AN ASSESSMENT OF FUTURE SURFACE WATER LEVELS OF THE LAKE CHAD AND CONSEQUENCES ON LIVELIHOODS

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ABSTRACT

The Lake Chad has once been one of the largest Lakes in the world but has undergone a drastic reduction in size to less than one tenth of its original size as a result of climate variability and anthropogenic activities. The ultimate aim of this paper is to assess the future surface water levels in the Lake Chad with respect to projected climate, specifically rainfall, river discharge and the impacts on the livelihoods. The study is limited to the period 2021-2050 using 1971-2000 as the base period. The assessment is based on precipitation model data of the IPCC's AR4 simulations and two EUWATCH project model data sets of discharge and Lake Chad surface storage. The results of the predictions indicate that there will mixture of increase and decrease in precipitation, river discharge and surface water level of the Lake Chad by 2050 but majority reveals reduction rate which will increase the impact on the basins livelihood dependants. This reduction is expected to negatively affect the livelihoods of the dependent communities thus, in the end, policy options are proposed to lessen this situation.

Keywords: Lake Chad, surface water resources, climate change projections, Livelihoods.

Introduction

Water as a resource is a renewable and an essential component of an ecosystem which is made available by the natural hydrologic cycle which occupies a special place among other natural resources. Water is the basis of life on earth and the main component of the environment and an essential element for human life. Water is also fundamental for sustaining a high quality of life and for economic and social development. Water exist in different states and sources, it is available on the surface as surface water in seas, oceans, rivers, lakes, ponds, stream and canals. It is naturally replaced by precipitation and lost through evaporation, evapotranspiration, subsurface seepage and discharge to other water bodies. It is also available beneath the surface as ground water in the soil and rocks as aquifers with its natural input as seepage from surface water and its output as springs, seepage to oceans and extraction by plants through their roots. Its total amount in the hydrosphere consists of the free water in liquid, solid, or gaseous states in the atmosphere, on the earth's surface, and in the earth crust (Shiklomanov, 2000). It further states that the hydrosphere contains a huge amount of water, about 1,386 million cubic kilometres (km3). However, about 97.5% of this amount is saline water found in the various world's seas and oceans, and only 2.5% is fresh water used for consumption. The greater portion of the fresh water (68.7%) is in the form of ice and permanent snow cover in the Antarctic, the Arctic, and mountainous regions. Fresh groundwater comprises 29.9% of fresh water resources. Only 0.26% of the total amount of fresh water on the earth is concentrated in lakes, reservoirs, and river systems. There has been significant impact of climate variability on water resources because of the connection of climate and the hydrological cycle which leads to regional variation of being that increase in temperature leads to increase in evaporation which leads to increase in precipitation. As a result of climate change and variability the dry parts of the world keeps on becoming drier and wet becomes wetter, this leads to occurrence of extreme hydrological events of drought and flood (IPCC, 2007). According to Oki et al, (2006) Water scarcity is expected to become an ever-increasing problem in the future, for various reasons. First, the distribution of precipitation in space and time is very uneven, leading to tremendous temporal variability in water resources worldwide. It has also been stated as a result of the impact of climate change and variability, climate models simulations for the 21st century are consistent in projecting precipitation increase in high latitudes areas of the world and the tropical areas, it also shows the likelihood in the decrease in precipitation in the sub-tropical and lower Mid latitude regions of the world (Bates, et al., 2008). It further stressed that water availability and river runoff will be affected as a result of the projected changes in the climate in the middle of the 21st century

A great deal of uncertainty remains with regard to the impacts of climate change in the western region in relation to rainfall, although there is general agreement that temperature will rise across the region (IPCC, 2007). The model projections of rainfall over West Africa are inconsistent, or weak, with some simulations suggesting that the region will become drier, and others predicting increases in rainfall over the 21st century. More needs to be done to apply appropriate regional scale models to aid the prediction of climate change in this region. However, in general, climate change scenarios predict reduced rainfall and increases in evaporation in most parts of the region. More specifically, an increase in the rate of desertification is predicted for the sahelian zone in the long run.

Water resources in the Lake Chad have been impacted by climate change as a result of climate change and development pressure that result from damming of upstream rivers that contributes water to the lake. According studies carried out by Barbier, (2002) and Thomas and Adams, (1999) states that the upstream construction of dams has affected the water that reaches the Lake Chad basin. Examples are the construction of Maga dam in Cameroon on the Lagone Chari River system and Hadeja/Jamare dams on the Yobe River in Nigeria.

The ultimate objective of this study is to assess the basin, in particular and changes in surface water levels in the lake from the present with respect to projected surface storage and river discharge by mid-21st century and what consequences this could have on livelihoods dependent on the lake.

Research Aims

The Lake Chad has been known for livelihoods dependants for years in the four riparian countries of Nigeria, Niger Chad and Cameroon that borders it. However, the decline in its surface water levels as a result of natural and anthropogenic activities and the resulting impacts on the livelihoods, livestock and local economies has been alarming prompting numerous efforts by the concerned governments through the Lake Chad Basin Commission, which is an intergovernmental organisation of countries in the Lake Chad basin which coordinates activities related to the Lake Chad basin (Musa et al., 2008).

The ultimate research question is therefore: *How can future climate projections related to the Lake Chad basin help improve livelihoods dependent on the Lake Chad?*

The sub research questions therefore become:

- How well do watch model data represent the current surface water level of the Lake Chad?
- What will be the surface water level of the Lake Chad by 2050?
- Will there be any significant change in the surface water level of the Lake by 2050?
- What are the important livelihoods currently dependent on the Lake?
- How will these livelihoods be affected by the possibility of change of the water level in the lake by 2050?
- What policy options can best ensure that the livelihoods are less impacted negatively?

Data description.

In carrying out the studies, three sets of data are utilised. The first set of data is for surface storage representing the amount of water stored in the basin measured in kilogram per square metre (kg/m^2), the second data set also utilised is the discharge data of the two major rivers that contribute water to the lake chad basin, Yobe river and Chari River respectively which both represent the amount of water they contribute to the basin measured in cubic meter per second (m^3/s). The third data set utilised for the study is data for precipitation which represents the amount of total rainfall received within the basin measured in measured in millimetre per day (mm/day).

Methodology

The objective of this the section is to give the details of steps taken in the analysis made to arrive at the precipitation, river discharge and surface storage projections for the study area. The research is done for the time period of thirty years, 1971 t0 2000 for the 20th and 2021 to 2050 for the 21st century respectively. The methods used for the study are divided into two sections, section one is entails of lab assessment for climate prediction that answers the first three sub research questions of the study that seeks to look at what is the present water level of the lake Chad, what will be the level of water by 2050 and weather if it should be any significant changes by 2050.the second section of the methods used in carrying out the study is literature based methodology that ,make use of relevant literature from journal, textbooks, government documents and any other policy document related to the study to answer the three sub research questions of the study that looks at the activities that take place in the lake Chad region on which the people depend on for their livelihood, the possibility of the livelihood been affected by possible disappearance on the water body as a result of climate change and other human related activities that can affect the free flow of water in to the lake and over extraction and utilization in the future by 2050.

Precipitation calculation of climatology

In carrying out the study, rainfall projection of the area was carried out been one of the source water to the lake. The basin is divided in to the two main contributory rivers of the lake Chad basin, Yobe River and Chari River respectively. The area extracted for Yobe is longitude 10^0 to 13^0 and latitude 12^0 to 14^0 while for the Chari river is Longitude 14^0 to 17^0 and latitude 10^0 to 13^0. Two sets of precipitation data are used. Rainfall climatology for the period of thirty years (1971-2000) was extracted from the observed cru data obtained from the climate research unit of East Anglia university. The second set of precipitation data used for the extraction of the climatology used in the study is the IPCC fourth assessment report model output data for 20th and 21st century. Data from IPCC models were used, the models a selected randomly without using any criteria. The same run were selected for all the models used in the study, thirty year climatology as done for the observed precipitation data was calculated for all the ten 20th century models for the same period of 1971-2000. Calculation of the future climatology of the study was done using the ten selected 21st century models for the time period of 2021 – 2050. Difference of the two calculated climatology's is calculated by subtracting the historical 20th century calculated climatology from the future 21st century climatology using.

Discharge data climatology calculation.

In carry out the research, river discharge data for the two major water contributory rivers to the lake chad basin are utilised. observed discharge data for Yobe and Chari river, recorded in Bagara (Diffa) gauge station on the Yobe river and the Chari river discharge recorded in N'djamena gauge station. The second set of data used for the study is the 20^{th} and 21^{st} model output discharge data used by the Eu watch which was run through five hydrological models. From the observed discharge data for both Yobe and Chari river, thirty years climatology 1971 to 2000 was extracted which represents the monthly average rainfall for thirty years over the two discharge points of Yobe river and Chari river. The calculated observed discharge climatology is used to validate the result of the calculated discharge climatology for the five models used for the study. Discharge model data for 20^{th} and 21^{st} century was downloaded from the eu watch website. Discharge climatology was calculated for the period of thirty years for both the present and future models data set, 1971 to 2000 for the 20^{th} century and 2021 to 2050 for the future discharge data for the three GCMs used in the study. The climatology is calculated for the discharge point in Chari river lat. 12.75 and long. 14.75, lat 13.75 and long. 13.25 for Yobe river. The discharge climatology difference of the present and future models was calculated by subtracting the present climatology from the future climatology. The subtracted climatology is used to determine the state of the discharge of the two rivers,.

Surface storage calculation of climatology.

In carrying out the study, surface storage for the study area (lat. 12.5 – 14.5^0 and lon. 13 – 15^0 , Lake Chad) is calculated using data downloaded from the eu watch website for the time period of 1971 to 2000 for the 20^{th} and 2021 to 2050 for the 21^{st} century respectively. Surface storage climatology is calculated by subtracting the 20^{th} century surface storage climatology from the 21^{st} century climatology to arrive at the rate of change in the future either increase or decrease in the surface storage of the lake Chad.

<u>Results and discussion</u>

This section presents the results of the prediction of precipitation, river discharge in the two sub-basins of Yobe and Chari and the surface storage representing the water level of the Lake Chad by 2050. It is all aimed at assessing the future of water resources in the Lake Chad basin and its possible expected consequences it may have on the livelihood of the basin's population.

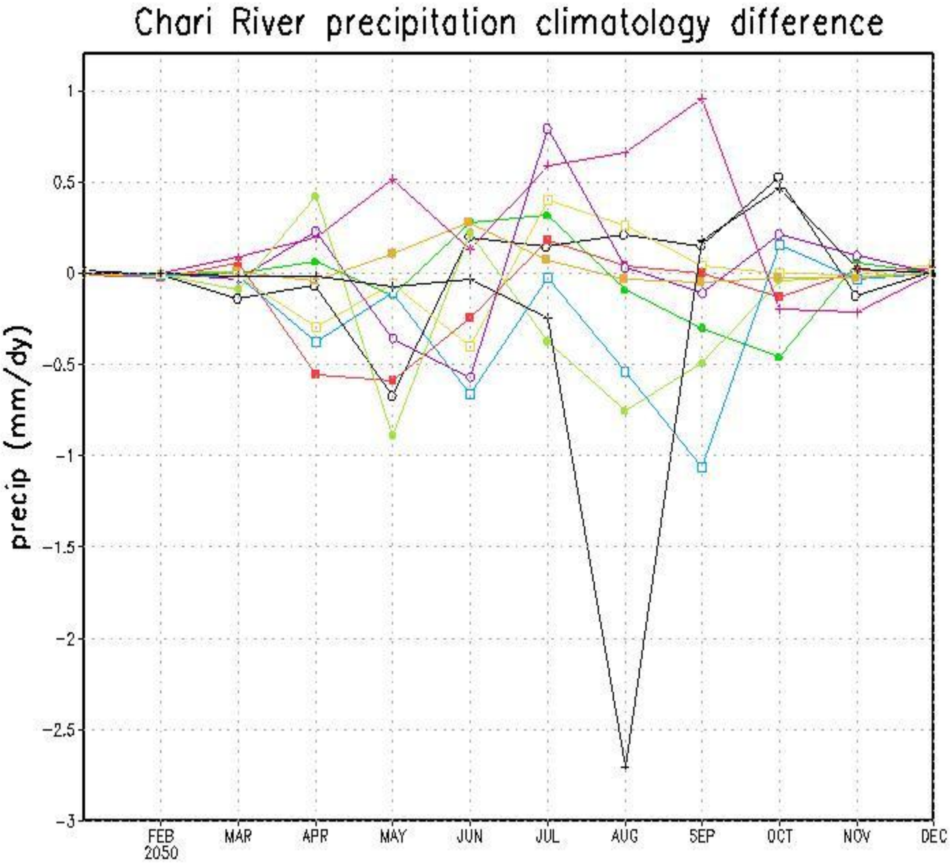

Figure 1

From the results obtained from the analysis of the prediction of rainfall in the Chari basin, Figure 1 of the study presents the difference of the calculated climatology of the ten 20th and 21st models rainfall of the area. It shows a mixture of increase and decrease in rainfall. The implication of the predicted future reduction in rainfall over the Chari river basin is that, it will negatively affect the volume of water that will be discharged to the Lake Chad from the sub basin. This will consequently affect the surface storage of the lake by 2050, which result in the continual shrinkage of the lake Chad being that Chari is the major water contributor, this shows that there will be more impact on the livelihoods of the basin's population.

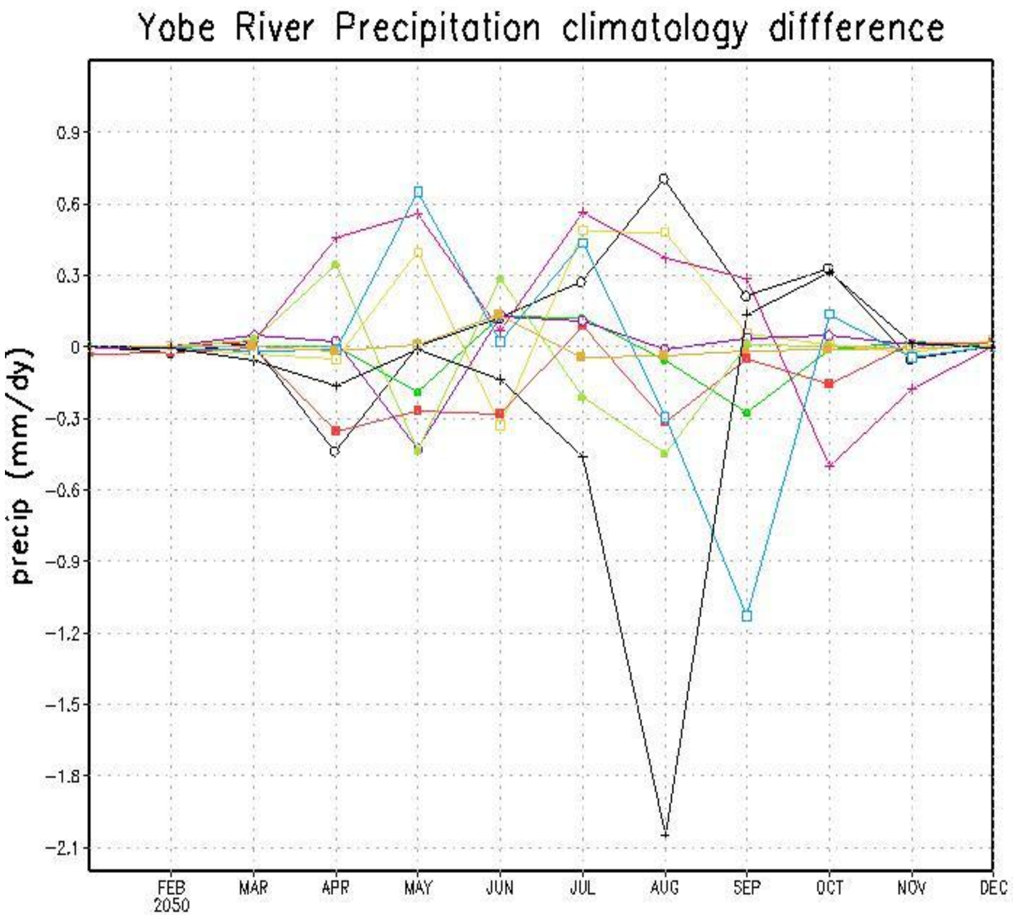

Figure 2

Figure 2 of the study presents the difference of the calculated climatology of the ten 20th and 21st models rainfall of the area. It reveals that there will be a slight reduction in the amount of rainfall in the future, the reduction is insignificant. NCAR model has predicted a drastic reduction of rainfall of about -2.0 mm in August whereas five shows a slight reduction of less than 0.6 mm and GFD models predict an increment of 0.7 mm in August. Based on the result of the prediction in the Yobe sub basin, it shows that there will be a slight reduction in the amount discharge that will run in the river being that rainfall is the single determinant of rainfall in the basin area. Rainfall is highly variable in the basin as it is determined by ITCZ as it reaches the basin in April and passes back over the basin in September (IUCN, 2006).

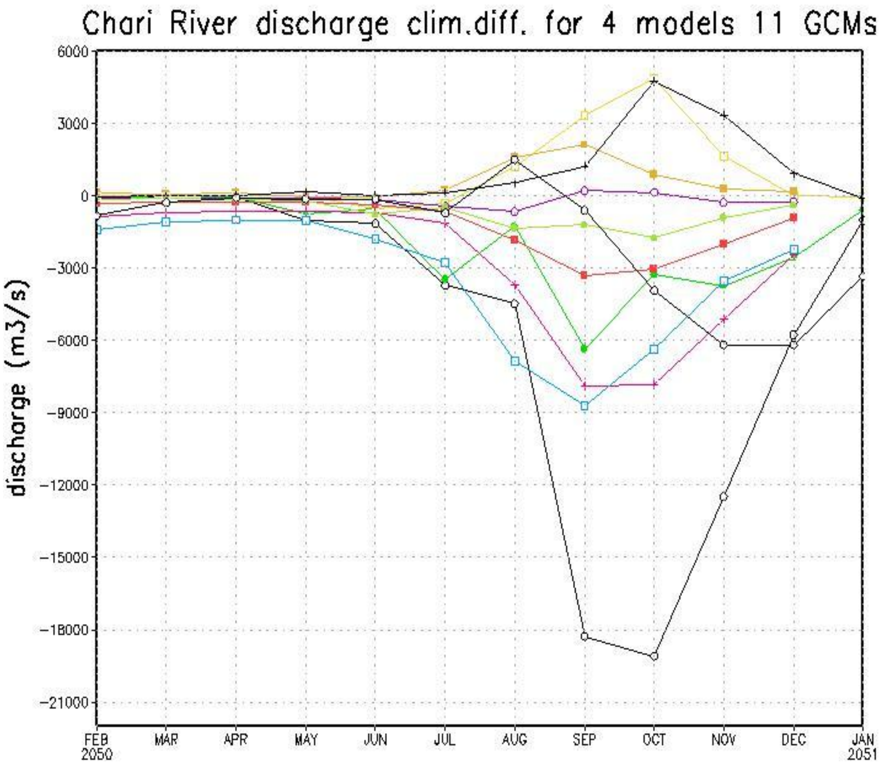

Figure 3

Figure 3 also clearly reveals a combination decrease and increase but majority shows a significant reduction in the flow rate of the river by 2050 for the majority of the GCMs used for the study. LPJML IPSL shows the highest reduction of -19000 m3/s in October and LPJML CNRM shows the highest increase of 4500 m3/s also in October, both of them are the same models but of different GCMs. It is observed that the reduction in the discharge rate of the river is as a result of the predicted reduction of rainfall in the sub basin base on AR4 models, and human activities that led to the alteration of the flow pattern of the river system upstream.

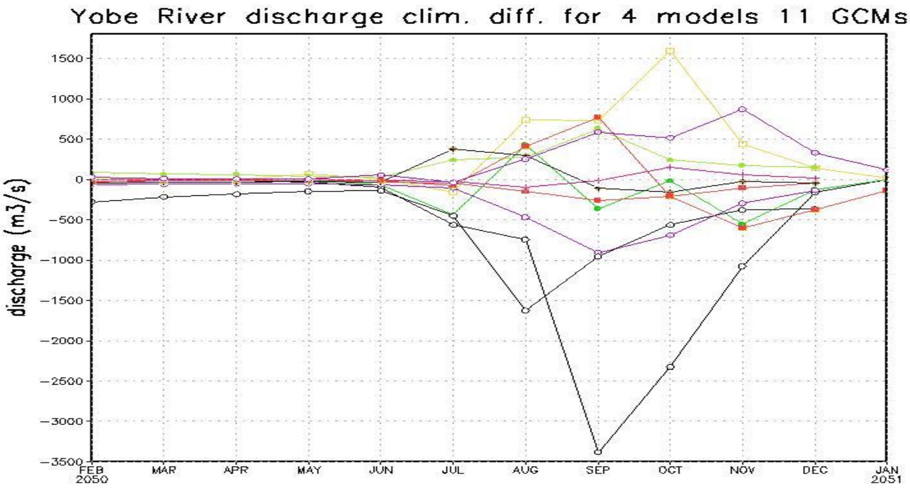

Figure 4

From the subtracted difference of the 20th and 21st century discharge climatology of Yobe river presented in Figure 4, it shows a significant combination of increase and decrease in the discharge rate with LPJML CNRM model showing a significant increase of 1500m3/s in the month of October, whereas the models with the highest discharge decrease of -3450 m3/s is LPJML IPSL in of September, followed by WATERGAP IPSL with a decrease of -1600 m3/s in August. This result of river discharge from the Yobe sub basin reveals that there will be a significant reduction in the rate of the river discharge in the future, which is a reflection of what has been predicted by IPCC AR4 models for precipitation. This will consequently affect the water level in the Lake chad, which leads to more adverse effect on the livelihood dependants of the basin. This discharge data used for the prediction is only available from the EUWATCH for two models used by the project, which gives limited the chance for wider comparison of the model predictions.

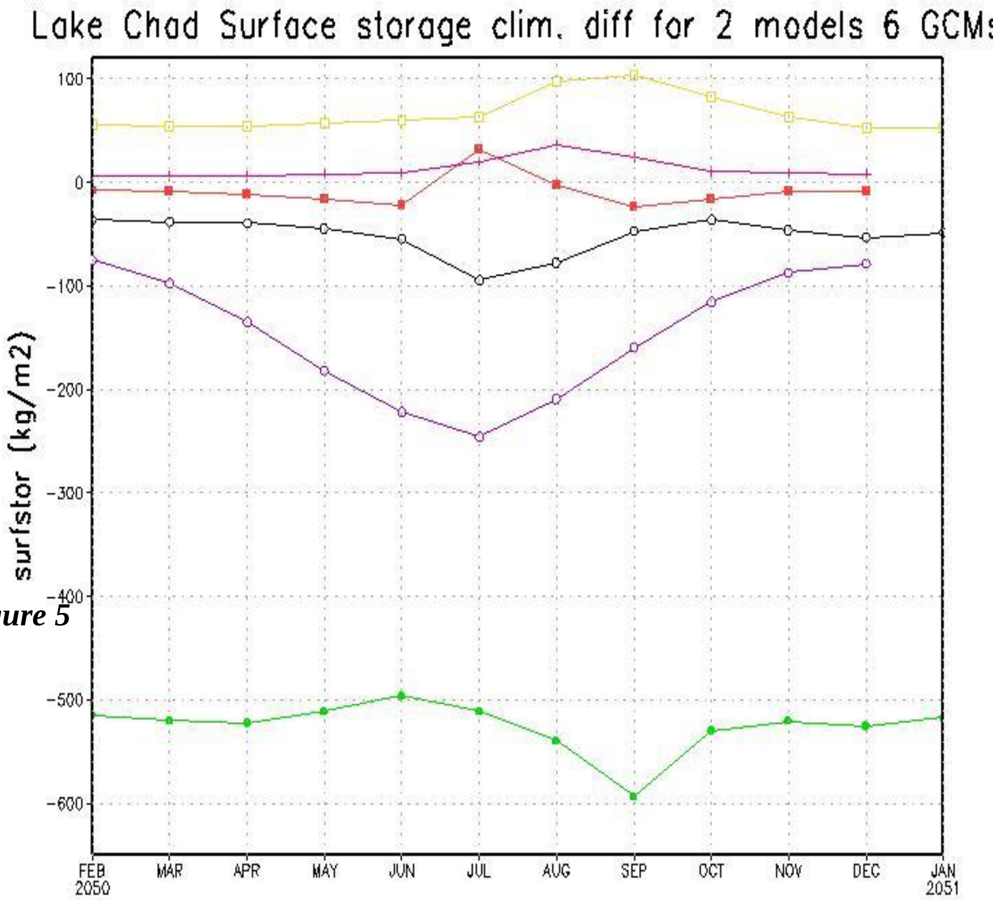

Figure 5

Figure 5

Figure 5 presents the climatology difference for the six GCMs of WATER GAP and LPJML models. The calculated difference reveals that three of the GCMs predicted a complete decrease in the water level of the lake, while WATER GAP ECHA model predicted an increment of 30 kg/m2 in the month of July and all the other months shows a reduction in the water level, the remaining two GCMs predicted an instrument in the water level with the highest level of 100 kg/m2. Base on the water level climatology difference of the six GCMs used in the study, it reveals that there will be an insignificant reduction in the water level of the Lake by 2050 which will affect the livelihood over 10 million people in the basin.

Livelihood dependants of Lake Chad and Lake's reduction consequences

Rainfall predicted over the two river basins that discharge water into the lake has shown a decrease by 2050 and the discharge of the two rivers calculated also shows a reduction in the flow of water from the two rivers by 2050, equally the surface storage level has also shown a reduction in future levels of the lake. Based on that, it has been concluded that the water level of the lake Chad will be reduced by 2050 base on the prediction used in the study which will affect the livelihoods dependants of the basin, Water in the form of rivers, lakes or streams is a source of human interdependence and supporting livelihoods. With increasing population and development there will be more pressure on existing water supply in Africa and the vulnerability of the populations depend on these resources continue to grow (Coe and Foley, 2001). For thousands of years Lake Chad have been a centre of development , trading and cultural exchange between the peoples living in the north of the Sahara and those to the south. It is a vitally important and the largest wetland in the Sahel region of Africa, it serves as a source of economic livelihood to as many as 30 million people , most of whom are farmers, fishermen and livestock breeders living the catchment areas of the four riparian countries of Chad, Niger, Nigeria and Cameroon (Musa et al., 2008). Agriculture is the main economic activity of approximately 60% of the basin's population (Odada, et al., 2003) with most common crops as cotton, sorghum, groundnuts, millet, cassava, rice and onions. Most farming in the Basin is rain-fed, cultivated and harvested by hand, and grown without the use of fertilizers and other agro-chemicals. Mixed cropping is widely practiced and rice is grown by both traditional and modern methods. Cotton is the most important cash crop in the region and is grown in southern Chad, northern Cameroon and Nigeria. Fishing activity in the Lake chad is an important livelihood of more than 10 million leaving around the basin. Fisheries of Lake Chad also provide the bulk of the protein requirement for the rural community. Additionally, fish supply from the region is known to account for over 70% of fish product traded in large urban markets of southern Nigeria, namely Onitsha, Enugu, Lagos, Ilorin and lbadan (Neiland et al., 1997). According to UNEP, (2004), animal husbandry in the lake chad region is a very important economic activity, the meat from livestock makes a major contribution to the dietary needs of the population. In the lake chad sector of Nigeria, Bono state is the livestock center in west Africa.

According to FAO, (2012) as a result of drying up of the lake water and the deterioration of the production capacity of the basin has affected all activities leading to forced migration and increased pressure on the natural resources and conflict between the population. As a result of the changing environmental conditions different sorts of conflicts among people around Lake Chad who compete for the increasingly scarce water and land resources continue to affect their livelihoods.

Policy options for Lake Chad

The Lake Chad basin is being faced with two broad challenges of water management, they are how to control the unsustainable water consumption in the basin and a way of enhancing water allocation mechanisms. Several approaches and solutions can be applied aimed at saving the 30 million people, who rely on the Lake for their livelihoods. Some of the necessary options needed to be applied to the lake Chad as mention by UNEP, (2004) are the option of inter basin water transfer project, which is a project that entails the diversion of 900 m3/s of water from the Ubangi, the major tributary of the Congo River in a navigable canal. The project comprises, construction of one dam at Palambo to regulate the flow on the Oubangui River in CAR; construction of one main canal to transfer water by gravity from Palambo Dam reservoir to Fafa-Ouham River in CAR and to link the two basins; river channel improvement works from Ouham River through Chari to Lake Chad. The project will have multiple goals of river transportation, electricity generation and to develop irrigation and agro industry in the region. It will also serve as a control measure to drought in Chad and a barrier against Sahara desert encroachment. The project requires huge financial commitment from the basin countries and donor agencies, if carried out it will boost economic and livelihood activities of the LCB being that they are all centred on the availability of water in the Lake. Environmental Impact assessment of the Project has already been carried out and agreement for the project has been arrived by the heads of State LCBC at their 14th summit held in Ndjamena in May 2012. The success of this solution is however not guaranteed knowing that it is highly subjected to future climate variability over the region. In this regard, and the fact that the creation of the artificial channel is a political decision that may not come to pass. (Kombe, 2009).

Another important policy options for the revival of the basins lost glory, is the implementation of the water allocation agreement between the basins member states for the for the purpose of effective management of the basin water resources. UNEP, (2004) states that a draft of the water allocation agreement has been prepared by FAO but was not ratified in 1969, a revised version was represented in the council meeting but is still under discussion by the member states of the LCBC. The benefit of the water allocation agreement in the basin is to increase water availability to the down streams users who rely on it for their livelihoods and to maintain the level of water in the lake during times of low precipitation, there by water users will not be able to abstract at a level that will cause flows to drop. The agreement will set minimum flow rates along the Kumodugu Yobe and Chari-Lagone subsystems so as to save the livelihood dependants on the water in the LCB. Policy options are also recommended for the sub basins of the Lake Chad such as the maintenance and improvements for safety and improved efficiency of dams and stream flow in the Kumodugu Yobe sub basin, subsidies to local irrigation farmers and implementation of water conservation methods. To combat sand dunes and the reversal of degradation trends in the basin (UNEP, 2004).

Conclusions

This main aim of this study is to assess the surface water levels of Lake Chad in 2050 as a result of changes in rainfall patterns and river discharge from present condition in order to determine what impact change could have on livelihoods directly dependent on the lake.

Results from the precipitation assessment indicates that the surface level will be lower in 2050 as compared to present conditions. This result generally agrees entirely with the assessment using EUWATCH data. The seemingly accurate nature of the results from the precipitation assessment notwithstanding, it is beset by the fact that it considers only precipitation and not other factors such as sub-surface runoff and evapotranspiration all of which contribute to river discharges, hence surface water levels. The EUWATCH data on the other hand captures all conditions necessary to estimate the water level. To measure the strength of the methods applied in estimating the future surface water level, a historical assessment is also conducted in which the surface level is estimated from recorded discharges of the lake. This result is compared with assessments based on the historically, 1971-2000, simulated precipitation of the same models used for the future assessment. An assessment based on EUWATCH data of the same historical period is also performed. Both results agree with the assessment based on the recorded discharges, thus giving strength to the methods applied to the future assessment. The general conclusion is, therefore, that the policy proposals given in order to ameliorate the impact on livelihoods are in the right direction.

REFERENCES.

1. Barbier, E. B., 2002. Upstream Dams and Downstream Water Allocation: The Case of the Hadeja Jama'are Floodplain, Northern Nigeria. Paper prepared for the Environmental Policy Forum, Centre for Environmental Science and Policy, Institute for International Studies, Stanford University.

2. Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., 2008. Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

3. Coe, M. T. and Foley, J. A., 2001. Human and natural impacts on the water research of Lake Chad basin. Journal of Geophysical Research. Vol. 106 No. D4 , 3349–3356.

4. FAO, 2012. Focus: on Lake chad. A system under threat. Available from: http://www.fao.org/nr/water/news/chad.html. Accessed on: 20/08/2012

5. 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.

6. IUCN, 2006. Water Audit for Kumodugu Yobe Basin. Afremedev consultancy services limited. Abujan Nigeria.

7. Kombe, M. D., 2009. The Project for water Transfer from Ubangi to lake Chad: Adaptive Water Management in the Lake Chad Basin. Addressing to Current Challenges and Adapting to future Needs. Stockholm: World Water Week.

8. Musa, I. K., Bila, M. And Mahaman, C., 2008. Saving the Lake Chad. Proceedings of Sirte Roundtable. Libya.

9. Neiland, A. E. et al., 1997. Characterization of the inland fisheries of N.E Nigeria including the Upper River Benue, Lake Chad and Nguru - Gashua Wetlands. University of Portsmouth Research paper pp.120

10. Odada, E. O., Oyebande, L. and Oguntola, J. A., 2003. Experience and lessons brief for lake Chad. Nigeria.

11. Oki, Taikan, Shinjiro and Kanae, 2006. Global Hydrological Cycles and World Water Resources. Science (313): 5790. 1068-1072.

12. Shiklomanov, I. A., 2000. Appraisal and assessment of world water resources. Water International, Volume 25, Number 1, Pages 11-32.

13. Thomas, D. H. L. and Adams, W. A., 1999. Adapting to Dams: Agrarian Change Downstream of the Tiga Dam, Northern Nigeria. World Development Vol. 27, No. 6.

14. UNEP, 2004. Fortnam, M.P. and Oguntola, J.A. (eds), Lake Chad Basin, GIWA Regional assessment 43, University of Kalmar, Kalmar, Sweden.