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Trends in Aridity of the Arid and Semi-Arid Regions of Northern Nigeria

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Abstract
Aridity index (AI) is a numerical indicator of the degree of dryness of the climate at a given location. These indicators serve to identify and delimit regions that suffer from a deficit of available water, a condition that can severely affect the effective use of agricultural land and water resources development. The focus of this paper is to determine the trend and map out the aridity of the drought prone areas of northern Nigeria. Three decade's (1981–2010) annual rainfall and, minimum and maximum temperature records for 11 synoptic meteorological stations were collected from NIMET Office, Lagos and used. De Martonne's aridity index formula was applied to the data and aridity indices were derived for the region. The derived aridity indices were subjected to time series analysis and classification of the region into aridity zones was carried out based on the derived aridity indices from which an aridity map of the region was produced. Results of the time series analysis show that only Kaduna indicated a decreasing aridity while the other stations exhibit a significantly positive tendency towards increasing dryness. The region is classified into four aridity zones based on the aridity indices as: slightly humid zone (Kaduna and Zaria areas), moderately arid areas (Yelwa, Gusau, Kano and Bauchi), semi arid regions (Sokoto, Potiskum, Maiduguri) and the arid zone (areas around Nguru, Hadejia and Kano). It is concluded that the drought prone areas of northern Nigeria are witnessing increasing aridity which accounts for the shrinking of most dams and other surface reservouirs in the region. This has necessitated accessing of underground water from even the third aquifer at some locations. It is recommended therefore, that the dredging of all the existing dams in northern Nigeria be undertaken in order to improve the storage of more water, just as proper water policy for its sustainable use be formulated by Nigeria.
Keywords: aquifer, aridity, drought, dryness, Indices, time series

1. INTRODUCTION

Climate change constitutes a serious environmental problem facing mankind in the 21st Century. This phenomenon has serious repercussions on man and his environment. Prominent among consequences of climate change are drought in the hinterland on the one hand and flooding and inundation of coastal lands on the other; affecting agriculture and food security, altering both surface and underground water supply and devastating ecosystems among others. It is now a topical issue that has been recognized at both national and international fora as a threat to sustainable development.

The Inter Governmental Panel on Climate Change (IPCC, 2007), reported that by 2020, agricultural production including access to food in many African countries will be compromised by climate variability and change. The area suitable for agriculture, the length of the growing season and yield potentials, particularly along the margins of the arid and semi arid areas of Africa are expected to decrease. In some countries in Africa, yields from rain-fed agriculture could be reduced by up to 50%. This would further adversely affect food security and exacerbate malnutrition in the continent. This is a threatening report that needs immediate and proactive action plan towards addressing the issue of food security in the drought prone areas of the world. Increasing aridity is a manifestation of climate change and it threatens both surface and underground water resources for agriculture. This paper aims at determining the current aridity status of the drought prone areas of northern Nigeria with a view to mapping out the region into various aridity zones based on current available meteorological data.

2. THE STUDY AREA

The drought prone areas of northern Nigeria lie within the Sudano-Sahelian region roughly north of Latitude 10^0N, delimited by latitude 14^0N; and between longitudes 2^0 44' E and 14^0 42'E (Fig. 1).

The area stretches from Kebbi through Niger, to Bauchi, Kaduna, Gombe and Borno up north, covering states like Yobe, Jigawa, Kano, Katsina, Zamfara and Sokoto states. Only northern part of Adamawa state experiences drought so the study area covers a total area of about 240,000k^2.

The climate of northern Nigeria north of latitude 10^0N is of tropical continental (AW) type characterized by distinct wet (April – October) and dry (November – March) seasons respectively as dictated by the oscillation of the Inter-tropical Discontinuity (ITD). The study area lies on the High Plains of northern Nigeria between about 450m and 750m above sea level with granitic inselbergs such as the Kufena hills of Zaria

and volcanic plateaux like the Jos Plateau occasionally interrupt the monotonous High Plain.

3. METHODOLOGY

Total annual rainfall and maximum and minimum temperature records for three decades (1981 – 2010) for 11 meteorological stations in northern Nigeria were sourced from the achieves of the Nigerian Meteorological Agency, Oshodi, Lagos. Various aridity indices have been developed and used by different researchers. Prominent among these are Palmer (1965) drought index (PSDI); Bhalme and Mooley (1980) drought index (BMDI); Oladipo, (1985) and De Martonne's Aridity index. In this study, the data collected were subjected to the De Martonne's (1926) Aridity Index model calculated as:

$$\text{Iar} = \frac{P}{T+10}$$

where P is precipitation and T is mean temperature in degree centigrade.

Although there are a number of aridity indices determination that have been proposed, De Martonne (1926) has been chosen for its simplicity and appropriateness to the data available and its good approximation to observed reality. It has the obvious advantage of showing the transition from one area to another, although it may be criticised because of its empirical nature. Nevertheless, it serves as a useful discreet tool in illustrating the slow transition between arid, semiarid and humid environment. De Martonne (1926) gave a table of aridity values for easy classification of areas into different climate zones as in Table 1.

Graphs of aridity indices were drawn for each station. Five year moving averages and trend lines are shown on each of the line graphs so as to show the trend in aridity with time over the region. Finally, an aridity map of northern Nigeria based on the current aridity indices is produced by using the ArcGIS software.

4. RESULTS AND DISCUSSIONS

Trend in the pattern of annual aridity for each station is presented in Figures 2 to 12. Table 2 shows trend in aridity at Bauchi over three decades. The trend shows that the mid 1980s experienced the least aridity. The degree of dryness then rose gradually to a peak between 1998 and 1999, dropped to a lower level and increased again in to the highest peak between 2010. In general aridity at Bauchi is on the increase as exhibited by the linear trend line.

Figure 3 shows the pattern of aridity at Kaduna. The peak of aridity occurred in 2002. Kaduna is the only station in the region that has shown a negative trend of aridity within the study period meaning that aridity is on the decrease in the area.

Trend in aridity over 30 years at Yelwa is indicated in Fig. 4. Two Peaks of dryness occurred at Yelwa within the three decades- in 1994 and 1999. Linear trend line of dryness at Yelwa shows a positive trend implying that aridity is on the increase.

The aridity pattern at Zaria is given in Fig. 5. From this figure, it is seen that Zaria has within these three decades under consideration witnessed a single peak of dryness which occurred in 2006. The variation within annual aridity at Zaria is very small. In general, the trend exhibits an increasing tendency.

Figure 6 gives the trend in aridity at Potiskum. From this figure, it could be seen that aridity at Potiskum was more severe in 1986/88 but fluctuates gradually thereafter. The linear trend line however, shows a general increasing tendency toward aridity at Potiskum.

Trends in aridity at Maiduguri and Kano are given in Figures 7 and 8 respectively. These two locations have similar pattern of aridity. Each station has two peaks of dryness. While the years 2005 and 2007 recorded the peak dryness at Maiduguri, 1997 and 2000 are the driest years at Kano between 1981 and 2010. At both stations, the linear trend lines show positive trends implying that both Maiduguri and Kano are experiencing increasing aridity.

In Fig.9 is displayed the pattern of aridity at Gusau. Gusau had experience high degree of aridity in 1991 but peak of aridity is recorded in 1993. Linear trend line equation indicates that Gusau is also getting drier and drier.

Nguru, at the northern extreme of Yobe state experienced the peak of aridity in 1994 and has continuously been witnessing increasing dryness over the years as indicated in Fig. 10.

Katsina and Sokoto exhibit similar pattern of dryness as given in Figures 11 and 12 respectively. Both had experience a mono peak of aridity between 1981 and 2010. While the driest year was 2000 at Katsina the driest period at Sokoto occurred in 2009. In general aridity is on the increase at the two stations as indicated by the trend line and linear trend line equations of the two respective graphs.

The increasing aridity in the drought prone areas of northern Nigeria has a lot of implications for sustainable water management and rain-fed agriculture in the region.

5. Classification of the Region into Climatic Zones

De Martonne's Aridity Index Classification as given in Table 1 was applied to the calculated mean annual aridity

indices and each station was classified according to the table into the appropriate climatic region it belongs as given in Table 2.

6. Mapping the Aridity of Northern Nigeria

The study area was mapped out based on the degree of aridity. The map is shown in Fig. 13.

Table 2 and Fig. 13, clearly show that the drought prone areas of northern Nigeria could be classified into four zones on the basis of their degree of aridity. These are: the slightly humid zone which includes Kaduna and Zaria. The second zone is the moderately arid areas consisting of places like Yelwa, Gusau, Kano and Bauchi. The semi arid region forms the third zone and is made up of Sokoto, Potiskum, Maiduguri and large area of Jigawa state. Lastly, the arid zone at the extreme northern part of the country, around areas such as Nguru and Kano, where the climatic conditions are similar to that of the desert. In general annual aridity tends to increase northwards from the equator.

7. SUMMARY

De Martonne's Aridity Index determination was used in estimating the aridity of the drought prone areas of northern Nigeria. It was observed that except for Kaduna, all other 10 stations exhibit increasing aridity. Four climatic zones were identified in the region based on the aridity of the stations as: slightly humid, moderately arid, semi arid and dry or arid.

8. CONCLUSION

From the results of this study, it is concluded that the drought prone areas of northern Nigeria are becoming drier by the day. This has a negative impact on the water resources of the region. It is not surprising therefore that most of the dams in this region are shrinking, aquifers are drying up forcing the accessing of underground water from the third aquifer at some locations.

It is recommended therefore, that the dredging of all the existing dams in northern Nigeria be undertaken in order to store up more water, just as proper water policy for sustainable use of water be produced by Nigeria.

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References

Bhalme, H. N. And Mooley, D. A. 1980. Large scale drought/floods and monsoon circulation. *Mon. Wea. Rev*. 108, 1197.

De Martonne, E. 1926. Aréisme et indice. *Conptes Rendus de L'Acad. Sci*. Paris 182: 1395 – 1398

Intergovernmental Panel on Climate Change (IPCC) 2007. Projected effects of climate change from the fourth IPCC assessment. In: Population and Development Review, 33(2), 417 - 420

Oladipo, E.O. 1985. A comparative performance analysis of three meteorological drought indices. *J. Climatology*, 5, 655 – 664

Palmer, W. C. 1965. Meteorological drought. U. S. Weather Bureau Res. Paper No. 45.

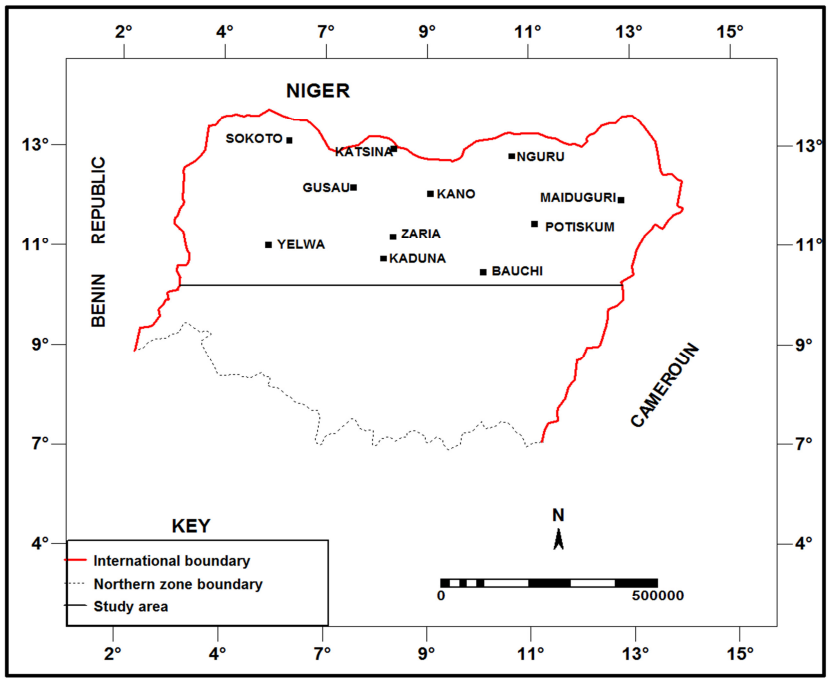

FIG. 1: MAP OF THE STUDY AREA AND SELECTED METEOROLOGICAL STATIONS.

Table 1: De Martonne's Aridity Index Classification

IDM	Climate Classification
I<14	Dry or arid
15≤I≤24	Semiarid
24<I≤30	Moderately arid
30<I≤35	Slightly humid
35<I≤40	Moderately humid
40<I≤50	Humid
50<I≤60	Very Humid
60<I≤187	Excessively humid

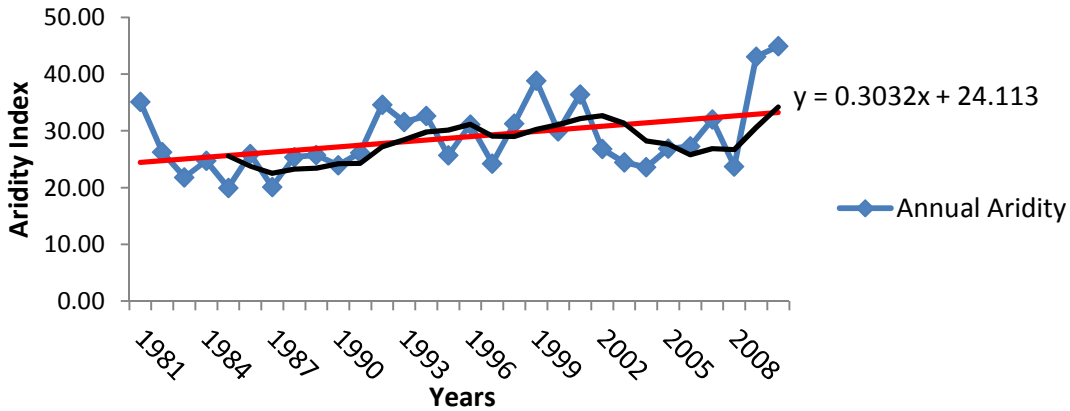

Fig. 2: Annual Aridity Index for Bauchi (1981 - 2010)

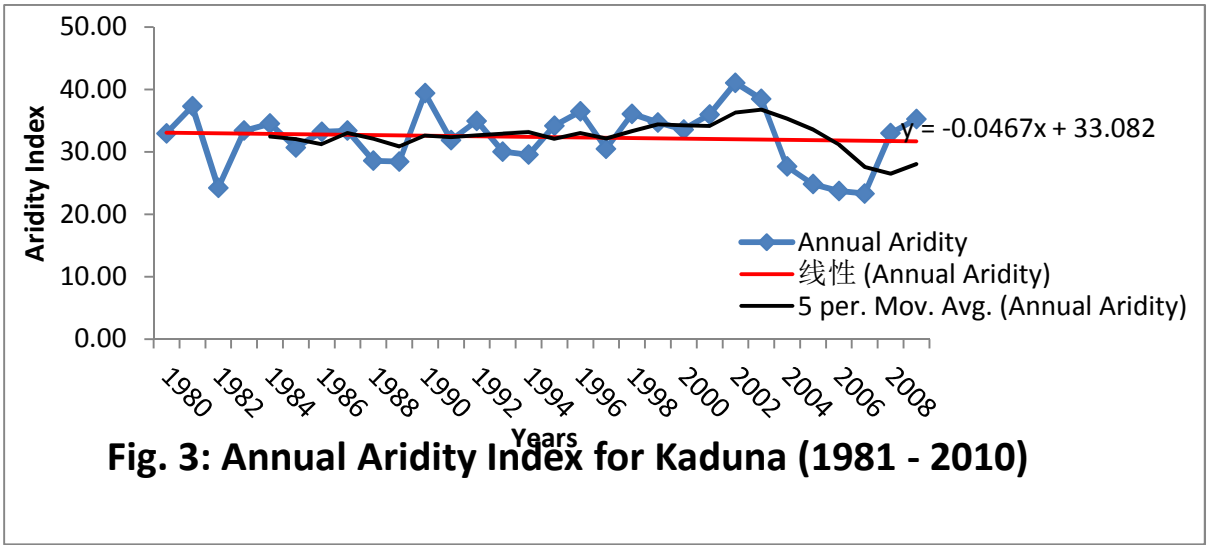

Fig. 3: Annual Aridity Index for Kaduna (1981 - 2010)

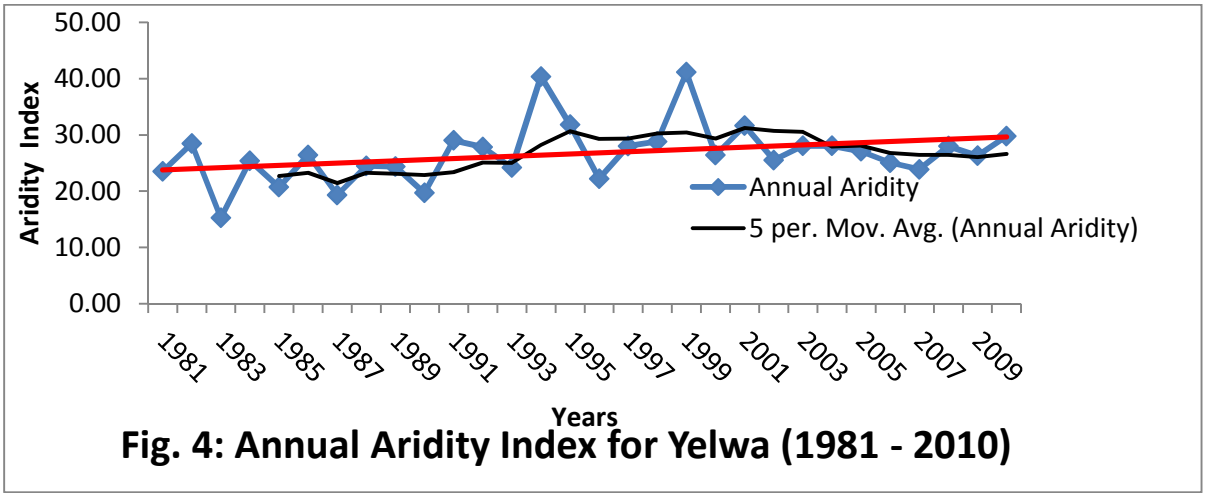

Fig. 4: Annual Aridity Index for Yelwa (1981 - 2010)

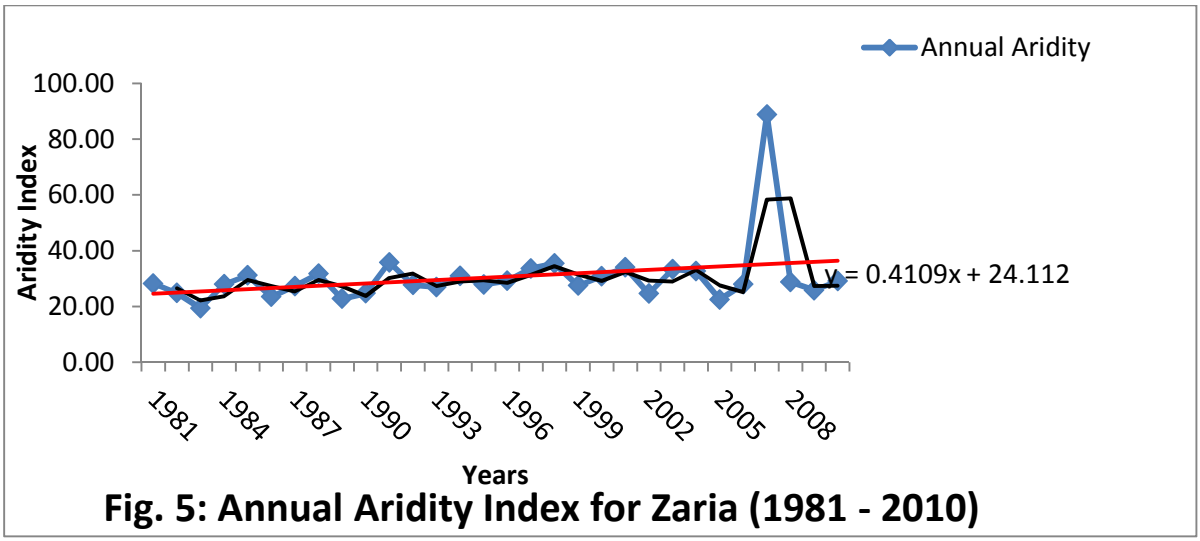

Fig. 5: Annual Aridity Index for Zaria (1981 - 2010)

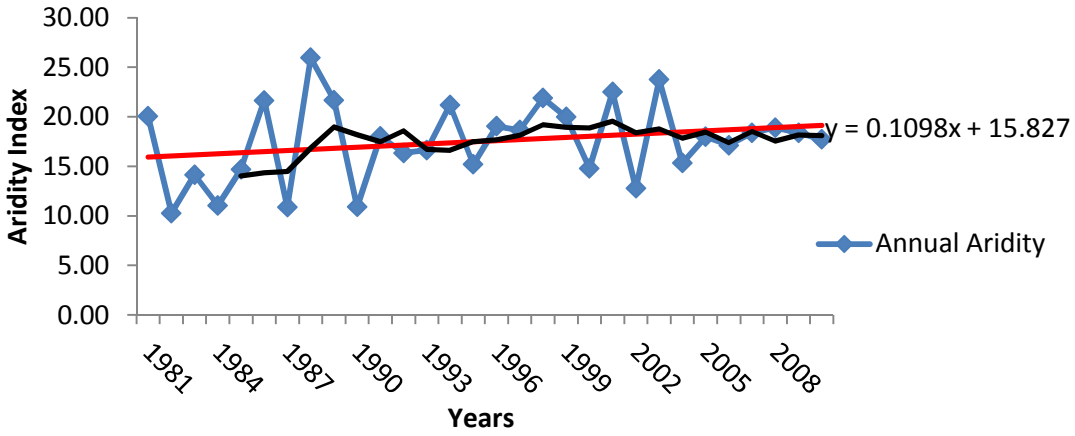

Fig. 6: Annual Aridity Index for Potiskum (1981 - 2010)

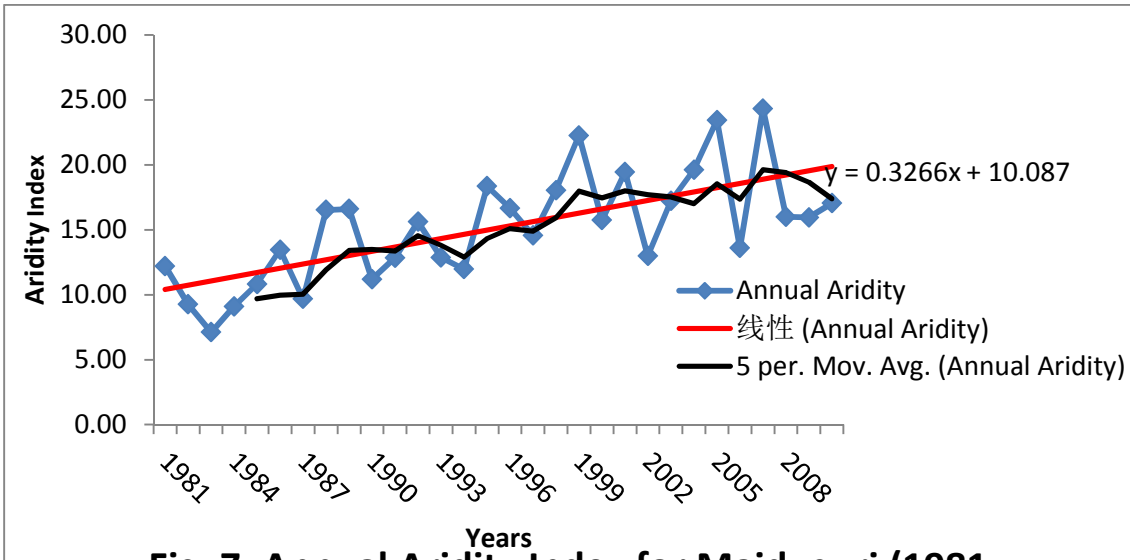

Fig. 7: Annual Aridity Index for Maiduguri (1981 - 2010)

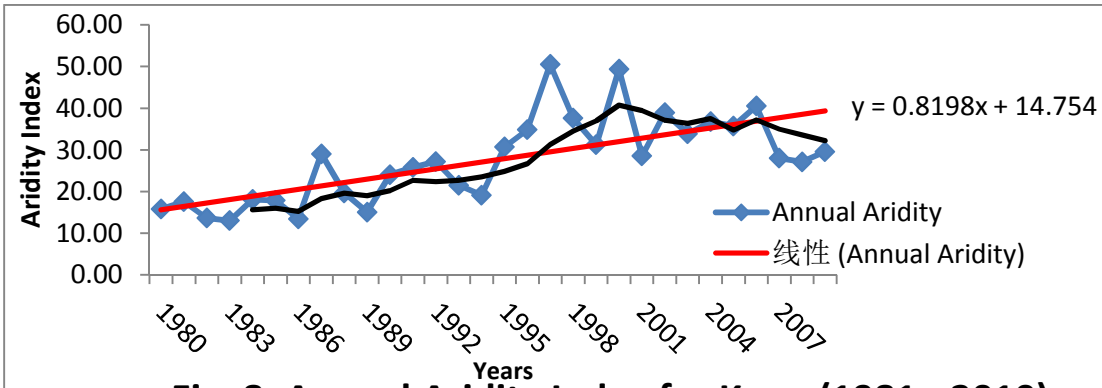

Fig. 8: Annual Aridity Index for Kano (1981 - 2010)

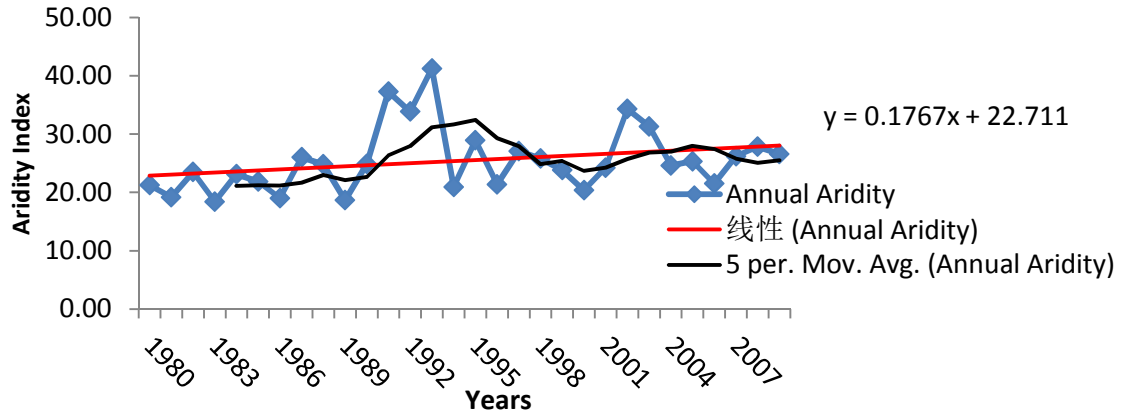

Fig. 9: Annual Aridity Index for Gusau (1981 - 2010)

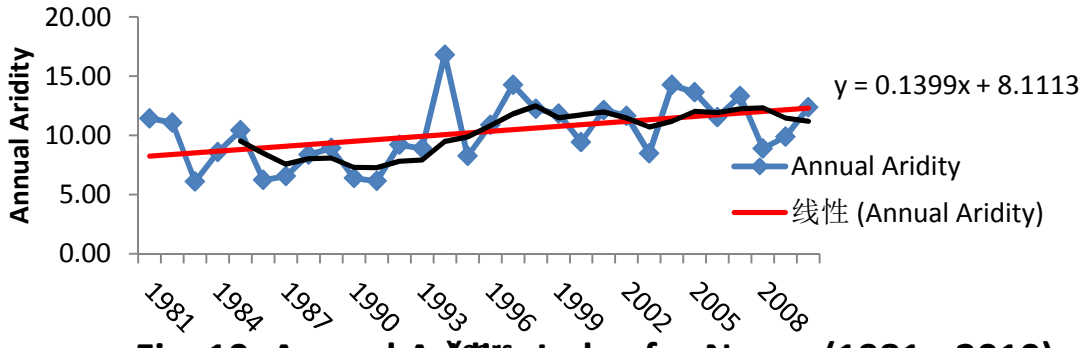

Fig. 10: Annual Aridity Index for Nguru (1981 - 2010)

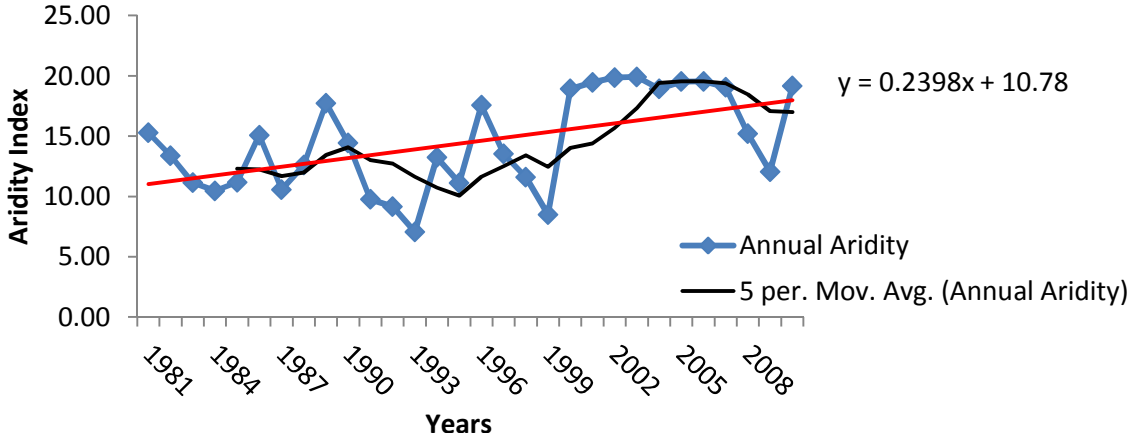

Fig. 11: Annual Aridity Index for Katsina (1981 - 2010)

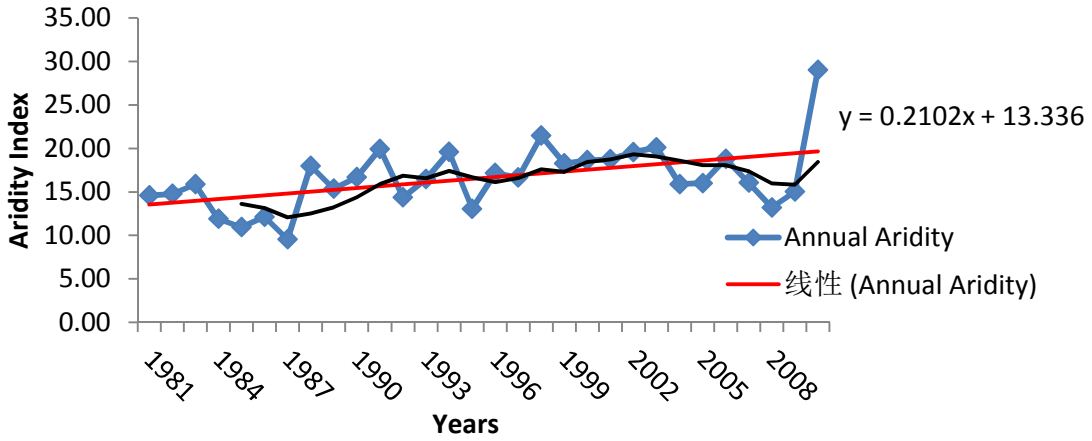

Fig. 12 Annual Aridity Index for Sokoto (1981 - 2010)

Table 2: Climatic Zones based on Mean Annual Aridity Index for the Drought Prone Areas of northern Nigeria.

S/No	Station	Aridity Index	Classification
1	Yelwa	26.7	Moderately Arid
2	Sokoto	16.59	Semi Arid
3	Gusau	25.45	Moderately Arid
4	Kaduna	32.36	Slightly Humid
5	Katsina	13.33	Dry or Arid
6	Zaria	30.48	Slightly Humid
7	Kano	27.46	Moderately Arid
8	Bauchi	28.81	Moderately Arid
9	Nguru	10.28	Dry or Arid
10	Potiskum	17.53	Semi Arid
11	Maiduguri	15.15	Semi Arid

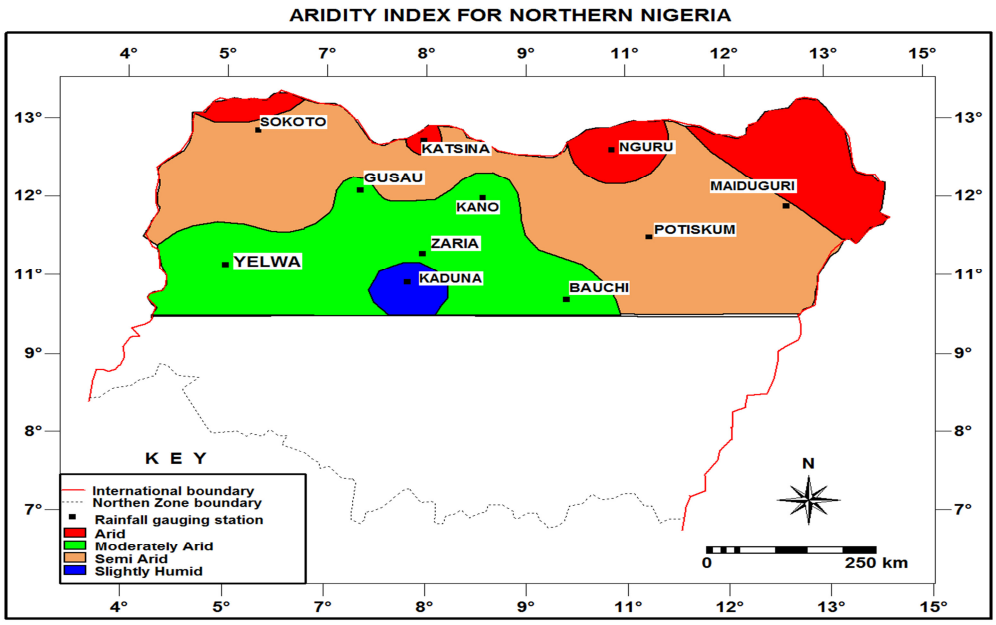

Figure 13: Aridity Map of the Drought Prone Areas of Northern Nigeria

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