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RESEARCH ARTICLE

The Combined Effect of Human Influence and Climate Variability on Water Bodies. A case study of receding Lake Chad in Sub-Saharan Africa.

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Abstract

Lake Chad is one of Africa's largest fresh water resources, boarded by four countries (Cameroon, Chad, Niger and Nigeria) and supports the lives of over 30 Million people living around the lake shores. Over the past four decades, Lake Chad has suffered a deterious environmental degradation. Loss of the lakes water due to climate variation has led to increased pressure on the natural resource which in turn has affected the various activities of the people depending on the lakes water. Climate variation coupled with the unsustainable use of the resources is on the increase: this has however increased the pressure on the lakes water which has affected the aquatic and terrestrial ecosystem, quantity and quality of fresh water, grazing land, reduced fish stocks, siltation and loss of vegetation. Against this back drop, this review examined the emerging and future human risk posed by the diminishing water resource of Lake Chad. It also explored how human influence interacts with the effect of climate change to induce the rapid shrinkage of the lake. It however concluded that, the lakes water resource is getting increasingly vulnerable, this vulnerability is due to several factors such as: over-exploitation of natural resources, widespread poverty, poor infrastructure, high illiteracy rates, conflicts, and dependence of a large share of its economies on climate-sensitive sectors (mainly rain-fed agriculture). These factors, coupled with limited institutional and technological capabilities, have contributed to the region's low adaptive capacity. The high physical sensitivity of the region to climate change has resulted in increased average temperatures and rainfall variability, both of which have severely affected food production, water resources, biodiversity, and human and livestock populations. Measures to protect the lake are not being implemented and hence strategic planning for protection and management of the lakes water needs to be put in place. Human activities need to be monitored and legislations set to checkmate the unsustainable use of the resources.

Introduction

The area near the surface of the earth is divided into four inter-connected "geo spheres". The atmosphere, biosphere, hydrosphere and the lithosphere. Scientist has classified life and materials on or near the surface of the earth to be of these four spheres, and these four spheres make up the environment. The four spheres are derived from the Greek words of stone (litho), air (atmo), water (hydro) and life (bio). The litho is the solid rock which comprises of in organic and composed of minerals. The bio comprises of all living organism, plants and animals, while atmo is the body of air which surrounds our planet. The hydro which is the main scope of this report comprises of all water on

or near the earth. This includes oceans, rivers, lakes, ponds and even moisture in the air. All the four geo spheres are filled with natural resources which man has exploited since his existence. Exploitation of these resources has been on the increase and this has led to over use of such resources in so many parts of the world leading to global climate change or what is called today as global warming.

Next to oxygen, water is about the most essential element for all forms of biological activity. Human beings, animals as well as plants depend absolutely on water for survival. Water is one of the most important natural resource on the surface of the earth; therefore its importance cannot be overemphasised (Hassan et al., 2013). Water covers a substantial part of the earth surface, fills the oceans, rivers, and lakes. It is found under the ground and in the air. These facts notwithstanding, it is interesting to note that there is hardly enough water to drink and meet other basic requirements and demands.

According to the united state geological survey, 97% of water on earth is salt water and only 3% is fresh water of which slightly over two-third is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is mainly found as ground water, with only a fraction presently found above the ground or in the air. Fresh water is a renewable resource, yet the world supply of clean fresh water is decreasing (Hoekstra 2006). Pure/clean water does not occur in its natural state due to the presence of dissolved or suspended impurities. The degree of impurities varies and are contributed to the water either naturally or as acidification of rainwater, surface runoff, dissolution underground and/or artificially by mans activities such as sewage, farming, mining, industrial discharge etc (Shiklomanoc 2000).

The availability of freshwater is one of the most critical environmental issues of our time and is particularly true in Africa where large portions of the continent are arid or semi-arid and the precipitation is highly variable. The relatively large population and delicate ecosystems therefore, depend on water resources that vary greatly due to climate fluctuations and human induced changes. With increasing population and development we can expect that the pressures on existing water supplies in Africa and the vulnerability of the populations dependent on these resources will continue to grow (Coe and Foley, 2001). The Lake Chad Basin serves as a source of freshwater to over 20 million people who depend on it for their livelihood. The Lake with its rich biodiversity also provides a source of fishery, pastoral and agricultural activities for the inhabitants in the Basin. However, the lake has continued to shrink owing to natural and anthropogenic forces. It is estimated in (Musa 2008) that between 1963 and 2007, the surface area of the lake has shrunk from 25,000 Km^2 to less than 3000 Km^2

2.0 WATER ACCESSIBILITY

The United Nations comprehensive assessment of fresh water defined access to water as the number of people who have reasonable means of obtaining sufficient amount of water that is safe for drinking, cooking, washing and other house hold activities expressed as the entire population. Access to safe water is a universal need and in fact a very important requirement (Hassan et al., 2013). Accessibility to water is critical to the development of human beings and a vital strategy for poverty reduction and includes a very important aspect of basic primary health care services. Inadequate safe water supply manifest in so many ways such as infant mortality, increased health care services, public servants productivity, decreased in school enrolment among others (World Bank 2002). Lack of access to portable water has been a thing of great global concern. In Nigeria, only 47% of the population have access to improved sources (World Bank 2000). According to the World Bank report (2000) on effective management of water resource in Africa, Africa despite having lower population than Asia, accounts for one-third of global population without access to improved water supply and has the lowest service coverage figures. This can be attributed to a number of factors such as increasing population leading to high demand for fresh water for domestic, industrial, agricultural and landscape management purposes. Above all, climate change has negatively affected water supply.

It was again predicted by the World Bank report on Africa that water scarcity will be one of the most important issues in the 21st century. The implications is that the 21st century has opened up with one of the most fundamental conditions of human development unmet, which is universal access to basic water services. The failure of international aid community of nations and local organisations to satisfy the basic human needs has led to substantial unnecessary and preventable human sufferings. Reports from development agencies, government, water commission and research institutes continually points to an impending water crises (Medalye 2008).

2.1 WATER DEMAND AND WATER USE

The demand for fresh water is steadily rising and as it is, water demand already exceed supply in many part of the world and as the world population continues to rise, so too does water demand. Fresh water availability and water use have been recognised as global issues and their consistent quantification is required to provide an integral view of water situation on earth. Lucas and Alejandra 2010 pointed out that the challenge and possible threats related to global change including climate change has also affected hydrological research which currently undergoes a change

in focus driven by increasing global and complex water problems. According to Evans et al., 2011, the demand for fresh water is rising but a variety of factors including population growth, water pollution, economic progress, land use and climate change renders its availability into the future uncertain. Alcamo et al., 2003 went further to add that the awareness of growing water scarcity has led to increasing interest in global modelling of water resources both in terms of supply and demand, with the sole aim of developing and implementing appropriate water resource infrastructure and management strategies.

Water use has almost tripled over the past 50 years and in some regions, the water demands already exceed supply (Hassan et al., 2013 and Vorosmarty et al., 2000). The world is facing a global water crisis; in many countries, current levels of water use are unsustainable with systems vulnerable to collapse from even small changes in water availability. The need for scientifically-based assessment of the potential impact on water resource of future change as a basis for society to adapt to such change is strong for most part of the world. Although the focus of such assessment has tendered to be climate change, socio-economic changes can have a significant impact on water availability on the four main use sectors i.e. domestic, agricultural, industrial (including energy) and environmental. Withdrawal and consumption of water is expected to continue to grow over the next 20-50 years (Cosgrove and Rijberman 2002) and constant changes in availability may drastically affect society and economic growth.

3.0 DESCRIPTION OF THE STUDY AREA

Lake Chad drainage basin is located between latitude 6˚ and 24˚ N and longitude 7˚ and 24˚ E. the drainage basin covers an area of 2,434,000 Km², an estimated 8% of the total African land surface area (UNEP 2004). Lake Chad is situated on the edge of the Sahara desert and provides a vital source of water to humans, livestock and wildlife communities. The climate is hot and dry with high variable annual rainfall ranging from 565mm in the 1950s to just about an average of 320mm in the 1980s (Olivry et al., 1996). According to Evans 1996 and Hammer 1986, Lake Chad is characterised by low rainfall accompanied by excessively high temperatures. The annual trend of temperature extreme is moderated by the onset of the raining season producing in the Lake Chad Basin, two annual hot peak periods. The first and somewhat the higher peak occur before the onset of the raining season while the second occurs just after the raining season. The excessive high temperatures characterise the climate to be dry with an average of 320mm of rain falling on the lake, evaporation is extremely high reaching rates of 2300mm per year (Evans 1996).

Over the past few decades, the region has experienced a series of devastating drought. The lake is one of Africa's largest fresh water lakes (USAID 1997), but has shrunk dramatically over the last 40 years (IUCN 2008). Back to back drought in the 1970s and 1980s has left the lake basin as well as the approaches to its management completely if not permanently changed. The negative changes include, shrinkage of Lake Chad and decreased flows in its major rivers (Garcia 2008); falling ground water tables (Bunu 1999); disappearance of specific plant species and reduction of canopy cover; loss of wild life population; increased soil erosion and/or loss of fertility; reduction in rain-fed and irrigated crops; and alteration of economic development parameters such as job opportunities, community organisation of labour terms of trade and rules governing access to natural resources (LCBC 1990). Furthermore, Sanni 2008 added that the adverse effects still include reduced fish stock, siltation and loss of vegetation and depletion of grazing land. Although the local people have lived with these problems for many years and have evolved ways of coping with them, albeit ineffectively for the most part, their scale and intensity are exacerbated by change as this adds another dimension to the matrix of global water insecurity.

3.1 HYDROLOGY, HYDROGEOLOGY AND WATER RESOURCES OF LAKE CHAD

Existing in an arid region, including the Sahara Desert, the Lake Chad Basin naturally has limited water resource. According to UNEP 2006, the entire western Sahel appears to have undergone an abrupt hydro-climatic transition from a wetter to a drier rainfall state. River inflow comes mainly from the Chari-Lagone (90%) and the Komadugu-Yobe (5%) river Basins. UNEP/DEWA 2003 presented that the total annual river inflow decreased from a pre-drought volume of 39.8Km³ to the present 21.8Km³; a decrease of 47%. During this same period, the total lake water input (including direct rainfall on the lake) decreased by 50%. Oyebande 1997 pointed out that the annual average temperatures of Lake Chad water varies between 25.5˚ and 27.5˚ with a PH level of between 7 and 8 in the southern pool and up to 9 in the northern pool. Water conductivity averages 450µs/cm, also salinity varies between 40-70mg/l in the southern region of the lake and an average of 700mg/l in the north.

Bunu 1999 and Olivry et al., 1996 showed ground water resource of the Lake Chad to be represented by two aquifer system.

- The phreatic aquifer which can be found at depths ranging from a few meters to about 50m. It has low mineralisation essentially similar to surface water.

- The confined and often artesian Pliocene aquifer; sometimes called the middle aquifer of the Chad formation. It varies in depth between 250-400m. It is well exploited in the Nigeria and extreme north of

Cameroon where many boreholes are constructed; this constitutes permanent drains of this aquifer. The aquifer has a lesser geographic extent compared to the above-noted water table aquifer (phreatic aquifer) and its water is older and more mineralised.

3.2 WATER USE IN THE LAKE CHAD

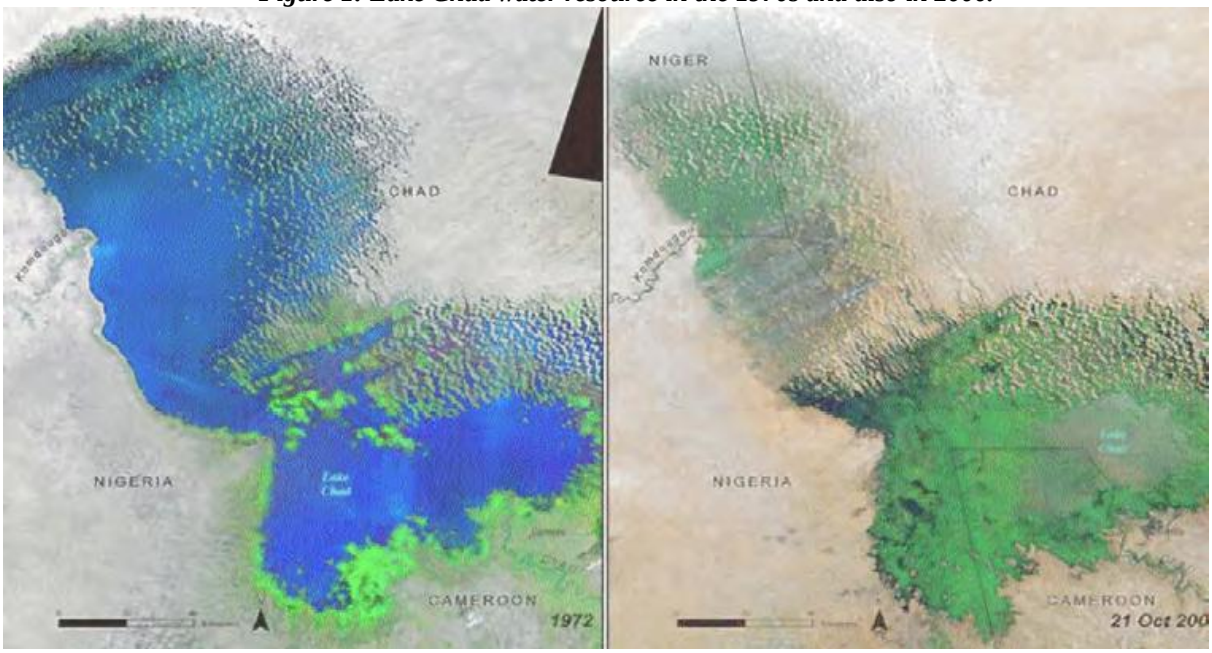
Since the 1960s, human demand for water near the Lake Chad has grown rapidly. Naturally, most of the earth's living resources are found in specific geographical locations such as the global coastal environment and the catchment basins of large river systems (Costanza et al., 1997). Furthermore, Michael 2002 added that a large portion of the world population live in close proximity to these regions and its frequent depended upon it for either part or much of food supply and industrial raw materials. This is however the same in the case of Lake Chad. Between 1960 and 1990, the number of people living in the lakes catchment area has doubled from 13million to 26million (UNEP/GRID 2008). With agriculture providing the main livelihood in 60% of the lake Basin, demand for water for irrigation is estimated to have quadrupled between 1983 and 1994 (UNEP 2006). At present, 135,000 hectares of land are irrigated in the lakes basin (DFID 2004). Unfortunately, since the drought of the early 1970s, the water level of Lake Chad has not been high enough to reach the intake canals of most irrigation systems (LCBC 2000).

In addition to irrigation, dams have influenced the rivers that fed Lake Chad. According to Adenle 2002, the indiscriminate construction of dams in the upper reaches of the Komadugu-Yobe has untold impact on the reduction in the area of the Nguru wetlands. The Mega Dam in Cameroon has also reduced the flow in the Chari-lagone River and seasonal inundation of the Yaere floodplain. In the Maiduguri urban area, there is a serious problem of lowering of groundwater level due to the indiscriminate withdrawal for water supply and the construction of Alau Dam which has resulted in the reduction of flooding over the Sambissa wetlands (Bunu 1999). In the Kano and Hadeja Basins, there are believed to be about 23 earth Dams. The upper Basin used to contribute approximately 7Km³/yr to Lake Chad. Today, the bulk of this water is impounded in reservoirs within Kano province in northern Nigeria and the system provides just 0.45Km³/yr (LCBC 2000).

4.0 CLIMATE VARIABILITY AND ITS EFFECT ON LAKE CHAD

Olivry et al., 1996, demonstrated from a long term hydrological observation that the volume of water stored in the Lake decreased from 40-100.10⁹m³ (in 1962) to 7-45.10⁹m³ (in 1990). The lake surface area was reduced dramatically from 25,000Km² (in 1960 to early 1970s) to 2,500Km² (in 1980 and beyond) so that about 90% of the originally inundated area has been exposed. See Figure1 below.

Figure 1: Lake Chad water resource in the 1970s and also in 2000.

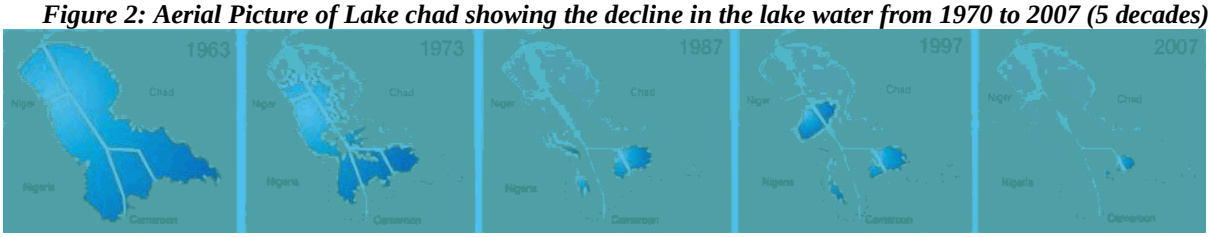


Source: Source: Musa (2008)

Climate variability in the Lake Chad means low rain fall, high evaporation and more demand for water which tends to reduce the lake water levels. This has however decreased fish production from 140,000 tons in the 1960s to a mere 70,000 tons in the 1980s (Ngounou 2009). Apart from long term periodic changes in the lake level, the basins ecosystem experience seasonal fluctuations that probably represent the most significant feature of the area around which people, animals and vegetation have had to adapt their life styles (Batello et al., 2004). The availability of water over the years depends on seasonal peaks of rainfall, river flow and lake level succeeding each other from July to January. When a resource becomes scarce, the interaction between the various users and the exploitation of water (both ground and surface water) becomes more critical (Rijsberman 2003). During the drought period of 1976-1993, (this is the longest and most intense in the century), northeast Nigeria experienced a 36% decrease in the mean annual rainfall (L'HÔte 2003). IPCC 2007 further stated that there are areas where the mean annual rainfall was even less than 15 to 30% in the 1960s.

Because of the decrease in rainfall, there was a reduction or rather absence of surface flooding in some areas of the basin, this affected lake water level which in turn affected fish production, irrigation/agricultural production, grazing land for cattle etc.

Figure 2: Aerial Picture of Lake chad showing the decline in the lake water from 1970 to 2007 (5 decades)



Source: Musa (2008)

4.1 HUMAN INFLUENCE ON LAKE CHAD

Increase in economic activities, which in turn increased population has resulted in several problems Lake Chad is facing today. These problems include; over fishing, over grazing, poor farming practices and deforestation in the lake basin (Adenle 2002). With a population growth rate of 2-3% per year (Ngounou 2009), more water is required for domestic use, irrigation and for animals. According to Adenle 2002, the indiscriminate construction of dams and irrigation practices has led to untold impact on the reduction of wetlands in the lake basins. While the virtual disappearance of the lake and poor land use has caused environmental degradation that further accelerates the rate of desertification in the area. This has led to the loss of an estimated 200,000 hectares of floodplains along the lake shores and rivers, which were critical fish breeding and nursery areas (Batello et al., 2004). According to Poryadin and Vinnicova 2001, water management and irrigation substantially modified the ecological condition influencing also the interaction between ground water and surface water.

Poverty, which often forces people to live in geographical unstable locations and inadequate shelters, the over utilization by the rural population of some of the remaining natural or semi natural land resource for grazing, wood for fuel, hunting and other purposes are also the major factors (Ngounou 2009). Inappropriate irrigation policy and land use planning and lack of appropriate institutional arrangement are all linked to the current trend towards increased vulnerability. In addition, restricted government budgets have relaxed the state control over the use of resources and have undercut the ability to implement corrective measures such as to fight drought and desertification (UNEP/GRID 2008).

4.2 COMBINED IMPACT OF CLIMATE CHANGE AND HUMAN INFLUENCE ON LAKE CHAD

Using an integrated biosphere model, run with and without extraction for irrigation, Coe and Foley 2001 concluded that water-level fluctuations in Lake Chad over the past 35 years have been caused by both climate variability and water use (human influence). Significant decrease in the direct rainfall since the 1960s has largely been responsible for the shrinkage of the lake. From 1960 to 1970, decrease in the lake level and surface area resulted primarily from long term climate change; with only 5% of the lake level decrease attributed to water management practices. However, in the 1970s with marked population increase, human activities began to play a more significant role in accelerating lake-level decline (Oyebande 2001). The onset of dry climatic conditions in the early 1970s induced people to dramatically increase their irrigation activities almost doubling water loss from Lake Chad (Coe and Foley 2001). Below is a table showing the various problems associated with both geographical location of Lake Chad as well as induced problems due to human activities.

Table 1: Environmental problems in the Lake Chad Region

Environmental problems associated with geographical location.	Environmental problems associated with human activities aimed at economic development.
Aridity (four climatic zones notably; hyper arid, arid,	Habitat and Community Modification

semi arid and sub-humid).	
Climate Variability	Unsustainable agricultural practices (Fishing and Grazing)
Persistent Drought (1970s – 1980s)	Mining
Desertification	Deforestation
Water shortages	Pollution
Erosion	Indiscriminate bush burning
	Sedimentation due to unsustainable farming and irrigation practices.

Compiled from Ngounou 2009 and The Natural Resource Group 2001

4.3 MEASURES FOR PROTECTION OF WATER RESOURCES AND ENVIRONMENT IN LAKE CHAD

Wirkus and Boge 2005 suggested that the management of water in a catchment requires integrated approaches and assessment in order to be able to adequately record and consider not only the natural features but also the social, cultural and economic conditions of the catchment area. Measures must be adopted for preventing and mitigating the impact of water shortages through both short term and medium term actions.

In planning the growth of the lakes basin, various factors should be considered in order to protect the water resource and the environment. Ngounou 2009 added that access to information is a factor that determines the degree of vulnerability and that local communities must become proactive participants in the process of water management by utilizing the knowledge they already have of their own environment and by increasing this knowledge with the assistance of experts and the experience of others.

High risk areas must be identified as well as their degree of vulnerability. Ground water vulnerability maps should be used to show how susceptible the aquifer is to contamination according to various factors of influence. Factors of influence should include; type of soil, depth of water table, aquifer importance etc. According to Batello et al., 2004, pastoralist and their cattle are a vital part of the ecosystem and often have a positive impact on the management and propagation of biodiversity and the maintenance of water resources. If sufficient resources are available, nomadic herding contributes to the sustainable use of grassland and prevents the degradation and desertification of the regions poor and fragile soils.

Papadimitrakis and Findikakis 2005 suggested that regular monitoring of the physical, chemical and biological parameters characterises water quality in rivers, lakes and reservoirs and is essential for protecting public health and assuring the long term reliability of these resources. The date collected from such monitoring will allow the early detection of changes and trends in water quality; it will provide the basis for calibration of predictive water quality and ecological models; allows alternative remediation strategies and contribute to the advancement of the fundamental understanding of the behaviour of these water bodies. As the water supplies are chiefly based in the Lake Chad basin, measures to protect ground water needs to be put in place around the lake basin.

Difficulties for the field of water management in the Chad basin are caused by insufficient understanding of the hydro-geologic system due to the fact that a lot of problems occur in river systems with different adjacent countries, the surface water has to be considered in its natural unit, while the ground water resources needs to be linked with their natural environment, the aquifer basin. Although both resources are in principle, complementary they have to be dealt with individually and they should be combined in the final process of integrated water resources management, in larger entities comprising both river basins and ground water basins (Ngounou 2009).

4.4 THE FUTURE

As the water level in Lake Chad continues to recede (shrink), its future as one of Africa's largest wetlands is becoming uncertain. With little fresh water entering the north basin from Komadugu-yobe, the basin will become more saline if it's isolated for long periods (Mendelsohn et al., 2000). Decline in vegetation associated with the lake ecosystem may result in increased erosion and ultimately in desertification. The IPCC has predicted reduced rainfall and runoff and increased desertification in the Sahelian belt near Lake Chad (IPCC 2007).

The biodiversity of fish and birds in the Lake Chad region is also under threat (Mendelsohn et al., 2000). The drying up of water basins and ponds both directly and indirectly will increase fish mortality. The *Alestes naremoze* specie that once contributed up to 80% of the total catch is becoming rare due to the disappearance of its natural spawning beds. Migrating birds like the European White Stork, which depends upon Lake Chad as a key resting place on their migration across the Sahara may no longer be able to complete this vital aspect of their life cycle. Diminishing water resource and continued ecosystem decline also have deterious impact on both the health as well as the economic lives of the people living around the Lake Chad. The northern states of Nigeria and Cameroon are among the poorest in these two countries. Around the lake, domestic plant and animal production may become untenable due to increasing soil erosion and desertification (Nami 2002).

For now, the future of the lake does look bleak. With high population growth rate, pressure on water resources in the lake basin will invariably continue. While in the past, Lake Chad has been able to rebound from low to high water levels; however, climate change and unsustainable water use may now act in concert to block the natural forces of recovery. While renewed rainfall has recently returned to the regions, it is however clear that the lakes future continues to hang in the balance-and will require very careful planning and multilateral management commitment in order to help salvage (prevent) one of Africa's greatest life forces from becoming yet another extinct resource.

5.0 CONCLUSIONS

Climate change is expected especially changes in rainfall patterns with resulting changes in agriculture, food and nutrition security, hydrological regimes of rivers and the Lake Chad leading to physical and economic water scarcity, and increased variability of droughts in the Lake Chad Basin. These effects, coupled with the low adaptive capacity because of poverty and low level of technology, dearth of information on climate science and poor land management practices will greatly reduce the predictability and increases the uncertainties of climate related disaster events in the Lake Chad Basin and other water bodies in Africa

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