AN ASSESSMENT OF RAINFALL IN KUMODUGU YOBE RIVER BASIN, NIGERIA.

Mohammed Bukar Ngamdu
Department of Geography, Yobe State University
P. M. B. 1144 Damaturu, Yobe State, Nigeria.

ABSTRACT

The paper is aimed at predicting rainfall in the Kumodugu Yobe basin by 2040 using three models used by the IPCC 4th assessment with the following procedure: looking at the climatology projected by each of the three models for the 20th century, looking at climatology projected at 2040 by each of the models and calculating the differences between the 21st and 20th century climatology's of the models. In Carrying out the studies one set of observed data and three sets of Models used by the IPCC 4th assessment were used; observed precipitation Data set, ncar models, giss model and the cccma models used for the studies. climate data analysis tools known as Climate Data Operators (CDO) was used in calculating the climatology of the data sets. The calculated climatology were plotted using the Grid analysis and display system (GRADS) software. The outcome of the studies shows that there would be considerably decrease in rainfall base he prediction by ncar model with 3 months of rainfall in July, October and November with two peaks compared to observed which gas one peak in August. The cccma model also has three months of rainfall with its peak in August and the giss models predicts that there would be rainfall for eight months over the area. The reduction in the rainfall over the area will lead to the reduction in the flow of the river and will consequently affect the livelihood of the people that depend on it in the drainage basin. The limitations of the study is the in availability of getting stream flow data of the Yobe river which is initially intended to be used in comparing the predicted rainfall and the flow of the river and the study would be of an importance for the proper planning by policy makers on issues related to rainfall in the area.

Keywords: *Rainfall, Prediction, Kumodugu Yobe*

Introduction

Nigeria has two distinct climate regions. The southern regions are of high humidity close the coast and receive high annual rainfalls while the situation in the north is almost the opposite of the situation in the south. The extreme north is entirely Sahelian, dry and of low annual rainfall. Rainfall in the region has considerably reduced over the years to the current average pattern of around three months per year (personal experience). The importance of rainfall to northern Nigeria is obviously attached to agriculture where more than 70% of region are subsistence farmers. The interest of this paper is however more on the ecological importance of rainfall in its relation to river discharges in the Kumodugu Yobe river basin.
In addition to ecological significance of the kumodugu Yobe River, for example its contribution as a source of the Lake Chad, part of which is in north-eastern Nigeria, it is also of significant socio-economic value to the population of northern Nigeria. The river has been dammed for irrigation and urban water supply. It is estimated that nearly 70% of its catchment is dependent on the river for their livelihoods including domestic water supply (IUCN, 2006). However, over the years, declining water levels in the river have been as a result of the declining rainfall and dams constructed in the upstream and in the long run this is expected to have serious implications for the numerous livelihoods dependent on the river. In this regard, it is therefore important that knowledge about the possible future flow patterns of the river is known that could be vital for key decisions, hence the aim of the paper. The paper considers possible

states of the river's flow by 2040 using three models used by the IPCC 4th assessment with the following procedure.

1. looking at the climatology projected by each of the three models for the 20th century
2. looking at climatology projected at 2040 by each of the models
3. calculating the differences between the 21st and 20th century climatology of the models

In addition to the model climatology of the 20th century in number 1 above, the paper will also look at the climatology of the observed rainfall for the same period, which will be used in describing the future state of the Yobe River due to similarity of the model to the observation.

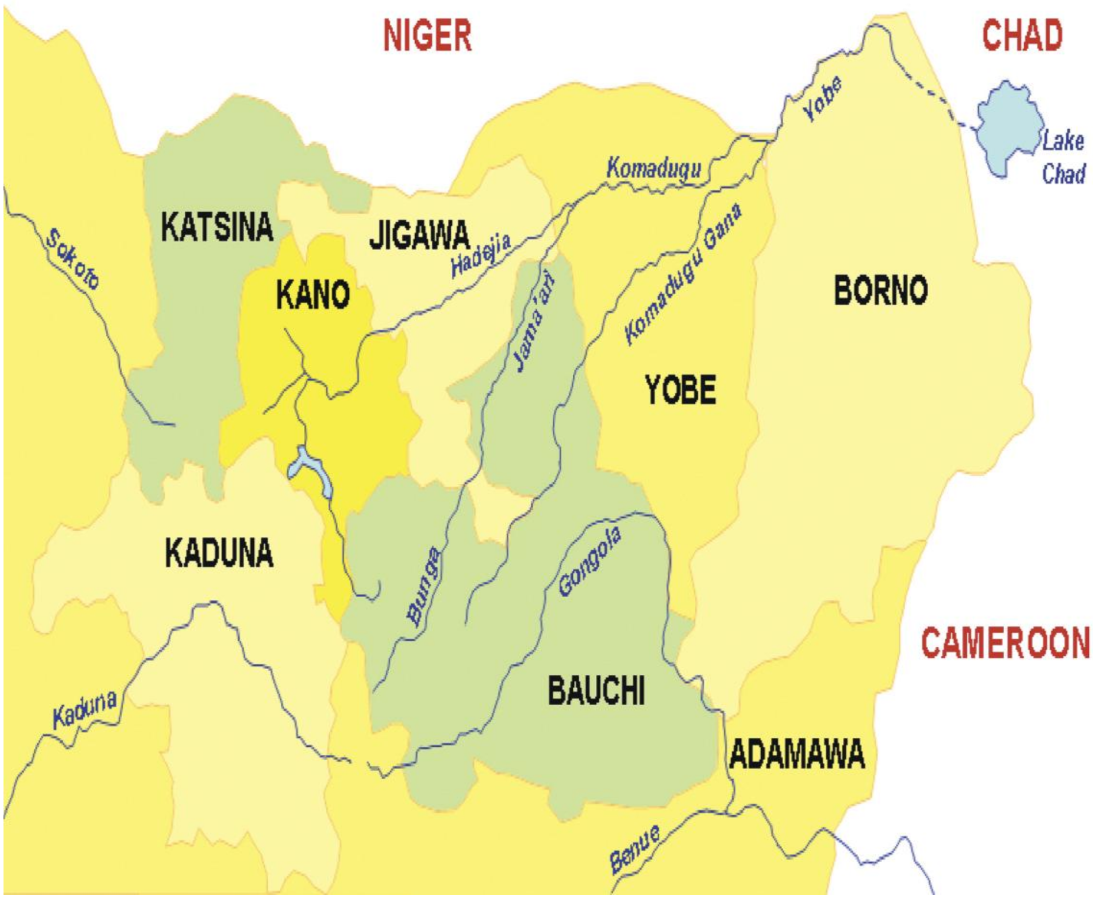
Rainfall in Nigeria

Rainfall varies across Space and time scale, In Nigeria there is variation across the various regions of the country and time. IPCC,(2007) projects that there would be variation in rainfall in the 21st century in the Sahel, the drier part will be more drier while the wetter parts would be more wetter. Variation in rainfall over the northern region of Nigeria is not strange because this part of Nigeria a significant portion of the Sudano sahelian ecological zone of west Africa. Most literatures (e.g.) on rainfall point to the fact that rainfall in Nigeria decreases as one moves from the south coastal region towards the north arid region. This variation in rainfall across the various regions accounts for the various ecological zone in Nigeria. Rainfall in the Northern part of Nigeria has a unimodal distribution, rainy season starts in June-July and reaches its peak in August and finishes rapidly in September to October. The Inter-Tropical Convergence Zone (ITCZ) is the most important climatic factor that influences rainfall in Nigeria (Ayoade 2004 and Adejuwon et al. 1990). It is the interaction of two major air masses; the Tropical Maritime (mT) and the Tropical Continental (cT), which meet along the (ITCZ). It is established that to the southern part of ITCZ, varying degrees of convective activity and precipitation takes place, whereas, little or no cloud development or precipitation occur to the northern part. In other words, rain falls mostly when an area is over-lain by the Tropical maritime (mT) air mass and ceases when the area is over lain by the Continental Tropical (cT) air mass. This makes the position of ITCZ a great determinant of most rainfall attributes in the region. Prominent among these attributes are the length of the rainy season. It, thus, appears as if the ITCZ is a rain-producing phenomenon in itself, but in reality, weather zones occur in a latitudinal spatial relationship to it (Iloeje 1981).

Ayoade, (2004) notes that the movement of the ITCZ is sun-synchronous with a six-week lag between the ITCZ's movement and the solar cycle; that the ITCZ reaches its northern limits between latitudes 19.6° N and 22.2° N in August, and its southern extremity between latitudes 5.2° N and 8° N in February. The study further notes that across Nigeria, rain falls mostly when an area is overlain by the mT air mass, and there is drought when the area is overlain by the cT air mass. However, other studies (e.g. Ishaku and Majid, 2010) have revealed that rainfall in Nigeria also depends other climatic factors other than increase of distance from the coastal region. They note that factors such as *relief, solar radiation, temperature*, and *winds* also contribute to the distribution of rainfall across Nigeria. They make the case of rainfall around areas of Jos Plateau, Mandara Highlands and Mambila Plateau, which receive high rainfall despite they are located far away in the northern Dry Region. However, a new climatic phenomenon of global influence, the EL Nino/Southern Oscillation is being stated as a significant cause of rainfall variability over space and time in West Africa (Chang 2002). ENSO teleconnection is defined in two ways, namely in association with the Sea-Level Pressure (SLP) and also in association with the Sea Surface Temperature (SST) Today, SST appears to be the most widely accepted parameter, by which ENSO investigated phenomenon produces a number of effects on the nature of rainfall.

Detail Description of Study Area

The part of the lake Chad basin within Nigeria is drained by five river systems. The largest of them, the Kumodugu Yobe system is the focus of this paper. Kumodugu Yobe Basin is situated in Nigeria between latitude 7°N- 14°N and Longitude 9°E - 13°E, covering an area of approximately 148,000 km^2, 57% of which lies in north eastern Nigeria and the rest in south eastern Niger. It represents approximately 35% of the conventional basin of Lake Chad. The Nigerian sector of Kumodugu Yobe Basin accounts for 95% of the basin's total contribution to the lake. The main rivers of the basin are the Hadeja and Jama'are Rivers that meet in the Hadeja-Nguru Wetlands to become the Yobe River that drains to Lake Chad. Historically, the Yobe River has been estimated to contribute only about 1-2% of the total flow into Lake Chad. The hydrology of the basin is complex: both the Hadeia and Jama'are river systems are "gaining" rivers until they cross the geological divide between the Basement Complex and the Chad Formation after which their flows decrease (Goes and Zabudum, 1998).



kumodugu yobe drainage basin: Source: Wikipedia (2012)

The hydrology of the internationally significant Hadeja-Nguru Wetlands where the two river systems meet is consequently very complex and has been the subject of numerous studies (Goes and Zabudum, 1998; IUCN, 2006). Seasonal flooding plays an essential role in maintaining the ecological system of the wetlands and enables both flood and recession farming to be conducted in the wetland region and along the lower reaches of the rivers. Artificial constraints upon the river systems have further increased the complexity of the hydrology. The Hadeja River system is thought to be more than 80% controlled by both the Tiga Dam constructed in 1974 on the Kano River and the Challawa Gorge Dam constructed in 1992 on the Challawa River (IUCN, 2006). These dams feed two large, formal irrigation schemes (Kano River Irrigation Project – KRIP, and the Hadeja Valley Irrigation Project – HVIP) near Kano and Hadeja respectively. Both also contribute to the Kano City Water Supply. The Jama'are River system is presently uncontrolled but plans do exist to build a dam at Kafin Zaki. Plans are already being considered for building a structure at the upstream end of the Nguru Wetlands to control the destination of the wetland's flow.

The basin lies largely within the Sudan Savannah agro-ecological region of West Africa. Its uplands are in the Northern Guinea zone while its floodplains in the north, mark the beginning of the Sahel.

Climate in Kumodugu Yobe Basin is determined by the movement of the ITCZ just as it is applicable to other parts of Nigeria, the ITCZ contact with the ground arrives from the southwest in April or May and passes back over the basin in September to October. During these transitional months the wedge of humid air is too thin for convective rain but line squalls are common providing intense, localized rainfall of short duration. For agricultural requirements, this type of rainfall is unreliable, because the ITCZ may either become stationary or oscillate before moving on. From June through September, the humid air mass is usually thick enough for convective rain, with the highest concentration generally occurring in August. The months of November to March are almost totally dry throughout the basin and river flows are essentially zero by the end of March. During this period, the cT air mass overlies the basin and winds, locally known as Harmattan (Ayuba and Dami, (2011).

Moving from the upland to the lowland areas that is from the upstream to the downstream portions of the rivers, a notable south-north decrease in rainfall and marked increases in both evaporation and evapotranspiration rates as a result with increase in temperature. That simply translates to saying that water demands by agriculture are considerably higher in the northern part of the Basin than in the south. Put differently, crops with low water requirement would do better in the northern part of the basin than crops with high water requirement.

It has generally been stated that River flows are determined by rain within its catchment area and, in the case of long rivers, by water imports from remote wetter areas, for instance river Niger that takes that has its source Guinea highlands . There is a large variability of flow. In a number of rivers a decreasing flow tendency has been observed in the last decades. For example, since 1970 the mean discharge of the River Niger at Koulikoro has nearly halved from its levels in the 1960s. Like Lake Chad, many other lakes have also contracted (Howell & Allan, 1994).

Methodology and description of data and Models

In Carrying out the studies, one set of observed data and three sets of Models used by the IPCC 4th assessment were used; observed precipitation Data set, ncar models, giss model and the cccma models used for the studies.

Precipitation Data

Precipitation data used is produced by the climate research unit (CRU), University of East Anglia and distributed by the British Atmosphere Data Centre. The data are gridded and collected stations worldwide where each grid value is a mean of all stations within the grid box and it is a high resolution monthly global data produced and distributed by the British Atmosphere Data Centre.

NCAR Pcm1 MODELS

The Parallel climate model (Pcm1) were produced by the National centre for atmospheric research Based in United States (US).it is a federally funded research and development centre devoted to service, research and education in the atmosphere and related physical, biological and social systems. it is sponsored by the U.S government , other national government and the private sector. The 20c3m is of global coverage for the period of 109 years (1890-1999), the sresa1b is also of global coverage for the period of 99 years (2000-2099) IPCC ,(2007).

CCCMA cgcm3 1 MODEL

The Coupled Global climate model (cgcm3) is the third version of the Canadian Centre for climate modelling and analysis (cccma) based in Canada, it makes use of the same components as used in the earlier versions. The 20c3m is of global coverage for the period of 150 years (1850-2000), the sresa1b is also of global coverage for the period of 299 years (2001-2300) which has a resolution of 3.75 degrees IPCC ,(2007).

GISS MODEL.

The NASA Goddard Institute for Space Studies (GISS) is a laboratory in the National Aeronautics and Space Administration's Goddard Space Flight Center's Earth Sciences Division and is based in the Morningside Heights neighborhood of New York City. It's objective is prediction of atmospheric and climate changes in the 21st century and combines analysis of comprehensive global datasets with global models of atmospheric, land surface, and oceanic processes. The model has a horizontal resolution of 8° latitude by 10° longitude, nine layers in the atmosphere extending to 10 mb, and two ground hydrology layers. The model accounts for both the seasonal and diurnal solar cycles in its temperature calculations. The 20c3m is for the period of 119 years (1880-1999), the sresa1b is also for the period of 99 years (2000-2099) IPCC ,(2007).

Methodology

Observed Precipitation data over a period of 30 years from 1961 to 1990 was extracted from climate research unit (cru) data set for the study area which is Kumodugu Yobe Basin, situated in Northern Nigeria between latitude 7^oN- 14^oN and Longitude 9^oE - 13^oE, covering an area of approximately 148,000 km^2. Also modelled Data over a period of 30 years for both 20^{th} century, from 1961 to 1990 and 21^{st} century, from 2011 to 2040 for the study area were extracted from the three models used for the study. Namely, Parallel climate model from National center for atmospheric research (NCAR pcm1), Coupled Global climate model from Canadian center for climate modeling and Analysis (CCCMA cgcm3) and Goddard institute for space studies from National Aeronautics and Space Administration (GISS model). The models were randomly selected from the models used by IPCC 4^{th} assessment report. The extracted data for the observation, 20^{th} century and 21^{st} Century model data were used to calculate the climatology, which is the monthly average of rainfall for the entire period over the study area using the climate data analysis tools, Climate Data Operators (CDO) with the CDO cammand cdo –r -fldmean –ymonmean sellonlatbox. The calculated climatologies were plotted using the Grid analysis and display system (GRADS) software. The calculated climatology for the observed and the three 20^{th} century models were plotted using the grads software to observe the differences in precipitation between the actual observed data and the three modelled data used in the study. Also the calculated climatology for the three 21^{st} century models used in the study were plotted using grads to observe the difference between precipitation over the study area by the three models used for the study. The subtracted difference of the climatology of the models were calculated using the CDO by subtracting the 20^{th} century calculated model climatology from the 21^{st} century calculated model climatology for all the three models used in the study. The calculated climatology difference in precipitation over the study for the three models were plotted using the Grid analysis and display system. Three plotting were used for the interpretation of the result obtained for precipitation pattern in the kumodugu Yobe drainage basin in relation to flow of the river system and other activities carried out in the area that depends on the flow of the river system in the basin.

Results and discussions.

The results obtained Shows that the time series analysis of climatology for the observed rainfall over the study area for a period of 30 years 1961 to 1990, it reveals that there is variation in rainfall over the period, the highest rainfall is observed in the August with about 7.4mm which reflects what is actually observed in the area, he months July 6.2mm, September 4.8mm,June 3.8mm, May 2.2mm, October 1.2mm, April1mm and March 0.2mm respectively. Based on what the graph shows it means the flow of the river system will be high during the months of July, August and September being that these are the months that records high rainfall and is the only source of water to the river system. During these period economic activities such as fishing and irrigation that rely on the flow of the river will be at its peak.

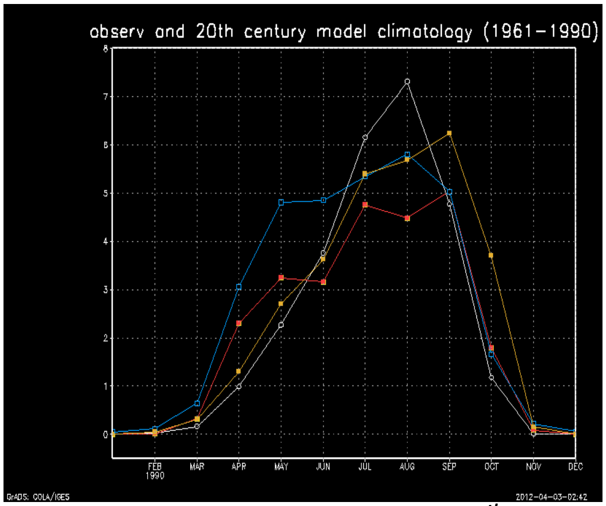


Fig.1. Climatology for Observed and 20th century Models

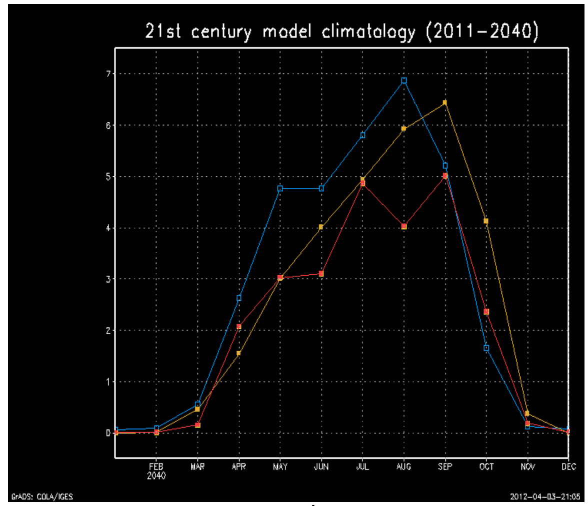


Fig.2. Climatology for 21st century Models

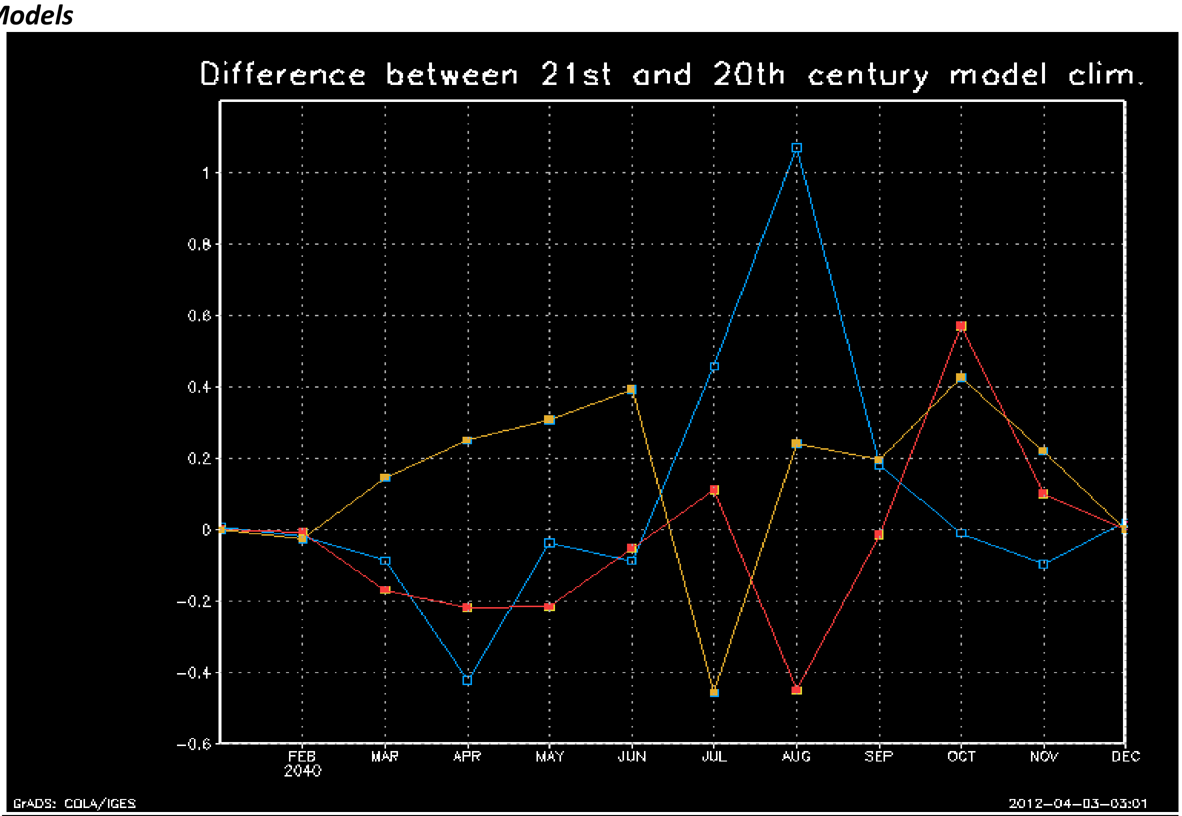


Fig.3. Climatology difference for 20th and 21st century Models.

White = Observation. **Blue** = cccma model.
Red = ncar model. **Yellow** = giss model.

From the information obtained from the studies figure one shows the calculated climatology for the observation and the three models used in the studies, that is ncar pcm1,cccma cgcm3 and giss model for a period of 30 years, 1961 to 1990 over the study area .The analysis reveals that the highest rainfall for the observation is in the month August, While for the models are, giss model has its peak in

September, compared to what is obtained in the real observation, cccma has its peak August which is in the same month with the actual observation but less in amount and it shows that ncar model has double peak in the month of July and September respectively. It means that there is little difference between the 20th century models and the observation being that all have their highest rainfall within the months of July, August and September which reflects the actual months that High rainfall is recorded over the study area being a semi-arid area. These are the period in which the flow of water in the river system is at its Peak being that rainfall is the only source of water to the river system over the area. it also shows that during these period economic activities would also be high being that the river is the single most important economic resource with more than 90% of the population depending on the river resources for their livelihood (Aminu *et al*., 2006).

Figure 2 shows the time series climatology for 21st century models used in the studies which reveals the prediction of rainfall over kumodugu Yobe basin for the period of 30 years 2011 to 2040. The result shows that the peak predicted period with the highest rainfall in the month of August by the cccma model with rainfall of 6.8mm, giss model predict its peak in September with rainfall of 6.4mm and ncar model with double peak in the month of July and September. It also shows that high rainfall will be received in the basin between the months of July, August and September, it means base on the prediction of the models during these period the flow of water in the river system will be at its peak being rain fall is the only source of water to the river in the drainage basin.

Figure 3 Shows the calculated difference between the 20th century and the 21st century climatology for the three models used in the study .**giss** model reveals that rainfall there will be rainfall for b months of March, April, May, June, August, September and November over the drainage basin, it predicts that there would be no rain in July compared to what is obtained in the observation. It means that there would be surplus water in basin which will favour economic activities of the area such as fishing, farming which all depend on the availability of water in the basin. Base on the prediction of **cccma** model there will be rainfall only for three months of June, July and August while there will be no rain for the rest of the months. It also has a similar pattern with the observed rainfall of the area which also shows the months of June, July and August as the months with rain been observed. The climatology difference for **ncar** model also shows that there will be rainfall over the area for three months on July, October and November, it also reveals that there will be two peaks of raining season within the year in the months of July and October which is not experience in the area, these situation is only experience in the southern coastal region of Nigeria where they have double maximum periods of rainy season with a short break in the month of August. the implications of the low rainfall predicted by the models, the economic activities of the area will be affected being that economic activities of the basin are mainly water dependent: agriculture, fishery, animal husbandry, and commerce. Another consequences of the reduction in rainfall as predicted by the models in the study area is the invasion of typha weeds which leads to the blockages the water way in the drainage basin, typha weed is favoured by the changes in the flow of the water in the drainage basin, Goess, (2001) noted typha weeds in the Yobe basin could be traced back to the early part of the 1990s when it was first observed in the Hadeja barrage. The weed thrives well in shallow (less than 1.5 m deep water) but more permanent water bodies. It hardly survives in seasonal rivers with marked period of dryness. It has been observed that the construction of dams, which diverts wet season flows for releases during the dry season, has created favourable condition for the development the invasive weed. He further stressed that among the circumstances that favour the invasion of the weeds in the area include the absence of fast flowing water due to silt blockages and aquatic vegetation growth, continually moist soil due to wet season diversion and dry season releases from dams and relatively nutrient rich water due to nutrient rich irrigation water from the fields.

Conclusions

The attempt to assess the rainfall over the kumodugu Yobe river basin in Northern Nigeria, the basin is drain by two rivers of kumodugu Yobe and kumodugu Gana. The Yobe river flows into the lake Chad, it is a is a sub catchment of the lake Chad Basin, The flow of the river in the basin over the year has considerably reduced due to the damming of the rivers up stream and coupled with the effect of climate change that affects the rainfall over the sahelian region, IPCC,(2007).The climatology of the basin was calculated using observed rainfall data and three models used by IPCC 4th assessment which were randomly selected. The outcome of the studies shows that there would be considerably decrease in rainfall base he prediction by ncar model with 3 months of rainfall in July, October and November with two peaks compared to observed which gas one peak in August. The cccma model also has three months of rainfall with its peak in August and the giss models predicts that there would be rainfall for eight months over the area. The reduction in the rainfall over the area will lead to the reduction in the flow of the river and will consequently affect the livelihood of the people that depend on it in the drainage basin. The limitations of the study is the in availability of getting stream flow data of the Yobe river which is initially intended to be used in comparing the predicted rainfall and the flow of the river and the study would be of an importance for the proper planning by policy makers on issues related to rainfall in the area.

REFRENCES

Adejuwon J.O, Balogun EE, Adejuwon S.A (1990) On the Annual and Seasonal Pattern of Rainfall Fluctuations in Sub-Saharan West Africa. International Journal of Climatology, 10: 810-848.

Aminu A., J.M. Jibrin, A. Suleiman, A. Mustapha, (2006) Improving Land and Water Resources Management in kumodugu yobe Basin: Socio-Economic and Environmental study; FMWR-IUCN-NCF kumodugu Yobe Basin Project, Kano

Ayoade, J.O. (2004) Introduction to climatology for the Tropics. Spectrum Books Limited, Nigeria.

Ayuba ,H. K. and Dami, A. (2011) Environmental Science, An Introductory Text. Apani Publications, Kaduna, Nigeria.

Goes B.J.M. and Zabudum A.N. (1998). Hydrology of the Hadejia-Jama'are-Yobe River Basin: 1996-1997. Hadejia-Nguru Wetlands Conservation Project, IUCN - The World Conservation Union, Nigeria.

Goes, B. J. M. (2001) Effects of damming the Hadejia River in semiarid northern Nigeria—lessons learnt for future management. Regional Management of Water Resources (Proceedings of a symposium held during the Sixth IAHS Scientific Assembly at Maastricht, The Netherlands, July 2001). IAHS Publ. no. 268, 2001.

Howell, P. P. & Allan, J. A. (eds.) (1994) The Nile - Sharing a Scarce Résonne. Cambridge University Press. Cambridge.

http://en.wikipedia.org/wiki/Yobe_River

IUCN, (2006) Water Audit for Kumodugu Yobe basin, Final Report. Afremedev Consultancy Services Limited.Nigeria.

Iloeje NP (1981) A New Geography of Nigeria. Revised Edition, London: Longman Publishers.

IPCC, (2007) The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Ishaku, H.T. and Majid, M. R. (2010) X-Raying Pattern and Variability North-eastern Nigeria: Impact to access water supply : Water Resource and protection, Science Research.

.