- Temperature Anomaly

Figure 6 shows long term mean–evapotranspiration amount in mm/day, which increases gradually up North. *Sabuwa, Dandume, Funtua, Faskari (approx. 80%), Bakori (approx.60%), Danja* and a part of *Kafur*, has a long term mean-evapotranspiration that varies between 62.56mm/day to about 65mm/day. *Kankara, Malumfashi, Kafur (50-60%), Musawa* (approx. 50%) and little of *Faskari* and *Bakori*, has a long term mean-evapotranspiration between 65.01mm/day and 68mm/day. For most part of *Dan Musa*, *Dutsin Ma*, Matazu and a little part of *Kankia* and *Safana*; plus a very tiny part of *Charanchi*, the long term mean-evapotranspiration amount falls between 68.01mm/day and 70mm/day.

In the far remote areas, that is; areas like *Kurfi*, *Kusada*, *Charanchi*, *Batsari* and part *of Ingawa*, *Bindawa*, *Rimi*, *Batagarawa*, *Jibia (up north)*, and *Safana*, *Dutsin Ma*, *Kankia*, *(down south)*, the long term mean-evapotranspiration amount falls between 70.01mm and 73 mm per day. In the far exterior part of *Katsina* (i.e. Katsina North), for places like; *Kaita*, *Mashi*, *Mai'Adua, Zango, Baure, Sandamu, Daura, Dutsi*, *Mani*, *Katsina and part of Ingawa*, *Bindawa*, *Rimi*, *Batagarawa and Jibia,* the long term mean-evapotranspiration amount ranges between 73.01mm and 76mm per day.

The distribution of evapotranspiration in the state is linked with the temperature pattern exhibited. A seasonal increase in the degree of dryness was made evident by the increase in evapotranspiration during the dry season of the state *(November – May, figure 6)* with the northern part losing more moisture at a higher rate (73.1–76 mm/day) compared to the southern part (62.56–65 mm/day), following the temperature distribution in the state. The significant increase in evapotranspiration in the last decade can be attributed to increasing vegetation depletion. *Abaje, (2014).*

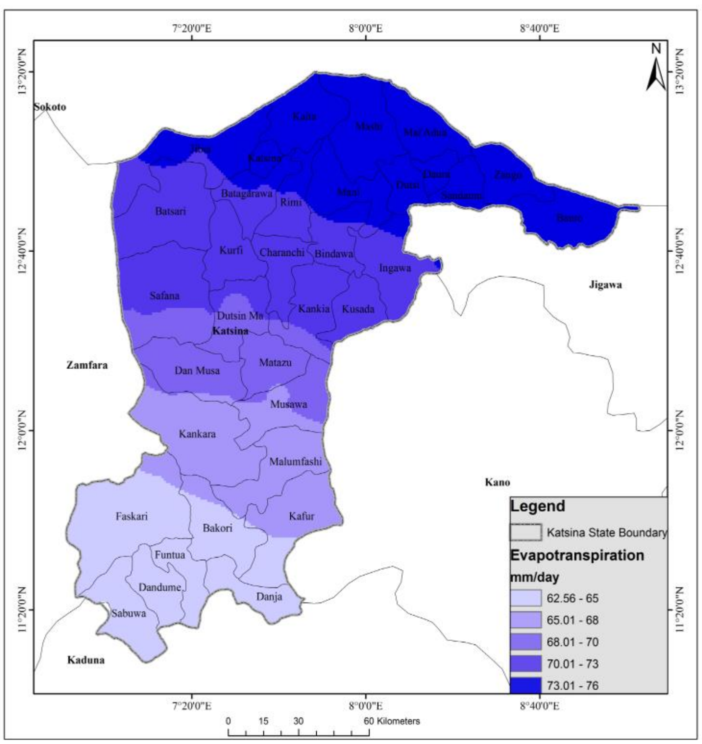

Fig 6:- Evapotranspiration Map

Figure 7 shows the anomaly of the rate of evapotranspiration from the long term mean evapotranspiration in the study area. The graph shows both the positive anomaly and the negative anomaly. The positive anomaly shows a high tendency for evapotranspiration, and the negative anomaly shows a low tendency for evapotranspiration. Between 1983 and 1985, Katsina state is seen to have the highest positive anomaly as 1.10mm/day and lowest negative anomaly as 1.02mm/day. Between 1985 and 1990, the highest positive anomaly is 1.50mm/day and the lowest negative anomaly is 2.01mm/day. Between 1990 and 1995, the state is seen to have the highest positive anomaly as 0.2mm/day and lowest negative anomaly as 2.07mm/day. Between 1995 and 2000, the highest positive anomaly is 0.79mm/day and the lowest negative anomaly is 1.19mm/day. Between 2000 and 2005, anomaly is seen to be on the rise, with highest positive anomaly of about 0.61mm/day and lowest negative anomaly of about 0.12mm/day. Between 2005 and 2010, the highest positive anomaly is 2.22mm/day and the lowest negative anomaly of about 0.06mm/day. Between 2010 and 2016, the highest positive anomaly is 1.03mm/day and the lowest negative anomaly of about 0.45mm/day.

In a nutshell, the highest (peak) positive anomaly record of 2.22mm/day for the 35 year period is seen to fall between 2005 and 2010 (i.e. closer to 2010) and the lowest (peak) negative anomaly (2.07mm/day) between 1990 and 1995. From 1981 to 1995, evapotranspiration rate is seen to drop more conversely (i.e. more negative) compared to the rapid positive evapotranspiration increase between year 2000 and 2016. This reveals a progressive increase in the rate of evapotranspiration as you move up north Katsina *(Figure 6)*. This affirms the increase in the rate of soil moisture loss in the northern region for the last decade *Abdulkadir,et al* (2013). This increase makes the state and its sub-region susceptible to extreme weather events, most prominently is the drought of *Dutsin-Ma LGA* as reported by Abaje *et al*, (2014).

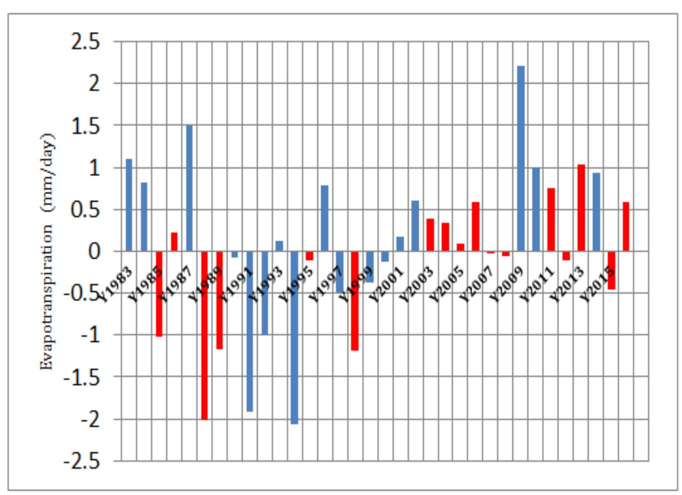

Fig 7:- Evapotranspiration Anomaly

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Table 2 and Figure 8 show the decadal trend of evapotranspiration for the months of the year. (*i.e.* January to December). The maxima and minima value of evapotranspiration for the 1st decadal distribution (1983-1990) is 7.64mm/day and 4.17mm/day respectively. The maxima and minima value of evapotranspiration for the 2nd decadal distribution (1991-2000) is 7.42mm/day and 3.75mm/day respectively. The maxima and minima value of evapotranspiration for the 3rd decadal distribution (2001-2010) is 7.89mm/day and 3.77mm/day respectively. The maxima and minima value of evapotranspiration for the 4th decadal distribution (2011-2016) is 7.73mm/day and 4.00mm/day respectively. The maxima and minima evapotranspiration values for the first-three decadal distribution falls in March and August for each of the decades, except for a shift in maxima from March to April for the last decadal distribution (2011-2016). The trend of Evapotranspiration is better summarized in Table 2 below.

Month	(1983-1990)		(1991-2000)		(2001-2010)		(2011-2016)	
	Month	Value	Month	Value	Month	Value	Month	Value
Maximum Value	Mar	7.64	Mar	7.42	Mar	7.89	April	7.73
Minimum Value	Aug	4.17	Aug	3.75	Aug	3.77	Aug	4.00

Table 2:- Months with Maximum and Minimum Evapotranspiration

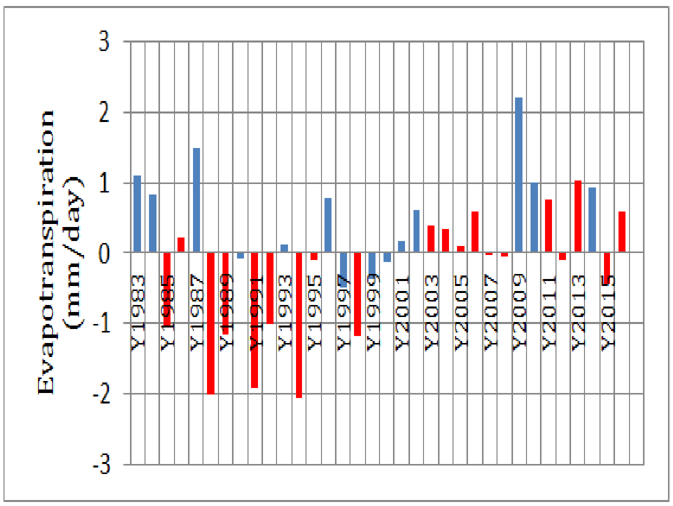

Fig 8:- Anomaly of Evapotranspiration in Katsina (1983-2016)

The Rainfall Map in Figure 9 shows the rainfall distribution over Katsina, with the Northernmost parts, consisting of Jibia, Batagarawa, Rimi, Bindawa, Ingawa, Mani, Dutsi, Sandamu, Zango, Baure, Mai'Adua, Mashi, Kaita, Katsina, and Northern Batsari receiving the least mean precipitation (590 – 700 mm) while the Southernmost part consisting of Sabuwa, Dandume, Fuskua, Faskari and Danja and a part of Kafur received the highest mean precipitation (851 –936mm) within the study period (1983 – 2016). The Central parts of the states consisting of Kafur, Kankara, Malumfashi, Musawa, Mutazu, Dan Musa, Dutsin Ma and Safana received a mean precipitation between 751 – 800 mm.

The spatial pattern of the rainfall distribution showed that an average precipitation ranging from 590 mm to 700 mm reached 5595 square kilometers (km^2) in the northern part, 701 mm to 850 mm reached 14,100 square kilometers (km^2) in the central part and 851 mm to 936 mm reached 4261.956 square kilometers in the Southern part. This spatial pattern of rainfall in Katsina displays a continual decrease in precipitation from southern to northern Katsina.

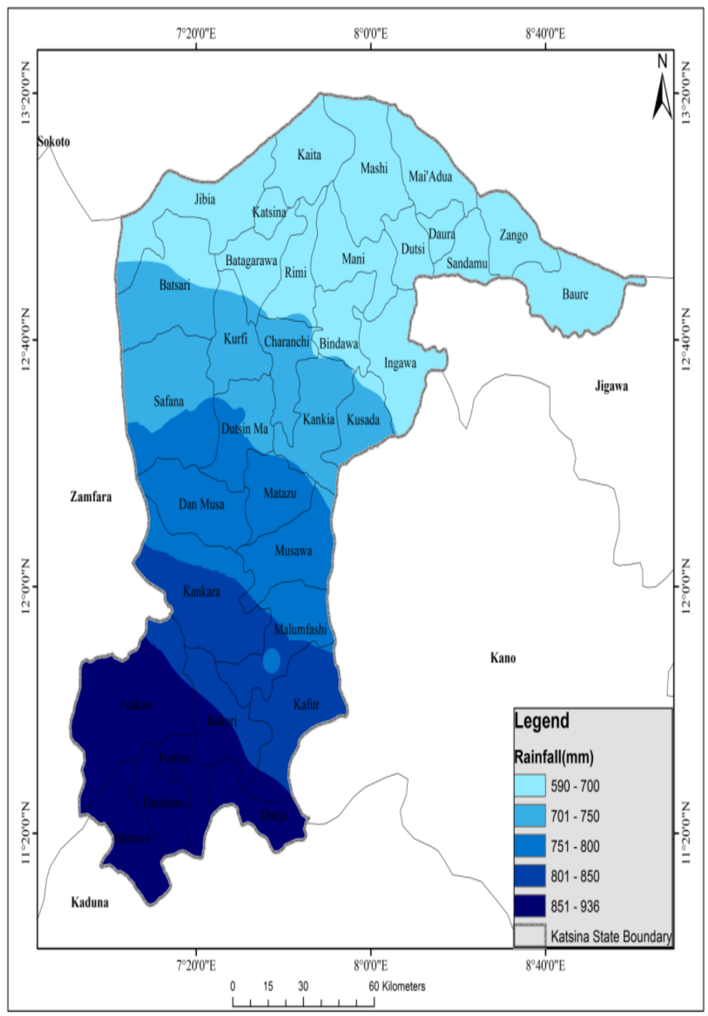

Fig 9:- Long Term Rainfall Map for Katsina

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Figure 10: shows a trend analysis of the mean precipitation distribution received in the three zones (North, Central, and South) of Katsina in comparison with the mean precipitation received within the climatic year (1983 – 2016). The mean annual precipitation received in Katsina varies between 766 mm at the start of the climatic year to 657 mm at the end of the climatic year. Katsina North received a mean annual precipitation of 696 mm at the start of the climatic year and 620 mm at the end of the climatic year. Katsina South received a mean annual precipitation of 854 mm at the start of the climatic year and 754 mm at the end of the climatic year while Katsina Central receives a mean annual precipitation of 767mm at the start of the climatic year and 596 mm at the end of the climatic year. The precipitation receipt in Katsina Central is a representative of the mean precipitation received in Katsina.

It recorded a maximum mean annual precipitation of 880 mm in 2010 and a minimum mean annual precipitation of 496 mm in 1986. In the same year, Katsina North, Central and South recorded a maximum mean annual precipitation of 770 mm, 880 mm and 997 mm, and a minimum of 423 mm, 496 and 586 mm, respectively. The trend of rainfall in Katsina further reiterates a continual decrease in precipitation from southern to northern Katsina. It also shows the proneness to aridity and drought in Katsina North.

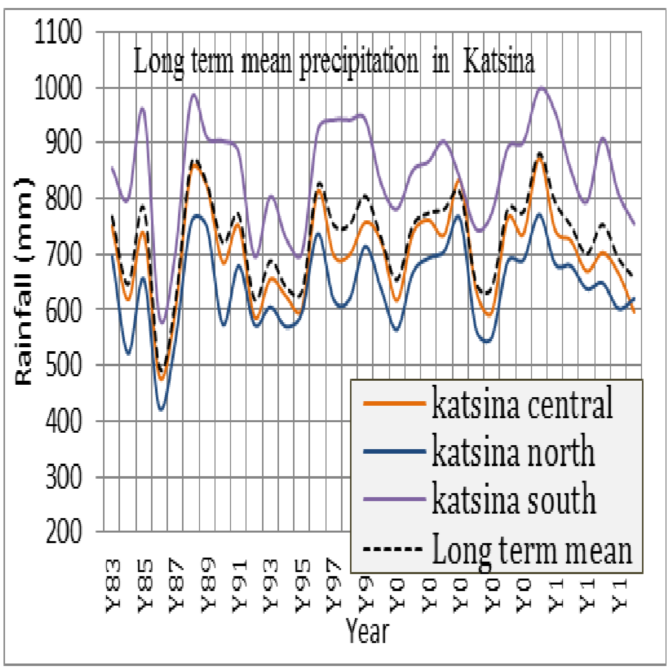

Fig 10:- Long term mean precipitation trend of Katsina three zones

Figure 11: shows the precipitation anomaly of Katsina in mm. The Anomaly graph indicates the normal mean precipitation that reaches Katsina. Excess Precipitation of 38.6 mm, 53.4 mm, 133.3 mm, 97.8 mm, 95.2 mm, 22.7 mm, 22.7 mm, 75.7 mm, 22.4 mm, 45.2 mm, 52.8 mm, 82.1 mm, 51.7 mm, 47.5 mm, 150.6 mm, 64.4 mm, 23.0 mm, 23.8 mm were experienced in 1983, 1985, 1988, 1989, 1991, 1996, 1997, 1998, 1999, 2002, 2003, 2004, 2005, 2008, 2009, 2010, 2011, 2012, 2014, respectively. Deficient Precipitation of 83.4 mm, 231.8 mm, 111.7 mm, 9.7 mm, 108.7 mm, 40.6 mm, 87.6 mm, 94.4 mm, 74.4 mm, 80.1 mm, 89.0 mm, 27.5 mm, 36.3 mm, and 70.3 mm were received in 1984, 1986, 1987, 1990, 1992, 1993, 1994, 1995, 2001, 2006, 2007, 2013, 2014, 2015 and 2016. This is better displayed in Table 4.1.

A continual trend of deficient rainfall was observed within 1992 to 1995, which could be indicative of a possible drought occurrence within that period. This was followed by a fluctuating pattern in the rainfall distribution over the following five years (1996 – 2000). While year 2000 recorded a zero anomaly in precipitation, 2002 – 2005 shows a positive anomaly in precipitation. 2010 recorded a high positive anomaly of 150 mm.

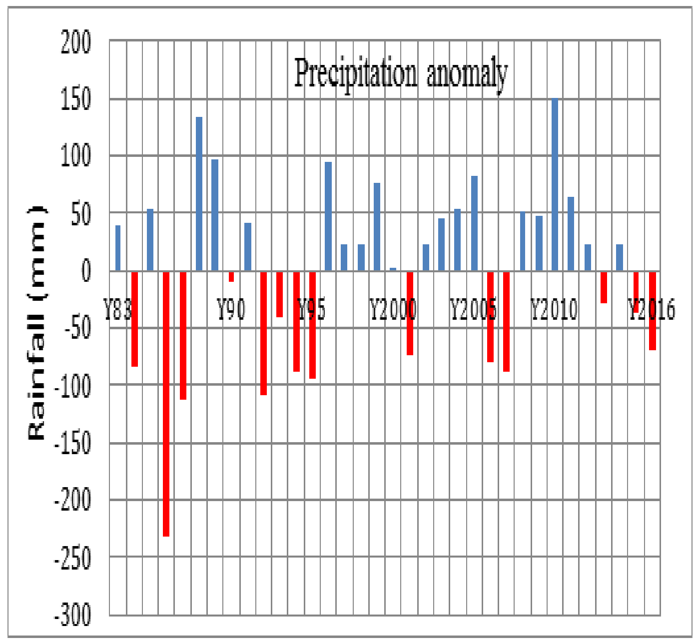

Fig 11:- Long Term Precipitation Anomaly of Katsina

The anomaly map further depicts the areas with deficient rainfall. A total area of 11, 343.20 square kilometres (km^2) received a deficient rainfall, with an anomaly ranging from 0 to (-142) mm over the period of study. An area of 12, 614.72 square kilometres (km^2)received an excess rainfall, with an anomaly ranging from 1 – 204 mm.

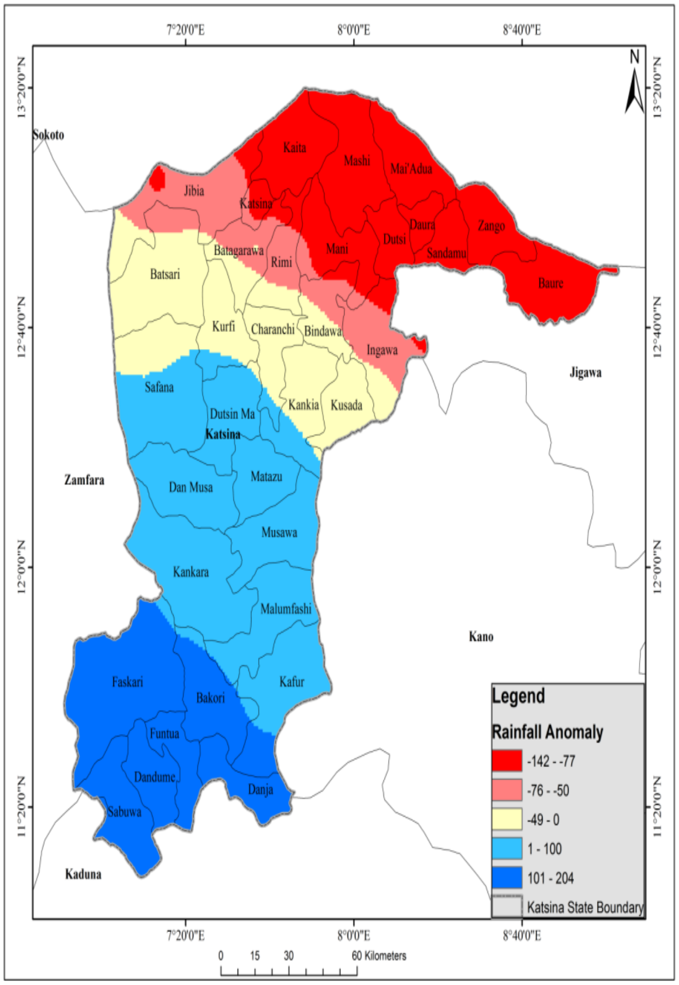

Fig 12:- Rainfall Anomaly Map

From the aridity map in Figure 13, a significant part of northern Katsina shows proneness to aridity. The map shows the distribution of aridity in Katsina. Using the United Nations Environmental Programme Aridity Index classification, the whole of Katsina falls under the semi-arid index (0.20 – 0.50). The northernmost part of Katsina exhibits a 0.26 – 0.3 index, which makes the area more prone to aridity. The northernmost areas are more susceptible to aridity. These sub regions similarly exhibited high evapotranspiration, high temperature and low rainfall.

The pattern of aridity, which is a combination of the different contributing factors of temperature, precipitation variation and the rate of evapotranspiration across the state can be accounted for by climate variability and change, human activities like deforestation, excessive felling of trees, overgrazing by livestock and uncontrolled farming, all of which contribute immensely to soil aridity. *Abdulkadir et al, 2013* classified Katsina as one of the extremely deficient moisture effectiveness zones in northern Nigeria. Evidently, there is an increasing aridity in the state which accounts for the shrinking of surface reservoirs (*Sawa et al, 2015*).

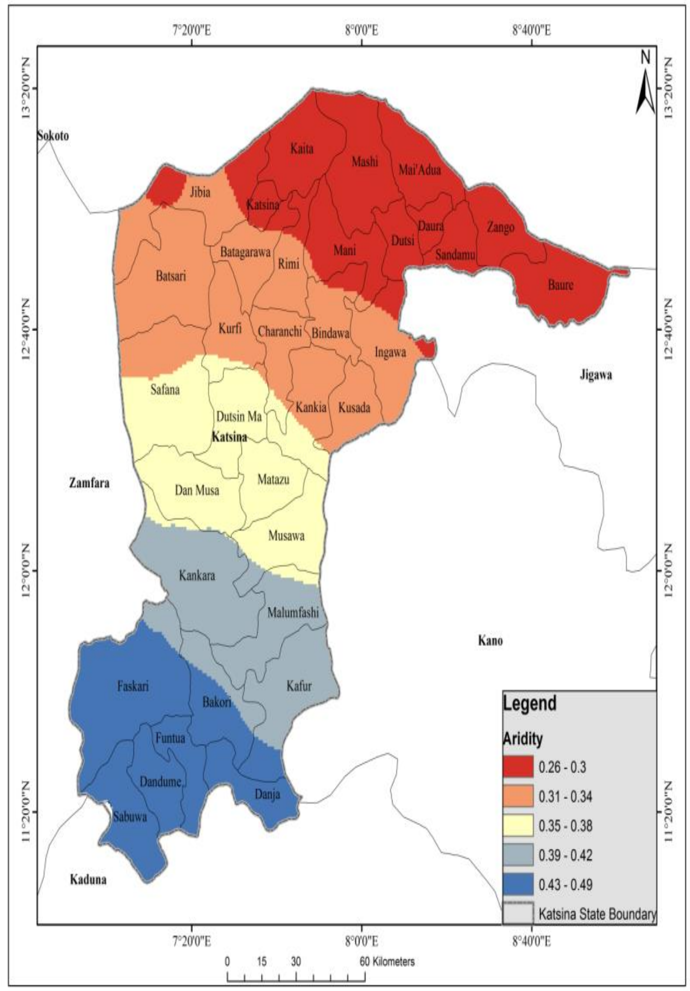

Fig 13:- Aridity map of Katsina state

S/N	Classes	Area (km^2)	Area (%)
1	0.26 – 0.30	6080.917	25.38166
2	0.31 – 0.34	6068.819	25.33116
3	0.35 – 0.38	4227.047	17.64363
4	0.39 – 0.42	3389.455	14.14754
5	0.43 – 0.49	4191.682	17.49602

Table 3:- Shows classes and area of aridity range in Katsina state

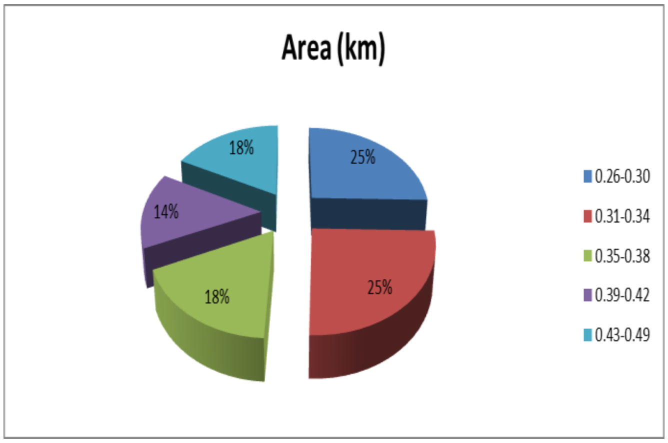

Fig 14:- Shows area in percentage of aridity classes

The temporal distribution of aridity in the state as shown in Figure 15 shows an evident increase in aridity in Katsina. It also shows a responsive behavior to changes in other climatic variables that influences aridity in the region; temperature, precipitation and evapotranspiration.

The last 6 years (2010 – 2016) of the study period, shows an increasing rate of aridity in the area of study. The trend shows that 1986 experienced the highest aridity while 1988 experienced the least aridity based on the UNEP Aridity Index. The study unveils the annual aridity rate with 1986 recorded as the driest year but the driest year recorded by Sawa *et al (2014)*, who based his study on a comparison of people's perception of the causes of climate variably, was 2000. This disparity in peak values of aridity could be due to the differences in the method of ascertaining the aridity index. While Sawa *et al* (2015) used the De Martonne's Aridity Formula; this study derived the aridity map from the UNEP Aridity Index formula.

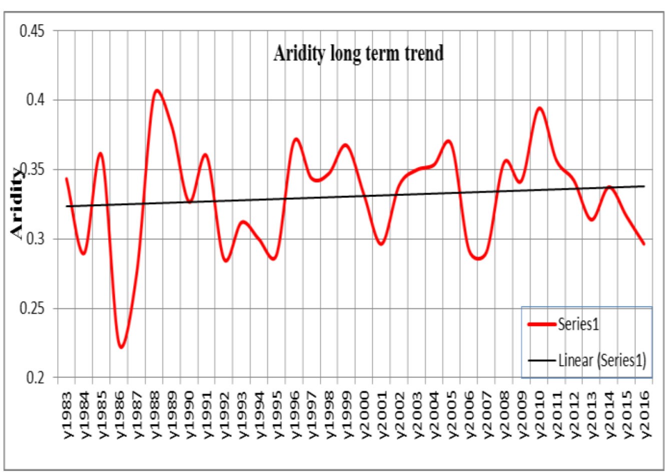

Fig 15:- Long term mean aridity trend of Katsina State

Figure 16 shows the temporal variation of aridity over Katsina during the study period. A negative anomaly was recorded in the first 6 years (1983 –1997) of the study period. The highest negative aridity anomaly was recorded in 1992 whereas the highest positive anomaly in aridity was recorded in 2011.

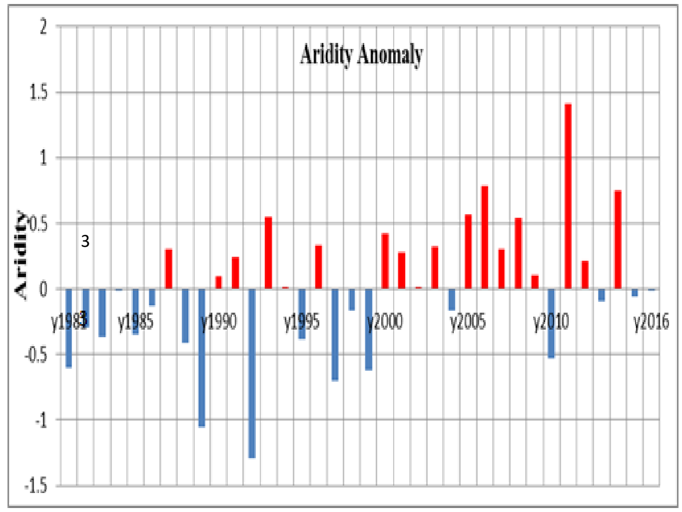

Fig 16:- Aridity anomaly trend of Katsina State

Aridity increase can arbitrarily affect the soil by altering soil PH. Soil PH increase with increasing aridity and temperature; tend to have negative effects on soil organic matter Jiao, F. et al., (2016). Decreasing soil pH with climatic condition can be attributed to the aridity induced decline of soil moisture and vegetation cover, both directly and indirectly. Reduction in vegetation cover combines with an increase in temperature to drive soil erosion that can remove fine, humus particles from the soil. Aridity induced reductions in availability of soil water will limit plants production capacity in Katsina state especially the northern part of Katsina state. The increasing aridity could further increase rate of evaporation into the atmosphere and would result in reducing the stream flow in the river, cause water shortage or insufficient water to livelihood and crops. This may also lead to lower yields of agricultural produce and the extinction of certain animal and crop species. Figure 3.11 shows an encroachment of the dryness in the northern part of the state into the relatively moist southern Katsina.

V. CONCLUSION

It can be concluded that rate of evapotranspiration and temperature is high in northern part of Katsina state with very low precipitation. There is high precipitation, low temperature and low evapotranspiration in southern part of Katsina that resulted to very low sensitive to aridity in this area, while high evaporation and low precipitation caused very high sensitive to aridity in Katsina north. Lower precipitation in Katsina north, together with high temperature, high evapotranspiration and low value of precipitation make the area prone to aridity, will have direct negative impact to livelihood and ecosystem in the northern part of the state. The climate variability and unambiguous rising in temperature and high rate of evapotranspiration has led to high degree of sensitivity to aridity in the northern part of Katsina due to human activities by logging the trees, bush burning, conversion of forested area to agricultural land are the factors responsible to these environmental problems (increase aridity in all part of the state). These problems will however, have significant negative impact on the vegetation cover and water deficiency that will be felt on rainfall distribution pattern, ecosystem and biodiversity in northern part of Katsina state.

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