

# Water Resources Protection in the Lake Chad Basin in the Changing Environment

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**Abstract:** Lake Chad occupies a special biogeographic position in the otherwise monotonous Sahelian region from Senegal to the Sudan. For several centuries, Lake Chad, one of the most significant water resources in central Africa, has been the controlling factor of regional co-operation and socio-economic development among the riparian countries. During the past four decades, the environmental degradation of the Lake Chad basin has been severe and gradually worsening in many areas. The Lake Chad basin has experienced large variations in the amount of rainfall, spatially and temporarily. Increasing pressure on natural resources has been exacerbated by the population growth (rate of 2.8%) and increase in irrigation. The pressure on the water resources has undergone drastic ecological changes, radical socio-economic changes, and tensions among water users are on the increase. The risk of anthropogenic impacts on soil and groundwater is high. Water resources are getting increasingly vulnerable and valuable in a competing semi-arid to arid environment. Strategic planning for protecting and utilizing the natural resources is absent. Preserving and managing the Chad basin water resources and its environment in an integrated and sustainable manner, is an increasingly urgent task for the riparian countries.

**Keywords:** Lake Chad basin, water resources, human impacts, climate variability, issues of sustainability

## 1. INTRODUCTION

In recent years, the international community has witnessed incidence of climate variability and human activities. While all countries are susceptible to climate variability, developing countries are much more severely affected, in terms of the percentage of economic losses in relation to their gross national product (GNP) (World Bank, 1993). During the past four decades, the Lake Chad basin (the basis for fishery and food production, the life-support of the 30 million rural inhabitants) is suffering from drought and desertification, leading to loss of biodiversity and a decline in all rural production, which has caused widespread poverty, malnutrition and migration. The situation is aggravated by obsolete management methods in nature protection and unreasonable utilisation of natural resources in the current social and economic circumstances. In this paper, we make the case that water resource protection from negative influences such as climate variability and human activities should be approached with great care. According to Messner (2005), about 120 billion Euros were spent in the European Union in 2001 for environmental protection and most of this money was spent to protect water resources.

## 2. DESCRIPTION OF THE STUDY AREA

Lake Chad is located between latitude 12°-14°30' N and longitude 13°-15°30' E and lies in the Sahel region of Africa (Fig. 1). The major economic activities of the population in the Chad basin are agriculture, stock breeding and fishing. Crops grown in the region are wetland rice, cotton, mouskwari, corn and other grains. The Lake Chad basin is characterized by a thick sequence of Cretaceous, Tertiary and Quaternary sediments deposited due to tectonic subsidence accompanied by sedimentation. The most important regional aquifer is the Quaternary aquifer. It consists of inter-bedded sequences of sands, clayey sands and sporadically gravel-sands (Ngounou Ngatcha, 1993;

Edmunds *et al.*, 1999; Djoret, 2000). The hydrology of the basin is dominated by the Logone-Chari Rivers, the Komadugu Yobe, the Yedseram and the El-Beïd. The almost total lack of relief in the region causes flooding to spread over a large area of the basin.

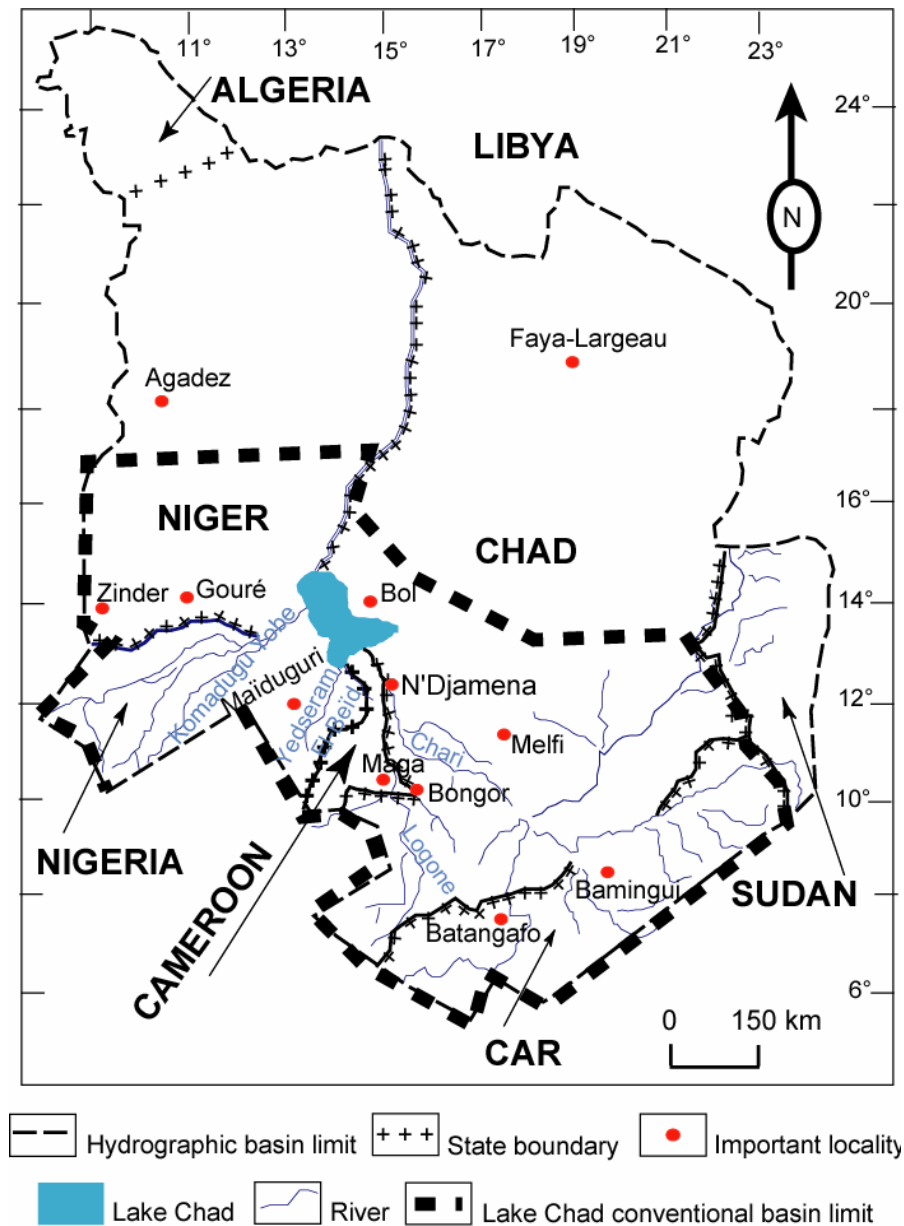


Figure 1. The Lake Chad catchment

Of the volume of water supplied to Lake Chad each year, the Logone-Chari accounts for more than 90 percent. According to Olivry *et al.* (1996), the upper Chari River discharges  $25.8 \text{ km}^3$  and receives  $12 \text{ km}^3$  from the Logone out of the  $16.8 \text{ km}^3$  discharge measured on the latter at Bongor. Thus, the Logone fed the Yaéré floodplains with  $3.6 \text{ km}^3$ . The Yaéré in turn is drained by the El-Beïd which restores  $1.2 \text{ km}^3$  to the Lake Chad from the overflows from the Logone (Fig. 2). The Lake Chad basin encompasses three climatic zones with an average annual rainfall generally decreasing from south of Lake Chad northwards. The precipitation regime differs significantly from one zone to another. The annual precipitation is around 500 to 1000 mm in the Sudan zone, 100 to 500 mm in the Sahel zone and less than 100 mm in the Sahara zone (Fig. 3). In the Lake Chad basin, the wet season occurs between June and September, and the dry season between October and May. Evaporation from free water surface is inversely correlated to rainfall. The total annual

evaporation is about 2500 mm/year. Yearly extremes in temperature range from 13°C (during wet season) to 45°C (during the day in April and May).

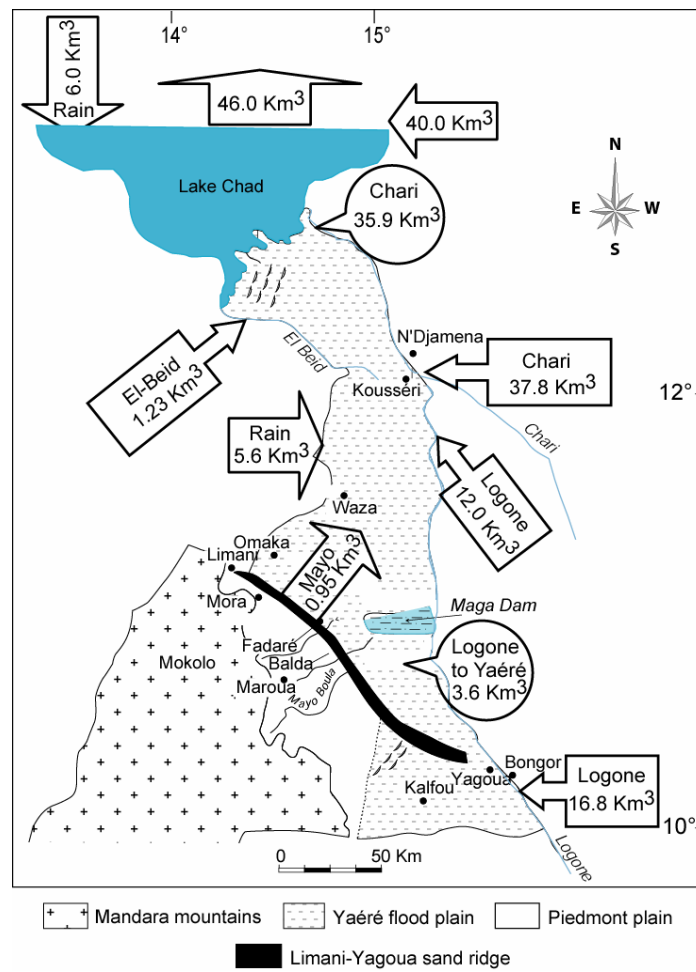


Figure 2. Elements of water balance in the Yaéré floodplain (Adapted from Olivry, 1986)

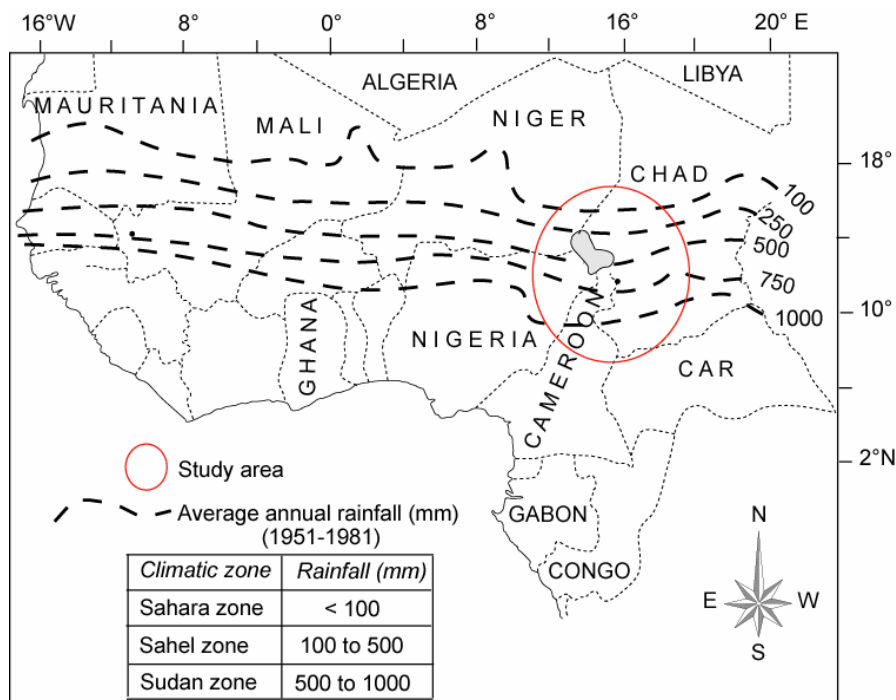


Figure 3. Average annual rainfall (mm) from 1951 to 1981 and climatic zones (Adapted from Niel et al., 2005)

### 3. CLIMATE VARIABILITY AND ITS EFFECT ON NATURAL RESOURCES

From long-term hydrological observations, Olivry *et al.* (1996) demonstrated that the volume of water stored in the lake decreased from  $40 - 100.10^9 \text{ m}^3$  (in 1962) to  $7 - 45.10^9 \text{ m}^3$  (in 1990). The lake surface area was reduced dramatically (Fig. 4) from 25,000 sq.km (in 1960) to 2,500 sq.km in 1976 so that about 90% of the originally inundated area has been exposed.

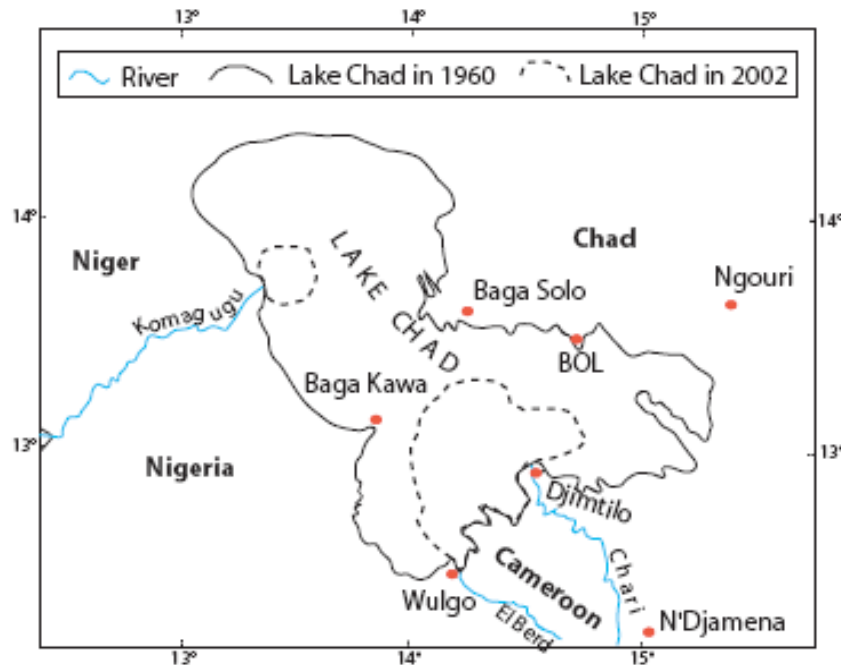


Figure 4. Character of the Lake Chad surface area in 1960 and 2002

Fish production decreased from 140000 tons in 1966 to 70000 tons in 1983. Many people lost their traditional livelihood (for example the food deficit in Chad was about 140 000 tons) and left the area. Apart from the long-term periodic changes in lake level, the basin's ecosystems experience seasonal fluctuations that probably represent the most significant feature of the area, around which people, animals and vegetation have had to adapt their lifestyles (Batello *et al.*, 2004). The availability of water over the year depends on the seasonal peaks of rainfall, river flow and lake level that succeed each other from July to January. When a resource becomes scarce, the interaction between the various users and the exploitation of groundwater and surface water become more critical (Rijsberman, 2003). Droughts from 1976 to 1993 represent the longest and most intense of the century (L'Hôte, 2003). During that period, NE Nigeria experienced a 36% decrease in the mean annual rainfall (Hulme, 1992) and in other areas; the mean annual rainfall was less than 15 to 30% of that in 1960 (Fig. 5).

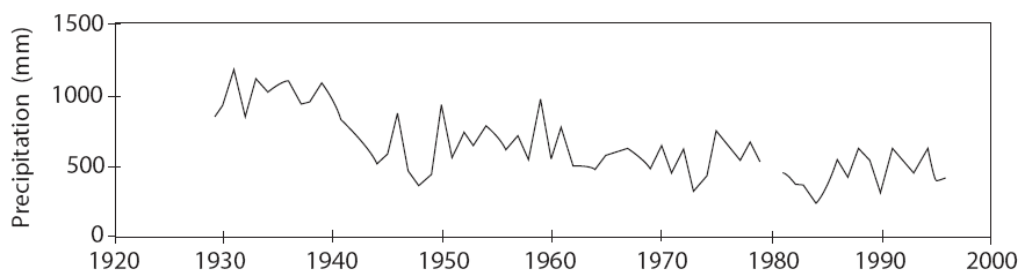


Figure 5. Variation in rainfall from 1930 to 2000 in the Lake Chad basin at N'Djamena

Because of the reduction or absence of surface flooding in some area of the Chad basin, young plants are mostly root shoots. Grass becomes thin; many animals are obliged to pass a large part of the dry season outside the protected area thus increasing susceptibility to poaching. The drop in productivity of pastures has provoked over exploitation of the space, which has exacerbated ethno-cultural tensions between stock-breeders and farmers who were all used to living together intelligently rather than in competition for water.

#### 4. HUMAN INFLUENCES IN THE LAKE CHAD BASIN

Increased economic activities, which led to an increase in population and standard of living, have resulted in over-fishing, over-grazing, poor farming practices and deforestation in the Lake Chad basin (Adenle, 2002). The increased population needs more drinking water, which is mainly extracted from groundwater. The population is growing at the rate of 2 to 3 percent per year. The projected population of the people who depend on the resources of the Lake Chad conventional basin (see Fig. 1) could exceed 50 million in 2050 (Table 1).

Table 1. Population and surface area of the Lake Chad conventional basin

Country	Lake Chad Conventional basin					Total
	Cameroon	Chad	Central Africa Republic	Niger	Nigeria	
Population (2001)	2671200	6428056	890400	305280	17648832	<b>27943768</b>
Population (2050)	5288976	12727550	1762992	604454	34944687	<b>55328659</b>
Surface area (km <sup>2</sup> )	56800	361098	197800	231325	205500	<b>1052523</b>

Unregulated human migration and the resulting activities (over-grazing and trampling by livestock, land clearing for agriculture, human settlements) have intensified soil degradation and put significant pressure on natural resources of the Chad basin. The characteristics and performance of the Lake Chad basin fisheries are closely linked to the regional hydrological regimes and distribution of water. This is largely determined by climatic patterns, but human activities, such as irrigation and dam construction, are also important.

Dam construction for irrigation on major influent rivers, such as the Logone in Cameroon and the Komadugu-Yobe in Nigeria, further altered the hydrological pattern in the Lake Chad basin. According to Adenle (2002), the indiscriminate construction of dams in the upper reaches of the Komadugu-Yobe has had untold impact on the reduction in the area of the Nguru wetlands, while the virtual disappearance of Lake Chad and poor land use has caused environmental degradation that further accelerates the rate of desertification in the area. This led to the loss of an estimated 200 000 ha of floodplains along the lakeshore and rivers, which were critical fish breeding and nursery areas (Batello *et al.*, 2004). The Maga Dam in Cameroon has reduced the flow of the Logone River and seasonal inundation of the Yaéré floodplain. In the Maiduguri urban area, there is a serious problem of lowering of the groundwater level because of the indiscriminate withdrawal for water supply and the construction of Alau Dam, which has resulted in the reduction of flooding over the Sambissa Wetland (JICA, 1995). In all the riparian countries, the implementation of fisheries management policies has often been weak, hindered by poor financial support and a failure to translate national policy declarations into locally adapted management systems. According to Poryadin & vinnicova (2001), water management and irrigation substantially modified the ecological conditions, influencing also the interaction between the groundwater and surface waters. In the Yaéré floodplain, hydro-agricultural development schemes, rice growing and the Maga Dam have caused localised outbreaks of many diseases (cholera, malaria, anaemia), and an increased incidence of some others. The presence of water is also the focal point for significant biological faunistic and floristic diversity (Fig. 6), and therefore of bacteria, viruses, fungi, and helminths, and related species that are potentially dangerous to man (Guégan, 2003).



Figure 6. The Lake Chad basin as a natural habitat for migratory birds

The expansion of agriculture in the Lake Chad basin is endangering the transhumant systems because it reduces the availability of feed resources. At the same time, the grasslands are under constant pressure to support a growing number of livestock (Batello *et al.*, 2004). In some countries of the Lake Chad basin Commission (LCBC) political instability also poses a threat to the proper management of the Chad basin's water resources.

Poverty, which often forces people to live in geographically unstable locations and in inadequate shelters, the over-utilization by the rural population of some of the remaining natural or semi-natural land resources for grazing, wood for fuel, hunting, and other purposes are also the major factors contributing to the creation of vulnerable communities. Conflicts between farmers and pastoralists have increased because they are competing for natural resources. Inappropriate irrigation policy and land use planning and lack of appropriate institutional arrangements 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. Due to the lack of sites with a standard biodiversity background, plant successions are very rapid (Lemoalle, 2002). High costs of fertilizers and difficult access to agricultural credit are behind the poor adoption of improved technologies that could increase the production in recessional land.

## 5. MEASURES FOR PROTECTION OF WATER RESOURCES AND ENVIRONMENT IN THE LAKE CHAD BASIN

The management of water in a catchment therefore requires integrative approaches and assessment criteria 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 (Wirkus & Böge, 2005). Measures must be adopted for preventing and mitigating the impact of water shortage through both short-term and medium-term actions. The action of both the state and communities in water management must be improved through better planning in order to reduce loss of life, property, and environmental assets. Any project in the Lake Chad basin must therefore focus on improving environmental conditions by paying attention to essential components of environment such as:

- drinking water; improving supply in terms of quality and quantity;
- reforestation; planting adequate vegetation to eliminate floodwater through evapotranspiration;
- health; supporting curative and preventive activities and epidemiological surveillance;
- land use; educate the population on incorrect land use which could increase vulnerability. A rational and restricted use of mineral fertilizers paying particular attention to kind, dose, time and method of their use;
- common legislation; at this time, there are no harmonized water laws and regulations in the sub-region. Since communities have different practices with respect to water, they may value it differently;

- enabling access to microcredits in order to favour direct investments by farmers;
- giving priority to demand and perceived needs, and adaptation to social and cultural models and consumption habits;
- a constant supervision of catchment area (a series of perpetual operations warranting against any risk of water pollution in the aquifers).

According to Batello *et al.* (2004), formal protection in the Lake Chad basin started in 1963 with the creation of the Zina-Waza Hunting Reserve (Cameroon). From the 1960s onwards, there has been a steady movement to create protected areas in the Central African Republic, Chad and Nigeria, based mostly on the presence of spectacular wildlife, such as elephants, giraffes and large antelopes. Since 2000, virtually the whole of Lake Chad has been proclaimed a transboundary Ramsar (the convention on wetlands, signed in Ramsar, Islamic Republic of Iran, in 1971, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources) site of international importance.

In planning the growth of the Lake Chad basin, various factors should be considered in order to protect the water resources and environment. Because access to information is a factor that determines the degree of vulnerability, 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. Systematic awareness-raising campaigns, carried out with the active participation of the population, will encourage people to live in safer environments.

High-risk areas must be identified, as well as their degree of vulnerability. Groundwater vulnerability maps show how susceptible the aquifer is to contamination from above, according to various factors of influence. Factors of influence are for example the type of soil, depth of groundwater table and aquifer importance. Meanwhile, great opportunities for saving Lake Chad are also possible by changing the irrigation and the cultivation system from the alluvial plain which could represent a contribution to reducing agricultural water consumption and limit groundwater pollution. Up to now, rice requiring basin irrigation has been cultivated in the Yaéré and Komadugu-Yobe plains. From July to September, the Lake level and river flows are at their minimum. From October, after the harvesting of millet and drying of natural grasslands, the animals return to the islands, and Lake fluctuations allow maize cropping in recessional land. In November, river flows reach their peak, and soils along the banks are flooded. In January, the river flow decreases, and agriculture is practised in the recessional land along the banks. The time and amount of the fluctuations are traditionally known by farmers and pastoralists, who have developed farming and grazing methods adapted to the water movements. The seasonal fluctuations in lake and river levels create large areas of land that are periodically covered and uncovered by water. As the water recedes, this land stores moisture that can be exploited for agricultural production. According to Batello *et al.* (2004), pastoralists 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 grasslands and prevents the degradation and desertification of the region's poor and fragile soils. The sustainability of irrigation projects is dependent on the consideration of environmental effects, as well as on the availability of funds for the maintenance of the implementation schemes. In Bulgaria the adaptation options for an increase of the irrigation effectiveness include: introduction of irrigation technologies with decreased water charges and without losses under water transport and spreading; restoring and reconstruction of the already constructed hydromeliorative fund; reconstruction and building of new test-pits for utilization of groundwater; utilization of waste water and drainage system water (Alexandrov & Genev, 2003). It is essential for irrigation projects to be planned and managed in the context of overall river basin and regional development plans, including both the upstream and downstream areas (Batello *et al.*, 2004).

It has been recognized that regular monitoring of the physical, chemical and biological parameters characterizing water quality in rivers, lakes and reservoirs used for water supply is essential for protecting public health and assuring the long term reliability of these resources (Papadimitrakakis & Findikakis, 2005). The data collected from such monitoring: a) allow the early detection of changes and trends in water quality, b) provide the basis for calibration of predictive water quality and ecological models, c) allow evaluation of alternative remediation strategies, and d) contribute to the advancement of the fundamental understanding of the behavior of these water bodies. Continuous water quality monitoring is also necessary for regulating land use around reservoirs, and for selecting proper treatment practices of row water.

The ideal integrated system for water quality management in water supply systems consists of three major components (Papadimitrakakis & Findikakis, 2005):

- a) a system of continuous automated, telemetric monitoring of water quality and other parameters that affect water quality, e.g. meteorologic and hydrologic data;
- b) computer models for the simulation of the recorded water quality, and other, not directly measured parameters, and;
- c) a decision support system, including a database and other software for storing, processing and analyzing the collected data.

The serious threat posed by water shortage therefore requires a concerted effort by the international community to support creative water management initiatives. Development and implementation of national and regional policies should be made with full awareness and respect of traditional management systems because these appear effective in regulating fishing, grazing, food collecting, and water harvesting.

Special attention should be given to the establishment of arrangements designed to strengthen the involvement of the scientific community in the elaboration of innovative approaches to water management, based on the recognition that the scientific community has played, and will continue to play, an active role in promoting initiatives in support of water shortage.

In urban areas, water supply companies can contribute to water resources protection, in a direct way through the acquisition of land, changing the land use from agricultural to a less harmful destination, such as a nature area. In an indirect way water supply companies may play a positive role in informing the authorities on deteriorations of water resources quality in their areas and reducing the public water demand by stimulating public awareness.

The existence of LCBC as the only intergovernmental river basin organization in the Lake Chad basin since 1964 is an important step in the direction of establishing the institutional support needed for protecting the water resources. The riparian states agreed on the recognition of the international status of the Lake Chad basin. The LCBC has very wide objectives which include regulation and control of the utilization of the water resources and other natural resources as well as the initiation, promotion and co-ordination of projects and settlement of disputes. While LCBC have good intentions to monitor, better understand, promote awareness of and conserve natural resources, there has been very little coordination of such efforts. This lack of coordination stems from often simple gaps in communication, lack of information-sharing, lack of a shared vision, lack of public participation, limited integrated planning systems, low degree of local stakeholders involvement, and lack of adequate knowledge of national policy, activities and orientation of water resources project at national level. As the water supplies are chiefly based on groundwater in the Lake Chad basin, the challenge that is being faced by the LCBC is to implement groundwater protection. Difficulties for the field of water management in the Chad basin are caused by insufficient understanding of the hydrogeologic 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, the river basin, while the groundwater resources need 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 only be combined in the final process of integrated water resource management, in larger entities comprising both river basins and groundwater basins. In all these

situations, cooperation between countries and harmonization of the water resources laws of the riparian countries are of primary importance in order to understand the problems, and to try to develop reliable solutions.

## 6. CONCLUSION AND OUTLOOK

The above-mentioned analysis suggests that climate variability and human intervention continue to pose a major challenge to the national and international communities. In the Lake Chad basin, water, of course, remains a deficient resource. Knowledge of the dangers posed by diffuse inputs into soils and groundwater and by intervention in the structure of the environment and the effects of such inputs is insufficient. Environmental policy objectives have not always been adequately implemented. Land and water management need to be integrated within basins or watersheds. Meanwhile, the sustainable existence of aquatic and wetland ecosystems in the Lake Chad basin depends upon the hydrological systems. Droughts have ruined crops and deepened the economic crisis already strongly felt in the country's rural areas, to the point that some of these areas face chronic food shortages. Adaptability and flexibility are the keywords for sustainable development in fragile ecosystems.

Water vulnerability constitute a research objective in collaboration with guardianship authorities which are called more than ever to look for scientific means reinforced by legal tools to protect water resources in the Lake Chad basin. The reduction of water consumption is a necessary step towards ensuring central drinking water supply in the Lake Chad basin. The potential contribution of science and technology over the next decade to reducing property loss and environmental damage from meteorological and hydrological origin should be greater. Protection measures will serve to safeguard water resources quality in the long term. Based on this review, our main recommendations are:

- the development of a reliable data base to support water management decisions in the Lake Chad basin;
- the preparation of monitoring guidelines for the Lake Chad basin;
- the transfer of knowledge among countries and the establishment of information exchange facilities;
- the promotion of education, training and research in order to support conservation and sustainable development of the Lake Chad basin;
- the strengthening of cooperation between member states of LCBC through coordinated research (by experts and researchers of each state), planning and management of mutually shared resources in the Lake Chad basin.

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