WATER STRESS PATTERN IN THE LAKE CHAD BASIN REGION (1960 - 2002): IMPLICATIONS ON THE LIVELIHOOD OF THE PEOPLE

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ABSTRACT

This review was designed to assess the status of the water level of the Lake Chad basin area between 1960 and 2002. The available hydro-climatic data obtained for the evaluation of trends in the basin were made between 1960 and 2002 water levels in the area. The data set for each station was analyzed using a second order polynomial curve. The findings revealed that the water levels varied from one part of the basin to another. Two locations showed rising trends in the measurable water levels from the early 1980s. For example, in Lai (Logone) a peak of about 230cm was reached around 1982. A gradual decline to less than 180cm then set in towards 2002, but did not reach as low as 160cm recorded in 1960. Therefore, acquisition of additional and more recent hydro-climatic data for effective predictive study as well as the restoration of the basin was recommended.

INTRODUCTION

In the recent decades, the open water surface of the Lake Chad has been reduced from approximately 25000km^2 in 1963 to less than 2000km^2 in the 1990s having impact on the basin's socio-economic activities and food security (Coe and Foley, 2001). The shrinkage of the Lake has been driven by both global and local causes: climate change and vastly increased competing demands on the Lake and its surrounding land have accelerated its shrinkage over the past years (Coe 2001). Water is one of the basic essentials of life. Our health depends on us having access to enough clean drinking water. Whenever water is taken from public water supply or other sources, it has an impact on the environment.

Increases in demand for water implies that our resources are coming under greater pressure (Coe and Foley, 2001; Environment Agency 2007). The uneven distribution over time and space of water resources and their modification through human use and abuse are sources of water crises in many parts of the world. In many areas hydrologic extremes have increased. Deaths and material damage from extreme floods can be high, and more intense droughts, affecting increasing numbers of people, have been observed already in this century. There are insufficient data to understand and predict the current and future quantity and quality of water resources, and political protocols and imperatives for sharing data are inadequate (WWAP, 2009).

Water stress is related to the amount of water available per person in a given area, both now and in the future. An area of serious water stress is defined as an area where the current household demand for water is a high proportion of the current effective rainfall or, the future household demand for water is likely to be a high proportion of the effective rainfall available to meet that demand. When the demand for water is high, it result in a serious level of stress on the available water resources (Environment Agency, 2007). Africa, in particular, remains mired in poverty (UNESCO, 2009) despite recent economic growth trends in some countries. In developed countries water storage ensures reliable sources of water for irrigation, water supply and hydropower as well as a buffer for flood management. Countries in Africa store only about 4% of annual renewable flows, compared with 70%-90% in many developed countries (UNW-DPC 2009). About 340 million Africans lack access to safe drinking water, and almost 500 million lack access to improved sanitation facilities (WWAP, 2009). The First African Water Week, convened in Tunis in March 2008, opened with a call for greater efforts to ensure water security nationally and regionally (UNESCO, 2009). Donald Kaberuka, president of the African Development Bank Group, emphasized that it is no longer acceptable that the African continent continues to utilize only 4% of its water resources, when a huge proportion of the people do not have access to safe water, and when large populations are faced with frequent water stress, floods and drought, in addition to food and energy shortages (UNESCO, 2009).

The result of water stress in the Lake Chad basin has been characterised by the drastic reduction in the volume of the water recharge from rainfall and rivers into the basin which has a serious consequence on the livelihood of the people of the area. This demand for an urgent attention to the status of Lake Chad basin as such changes in the level of the water can no longer sustain the livelihood of the people in this region. Therefore, in order to understand the situation of the water stress of the people of this area there is the need to establish and evaluate the water levels of the basin.

This however, suggests the need to ascertain the water levels in lakes and rivers. They are an important hydrological parameter indicating how much water comes from the rains and the drainage channels and empting into the basin. With respect to rainfall, water level does not only reflects the amount of rain in a given period but also its spread. The higher the frequency and volume of rain, the greater the volume of water in the lake after saturation and therefore the higher the volume measurable in the lake (Salman and Momha, 2009). This also implies that the higher the volume of water in the basin the less the water stress for human and animal consumption in the region and vice versa. The main objective of this study is to assess water level with a view to evaluating trends in the aridity of the region.

THE LAKE CHAD BASIN REGION AND WATER STRESS

Lake Chad is situated at the southern fringe of the Sahara desert, east of the Sahel region between 12^{o} 20 and 14^{o} 20 latitude North; 13^{o} and 15^{o} 20 longitude East (Figure 1). It was considered as a Ramsar site of the world importance because of its biodiversity. Lake Chad is a fresh water reserve with only 5 percent of salinity and bordered by Cameroon, Niger, Nigeria and Chad. Its floor depth varies between 1.5 and 10.5 metres and it is about 215 metres above sea level, with apparently no outlet (Endoreic Lake). Komadugu-Yobe sub-basin (148,000kms of) and its upper basins provide natural flow of about 7km/per annum, the bulk of which is the reservoirs of Kano state. Only a volume of 0.45km/per annum enters Lake Chad. The Chari-Logone sub-basin has a surface area of about 590,000km and provides water for vast stretches of wetlands, yaeres floodplains (6000km of the active surface areas, wet years. The hydrological active zone of the basin is smaller in size (984455 km) and it includes 5 riparian countries. The topographic surface of the basin (2381635 km) covers vast areas of desert zones of Niger and Chad, which are now cut off from the Lake itself from the hydrological perspective. However, human consumption and its impact on the mass of the water is negligible, less than 3 percent of the basin discharge.

On the contrary, losses caused by evaporation in the Yaeres wetlands are significant. Broadly speaking, the climate gradient in the Lake Chad Basin region is characterized by increased aridity towards the North and the East: rainfall decreases, temperatures and evaporation increase with significant reduction of relative humidity. Moreover, the high rate of evaporation in the lake due to its proximity with the Sahara desert has paradoxically, not affected the relatively low salinity of its waters. Lake Chad is still a fresh water lake and losses in the Lake's waters is also due to infiltration (18 percent of its annual inflows) towards phreatic water tables, the level of which have become lower than that of the Lake itself (Eberschweiler, 1993; Kombe, 2009).

MATERIALS AND METHODS

The type of data collected, analyzed and interpreted for this study is hydrologic data for water levels in the Lake Chad basin. These were obtained from the Lake Chad Basin Commission in N'Djamena Chad. This data set is needed for the evaluation of trends in the dry basin between 1960 and 2002. Data for annual water level were for synoptic meteorological stations within the basin. These included N'Djamena, Mao, Bousso, SARH, Lai (Logone), Djimtilo (near Lake), Bol (Lake) (LCBC, 2007). The Geographic locations of these observed stations are shown on table 1. The hydrologic data set for each stations were analyzed using a second order polynomial curve. Technically, the term "polynomial" should only refer to sums of many terms, but the term is used to refer to anything from one term to a zillion terms. However, the shorter polynomials do have their own names:

a) a one-term polynomial, such as $2x$ or $4x^2$, may also be called a "mononomial"

b) a two-term polynomial, such as $2x + y$ or $x^2 - 4$, may also be called a "binomial"

c) a three-term polynomial, such as $2x + y + z$ or $x^4 + 4x^2 - 4$, may also be called a "trinomial"

Mathematically, a polynomial is an expression that is constructed from one or more variables and constants, using only the operations of addition, subtraction, multiplication, and constant positive whole number exponents. For example, $x^2 - 4x + 7$ is a polynomial. A second-degree polynomial, such as $4x^2$, $x^2 - 9$, or $ax^2 + b^x + c$, is also called a "quadratic" curve. Polynomial involves partitioning the between-groups sum of squares into trend components. When this option is selected with balanced designs, SPSS 8 package computes the sum of squares for each order polynomial from weighted polynomial contrasts, using the group code as the metric. These contrasts are orthogonal; hence, the sum of squares for each order polynomial is statistically independent. If the design is unbalanced and there is equal spacing between groups, it also computes sums of squares using the unweighted polynomial contrasts, which are orthogonal. The deviation sums of squares are always calculated from the weighted sums of squares. The least squares fit through points are calculated by using the following equation:

$$y = b + c_1^{\,x} + c_2x^2 + c_3x^3 + \ldots\ldots.. + c_6x^6$$

Where b and $c_1 \ldots . c_6$ are constants.

RESULTS AND DISCUSSION

The available hydro-climatic data for the periods were collected from different parts of the basin: Lai known as Logone is located in Cameroon and the rest-N'Djamena Aero, Mao and Sarh Meteo, Bousso, Djimtilo (near Lake), Bol - in Chad republic table 1 shows the geographic location of the stations in the basin. Figure 1- 4: show the trends in the measured water levels in Lai (Logone), Bousso, Djimtilo and Bol all located within the basin between 1960 and 2002. The measurements are available in intervals of two years. The highest water level in Lai-Logone was recorded in 1982 (265.9cm) and the lowest in 1964 (140.7cm).

Table1: Geographic Locations of the observed stations

Stations	Latitude	Longitude East
1. Bousso	N 10^{0} 30' 00"	E 016^{0} 43' 06"
2. Djimtilo	N 12^{0} 50' 30"	E 014^{0} 42' 46"
3. Sarh1164	N 09^{0} 09' 00"	E 018^{0} 25' 00"
4. N'Djamena	N 12^{0} 07' 00"	E 015^{0} 02' 00"
5. Mao	N 11^{0} 36' 00"	E 015^{0} 17' 00"
6. Lai (Logone)	N 09^{0} 24' 00"	E 016^{0}18' 00"

Table 2: Annual Rainfall around Lake Chad Basin (1960 - 2002)

Year	A	B	C
1960	533	189	1161
1962	490	441	918
1964	477	323	1064
1966	593	272	829
1968	561	224	1008
1970	653	217	998
1972	603	1096	906
1974	424	287	1079
1976	651	264	970
1978	666	962	891
1980	451	823	924
1982	382	87	1258
1984	226	117	699
1986	556	176	681
1988	627	225	1005
1990	329	186	729
1992	537	178	874
1994	639	195	1113
1996	472	75	1133
1998	731	119	1122
2000	746	122	1154
2002	767	132	1167

A = N'DJAMENA AERO (mm)
B = MAO (mm)
C = SARH CT1161 (mm)

Sources: Lake Chad Basin Commission (LCBC) Ndjamena

The table 2 shows the trend in annual precipitation in the selected stations from 1960 to 2003. In general, the total annual rainfall varies a great deal over the period under consideration. For example, N'Djamena Aero had its highest precipitation in year 2002 and the lowest in 1984 (767mm and 226mm) respectively. Mao recorded its highest precipitation of 1075mm in 1996 and it's lowest of 75mm in 1972. Sarh Meteo recorded the highest precipitation in 1982 (1258mm) and the lowest in 1986 (681mm). This distribution of rainfall trends from 1960 to 2002 in the three stations of the basin revealed that Sarh Meteo station has the highest rainfall total among the three stations for which there are comprehensive data (Dami, 2008).

In Bousso the highest level of 390cm was recorded in 2002 and the lowest level of 104.7cm in 1972. For Djimtilo (near the Lake) the highest water level of 518.01cm was measured in 1964 and the lowest of 113.1cm in 1962. Measurement in Bol (Lake) show a slightly different pattern in terms of the period in which extreme values were recorded (Dami, 2008). Its highest water level was recorded in 1968 (388.59cm) and the lowest in 1992 (77.2cm). From the data sets Djimtilo (near the Lake) has the total highest annual water levels from 1960 to 2002 among the three locations. In Lai (Logone), water level varied greatly over the 42 year period.

The polynomial curve fitted for the data however showed that a peak of about 230cm was reached around 1982. A decline then sets in towards 2002, but did not reach the low of 160cm recorded in 1960. In Bousso, the polynomial trend depicted in Lai was reversed. In this locality, the water level showed a continued decrease to a low level of about 152 cm around 1980. Thereafter the level began to show a progressive rise to an all time high of more than 300cm in 2002 (Dami, 2008). The trends in Djimtilo and Bol are different from those of Bousso and Lai that water levels show a general decline from 1960 to 2002. For instance in Djmtilo, the level progressively dropped from about 380cm in 1960 to about 280cm in 2002.

The driving factors of water pressures: Alongside the natural forces affecting water resources are new human activities that have become the primary 'drivers' of the pressures affecting our planet's water systems. These pressures are most often related to human activities and economic growth. Our requirements for water to meet our fundamental needs and our collective pursuit of higher living standards, coupled with the need for water to sustain our planet's fragile ecosystems, make water unique among natural resources. Drivers should not be considered in isolation of related socioeconomic and political factors or of other drivers. Many natural links also influence how drivers affect changes, directly and indirectly.

Water properties are governed by biological, chemical and physical laws that define the quantity and quality of water resources, regardless of human influences that are linked in various ways. Superimposed on these natural processes are human activities that intensify these processes and disrupt the natural balance of water systems. Economic growth, a principal driver of water use, is affected by a wide range of policy decisions, from international trade to education and public health, while the potential rate of economic growth can be affected by demographic variables such as population growth and distribution (local workforce availability) and social characteristics (workforce capacity and the role of women) and by the availability of new technologies.

Water availability is also directly subject to the impacts of climate change, which also can exert additional pressures on the other drivers. The result of these combined and interacting forces is a continuously increasing demand for finite water resources for which there are no known substitutes yet (Global Water Partnership, 2000). When water resources of acceptable quality can no longer be provided in sustainable quantities, the outcome can be overexploitation of aquatic ecosystems. The ultimate losers are the exploited aquatic ecosystems and the organisms (including humans) dependent on them for survival and well-being. Human activities and processes of all types - demographic, economic and social can exert pressures on water resources and need to be managed. These pressures are in turn affected by a range of factors such as technological innovation, institutional and financial conditions and climate change.

Demographic drivers: Population dynamics (growth, gender and age distribution, migration) create pressures on freshwater resources through increased water demands and pollution. Changes in the natural landscape associated with population dynamics (migration, urbanization) can create additional pressures on local water resources and the need for more water-related services.

Economic drivers: Growth and changes in the global economy are having far- reaching impacts on water resources and their use. Growing international trade in goods and services can aggravate water stress in some countries while relieving it in others through flows of 'virtual water' (water embedded in products and used in their production, particularly in the form of imported agricultural commodities).

Social drivers: Social drivers are mainly about individual rather than collective actions and about the way people think and act on a day-to-day basis. Social drivers influence of groundwater, lack of planning, degradation of ecosystems, weakened flood protection, urban expansion leading to heightened water tensions, and other harmful effects.

Climate change and possible futures: The external drivers of change, strongly connected, create complex challenges and opportunities for water managers and decision-makers in government, the private sector and civil society. Climate change and variability, while seldom the main stressors on sustainable development, can impede or even reverse development gains. There is evidence that the global climate is changing and sometime the change is human-induced (IPCC, 2007). The main impacts of climate change on humans and the environment occur through water. Climate change is a fundamental driver of changes in water resources and an additional stressor through its effects on external drivers. Policies and practices for mitigating climate change or adapting to it can have impacts on water resources, and the way we manage water can affect the climate. Public policy, so far dominated by mitigation, could benefit from a better balance between mitigation and adaptation. Mitigation is termed as an anthropogenic intervention to reduce the emissions or enhance the sinks of greenhouse gases and adaptation strategy on the other hand has to do with an ability to cope or the degree to which adjustments are possible in practice, processes or structures of systems to projected or actual change of climate (IPCC, 2007).

Carbon is a measure of the anthropogenic causes of climate change - water is a measure of its impacts. The international community also has to balance investing for tomorrow's likely problems of greater climate variability and global warming against investing for today's problems of climate variability to disease, climate shocks and environmental degradation. Water of the right quality can improve health through better sanitation and hygiene and, when applied at the right time, can enhance the productivity of land, labour and other productive inputs. In addition, healthy freshwater ecosystems provide multiple goods and services essential to life and livelihood.

Impact of water use on water systems and the environment: The pattern and intensity of human activity have disrupted - through impacts on quantity and quality - the role of water as the prime environmental agent. In some areas depletion and pollution of economically important river basins and associated aquifers have gone beyond the point of no return, and coping with a future without reliable water resources systems is now a real prospect in parts of the world. While the intensity of groundwater use, partly encouraged by subsidized rural electrification, has led to the emergence of many groundwater-dependent economies, their future is now threatened by aquifer depletion and pollution (Global Water Partnership, 2000).

Prospects for relaxing use of these key aquifers, remediating water quality and restoring groundwater services to ecosystems look remote unless alternative management approaches are developed. Our ability to maintain the environmental services we depend on has improved but remains constrained by an incomplete understanding of the magnitude and impact of pollution, the resilience of affected ecosystems and the social institutions that use and manage water resources systems.

A failure to monitor the negative impacts of water use on the environment and institutional weaknesses in many developing countries prevent effective enforcement of regulatory provisions. Relevant information about pollution loads and changes in water quality is lacking precisely where water use is most intense - in densely populated developing countries. As a result, the often serious impacts of polluting activities on the health of people and ecosystems remain largely unreported. Still, there are signs of progress in how pollution and the risks of pollution can be mitigated and trends in environmental degradation reversed.

Managing competition for water and the pressure on ecosystem: Competition for water and shortcomings in managing it to meet the needs of society and the environment call for enhanced societal responses through improved management, better legislation and more effective and transparent allocation mechanisms. Challenges include wise planning for water resources, evaluation of availability and needs in a watershed, possible reallocation or storage expansion in existing reservoirs, more emphasis on water demand management, a better balance between equity and efficiency in water use, reducing inadequacies in legislative and institutional frameworks and containing the rising financial burden of ageing infrastructure. Water management choices should emerge from informed consultation and negotiation on the costs and benefits of all options after considering basin interconnectedness, relationships between land and water resources, and the consistency and coherence of decisions with other government policies.

CONCLUSION

The Lake Chad basin will remain an important region in Africa as many people had their roots there and the restoration of the drying Lake Chad therefore remains a serious concern to many: farmers, fishermen, politicians etc. This study has pointed in part to the possibility that the drought and water stress being experienced in the region may all together be partly a cyclic event that could be passing away given the tendencies towards wetter conditions in the region. What is not known is how fast the natural change will happen to effect a full restoration of socio-economic life in the basin.

From this study, it can be concluded that trends in water levels of the lake have varied from one point of the basin to another. While some locations appear to be getting wetter, others are getting drier. Thus, although more data are needed to draw a firm conclusion on the trends in the environment of the basin, it is possible that the aridity that had been experienced in the past have not come to stay. Consequently, all the efforts that have been in place geared towards the restoration of the basin must be intensified. For example, the efforts to clear the channel to prevent blockage by typha grasses and silt must be intensified. Also, a proactive allocation of water among the various communities in the basin must be pursued to ensure that everyone has access and water use is optimized.

Figure 1: Map showing the Lake Chad basin region

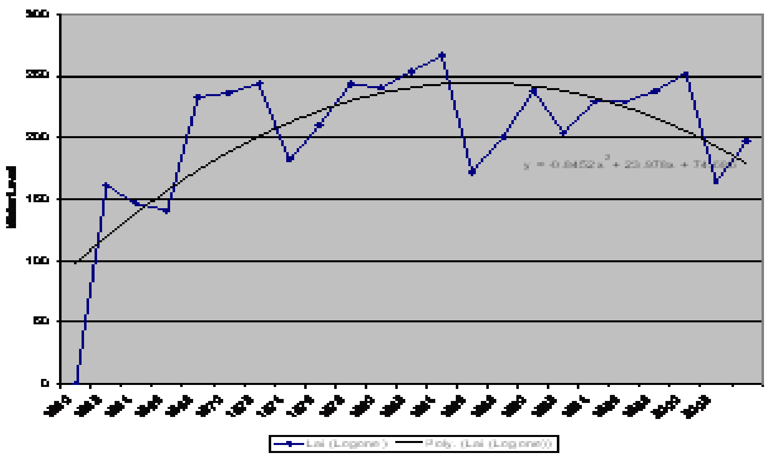

Figure 2: Annual Water level Pattern for Lai (Logone) from 1960 to 2002

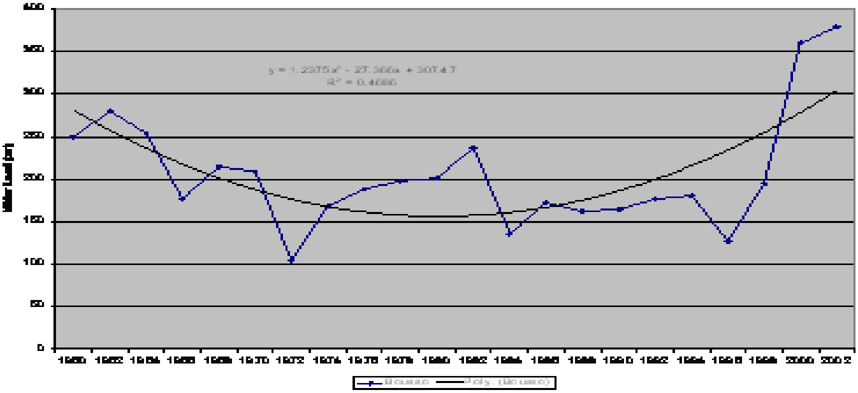

Figure 3: Annual Water Level Pattern for Bousso from 1960 to 2002

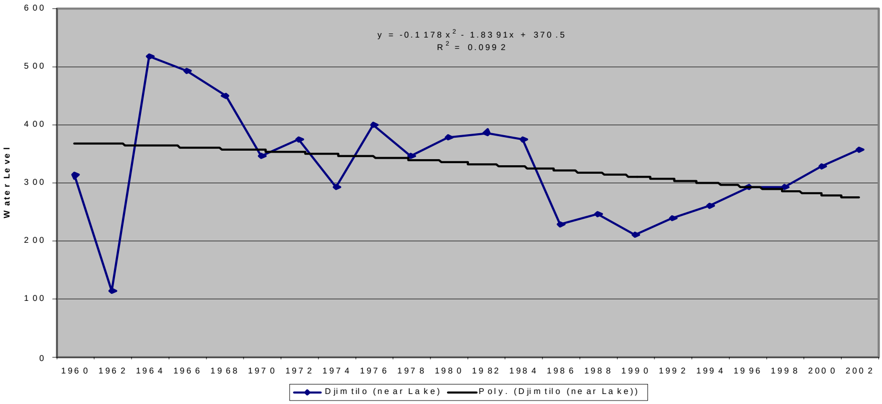

Figure 4: Annual water level pattern for Djimtilo from 1960 to 2002

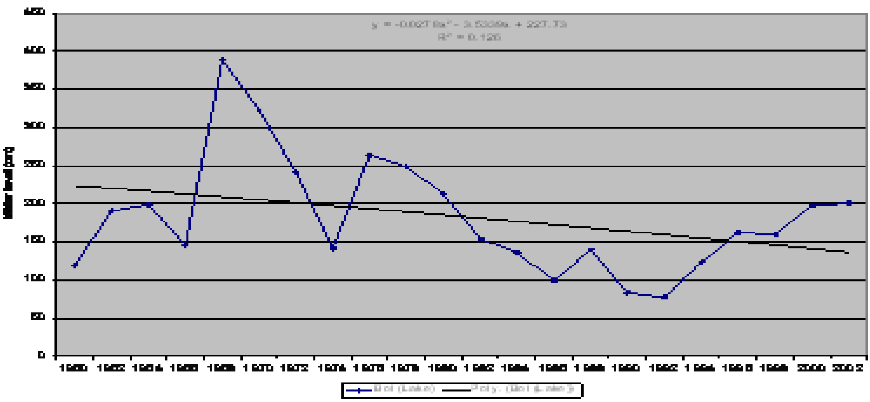

Figure 5: Annual Water Level Pattern for Bol (Lake) from 1960 to 2002

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