FAOWATER

Seminar Proceedings

Adaptive Water Management in the Lake Chad Basin

Addressing current challenges and adapting to future needs

World Water Week, Stockholm, August 16-22, 2009

Adaptive Water Management in the Lake Chad Basin

Addressing current challenges and adapting to future needs

World Water Week, Stockholm, August 16-22, 2009

Contents

Acknowledgements

The authors wish to express their gratitude to the following persons for their support; namely: Claudia Casarotto for the technical revision and Edith Mahabir for editing. Thanks to their continuous support and prompt action, it was possible to meet the very narrow deadline to produce it.

Seminar Overview

Maher Salman, Technical Officer, NRL, FAO

Alex Blériot Momha, Director of Information, LCBC

The entire geographical basin of the Lake Chad covers 8 percent of the surface area of the African continent, shared between the countries of Algeria, Cameroon, Central African Republic, Chad, Libya, Niger, Nigeria and Sudan.

In recent decades, the open water surface of Lake Chad has reduced from approximately 25 000 km^2 in 1963, to less than 2 000 km^2 in the 1990s heavily impacting the Basin's economic activities and food security. 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.

The problem of the Lake Chad is actually manifold, as listed below:

- The variability of the hydrological regime and the dramatic decrease in freshwater availability.
- The relatively high rating of water pollution mainly due to commercial cotton and rice production known to use large quantities of agro-chemicals.
- The low viability of biological resources which pertains to the inability of the regenerative rates of the plant and animal resources to keep pace with exploitation and disturbances.
- The loss of biodiversity, in particular loss of plant and animal species, as well as damages to ecosystem health.
- The destruction and modification of ecosystem due to the change of the Lake from an open water system to a marshy environment.
- The sedimentation of rivers and water courses that has led to a reduction in the inflows to the Lake.
- The proliferation of invasive species.

It is still possible for this situation to worsen in future and this will have significant impact on the local economy, the Lake and its tributaries (Chari and Logone). The Lake's wildlife and riparian populations incessantly migrate in search of areas with water around the Lake and their survival is seriously affected. The vulnerable populations are forced onto rural exodus and compelled to migrate across the borders to live as climatic refugees.

Several approaches and solutions can be proposed to contribute to saving Lake Chad and in turn provide the almost 30 million people, who rely on the Lake for their livelihoods, with adequate economic and social development opportunities. Led by the conviction that there cannot be enough water saving from efficient management only, due to the high evaporation, a call was made for the adoption of measures beyond the convention of the available water resources in the Basin. The supply management has, however, been dominating while less attention has been given to demand management. The combination of both as well as the introduction of emergent measures that respond to the global cause of the problem is, therefore, needed within an adaptive framework to save the Lake.

This seminar will thus address the current challenges in the Basin and will explore opportunities for an Adaptive Water Management and possible future strategies to be adopted to replenish the Lake and to safeguard its surrounding livelihood. In particular it will address:

- The aquifer recharge and storage systems to halt the high level of evapotranspiration.
- The Chari-Longone water transfer project.
- The application of climate adaptation systems and the improvement of predictability systems.
- The appraisal and the up-scaling of water conservation and small-scale agriculture technologies.

One of the main challenges that the Lake Chad Basin is facing is related to the high level of evapotranspiration caused by the high temperatures throughout the year – a value of around 2 200 mm/year has been estimated for potential evapotranspiration. The high temperatures also limit the potential of natural recharge as most of the precipitation evaporates as soon as it falls. Recharge could be artificially enhanced by injection of clean surface water or grey water; or by construction of subsurface dams as it has been applied in Niger.

Research studies have shown that high evapotranspiration in the Lake Chad area involves not only surface water but also groundwater. The storage of large volumes of surface water into the underground could surely help to reduce its evaporation. However, the past years have shown that the healthiness of Lake Chad depends very much on the surface water availability or river discharge. Therefore, any conservation methodology like artificial recharge can be applied at small scale, when the needed volumes of water do not significantly reduce the river discharge.

Artificial recharge involves injection wells and surface infiltration systems. Due to the fact that injection through wells requires some engineering skills as well as pre-treatment of the water to avoid clogging, this methodology is generally considered as cost-intensive compared to surface infiltration. On the other side, surface infiltration needs highly permeable soils and sufficient depth to groundwater to be practicable. However, artificial recharge in the Lake Chad Basin can be applied only at a small scale. Medium to large scale systems require large volumes of water that are also needed for the preservation of the level of Lake Chad.

In order to adapt and reduce the harmful effects of climate change, the Lake Chad Basin Commission also engaged in the study of the possibility to adopt a surface water recharge system, through the transfer of some of the waters from the Oubangui Basin to the Lake Chad Basin. The aim of the water transfer project is to construct a navigable channel using some inflows from Oubangui to supply Lake Chad with water. This arrangement will have multiple goals: to ensure river transportation in order to transfer goods from east to west across Africa; to produce electricity; and to develop irrigation and agro-industry in the region.

In addition to its capacity for drought control in Chad, the gradual restoration of the level of Lake Chad will also serve as a barrier against Sahara desert encroachment. The project can be used as a real impetus for the rehabilitation of fisheries and irrigated farming on the banks of the Lake and of the Chari River, and it will help to connect LCBC countries to the two Republics of Congo by a navigable channel. Also, the permanent navigability of Oubangui, which flows mainly in DRC and in the Republic of Congo, is vital to the northern areas of the two countries which are accessible only this way. Finally, the project, through the construction of the Palambo dam, will greatly extend the supply of electricity.

It is nonetheless necessary to conduct profound and detailed social and environemtnal impact assessment studies, particularly considering the negative impacts the project could have on both the Lake Chad Basin and the Congo Basin. In particular, attention should be paid to the final quality of the water that results from the mixing of the waters of the Lake Chad Basin and the Oubangui and the effect this will have on the ecosystems. There are also often public health impacts associated with water transfer canals that can serve as water-borne disease vectors as well as severe impacts on the socio-economic activities (fisheries, animal husbandry, agriculture, etc.). Moreover, the reduction in the flow of Oubangui, as also a result of climate change, is of great concern to the riparian states when thinking about a possible transfer of part of such a volume of water into another basin.

The feasibility study of the project may respond to this need and will identify the main environmental stakes and impacts.

The effect of climate change, coupled with several anthropogenic effects, is considered as one of the main causes of the severe depletion of the Lake. Therefore, it is urgent to enhance the traditional climate change adaptation strategies already put in place on the Lake Basin though the development of effective climate predictability systems.

Humans have been adapting to changing climatic conditions and to the impact of extreme climate events in the Lake Chad Basin for several centuries. Much of this adaptation occurred gradually and spontaneously and the economies of many local communities in the basin to this day still depend on sophisticated production and social systems adapted to manage climate risk and variability. Unfortunately, with increasing population, poverty, illiteracy, globalization, coupled with the rapid preponderance of climate related risks in recent decades and the resulting patterns of loss, there seems to a breakdown in the effectiveness of spontaneous adaptation and coping strategies.

Knowledge of current adaptation and predictability systems to natural climate variability can reduce vulnerability in the short-term and provide insights and experience that could enhance resilience to long-term climate change in the Lake Chad Basin, especially as it relates to water management. Planned adaptation, therefore, becomes crucial. Other measures recommended include more capacity building efforts, improvements of better forecasting and early warning systems, increased donor funding on climate adaptation technologies, environmental education and planning, information pooling, the exchange of information on best practices, integrated water resource management approach, strengthened technical cooperation and close cooperation with policymakers and all stakeholders within the Lake Chad Basin.

The depletion of Lake Chad poses a pressing challenge also to irrigated agriculture which is an important water consumer and the source of livelihoods for the overwhelming majority of the population: 75 to 80 percent of the farming population consists of traditional smallholders, producing mainly staple foods for household consumption and with relatively marginal connections to market. Due to scarcity of water resources and poor performance of many large scale irrigation schemes interest has been developing in recent years for seeking ways to improve the productivity and livelihoods of the small-scale farmers – typically farmers in Lake Chad Basin – and at the same time to improve water use (efficiency and conservation).

Recently, a number of innovations have been developed for small-scale farmers to manage water and increase water use efficiency with simple, affordable agricultural water management technologies for more productive and profitable farming. Traditional small- scale irrigation using simple water lifting techniques (buckets, shaduf, treadle pumps, motorized pumps, etc.) were long employed in the region and recently in some countries in the region (Niger, Nigeria, Burkina Faso, Senegal, Mali, etc.). The introduction of small-scale irrigation technologies – such as drip irrigation, micro/mini sprinkler, PVC pipes, tubewells and wrapped filter - has led to rapid expansion and intensification of irrigation showing the existence of an enormous potential to successfully harness smallholder production. In other respects, a range of rainwater harvesting techniques has been utilized with success in the region (Niger and Burkina Faso) to stabilize and increase the yields of rainfed crops.

However, small-scale technologies are not a panacea; there are a lot of examples where these technologies have been unsuccessful in their performance, application, dissemination or adoption. The challenge is to adapt these technologies to local circumstances and to plan and implement them within the much broader framework of agricultural and rural development, in ways that yield optimal returns for poverty reduction up-scaling smallholder farming systems and saving scarce water.

Increasing temperatures, erratic rainfall, mismanagement and over-use are contributing to the shrinkage of Lake Chad, and putting the lives of some 33 million inhabitants at risk. The campaign to save Lake Chad was launched 14 years ago with a plan conceived by the Lake Chad Basin Commission - a group comprising Nigeria, Niger and Chad. However, due to the magnitude of the task, too little has happened since then. African leaders are strongly committed to saving Lake Chad and to enhance the adaptive and sustainable management of the natural resources and biodiversity of the Lake Chad Basin for the benefit of present and future generations. However, they are only too aware that they cannot do it alone. They require support and assistance from all development partners and indeed the international community to save Lake Chad, thus recognizing their role and responsibility in conserving the global value of the largest, freshwater reservoir in the Sahel region of Africa.

The Project for Water Transfer from Oubangui to Lake Chad

Michel Dimbele Kombe

Director of Water resources and Environment

Lake Chad Basin Commission

Presentation of Lake Chad

Figure 1. The Lake Chad Basin

Lake Chad is situated at the southern fringe of the Sahara desert, east of the Sahel region between 12°20 and 14°20 latitude North; 13° and 15°20 longitude East. Considered as a Ramsar site of world importance because of its biodiversity, Lake Chad is a freshwater reserve with only 5 percent of salt content and it is bordered by Cameroon, Niger, Nigeria and Chad. Its depth varies between 1.5 and 10.5 metres and it is about 215 metres above sea level, with apparently no outlet (endoreic lake).

The Komadugu-Yobe sub-basin (148 000 km^2) and its upper basins provide natural inflows of about 7 km^2/

annum, the bulk of which is retained in the reservoirs of Kano State. Only a volume of 0.45 km^2/annum enters Lake Chad.

The Chari-Logone sub-basin has a surface area of about 590 000 km^2 and provides water for vast stretches of wetlands, Yaeres floodplains, (6 000 km^2 of active surface area, wet years). It provides an average of 37.8 km^2/year to Lake Chad. These two water courses from the Central African Republic contribute 95 percent of total inflows into Lake Chad.

The hydrological active zone of the basin is smaller in size (984 455 km^2) and it includes 5 riparian countries. The topographic surface of the basin (2 381 635 km^2) covers vast areas of desert zones of Niger and Chad, which are now cut off from the Lake itself from the hydrological point of view.

However, human consumption and its impact on the mass of water is negligible, less than 3 percent of the basin's discharge. On the contrary, losses caused by evaporation in the Yaeres wetlands are significant.

For millennia, Lake Chad has been a historic centre for development and cultural exchanges between the people living north and south of the Sahara, respectively. Their major economic activities are: fishing, agriculture, commerce, natron mining and tourism.

Fishing on Lake Chad is a very lucrative activity, between Baga Doro market in the south of Nigeria, the market of N'Djamena in Chad and Lake Chad. Between 1960 and 2001, average catches of fish in Lake Chad varied between 50 000 and 80 000 tonnes (T. Jolley et al., 2002). The riparian population of Lake Chad is estimated at 20 million inhabitants. This number may increase to 35 million in 2010.

In May 1964, the Fort Lamy Convention was signed by the four riparian countries of Lake Chad to establish the LCBC and deal with development problems centred on Lake Chad in a zone called the "conventional basin". It is for the most efficient use possible of the waters of the Lake Chad Basin, to coordinate regional development and provide assistance to the settlement of conflicts that may occur between the Member States. The Central African Republic became a member of LCBC since 1994 and the new "conventional basin" was extended to include the upper basins of Chari-Logone systems and Komadugu-Yobe. The mandate of LCBC henceforth extends to the active basin measuring 966 955 km^2. Libya became a member in 2008, while Sudan is still an observer.

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.

Figure 2. Fishing on Lake Chad

Figure 3. LCBC Member Countries presentation

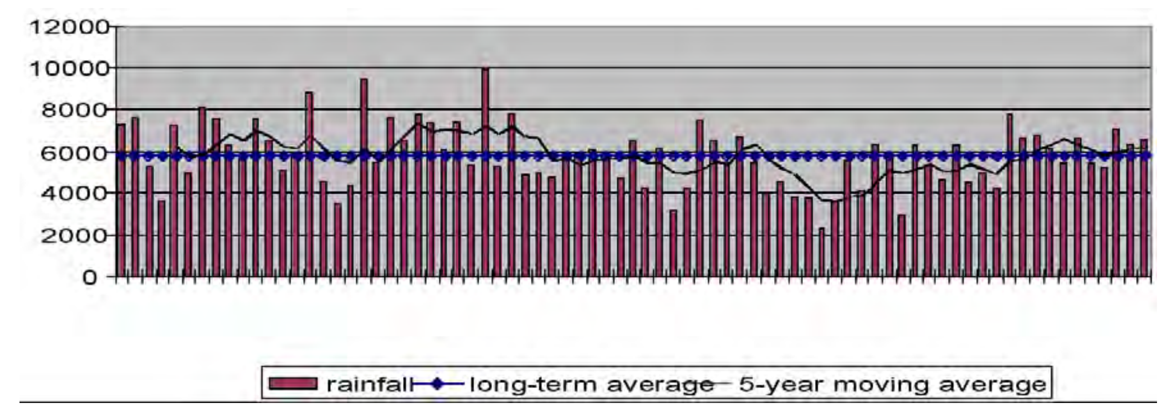
Moreover, the high rate of evaporation in the lake due to its proximity with the Sahara desert has, paradoxically, not affected the relatively low salt content of its waters. Lake Chad is still a freshwater lake and research indicates that loss in the Lake's waters is also due to infiltrations (18 percent of its annual inflows) towards phreatic water tables, the levels of which have become lower than that of the Lake itself.

The Effects Of Climate Change And Its Consequences

In the 1960s, the surface area of Lake Chad gradually reduced from 25 000 km^2 to less than 2 500 km^2 today. The causes are climate change (UNDP & ORSTOM, 1988), which is responsible for diminishing rainfall in the region, and irrigation requirements representing 5 percent of the Lake's volume.

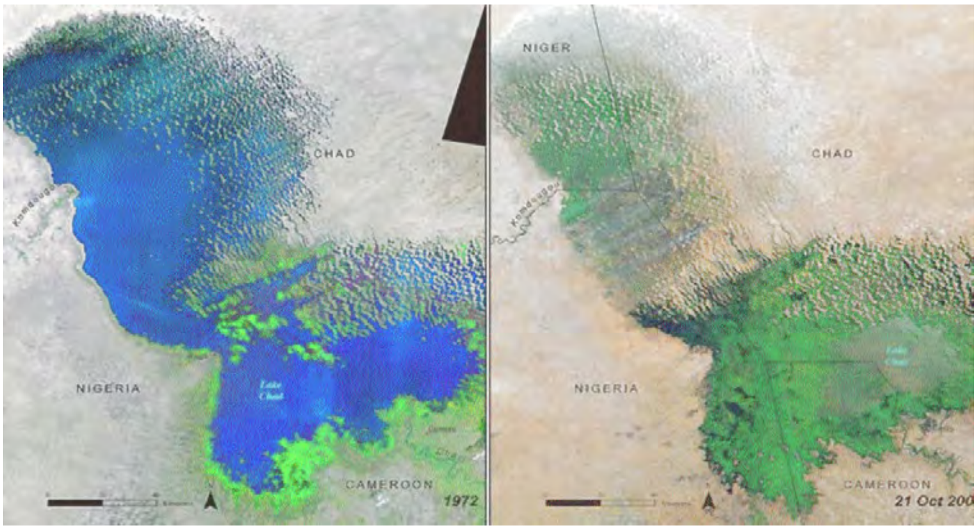
In fact, the long drought which started in 1973 and worsened in the 1980s is still in our memory. For the period 1971-1990, the average discharge of Chari reduced to 21.8 km^2 because of changes in the rainfall pattern of the basin.

Figure 4. Rainfall in N'Djamena (1932-2008)



Under these conditions, the Lake got divided into two parts: the completely dry and vegetation-covered north basin and the south basin which remained wet as a result of direct inflows from the Chari River.

Figure 5. Satellite images of Lake Chad, (NASA, 1972 and 2007)



It is still possible for this situation to worsen in future and this will have significant impact on the local economy, the lake and its tributaries (Chari and Logone). The Lake's wildlife and riparian populations incessantly migrate in search of areas with water around the Lake and their survival is seriously affected. The vulnerable populations are forced onto rural exodus and compelled to migrate across the borders to live as climatic refugees.

It therefore became necessary for LCBC to study the possibility of transferring some of the waters from the Oubangui Basin to the Lake Chad Basin, in order to adapt and reduce the harmful effects of climate change.

The Project "For Water Transfer from Oubangui to Lake Chad"

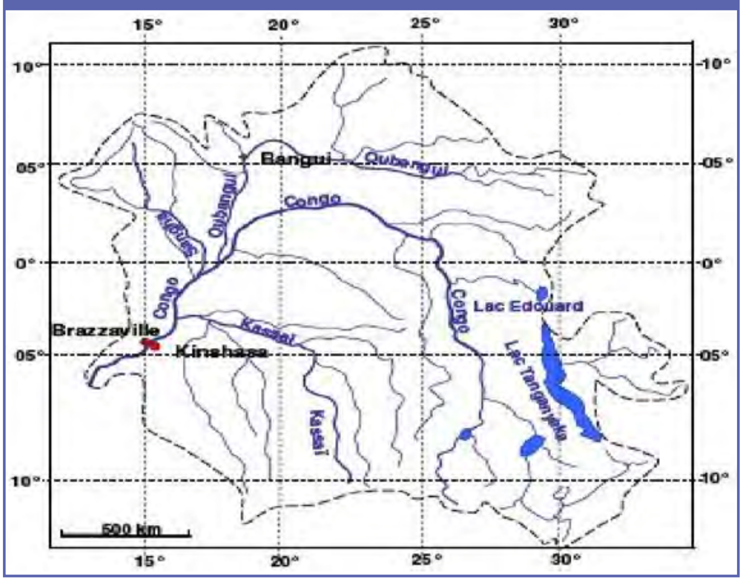
From the start, the idea of the project was developed in 1988 by BONIFICA, an Italian consultancy firm, as part of the big TRANSQUA project, then by the National Electricity Corporation of Nigeria (NEPA). The aim was to construct a navigable channel using some inflows from Oubangui to supply Lake Chad with water. This arrangement will have multiple goals: a) ensure river transportation in order to transfer goods from east to west across Africa; b) produce electricity; and c) develop irrigation and agro-industry in the region.

The project plans to construct a retention dam at Palambo (upstream of Bangui, Central African Republic) to serve as a catchment area. The high flow through pumping gets into river Fafa, a tributary of Ouham and by gravity through a 1350 km long feeder channel to the Chari and Lake Chad hydrographic system.

Figure 6. View of Palambo site, 65 km from Bangui in CAR

Indeed, the Central African portion of the Lake Chad Basin concerned with the water transfer covers a surface area of 197 800 km^2, it is the most populated area of the country with an agricultural potential based essentially on cotton (60 000 tonnes of cotton between 60-70) and food products: millet-sorghum (55 000 tonnes), and animal husbandry (10 to 12 million cattle). There are no hydraulic works in this area. However, the largest national parks or reserves are many in the area, especially Manovo-Gounda and Bamingui-Bangoran.

Figure 7. Congo Basin; 3 632 000 km^2



The Congo Basin covers a surface area of 3 632 000 km^2, while Oubangui which is one of the tributaries of the Congo River had a discharge of 4000 m^2/s in the 1960s and approximately 3500 m^2/s since the 1970s.

3-1. Socio-economic benefits

The Central African Republic (CAR) and Chad as well as the North of Democratic Republic of Congo (DRC), cover an area with no direct access to the sea. Their economy is strongly penalized by this natural phenomenon. Trade in this area is therefore exclusively dependent, for importation of goods, on the trans-equatorial river way which goes from Bangui, on to Oubangui, to Pointe Noire in Congo Brazzaville or Matadi in DRC. For CAR, another way is by road, called the "Trans-Cameroonian", going from Bangui to Douala. However, all the traffic, especially the weighty ones, cannot economically be transported using this way, so there was need to seek another alternative for the total opening up of this country.

In addition to its capacity for drought control in Chad, the gradual restoration of the Lake Chad's level will also serve as a barrier against Sahara desert encroachment. The project can be used as a real impetus for the rehabilitation of fisheries and irrigated farming on the banks of the lake and of the Chari River, and it will help to connect LCBC countries to the two Republics of Congo by a navigable channel. The water transfer from Oubangui into the Benue/Niger system by a channel connecting Chari to Logone and Mayo Kebbi will facilitate navigation and transportation of goods from Port Harcourt in Nigeria to Bangui via Bouca (CAR), and this will open up CAR completely.

Also, the permanent navigability of Oubangui, which flows mainly in DRC and in the Republic of Congo, is vital to the northern areas of the two countries which are accessible only this way. This is the reason why, considering the possibility of extending the supply of electricity to some of these areas, these two countries are supporting the Palambo dam project.

In 1989, the Lake Chad Basin Commission (LCBC) was interested after carrying out a diagnostic study of the environmental degradation of the entire conventional basin of Lake Chad. The study was followed by the preparation and signing in 1994 by the Heads of State of a "Master Plan for the environmentally sound management of the natural resources of the Lake Chad conventional basin" which was prepared in collaboration with the FAO, UNEP and UNSO.

Among the 36 priority projects contained in the action plan of the Master Plan, was included the project for "Water Transfer from Oubangui to Lake Chad". Considered to be an urgent need to address the shrinking of Lake Chad, the LCBC Heads of State also included it in the campaign to save Lake Chad and launched it in Abuja, Nigeria, in 1994 and, at the same time, accepted the CAR as a member of LCBC. At that time, the ADB, Islamic Bank and the Economic Commission for Africa (ECA) also became interested in the project.

3-2. Feasibility study of water transfer from Oubangui to Lake Chad

The feasibility study of the project for water transfer from Oubangui to Lake Chad was launched in 1994 by the 10th Summit of Heads of State held in Abuja, Nigeria. The LCBC Member Countries should contribute one million dollars seed money for the feasibility study, in accordance with the contribution formula in force in LCBC. The project has the support of LCBC Member States' parliamentarians and Nigeria made an exceptional contribution to the tune of 5 million US dollars, as supplementary funds for the financing of the entire feasibility study. A project technical committee was set up, preceded by the admission of the two Congo, riparian countries of Congo-Oubangui, as privileged observers. Then the first Call for international tender for the feasibility study was launched in September 2001. A ministerial committee was also set up (2002) around CAR to review the terms of reference and ensure that the interests of the two countries are really taken into account. The no-objection of the Republic of Congo was received in 2003 and later that of DR Congo.

According to the terms of reference for the project, the main objectives of the studies consists of preparing a feasibility study for: i) a solution of low water support of the Oubangui by means of a reserve dam at Palambo, to ensure water transfer, energy production and a river flow to enable navigation in difficult periods; ii) water transfer from Oubangui to Lake Chad to stop the lake from drying up and gradually re-establish its level; iii) taking into account the concerns of the riparian countries of Oubangui tributaries which are not yet members of the LCBC.

As supplementary objectives, the studies will also help in: a) the production of electrical energy through a hydroelectric powerhouse at Palambo site; b) production of a certain flow towards river Logone, then river Benoué via Mayo Kebbi, in order to improve navigation conditions between Port Harcourt (Nigeria) and Bouca (Central Africa); and c) enable navigation between Chad and Oubangui.

There would be three kinds of environmental stakes:

1) Those relating to the waters transfer from Oubangui
- Impact on far stretching floodplains (Yaeres) and their uses on lower Chari, Logone and Chari-Benoue channels.
- Displacement of the people and villages on work sites.
- Opportunities offered for big irrigation and economic opportunities.

2) Those relating to the creation of Palambo dam
- Impacts on the zone which is to be sunk by the reservoir.
- Impact on far stretching floodplains (Yaeres) and their uses on lower Chari, Logone and Chari-Benoue channels.
- Displacement of the people and villages on work sites.
- Opportunities offered for big irrigation and economic opportunities.
- The impact of a change in the water regime downstream of the dam, beneficial when it improves navigation and to be determined when it improves animal or vegetation production linked to the flood and low water regime.
- The impact linked to the new mode of managing the waters of Oubangui, on existing works downstream or future works (with particular attention for non-member countries of LCBC)

3) The chemistry of mixing the two types of water
- Transfer of physico-chemical and biological constituents from "Oubangui" aquatic milieu towards ecosystems of the Lake Chad Basin (and, to a lesser extent, those of Niger basin in spite of a "dry passage"), accompanied by the risk of altering and destabilizing the current ecology of this basin.

However, the dam at Palambo and the crossing of the chain of mountains, the "dorsale oubanguienne" which is situated between Oubangui Basin and the Lake Chad Basin are considered to be among the most important of the works and those that would require very special attention.

In 2008, an international invitation to tender resulted in the selection of a Canadian firm, CIMA-International, which is to carry out the studies. A consultation contract amounting to US$ 3 943 296 HTT was signed between the LCBC and the consultant on 16 July 2009, and work is to commence by the end of August 2009, for a duration of 23 months. The various stages for the implementation of the project are: 1) data collection/review/analysis; 2) project planning: supplementary studies, alternative scenarios prepared with enhanced recommendations-for the crossing of the ridge separating the two basins; and 3) preparation of TORs of the detailed Engineering design, Tender Documents and submission.

3-3. Socio-economic and environmental impacts

At the stage of the feasibility study, the studies relating to the environment will identify the main environmental stakes and impacts in order to: i) to guide technical choices regarding the works; ii) to estimate the costs of compensation and mitigation; costs to be taken into account in the evaluation of the feasibility of the project. The studies shall also define the arguments establishing the environmental justification of the project. The study will define the necessary deepening of the environmental analyses at the further stage of detailed studies for the different project components.

The aim of the study will be to assess the general environmental impact of the water transfer project and its different components, especially for the dam and power plant at Palambo, locally as well as downstream, up to the confluence of Oubangui and Congo rivers.

These impacts relate to the local populations and the villages to be resettled on works site, navigability of Oubangui and Congo rivers, existing or planned development works in the Oubangui and Congo basins such as the Inga dam in DRC, socio-economic activities (fisheries, animal husbandry, agriculture, etc.), the chemistry when mixing two types of water, the area which will be submerged by the reservoir, the very extensive floodplains (Yaeres) and their uses on the lower reaches of Chari, on the Logone and in the area of the Chari-Benue channel, the modification to the hydraulic regime downstream of the dam.

The reduction in the flow of Oubangui, as also a result of the climate change, is of great concern to the riparian states when thinking about a possible transfer of part of such a volume of water into another basin.

According to these States, there is not enough water anymore and the LCBC's TORs do not encompass all the environmental problems which will arise from the water transfer if it is feasible.

In the past, development partners, the World Bank, the German Co-operation, FAO for water and agriculture assisted LCBC in the elaboration of the aforesaid TORs. However, all the same, these riparian States decided on their own behalf to recruit a consultant to carry out a study of the impacts of the water transfer from Oubangui to the Lake Chad, on the entire Congo Basin.

LCBC and the Congo-Oubangui-Sangha International Commission (CICOS), the authority which has the mandate of the Economic Community of Central African States (ECCAS), cooperate closely for the evaluation of costs and mitigation of related effects. A Memorandum of Understanding was signed between the two Commissions, CICOS/LCBC, on 12 December 2006, for a joint supervision of the project.

The Application of Climate Adaptation Systems and Improvement of Predictability Systems in the Lake Chad Basin

Dr H.K. Ayouba

Department of Geography, Faculty of Social Sciences

University of Maiduguri, PMB 1069 Maiduguri

Borno State, Nigeria

Introduction

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 the over 20 million people who depend on it for their livelihood. The Lake (Figure 1) 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 (Musa et al., 2008) that between 1963 and 2007, the surface area of the lake has shrunk from 25 000 km2 to less than 3 000 km2 (Figure 2). The Lake Chad Basin today is replete with many environmental problems (Table 1).

Table 1: Major environmental problems in the Lake Chad Basin

Environmental problems associated with the geographical location	Environmental problems associated with activities aimed at economic development
• Aridity (4 climatic zones, notably; hyper arid, arid, semi-arid, and sub-humid) • Climate variability • Persistent droughts (1970-1980s) • Desertification • Water shortage • Erosion	• Deforestation • Habitat and community modification Unsustainable agricultural practices (fishing, grazing, farming, irrigation) • Mining • Pollution • Sedimentation due to unsustainable farming practices • Invasive weeds • Indiscriminate bush burning

A situation analysis carried out by the LCBC (2000) revealed the following changes and developmental activities, which have influenced the state of affairs in the Lake Chad Basin:

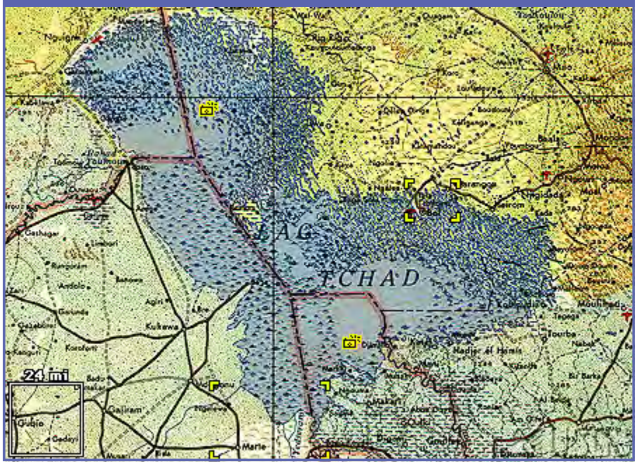
- Severe climatic changes in the Sahel over the last 30 years.
- Poor decision making as reflected in the adoption of development policies, which focused on short-term solutions (e.g. construction of large-scale dams).
- Lack of integrated water and environmental management policies as a result of insufficient knowledge of water resources and functioning of aquatic ecosystems.
- Weak coordination through low-level of stakeholder participation.

A number of challenges that limit effective integrated management and development of the Lake Chad Basin therefore became eminent. These included the conservation of available limited water resources, restoration of the lake level and its ecosystem, tackling the problem of drought and desertification arising from rainfall deficits, inefficient system of data collection, and regional cooperation and networking.

Climate change is expected to further compound these problems in the region through changing rainfall patterns with resulting impact on the hydrological regimes, agriculture, food production and nutrition security. It is also expected to bring about increased temperatures, increase in the prevalence of vector-borne diseases, decreased water security, sea-level rise, and increased variability of floods and droughts (DFID, 2004). Rising global temperatures will lead to increased flooding in coastal areas, cause a decline in agricultural production, threaten biodiversity and the productivity of natural resources and exacerbate desertification. No doubt, climate change will have disproportionately adverse effects on Africa's agriculture-based economy (Mendelsohn et al., 2000, Deschenes and Greenstone, 2007).

Recent studies have confirmed that particularly the arid and semi-arid regions of Africa are the most vulnerable areas to climate variability and change because of multiple stresses and low adaptive capacity (Osman-Elasha, 2007; IPCC WGII, 2007). 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 rainfed 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.

Figure 1. Lake Chad *Source: USGS/EROS*



Unfortunately, the knowledge/information base for decision making on expected impacts and the required adaptation measures are still very low. A major constraint to understanding current and future climate variability and change is the lack of observational climatic data in Africa. This lack of data limits, for example, regional diagnostic studies (which can identify the structure of dry and wet years) and their impacts; it also impinges on effective application of climate adaptation and predictability systems in managing water resources in African dry lands. Knowledge of current adaptation and predictability systems to natural climate variability can reduce vulnerability in the short term and provide insights and experience that could enhance resilience to long-term climate change in the Lake Chad Basin, especially as it relates to water management.

Figure 2. Lake Chad levels (1963-2007) *Source: Musa I K et al. (2008)*

Breakdown in Spontaneous Adaptation and Predictability Systems in the Lake Chad Basin

It is widely acknowledged that climate change is now inevitable and adaptation, through a range of technical, regulatory and behavioural changes, is one of the key methods available to society for dealing with climate change. Adaptations are adjustments or interventions, which take place in order to manage the losses or take advantage of the opportunities presented by a changing climate (IPCC, 2001). Various types of adaptation can be distinguished:

- **Anticipatory adaptation** (also referred to as proactive adaptation) – adaptation that takes place before impacts of climate change are observed.
- **Autonomous adaptation** (also referred to as spontaneous adaptation) - adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems.
- **Planned adaptation** - adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain or achieve a desired state.
- **Private adaptation** - adaptation that is initiated and implemented by individuals, households or private companies. This is usually in the actor's rational interest.
- Public adaptation - adaptation that is initiated and implemented by governments at all levels. It is usually directed at collective needs.
- **Reactive adaptation** - adaptation that takes place after impacts of climate change have been observed.

Adaptation is thus the process of improving society's ability to cope with changes in climatic conditions across time scales, from short term (for example, seasonal to annual) to the long term (example, decades to centuries). The IPCC (2001) defines adaptive capacity as the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. The goal of an adaptation is to increase the capacity of a system to survive external shocks or change.

Humans have been adapting to changing climatic conditions and to the impact of extreme climate events in the Lake Chad Basin for several centuries. Much of this adaptation occurred gradually and spontaneously and the economies of many local communities in the basin to this day still depend on sophisticated production and social systems adapted to manage climate risk and variability. These adaptive systems included finding alternative opportunities; liquidating assets; gathering and selling of non-timber forest products; intensification of farming, often associated with rapid and unsuccessful sowings of the principal crops at the onset of the rains and application of manure. These also involved soil management practices including the application of organic manure, animal kraaling on farmlands, ash and mulching; intercropping, especially the wisdom of combining millet (tolerant to drought and fast-maturing) with guinea corn (resistant to grasshoppers, and able to use late rain and residual soil moisture); adoption of cropping practices that maintain a more closed ground cover over longer periods (including crop rotation, planting of cover crops, and reduced or minimum tillage - combined with integrated nutrient management); seasonal migration to urban canters; the use of short and long handed hoes as against tractors; migrant farming; irrigation in the dry season; water harvesting in inter-dune depressions, excavated pits, etc. by pastoralists; deferred grazing; agro forestry and community woodlots; and afforestation, amongst others.

Much natural resource based development over centuries in the Basin has depended on traditional knowledge of weather forecast handed down from generation to generation, intuition and spontaneous adaptation to the changing environmental conditions. Unfortunately, with increasing population, poverty, illiteracy coupled with the rapid preponderance of climate related risks in recent decades and the resulting patterns of loss, there seems to a breakdown in the effectiveness of spontaneous adaptation and coping strategies. As a result, people play one kind of risk off against another in search of a "less bad" scenario (UNDP, 2002). Many highly vulnerable communities may deliberately choose to inhabit a hazard prone environment if this reduces other risks, related to income generation for example. On the other hand, factors such as poverty, limits to migration, land tenure systems, migration between ecologically distinct areas and a continuous reduction in terms of knowledge of ecosystems, inevitably place barriers to spontaneous adaptation.

The processes of climate change have stacked the odds even higher against successful adaptation. As the causal processes of risk become increasingly global, the options available to local communities and other local stakeholders to influence risk generation processes becomes restricted, or non-existent. This growing complexity of risk, due to both economic globalization as well as to global climate change, greatly reduces the predictability and increases the uncertainties of climate related disaster events in the Lake Chad Basin. The dearth of information concerning climate change forecasting (on seasonal and long-term climate changes) increases the failure associated with the adoption of new technologies and adaptation measures.

Towards Sustainable Climate Adaptation And Predictability Systems In The Lake Chad Basin

Addressing current challenges and adapting to future needs

Due to the limited technical understanding of climate in Africa in general and the restricted resource and expertise in handling climate issues, it becomes increasingly essential to raise Africa's capacity to handle climate variability, increase the resilience and reduce the vulnerability of the continent to climate variability and change (DFID 2004). Inadequate climate data is a major constraint in developing an accurate understanding of the current and future climate variability and change in the Lake Chad Basin. It is also a constraint to effective assessment of the predictability of climate on seasonal and inter-annual time scales for the region. The provision of climate information and predictions will greatly improve economic and social decision-making and support sustainable development. There has yet to be an integrated programme target at the Lake Chad Basin that is geared towards capacity building of scientists to observe, predict and model climate scenarios appropriate to the assessment of impacts and vulnerability in the Basin.

Other challenges include the dearth of information on appropriate adaptation options and inadequate funding for local communities to get the necessary technologies that will facilitate adapting to climate change. A number of options and initiatives have been identified to address African resource and capacity gaps in the areas of observations, research and model development, prediction activities, and of the delivery of climate services. These options are essential for the Lake Chad Basin. In order to improve climate adaptation and predictability systems in the Lake Chad Basin, more capacity efforts are needed to train scientists within the region in the development and application of downscaling techniques. There is need to develop networks for collaboration and information sharing where scientists, decision-makers and practitioners could share knowledge and experiences on climate change adaptation and predictability systems, increase donor funding on climate adaptation systems as well as the improvement of historical data. A Climate Information and Prediction Services (CLIPS) programme needs to be established in the region in order to collate research data and promote the development of, access to, and use of such information on projected climate change. It is important to link research to policy-making, with an emphasis on getting research results to appropriate target groups and to link research to existing local knowledge of climate related hazards and involving local communities in adaptation decision making. There is need to build credibility of rainfall forecasts and improve their dissemination and use.

The World Meteorological Organization (WMO) being the specialized UN agency on weather and climate, through its global network of National Meteorological and Hydrological Services (NMHS) and Regional Climate Outlook Forums can assist the Lake Chad Basin in the area of capacity building that would improve weather and climate observation, monitoring and scientific understanding of climate processes. Agriculture is typically the most important sector in the Lake Chad Basin. Farmers practice subsistence agriculture and productivity of the agricultural systems depend heavily on prevailing rainfall and temperature patterns. Seasonal shifts in meteorological parameters and climate change strongly impact on agricultural productivity, affecting food security. It is imperative for decision-makers, including farmers, herders and other user-groups, to receive climate information in a timely and easy-to-understand manner. Emphasis must be placed on clear, precise and user-targeted information and climate predictions and the provision of sector-specific climate services, including advice, tools and expertise to meet the needs and requirements of adaptation strategies as well as decision-making. Government policies should therefore support research and development on appropriate technologies to help farmers adapt to changes in climatic conditions. Examples of such policy measures include crop development and improving climate information forecasting.

A lot could also be achieved in the Lake Chad Basin through capacity building that will further strengthen early warning systems by collaborating with the Observing System Research and Predictability Experiment (THORPEX), a part of the WMO world weather research programme (WWRP). The purpose will be to provide accurate, timely, specific and definite weather warnings in a form that can be used to improve weather forecasting in the region.

The International community can assist in supporting local adaptation initiatives in the Lake Chad Basin through the following measures: First, support countries within the basin with much needed funds to prepare National Adaptation Action Plans that takes a comprehensive view of future development paths and expected climate change impacts. Second, the International community could assist in the provision of insurance against climate risks. Individuals, communities and countries within the Lake Chad Basin have no insurance against extreme weather events and the private insurance industry is poorly developed. The need and opportunity exists to develop public-private partnerships to expand insurance against climate-related events in the region. Such initiatives could serve three purposes (Yohe et al, 2007): first, they spread risk; second, they could ensure continuity of government operations after a severe loss event; and third, and most important in the adaptation context, they could help to ensure that adequate adaptation measures are taken. The objective of insurance in this case will be to reduce vulnerability by encouraging, facilitating, or even mandating the adoption of adaptation measures. Insurance could be made at concessionary rates, subject to the insured activity or property meeting certain adaptation or vulnerability reduction requirements.

Most river basins across the globe are drying up and signs abound that the world is heading towards a water crisis. IFPRI research shows that if current trends continue, water scarcity will likely cause annual global losses of 350 million metric tonnes of food production by 2025, leading to an inevitable rise in food prices (IFPRI, 2009). Many parts of the world already feel the effects of too little water. More than 1 billion people live in areas with insufficient water to meet their needs. The Lake Chad Basin, in particular, faces two types of water scarcity - physical water scarcity, due to its geographical location in the semi-arid region; and economic water scarcity, because the region has not developed appropriate technologies to effectively use its water resources. Both types of scarcity pose unique challenges for water management in the basin.

The first option for tackling water scarcity in the Lake Chad Basin will require better management of existing water resources. Productivity could be increased without necessarily expanding the amount of land or the amount of water available. This means 'more crop per drop' (IFPRI, 2009). The current irrigation practices (for example, use of water pumps) allow for substantial amounts of water being lost. Better water storage and delivery techniques are needed to effectively harvest rainwater. Improving water productivity also requires considering emerging technologies including drip irrigation, adoption of integrated water resource management (IWRM) approach, and use of genetically modified crops that have the potential to cope with water-related stresses under both rainfed and irrigated farming. Another technique called fertigation can be used to improve water management and plant nutrition in the Lake Chad Basin. There is urgent need for funds to support fertigation research in the region. Using Isotope hydrology can also help track the movement of water in underground and groundwater systems by measuring the subtle changes in water molecules. This application of nuclear technology helps find new sources of water, better manage existing sources, and monitor changes in vulnerable areas.

Better coordination and cooperation are needed at the local, national and regional levels in the basin especially as the lake water is shared by different countries so that there are no conflicts. Another option is to levy charges on bulk water users (for example, irrigation farmers using water pumps and bottling companies amongst others). Water pricing can give users an incentive to use water more efficiently, and thus reduce overall demand. The United Nations has designated 2005 to 2015 the Water for Life Decade. Thus, with the right policies, the right technologies and adequate capacity and sensitization, a major water crisis is avoidable in the Lake

Chad Basin.

Much can be achieved by mainstreaming climate adaptation into development planning in the Lake Chad Basin. Long-term economic growth cannot be sustained without ensuring that emerging patterns of agriculture and trade do not impinge on ecological health and resilience. Adaptation to climate should not be seen as a stand-alone activity, but it should be integrated into development projects, plans, policies and strategies. In this vein, all stakeholders within the Lake Chad Basin (Community-based organizations, non-governmental organizations, Governments through its Ministries of Environment, Water, Agriculture, research institutes and Departments of Meteorology, need to raise more awareness of the changes in climatic conditions through appropriate communication pathways (for example, extension services, radio and televisions, farmers associations and input and output dealers, amongst others).

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 greatly reduces the predictability and increases the uncertainties of climate related disaster events in the Lake Chad Basin. There also seems to be a breakdown on the effectiveness in spontaneous adaptation and traditional coping strategies. Measures related to improved adaptation and prediction systems, environmental planning, information pooling, the exchange of information on best practices, strengthened technical cooperation and close cooperation with policy-makers and all stakeholders must be implemented urgently in the Lake Chad Basin.

References

Coe, M. T., & Foley, J.A. (2001). Human and natural impacts on the water resources of the Lake Chad basin, J. Geophys. Res., 106(D4), 3349–3356.

Deschenes, O. & Greenstone, M. (2007). The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. American Economic review 97 (1): 354-85.

DFID (2004). Key sheet 7 Adaptation to climate change: The right information can help the poor to cope/Global and Local Environment Team, Policy Division.

IFPRI (2009). International Food Policy Research Institute, Vol.1, p.9.

IPCC WGII (2007). IPCC Working Group II Contribution to the Intergovernmental Panel on Climate Change. Fourth Assessment Report, Summary for Policymakers, 23pp.

Lake Chad Basin Commission (2000). Integrated River basin management: Challenges of the Lake Chad Basin. Vision 2025.

Mendelsohn R, Dinar A, & Dalfelt, A. (2000). Climate change impacts on African agriculture. Centre for Environmental Economics and policy in Africa. Http://www.ceepa.co.za/climate_change/pdf/ (5-22-01) afrckgrnd-impact.pdf.

Musa I K et al. (2008). Saving Lake Chad. Proceedings of Sirte Roundtable (LCBC and ICID), 17 December, Libya

Osman-Elasha, B. (2007). Africa's vulnerability: environmental stress and climate change. Tiempo 63, pp3-9.

UNDP (2002). A Climate Risk Management Approach to Disaster Reduction and Adaptation to Climate Change.

UNDP Expert Group Meeting Integrating Disaster Reduction with Adaptation to Climate Change, Havana, June 19-21, 2002

Yohe, G.W., Tol, R.S.J. & Murphy, D. (2007). 'On Setting Near-Term Climate Policy while the Dust Begins to Settle -- The Legacy of the Stern Review', Energy & Environment, 18, 621-633.

The Aquifer Recharge and Storage Systems to Halt the High Level of Evapotranspiration

Dr. Sara Vassolo

Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Germany

Project: Lake Chad – Sustainable Water Resources

Introduction

The climate of the Lake Chad Basin is characterized by high temperatures throughout the year, intense solar radiation, strong winds, and a potential evapotranspiration that surpasses by far the annual precipitation. These properties lead to a high evapotranspiration of both shallow groundwater and surface water.

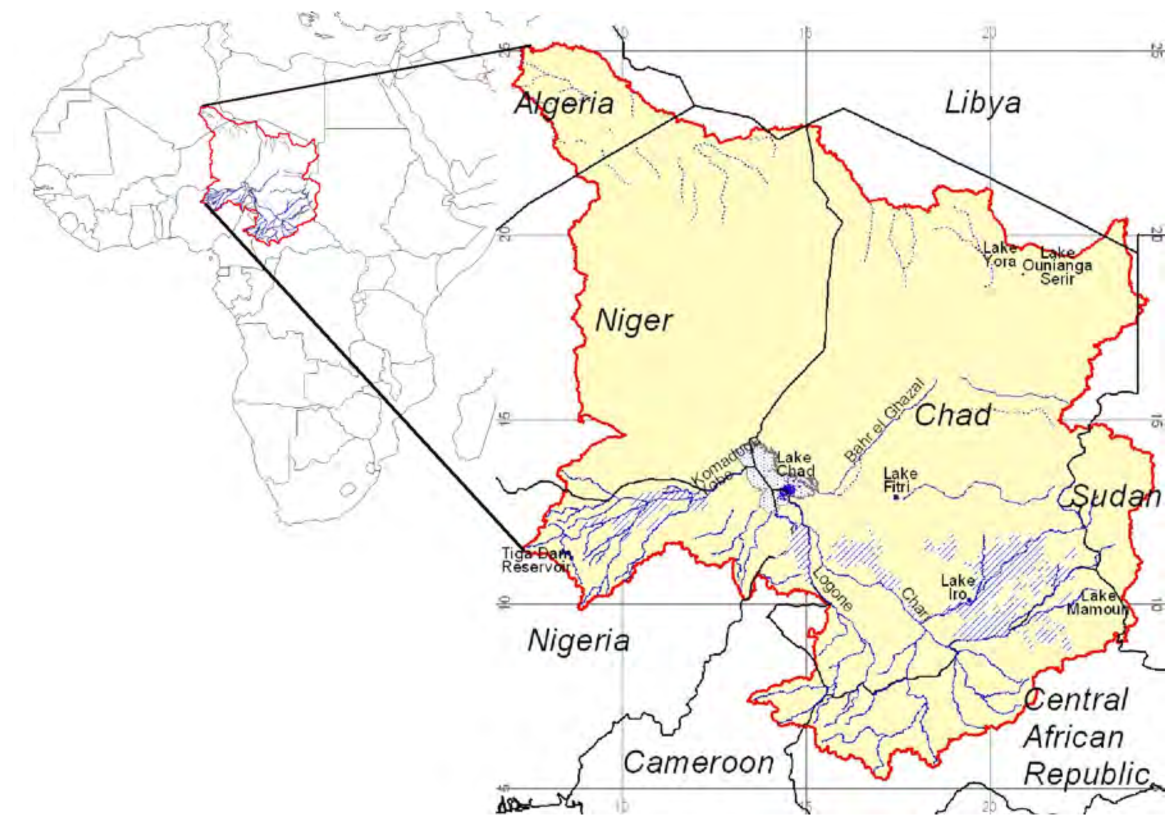
A reduction of the shallow groundwater evapotranspiration is not feasible because it would imply to drop the groundwater table to such a depth that water rising capillarity does not reach the ground surface or to such a depth that there is no influence of deep roots from trees or shrubs. However, it is possible to apply artificial recharge measures to reduce the evaporation from surface water using the storage ability of the aquifers.

This paper first describes the hydrogeological situation of the Lake Chad Basin. Further, different methodologies are presented that are commonly used to reduce the high level of evaporation from surface water. Artificial recharge can be performed in the Lake Chad Basin using injection of water in wells or surface infiltration, but only at a small scale. Medium to large scale infiltration systems need large volumes of water and their application would reduce considerably river discharge. In addition this water is necessary to maintain the level of the Lake Chad.

Getting to Know the Lake Chad Basin

The Lake Chad Basin is located in the central part of Northern Africa and occupies an area of about 2 300 000 km^2 (Figure 1).

Figure 1. Location of the Lake Chad Basin.



The basin is an extended plain mostly covered by medium to fine-grained sands except on its borders. The surface height varies from 3 300 metres above mean sea level (amsl) in the north (Tibesti Mountains); 3 000 metres in the NW (Ahaggar Mountains) and 3 300 metres NN in the SW (Adamawa Plateau) (Figure 2) to 180 metres amsl in the Pays Bas (lowlands). The area with heights below 320 metres amsl in Figure 3 corresponds to the extension of the paleo Megalake Chad that has been described by Leblanc et al. (2006).

The central part of the basin is characterized by two different landscapes subdivided by the 14°N parallel: sand dunes and the absence of surface water sources are typical for the northern part (Kanem), while the south is richly watered by two main rivers that discharge in the lake. They are the Chari-Logone that supplies about 95 percent of the annual volume of water that reaches the lake and the Komadugu-Yobe that provides about 3 percent of the annual inflow into the lake (Figure 4). The precipitation over the lake surface completes the remaining 2 percent.

Within the basin there are very important and well-known swamp regions: the Yaérés in the extreme north of Cameroon, the Lake Chad itself, Lake Fitri, the Massénya and the Salamat to the south and southeast of the Lake Chad respectively, and the Komadugu-Yobe to the north-east of Nigeria (Figure 4).

Figure 2. Topography of the area, heights in m above mean sea level (amsl). A flat plain of less than 380 m amsl occupies the central part of the basin, based on SRTM30 data (USGS Shuttle Radar Topography Mission).

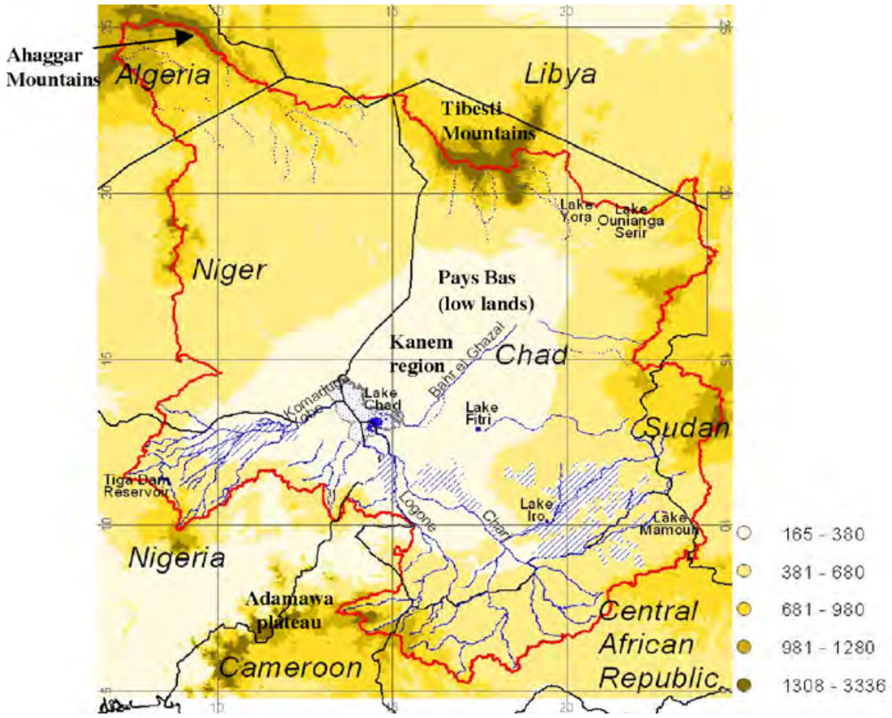


Figure 3. Detailed information on the lower region based in STRM30 data (USGS Shuttle Radar Topography Mission). Heights in m above mean sea level (amsl). The surface below 320 m amsl corresponds to the Megalake Chad (Leblanc et al., 2006).

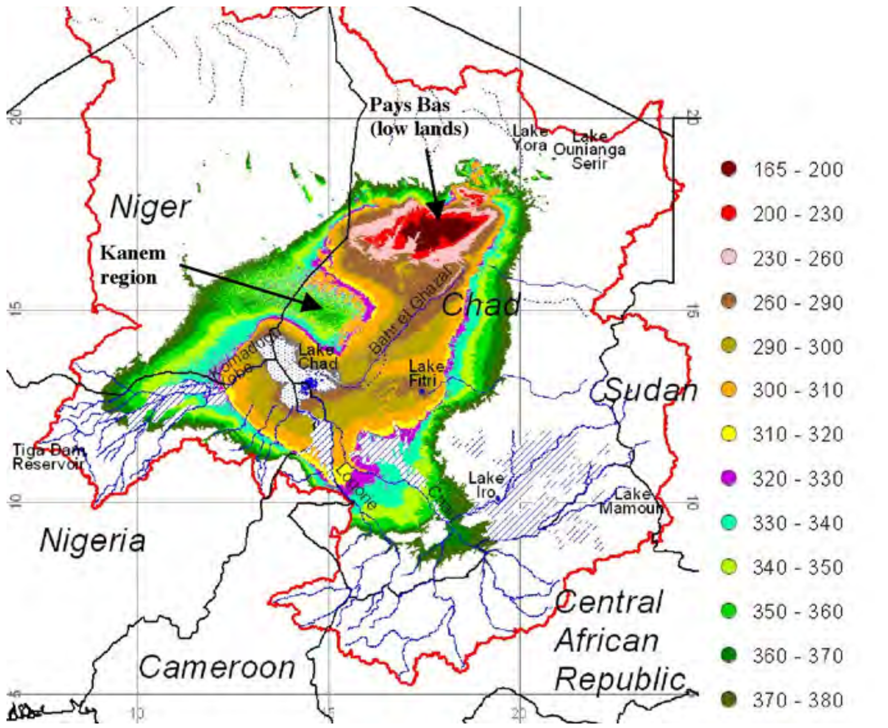


Figure 4. Surface water and swamps within the Lake Chad Basin.

Climatically the basin is characterized by three different zones: hyper-arid to arid in the north, semi-arid in the centre and subtropical in the south. Mean annual rainfall varies from less than 50 mm in the north to above 1000 mm in the south. High temperatures throughout the year, very low humidity except during the rainy season from June to August, intense solar radiation and strong winds lead to a high annual potential evapotranspiration of around 2 200 mm (Carmouze, 1976).

Geology of the Basin

Most of the Lake Chad Basin is covered by Quaternary sands (Figure 5) of different depositional origins. In the northern part of the basin prevails an aeolic deposition with the presence of dunes (Kanem region). Fluviatile, lacustrine and deltaic depositions that result in alternating sequences of thin layers of sand and clay and mainly clayey soils on the surface are typical in the south.

At a depth of some 75 metres appears a thick layer of some 280 metres of clay from the Upper Pliocene age (Figure 6). This layer is almost impermeable and separates the Quaternary sands above from the Lower Pliocene below. The Lower Pliocene is composed of sand and sandstone and has a thickness of 30 metres, underlain by the sandstones of the Continental Terminal (Tertiary) with a thickness of some 150 metres. The deepest aquifer is the sandstone of the Continental Hamadien (Cretaceous), but it has not been studied yet and its extension is unknown. Granitic rocks of the basement build the basis of the basin.

Figure 5. Geology of the Lake Chad Basin.

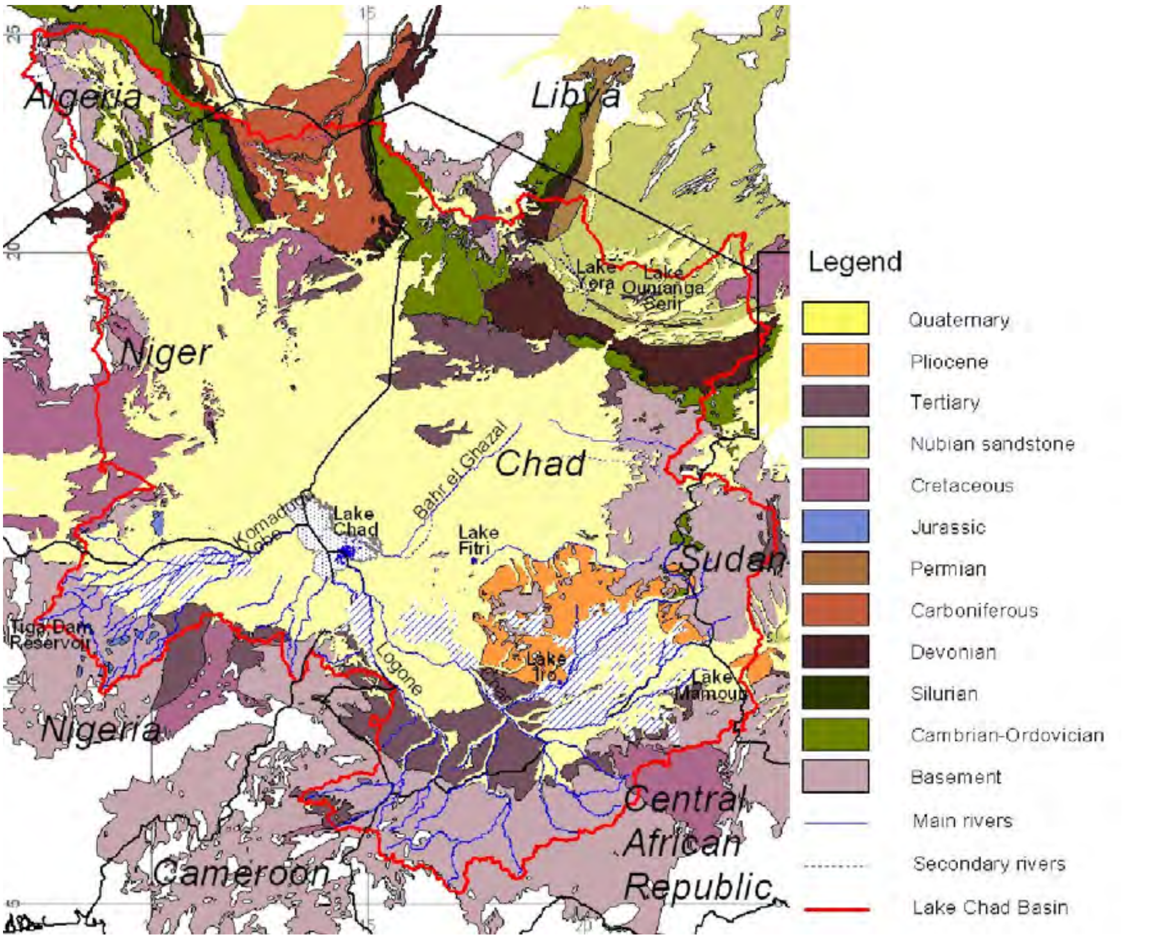
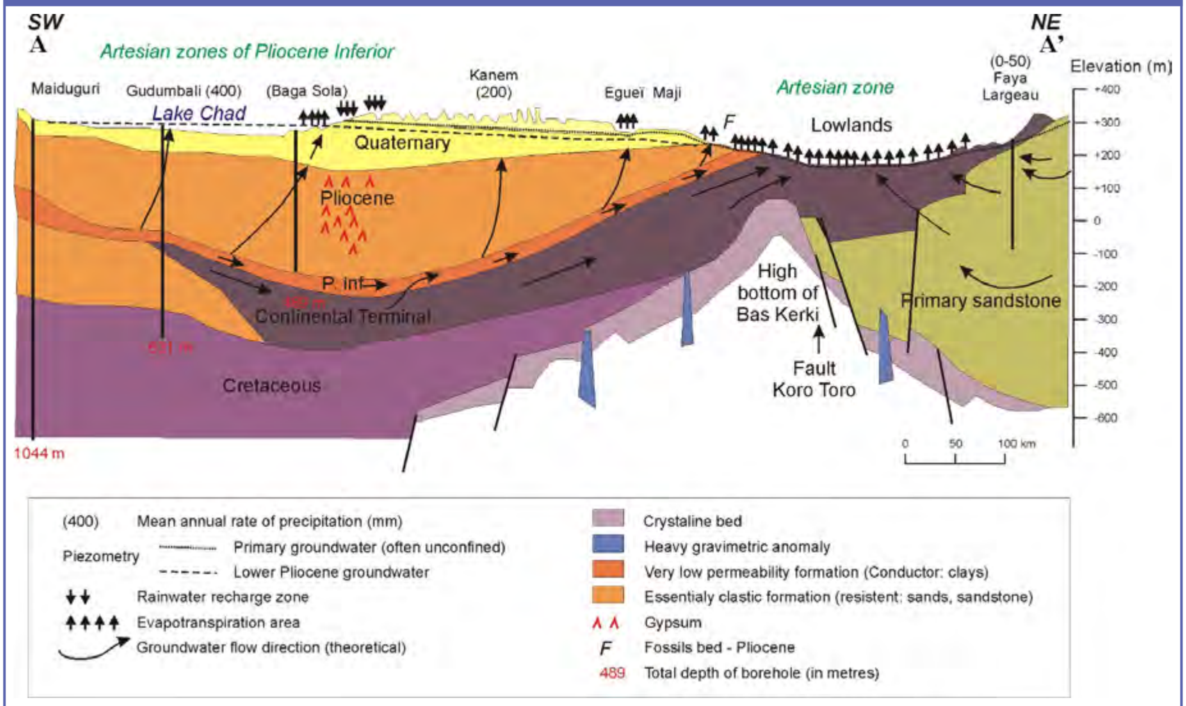


Figure 6. Cross-section with the geology in depth, drawn between Maiduguri to the SW and Faya Largeau to the NE of the Lake Chad Basin (after Schneider & Wolff, 1992).



Hydrogeology of the Basin

The upper Quaternary medium to fine-grained sands act as an unconfined aquifer. South of the 14°N parallel this aquifer shows a low hydraulic conductivity, especially vertical, due to the sequences of sand and clay. Furthermore, due to its flatness and low gradient (in average 0.0005), the horizontal flow is very slow or quasi-null.

The underlying low permeable clays of the Upper Pliocene build an aquitard that confines the sandstones of the Lower Pliocene and Continental Terminal (CT) causing a widespread system of artesian wells in the area, especially in the central part of the basin. According to Eberschweiler (1993), both the Pliocene and the CT have similar good hydrogeological properties and comparable water chemistry, therefore they can be considered as a single aquifer.

As already mentioned, there are very few data concerning the Continental Hamadien, therefore, it is very difficult to describe its extension and estimate its hydrogeological properties. The granitic rocks of the basement build the basis of the hydrogeological system.

Aquifer recharge to the upper unconfined sands depends enormously on the availability of water from precipitation and the deposition characteristics of the aquifer. Indirect recharge takes place in the southern part of the basin, where the recharge is generally a product of surface water percolation from flooded areas, rivers and lakes. In the north, there is direct recharge, mainly caused by direct percolation of accumulated precipitation in the valleys between the dunes.

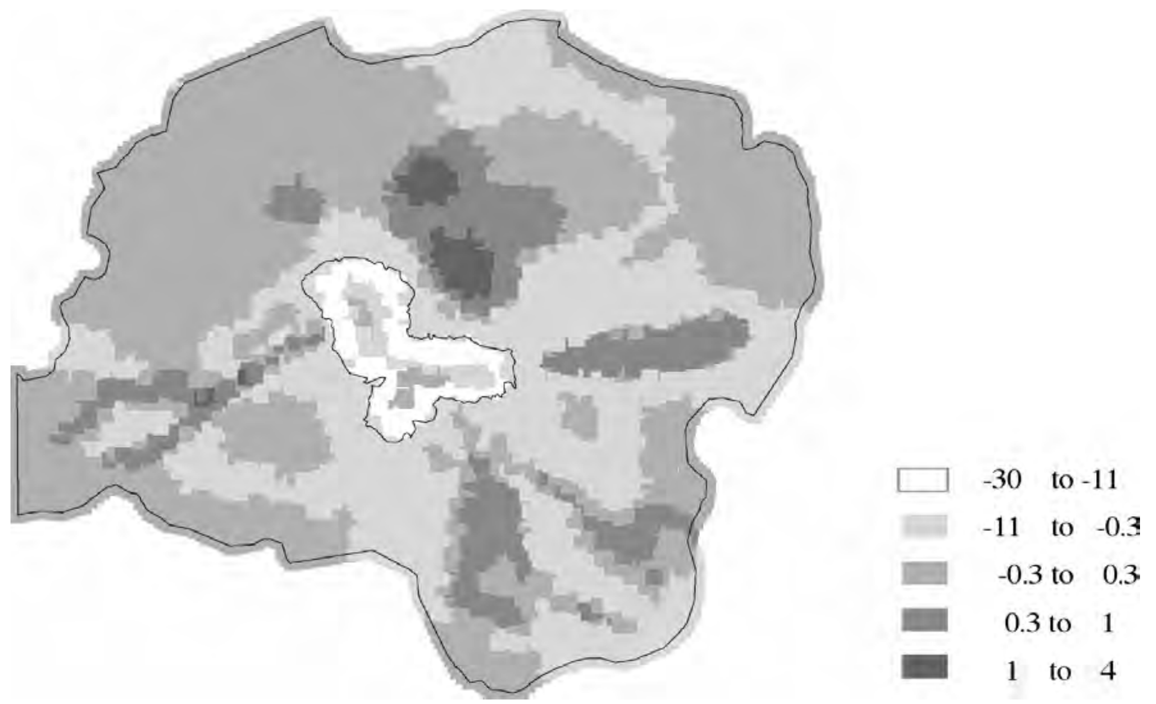
The prevailing high temperatures and low humidity limit the potential of natural recharge as most of the precipitation evaporates as soon as it falls. However, by means of groundwater modelling Boronina et al. (2007) (Figure 7) estimate mean annual recharge figures in the ranges of 1 to 4 mm, or one percent of mean annual precipitation, for the dunes of the Kanem region to the north of the lake and 0.3 to 1 mm, or 0.1 percent of mean annual precipitation, for the riverbeds and swamp areas to the south. The negative values in Figure 7 mean evaporation from water table, which is present along the lake's perimeter. Negative figures appear also in the southern part of the basin, where the sands are generally covered by clay.

Aquifer recharge to the upper unconfined sands depends enormously on the availability of water from precipitation and the deposition characteristics of the aquifer. Indirect recharge takes place in the southern part of the basin, where the recharge is generally a product of surface water percolation from flooded areas, rivers and lakes. In the north, there is direct recharge, mainly caused by direct percolation of accumulated precipitation in the valleys between the dunes.

The prevailing high temperatures and low humidity limit the potential of natural recharge as most of the precipitation evaporates as soon as it falls. However, by means of groundwater modelling Boronina et al. (2007) (Figure 7) estimate mean annual recharge figures in the ranges of 1 to 4 mm, or one percent of mean annual precipitation, for the dunes of the Kanem region to the north of the lake and 0.3 to 1 mm, or 0.1 percent of mean annual precipitation, for the riverbeds and swamp areas to the south. The negative values in Figure 7 mean evaporation from water table, which is present along the lake's perimeter. Negative figures appear also in the southern part of the basin, where the sands are generally covered by clay.

Aquitard is a geologic formation that may contain water but is uncapable of transferring that water to the surface or to another geologic formation.

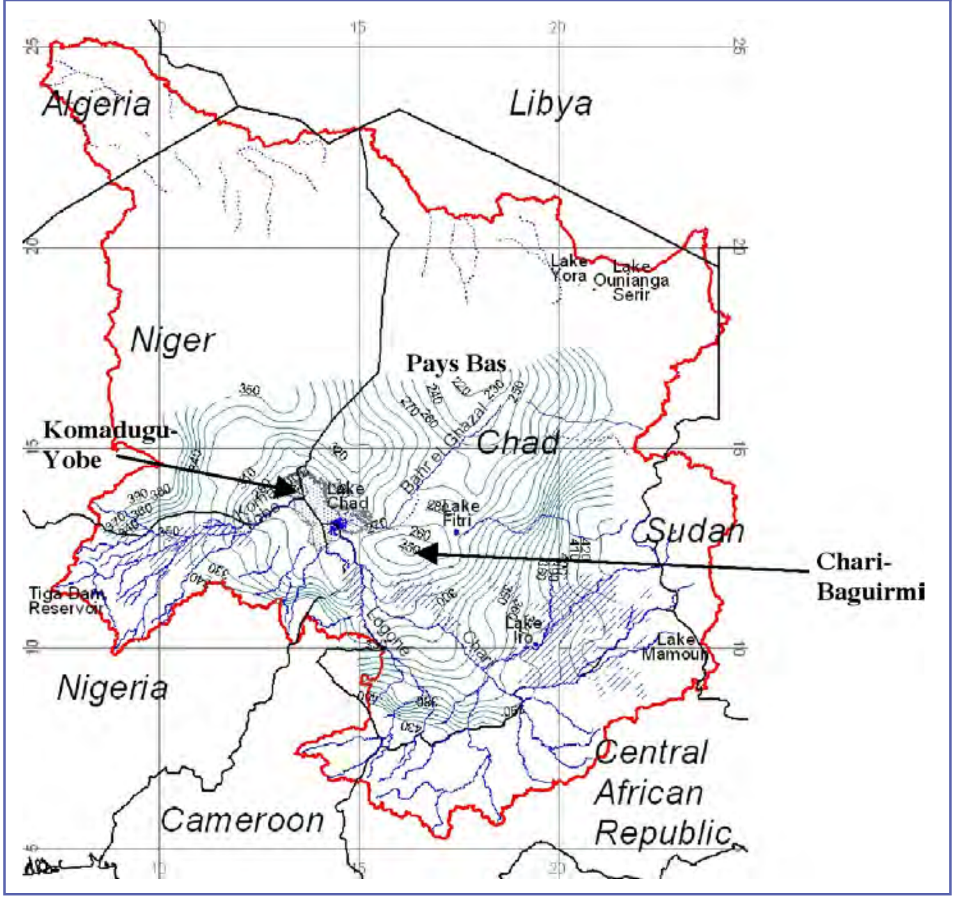
Figure 7. Distribution of recharge (mm/a) for the Quaternary sands, according to Boronina et al. (2007). The highest recharge rates take place in the dunes of the Kanem region as well as along the river valleys and swamp areas.



Recharge to the Lower Pliocene and the CT takes place at their outcrops, either at the border or outside of the basin (Figure 5).

The groundwater contours for the unconfined upper aquifer show three regional depressions (Figure 8). The Pays Bas in the north, the Chari-Baguirmi to the south-east of the lake, and the Komadugu-Yobe at the north-eastern border between Niger and Nigeria. It appears that all of them are the result of enhanced evaporation from the water table through capillarity; or transpiration from trees and shrubs, whose roots reach the water table. A research study performed by BGR concerning the Chari-Baguirmi depression estimates a total evapotranspiration volume of 25 000 000 m^2 at an annual rate of 1.3 mm/a for an area of 19 000 km^2.

Figure 8. Groundwater contours for the unconfined aquifer. They show three regional depressions caused by evaporation of groundwater from the aquifer.



How to Reduce Evaporation?

The research studies have shown that high evapotranspiration in the Lake Chad area involves not only surface water but also groundwater. Reduction of evapotranspiration from groundwater is only possible if the water table is lowered below the depth at which capillarity takes place or the depth reached by deep roots of trees. Due to the fact that evaporation from groundwater is a regional effect, such a measure is considered as unfeasible.
The storage of large volumes of surface water into the underground could surely help to reduce its evaporation. However, the past years have shown that the healthiness of the Lake Chad very much depends on the surface water availability or river discharge. Therefore, any conservation methodology such as artificial recharge can be applied on a small scale, when the needed volumes of water do not significantly reduce the river discharge.
Artificial recharge involves injection wells and surface infiltration systems. Due to the fact that injection through wells requires some engineering skills as well as pre-treatment of the water to avoid clogging, this methodology is generally considered as cost-intensive compared to surface infiltration. On the other hand, surface infiltration needs highly permeable soils and sufficient depth to groundwater to be practicable.

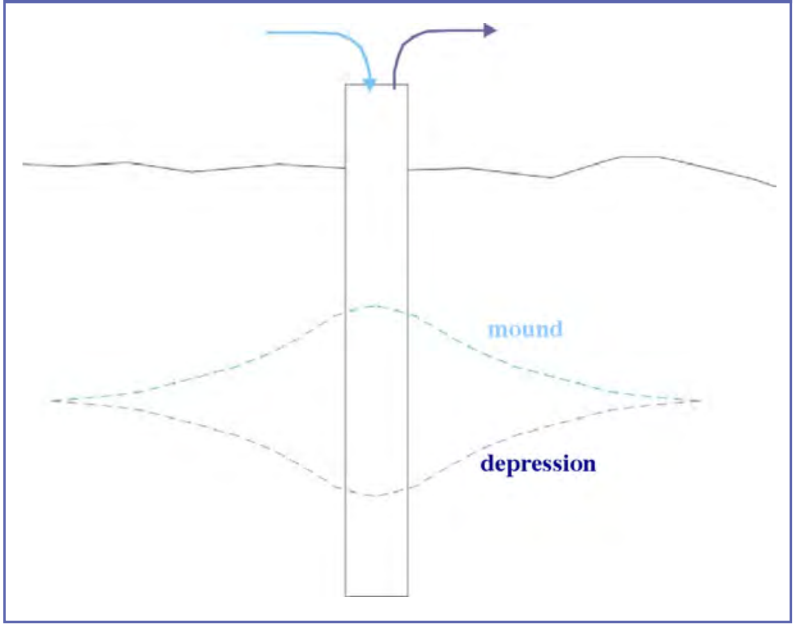
5-1. Injection of water

Injection of water can be applied for both confined and unconfined aquifers. Surface water from rivers, canals, lakes and reservoirs; untreated groundwater or reclaimed water from treatment plants can be used for injection. Pyne (1995) recommends pursuing the following steps:

- Preliminary feasibility assessment and conceptual design. Many times this step has been omitted, which often causes problems in the performance of the system and the consequent loss of confidence in the method.
- Field investigation and test programme. This phase is crucial, as it shows whether the method is technically, environmentally and economically sound to be applied or not.
- Construction of recharge systems at the necessary scale or the widespread application of the methodology.

Injection has been applied to recover over-pumped aquifers, but also to store water during periods of water surplus to allow extraction when water is needed using the same well (Figure 9). This last methodology is known in the literature as “aquifer storage and recovery” or ASR (Gale, 2005). ASR can be applied to produce a mound of freshwater in a brackish environment that can be extracted at a later stage for example to supply small communities with drinking water.

Figure 9. Aquifer storage and recovery (ASR) methodology. Water is injected into the aquifer to be re-extracted at a later stage.



Another way of applying injection through wells is the "aquifer storage, transfer and recovery" (ASTR) method. In this case water is injected in a well and extracted from another well after a certain passage in the underground. This kind of method, if used with reclaimed water, exploits the natural filter capacity of the aquifer to reduce the bacteriological contamination. However, clogging is frequent here and regular rehabilitation measures are necessary to ensure the good functioning of the system.

Aquifer recharge by injection has been well proved in sandy aquifers like the upper unconfined aquifer in the Lake Chad Basin. However, injection of surface water into fractured aquifers is becoming more and more used, like in Windhoek, Namibia, where purified dam water is injected in fractured layers of quartzite embedded in a schist matrix (Murray, 2004).

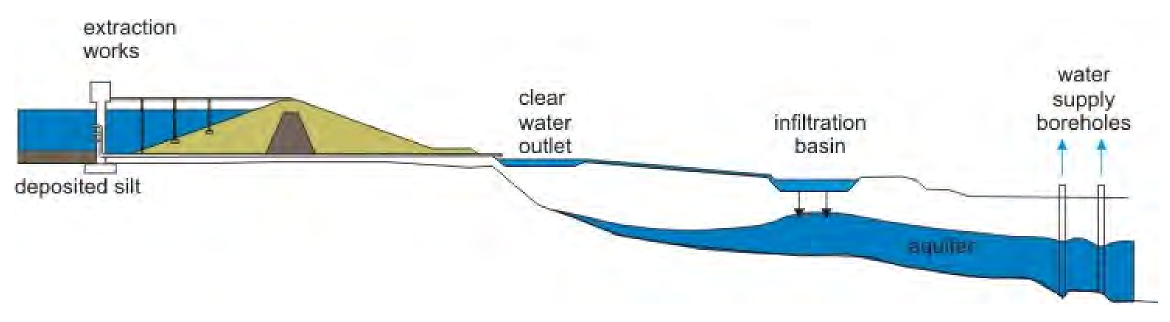
5-2. Surface infiltration

Surface infiltration requires good permeable soils and an important volume of accumulated water that will percolate down to the water table by gravity. It is applicable only to unconfined aquifers.

Surface infiltration can be done with:

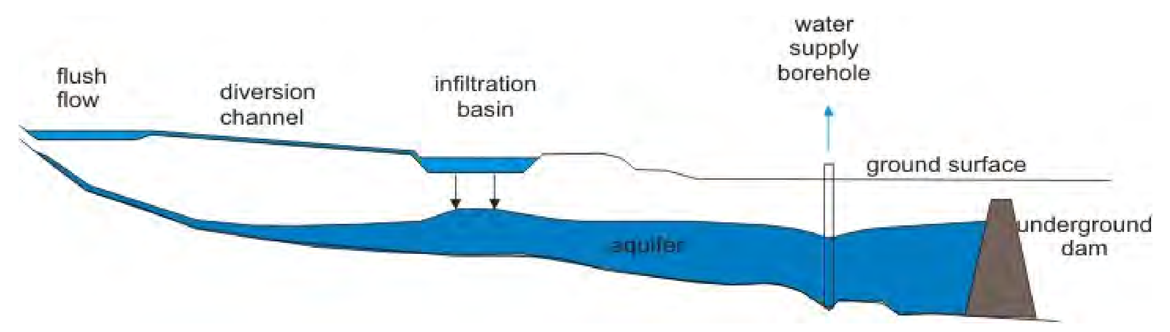
- Storage of river water in a dam reservoir to allow the deposition of transported fine material and later feed infiltration ponds. This method is in operation in the Omaruru Delta, Namibia (Christelis & Struckmeier, 2001) to replenish the aquifer (Figure 10).

Figure 10. Artificial recharge in the Omaruru Delta using river water stored in a reservoir (modified from S. Müller in Christelis & Struckmeier, 2001).



- Diversion of flush flows into secondary channels or basins to enhance the recharge produced by the precipitation. The construction of an additional underground dam can help to avoid rapid flow of artificially recharged groundwater. This method has been applied in Iférouane, north Niger (Schmidt et al., 1975) (Figure 11).

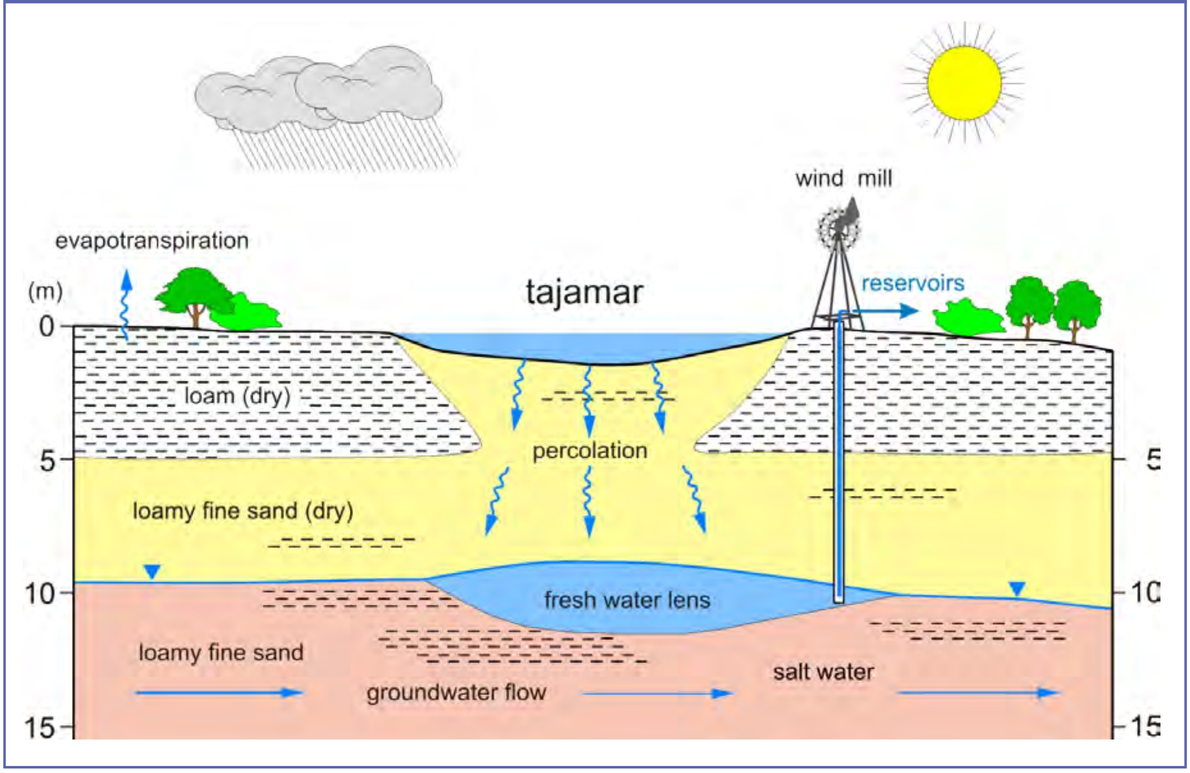
Figure 11. Artificial recharge using flush flow diversion. The additional dam constructed in the aquifer hinders the groundwater flow and helps to raise the groundwater level for a better use of the recharge.



The swamps in the Lake Chad Basin act as "natural infiltration ponds". Flush floods produced after downpours divert and accumulate in these areas to recharge the aquifer over a much longer period of time.

- Harvesting of precipitation into ponds. Accumulated water percolates and locally enhances the recharge. This method was applied in the tajamares in Eastern Paraguay (von Hoyer et al., 2000). Here the artificially recharged water is the only source of freshwater as the regional aquifer contains brackish groundwater (Figure 12).

Figure 12. Surface infiltration of rainfall water for drinking water supply (after von Hoyer et al., 2000).



- Interdune infiltration, as is used in the coastal areas of South Africa and the Netherlands (Gale, 2005). River water is diverted into the valley between the dunes for infiltration. The produced mounds are crucial, for example, to avoid sea water infiltration.

5-3. Which method is applicable to the Lake Chad Basin?

If used on a small scale, all the above-mentioned methodologies are applicable in the upper Quaternary sands of the Lake Chad Basin, depending on the hydrogeological characteristics of the site and the goal of the artificial recharge.

The northern part of the area has the best hydrogeological properties for the application of artificial recharge because the aquifer is composed of clean well-rounded sands. However, there is no surface water available to the north of the 14° parallel.

To the south of the 14° parallel, there is sufficient surface water to permit artificial recharge, but the clayey soils hinder the surface infiltration. Further, the aquifer is composed of a succession of thin sand and clay layers, which hampers the injection into wells. Injection performs well in sandy layers.

Anyhow, artificial recharge in the Lake Chad Basin can be applied only on a small scale. Medium to large scale systems require large volumes of water that are also needed for the preservation of the level of Lake Chad.

References

Boronina, A.; Favreau, G.; Coudrain, A.; Leduc, Ch. & Dieulin, C. (2007): Hydrogeology of the phreatic aquifer in the Lake Chad basin: groundwater modeling in conditions of data scarcity. HydroSciences, IRD-Université de Montpellier II, Case courrier MSE 300, avenue Emile Jeanbrau, 34095 Montpellier Cedex 5, France.

Carmouze, J.-P. (1976): Les grands traits de l'hydrologie et de l'hydrochimie du Lac Tchad. Cahier O.R.S .T.O.M., sér. Hydrobiologie, vol. X, N° 1, 1976, pp. 33-56.

Christelis, G. & Struckmeier, W. (2001): Groundwater in Namibia: Explanation to the Hydrogeological Map. Ministry of Agriculture, Water and Rural Development, Namibia.

Eberschweiler, Ch. (1993): Monitoring and management of groundwater resources in the Lake Chad Basin. Final Report. BRGM-LCBC. Funding: Fonds d'Aide et de Coopération de la République Française Convention N° 98/C88/ITE.

Gale, I. (2005): Strategies for Managed Aquifer Recharge (MAR) in semi-arid areas. UNESCO-IHP.

Leblanc, M.; Favreau, G. ; Maley, J. ; Nazoumou, Y. ; Leduc, Ch. ; Stagnitti, F. ; van Oevelen, P.-J. ; Delclaux, F. & Lemoalle, J. (2006) : Reconstruction of Megalake Chad using Shuttle Radar Topographic Mission data. Science Direct: Palaeogeography, Palaeo-climatology, Palaeoecology No. 239, pp. 16–27. doi:10.1016/j.palaeo.2006.01.003.

Murray, E.C. (2004): Artificial groundwater recharge: Wise water management for towns and cities. Water Research Commission Report TT 219/03, Pretoria, South Africa. ISBN 1-77005-092-2.

Pyne, D. (1995): Groundwater Recharge and Wells: A guide to aquifer storage recovery. Lewis Publishers. 376 pp. ISBN: 1-56670-097-3.

Schmidt, G.; Boeckh, E.; Klein-Bornhorst, A. (1975): Projets d'infrastructure a l'investissement humain au Niger, projets Iférouane et Timia dans l'Aïr. Unpublished.

Schneider, J.L. & Wolff, J.P. (1992): Carte géologique et cartes hydrogéologiques à 1/1,500,000 de la Républic du Tchad : Mémoire explicatif. Document du BRGM N° 209, Vol. 2. Éditions du BRGM.

Von Hoyer, M.; Junker, M.; Centurión, C.; Irrazábal Sosa, D.; Larroza, F.; Fariña, S.; Paredes Rolón, J.L. (2000): Sustained Water Supply by Artificial Groundwater Recharge in the Chaco of Paraguay. Zeitschrift für Angewandte Geologie. Sonderheft: Geoscientific Cooperation with Latin America. Bundesanstalt für Geowissenschaften und Rohstoffe.

Appraisal and Up-Scaling of Water Conservation and Small-Scale Agriculture Technologies

Amadou Allahoury Diallo

Senior Agriculture Water Management Expert

Introduction

In recent decades, the open water surface of Lake Chad has reduced from approximately 25 000 km^2 in 1963, to less than 2 000 km^2 in the 1990s heavily impacting the Basin's economic activities and food security. 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.

Led by the conviction that there cannot be much water saving from efficient management only, due to the high evaporation, a call was made for the adoption of measures beyond the convention of the available water resources in the Basin. The supply management has, however, been dominating while less attention has been given to demand management. The combination of both as well as the introduction of emergent measures that respond to the global cause of the problem is therefore, needed within an adaptive framework to save the Lake.

In the Lake Chad basin, irrigated agriculture which is an important water consumer, is not only facing the challenges of decreasing water availability but also increasing challenges of rapid population growth and decreasing availability of land. Due to scarcity of water resources and poor performance of many large scale irrigation schemes, interest has been developing in recent years for seeking ways to improve the productivity and livelihoods of the small-scale farmers – typically farmers in Lake Chad basin - and at the same time to improve water use (efficiency and conservation).

Recently, a number of innovations have been developed for small-scale farmers to manage water and increase water use efficiency with simple, affordable AWM technologies (IWMI, 2007; Polak and Yoder, 2006; Namara, et al., 2007) for more productive and profitable farming.

This paper will look at the status of small-scale agriculture development in the region, review the innovative technologies for water conservation and small-scale irrigation and considerations to up- scale these technologies the Lake Chad Basin.

Status Of Small-Scale Agriculture In Lake Chad Basin (LCB)

Like every where in sub-Saharan Africa, the overwhelming majority of the population of the Lake Chad basin is rural, poor and depends on agriculture for its livelihoods. Seventy-five to 80 percent of the farming population consists of traditional smallholders, producing mainly staple foods for household consumption and with relatively marginal connections to market (IFAD-FAO, 2008). Small-scale agricultural growth is therefore the key to the region for poverty reduction and economic growth and small-scale farmers should be perceived as key players in increasing all agricultural production and achieving food security.

Unfortunately, small-scale agriculture in the region, which is mostly rainfed, is practiced under conditions of a fragile natural resource base and variable rainfall. It is therefore an activity which is vulnerable to the dry and uncertain climate of the region and to other natural hazards; hence output is variable from year to year and the GDP growth rates vary considerably, in line with the wide swings of this output. Thus, the stabilization and improvement of the production through better water control should be a priority in the region.

Water control for agriculture development in LCB countries has been constrained by the high cost of modern irrigation schemes constructed until now as well as the complexity of their management. The investment cost of a full-control irrigation scheme in Niger is US$ 10 000-25 000/ha, and the existing irrigation schemes faced mismanagement that had caused rapid deterioration of the water control infrastructure resulting in water losses and farmer impoverishment. Hence, one key factor for increasing the agricultural productivity of small farmers is access to affordable and efficient irrigation technologies.

Traditional small-scale irrigation using simple water lifting techniques (shaduf, bucket, etc.) were long employed in the region and recently in some countries in the region (Niger, Nigeria, Burkina Faso, Senegal, Mali, etc.), the introduction of small-scale irrigation technologies has led to rapid expansion and intensification of irrigation showing the existence of an enormous potential to successfully harness smallholder production. In other respects, a range of rainwater harvesting techniques has been utilized with success in the region (Niger and Burkina Faso) to stabilize and increase the yields of rainfed crops. However, small-scale technologies are not a panacea; there are a lot of examples where these technologies have been unsuccessful in their performance, application, dissemination or adoption. The challenge is how to have a successful strategy for adoption and dissemination of technologies to up-scale smallholder farming systems and save scarce water.

Review of Small-Scale Irrigation Technologies Promoted in the Region

The technologies that have recently been developed with success in the region are described below.

3-1. Treadle pump

The treadle pump (also known as Pedal pump) originated in Bangladesh in the early 1980s. In late 1990 its dissemination began and at the end of 1990s it became well-known and adopted in some Africa countries such as Senegal, Mali, Kenya, Burkina Faso, Niger and Zambia. The standard version can lift 5 000 to 7 000 litres of water an hour from wells, boreholes or surface water sources for a suction head of up to 7 metres. It is foot operated; one person, whether a man, woman or even a child, can operate the pump by manipulating his/her body weight on two foot pedals or treadles while holding a frame for support. Because the pump employs the user's body weight and leg muscles, it is much less tiring than other manual pumps that utilize the upper body and arm muscles. Fabricated from locally available materials, it can be manufactured by metal working shops equipped with welders and simple hand tools such as those frequently found in large numbers in sub-Saharan African capitals and many secondary towns.

The pedal pump is ideal for areas where the water table is high, ranging from 0 to 7 metres below the ground. At a lift of 4.5 metres, the treadle pump has a discharge of 1.7 1/sec. Drawing water from a surface water source or from a well with sufficient capacity; this pump can irrigate an area of approximately one-half hectare.

In the past small farmers used locally built water lifting devices, such as buckets, to irrigate their small land holdings. Drawing water manually from rivers, canals and wells with these devices has many disadvantages, the main being that they are very laborious and time consuming; and restricted to surface water or open wells.

For small farmers diesel and electric pumps are too expensive to purchase, operate and maintain for irrigating a small plot. Compared to the traditional water lifting devices and the costly diesel and electric pumps, treadle pumps have the following advantages:

- Easy to operate. One just has to pedal to lift water from a tubewell. It is so easy that even a child, a woman or even an old person can operate the pump. Adults can operate for hours at a time. It is possible to pedal while in a sitting position. In addition to being easier to operate the treadle pump delivers much more water for an equal lift and pumping period than a hand pump.

- Light and portable. A farmer can easily carry the treadle pump (except the concrete model) on his/her head or shoulder or can transport it in a cycle carrier. This is important for farmers who have a number of small plots in different locations. They can buy one pump, drill a borehole on each plot and shift the pump from one plot to another for irrigation.

- Increases irrigated area and production: treadle pump supplies significantly greater flow rates than the traditional systems, thus will increase irrigated surface areas and reduce irrigation labour time relative to the original irrigated surface area, resulting in increased production (Hyman, 1995 and Gay, 1994). Treadle pump technology allowed a doubling of the cultivated area (World Bank, 2002b).

- Affordable and cost-effective: It is cheaper than diesel and electric pumps. In Niger, the pump costs approximately from US$60 to 100 and increases income, namely the income of a family by around US$100 per year. Surveys conducted by EnterpriseWorks/VITA, in Niger and neighbouring countries show that farmers that have purchased a treadle pump increase their annual income by $400 to over $1200 due to increases in the area that they are able to irrigate. The life of the treadle pump is about 7 years, but many of them work for longer than that. The operating cost is household labour. A marginal farmer can easily get full return of his/her investment within three to four months of purchase and usage. Besides, there is no need for diesel, electricity or battery to operate the treadle pump.

3-2. Motorized pumps

Most West African countries have experienced a significant increase in the number of motorized pumps in the last 20 years. While there is some limited use of diesel-powered irrigation pumps, the vast majority of these pumps consist of gasoline engines of 2-5 horsepower coupled with a low lift centrifugal pump. "The purchase price in West Africa of a Japanese-made gasoline motorized pump set of about 1.5 to 4 KW design output is usually in the range US$300 -600, and a diesel is around US$990. Indian-made pump sets tend to cost US$180, while those made in China are considerably cheaper at around US$110" (IPTRID, 2004). All these pumps are often used in applications for which they are seriously overpowered, resulting in unnecessarily high running costs. The major advantages of motorized pumps are their considerable capacity relative to traditional water lifting means, making it possible to expand irrigated surface areas. Disadvantages include: high capital costs; high recurrent costs; and high maintenance levels. In Niger, yields in irrigated horticulture from motorized pumps have improved considerably: according to "Projet de Promotion de l'irrigation Privée" figures, onion yields have risen from 26 tonne/ha to 41 tonne/ha between 2001 and 2006, and yields of peppers have gone up from 11 tonne/ha to 19 tonne/ha. Income per hectare from onions and peppers has gone up by 80 percent. Rates of return are high and farmers make good money from the investments; but returns are lower than for treadle pumps, because of the energy cost and the gap is growing with the rise in energy costs.

The suction lift of the majority of mechanized pumps used in sub-Saharan Africa is theoretically limited to 6-7 metres. In Niger a survey of motorized farmers around Maradi found that the net suction head is actually between 2 and 5 metres (Gay, 1994). At these relatively shallow depths the recharge rate will not be as high as it is at greater heads. Low recharge rates will limit the potential for irrigated agriculture and increase the pumping cost as pump users choose to run the engine at slower than optimal speed to better match the pump's discharge capacity with the well's recharge rate, thereby increasing fuel consumption per cubic metre of water pumped. Farms cannot grow as much as they might, and some areas will never develop irrigated agriculture at all because the aquifer is too deep to be tapped by standard centrifugal pumps. Low-cost jet pumps in conjunction with centrifugal pumps have the potential for lifting water from aquifers up to 30 metres in depth. The potential for immediate impact is considerable. Not only would new mechanized farmers be interested in such technology but hundreds, perhaps thousands, of farmers who are already using centrifugal pumps would have the opportunity, at very low incremental cost (approximately US$50 per unit, if produced locally) to expand surface areas under irrigation by pumping deeper, more abundant groundwater.

3-3. Drip irrigation

Drip irrigation is one of the most effective water saving technologies and has been used in developed countries for a long time. However, drip irrigation developed in industrialized countries is a costly (up to US$1 800/ha) and sophisticated equipment. The costs are too high and it is not practical for smallholders if it cannot be broken down to small plot sizes. Only the development of less sophisticated, but much cheaper drip equipment can give to small farmers an opportunity to afford the technology. This is the case nowadays in India and Nepal where small-scale low-cost drip irrigation systems are very common. The technology is slowly becoming available to smallholder farmers in dryland regions of Africa. Usually, the low-cost drip system consists of: (i) the reservoir (bucket, drum or concrete rings) whose capacity is determined by the size of the field to be irrigated and the evaporation averages in the region, for example a 200-litre oil drum can be used as the reservoir for 40 m^2, and if the drum is filled twice during the day, the field can cover 80 m^2 ; (ii) the basic low pressure drip kit is composed of taps or control valves, a filter and pipes (tubes) or lay flats with micro emitters depending on available space. The drip kit is assembled and available in the form of complete package kit for a fixed area and size. Advantages of the system are:

- Great reduction in the amount of water needed for growing crop: Other kinds of irrigation, including hand watering, need many times more water than drip irrigation. There are applied water savings of from 50 to 80 percent (IDE, 2003) compared to most traditional surface irrigation methods, thus a larger cropped area can be irrigated from a given supply of water. More importantly, from a basin-wide water resources perspective, the production per unit of water depleted by evaporation, transpiration and salt-loading is often increased by 30 to 50 percent.

- Labour saving: a farmer or his children can irrigate a plot quickly by filling the reservoir once or twice a day. For larger plots, watering all the plants by hand throughout the growing season is the most time-consuming part of the job. With drip irrigation, there are not many weeds to control as almost all the water goes directly to the planted crop.

- Affordability: The irrigation systems are available in affordable sizes at low prices as compared to other costly irrigation systems. For instance, in Niger, the 20 m^2 tube drip kit disseminated by IDE International is about US$10 and 100 m^2 US$20.The price of the lay flat drip kit is about 40 percent less than the tube drip kit.

- Cost effective: A slow, regular and uniform application of water and nutrients to the plants increases production and improves quality. Drip irrigation has high potential for helping small-scale farmers to grow vegetables and fruit all the year round, especially during the long dry season. An economic impact survey conduced by Winrock International in Mali (2007) showed that for each FCFA1.00 invested in drip kit equipment by the farmers, FCFA3.85 of additional income is gained. "This ration 3.85/1 is the engine of the success of introduction of the technology on a commercial way" (Winrock International Mali, 2007). ICRISAT has developed in Niger, based on drip irrigation, Africa Market Garden system (AMG). It is a mix of crops (horticulture and date palm) irrigated through drip kit. The cost of setting up a typical AMG (500 m^2) in the Sahel is about $250. The savings in labour costs for irrigation only can pay for the system within 10 months. Experience from different countries shows that the materials used – if well cared for – can last five years or longer.

- Low negative environmental impacts: drip irrigation overcomes the negative impacts on environment due to salinization of soil and groundwater in surface irrigated systems. High yields can be obtained even with high salinity water because the slow and regular application of water decreases the concentration of salts in the active root zone. With drip irrigation there are fewer disease problems that come from soil being splashed onto the plants during hand watering - such as the various mould and powdery mildew (funga) diseases.

3-4. Micro/Mini-sprinklers

The micro/mini-sprinkler kit is a low cost and water-saving technology promoted by IDE in Asia (India, Bangladesh and Nepal), it is very new in Africa (Zambia and Ethiopia). Micro and Mini sprinkler kits are available in sizes from 100 to 1000 m^2. Systems for more than 1000 m^2 can be customized to suit specific requirements. Micro-sprinklers are spaced at 3 m x 3 m mini-sprinklers are spaced at 6 m x 6 m in order to produce uniform wetting. Micro-sprinklers require 5 m to 10 m operating pressure whereas mini-sprinkler requires 10 to 15 meters of operating pressure. Micro and Mini sprinklers can be shifted from one place to other to cover larger areas. The 250 m^2 kit costs US$20 in India.

3-5. PVC Pipes

The cost of irrigation water lifted using mechanized means is increased due to inefficient water distribution methods (frequently unlined canals that permit water losses through seepage) and/or the high cost of reinforced distribution hose. PVC pipe is water saving and an inexpensive water distribution technology. Its utilization will lower the unit cost of irrigation water. In Niger, the "Projet de Promotion de l'Irrigation Privée" has tested and promoted the PVC pipe (also called Californian System) as a low-cost and water saving distribution technology. The impact tracking system of the project shows that the technology has many advantages compared to unlined irrigation canals. It saves water, for instance, with unlined irrigation canals the water losses are from 30 to 70 percent while with PVC pipes water losses are about 15 percent. It saves time as well (around 60 percent) and it is cost effective (the fuel cost is reduced about 30 percent when using the gasoline pump and PVC for irrigation). Other promising low-cost and water saving technologies include lined canals, lightweight plasticized hose, and thin-walled water holding tanks.

3-6. Groundwater development: tubewells and wrapped filter

Tubewells: they are a cost-effective source of irrigation water for many small farmers where groundwater is available at less than 20 metres below the surface. The technology is not complicated, and the acceptance by farmers and poor rural communities is rapid. Shallow tubewells can be drilled by hand with simple soil auger-type tool, by power rotary drilling, or with a drilling method called "jetting" or washboarding". Shallow tubewells have been widely disseminated in Niger and North Nigeria and to a lesser extent in some other West African countries (e.g. Benin, Senegal and Mali), where groundwater depth is less than 8 metres. This technology is inexpensive and quickly installed. In Niger the hand augured tubewell costs as little as US$40 for a 4 metre deep well. Working in teams of two workers, two such tubewells can be installed daily. Depending on the aquifer and soil conditions, hand augured tubewells can yield up to 14 m^2 of water per hour. In Nigeria the National Fadama Development project centred on developing small-scale irrigation through extraction of shallow groundwater with tubewell–gasoline pump package has resulted in irrigating 30 000 hectares of land and a boost to farmer income; the economic rate of the project was estimated at 40 percent (World Bank Source book, 2004).

Wrapped filter: The ability of some farmers to expand their irrigated area or provide crops with a larger amount of water is sometimes limited by insufficient water availability due to low well recharge rates. In Senegal it has been found that hand-dug, cement-lined wells typically have overnight recharge rates of 3-4 m3 of water and this amount can easily be pumped out in less than an hour. Deepening cement-lined wells by adding cement rings is time consuming, expensive, and might allow more fine sand to enter the well - reducing the well's capacity and water quality. In addition, as in the case of newly constructed hand-dug wells, deepening a well using traditional methods is dangerous. The wrapped filter reduces this risk. The installation of a wrapped screen in a short bore-hole at the bottom of existing cement lined well is a cost-effective alternative for farmers in areas with sandy soil and low well recharge rates. Although results might differ depending on local conditions, field tests conducted in Senegal in 1994 found that well recharge rate increased by 100 percent following installation of the wrapped filter. Wrapped screens are made of PVC tubing with drilled perforations wrapped with a single outer layer of permeable fabric (usually locally purchased woven polyester) that is stitched around the entire circumference of the screen to prevent sand from entering the PVC cylinder and clogging it once drilled and wrapped, the wrapped screen is driven into the bottom of a well by water pressure applied through a PVC pipe using a motorized pump. For installation, the wrapped screen is attached to the end pipe of the pump where water normally comes out. The cost to the farmer is approximately US$60.

Review of Water Haversting Techiques and Conservation Agriculture/Farming (CA/F)

4-1. Water harvesting techniques

"Water harvesting" is the general name used for all the different techniques to collect runoff or flood water for storage in the soil profile or in tanks so that it can be used for the production of crops, trees or fodder. "Water harvesting" also can be the collection of runoff water for human or livestock consumption. In this paper this type of water harvesting will not be discussed. The benefit of water harvesting is not only to secure and increase crop production in semi-arid regions where rainfall is normally high enough for crop production or to make crop production possible in regions were rainfall is normally not sufficient, but also to stop soil erosion and to recharge aquifers tapped for irrigation. An underestimated benefit of water harvesting is also the improvement of soil fertility. Silt, manure and other organic matter is "harvested" or kept in place together with the water. The soil profile stays moist for a longer time, which stimulates soil life so that the formation of stable humus, the nutrient availability, and the water holding capacity are improved. Capturing runoff through water harvesting can be done by multiple techniques, both individual and collective, and often a combination of techniques is used. Techniques need to be adapted to the local conditions. A recent study in Niger, suggests that some of the improved lands through water harvesting for rainfed agriculture, could be producing cereals at yields of 400-1 500 kg/ha instead of 100-200 kg/ha before improvement. It may be noted that "water harvesting increases yields by an average of 50 percent for very little investment". Some of the most known water harvesting techniques are:

- **Water pockets** - holes for seeding, runoff collection and management of organic matter ("zai" in Burkina Faso, "tassa" in Niger and "covas" in Cape Verde). This technique utilize shallow pits (about 0.6 m in diameter and 0.3 m in depth), in which 4 to 8 seeds of cereal crops (millet, maize or sorghum) are planted. Manure is usually added into the pit to improve fertility. It works by a combination of water harvesting and conservation of both moisture and soil fertility pit.

- **Semi-circular bunds** (also known as demi-lune or crescent-shaped bund or shaped ridges). They involve making earth bunds in the shape of a semi-circle with the tip of the bunds on the contour. The dimensions of the holes and the spacing of the contours are dictated by the type of the crop or the farming system. The excavated planting pits are filled with a mixture of organic manure and topsoil to provide the required fertility and to help retain moisture. They are found in areas where annual rainfall ranges from 200 mm to 300 mm, and land slopes are less than 2 percent steepness for both rangeland rehabilitation and annual crops (millet and sorghum).

- **Contour stone bunds:** the contour stone bunds are buffer strips created by arranging stones across the slope on the contour to form a barrier. However, the crop is grown just ahead of the stone bund, leaving the upper end of the terrace free to make a catchment. Since the bunds are permeable they slow down the runoff rate, filter it and spread the water over the field, thus enhancing water infiltration and reducing erosion. Stone bunds are commonly practiced in Sahel (areas receiving 200–750 mm of annual rainfall). They are usually spaced about 15-30 metres apart and can be reinforced with earth or crop residues to make them more stable. Stone bunds are especially safer to use since they form a porous barrier, which slows down runoff, and is unlikely to fail in case of extreme flooding. The stone bund is particularly attractive to farmers because of its ability to be implemented on fields already under cultivation. Data from Kenya (Assessment of Best Practices and Experience in Water Harvesting; AfDB) suggest that there are considerable yield advantages in using the contour system. When used in combination with appropriate crops, it also has a demonstrated ability to reduce the risk of crop failure due to drought by concentrating the runoff. This technology has been used with millet, cowpeas and sorghum. The application and effectiveness of the technology is believed to be greatest in those areas where soils have been degraded to the extent that the people cannot reverse the trend using their own resources. An external input of mechanical equipment can have a large impact in these situations.

- **Tied Contour Ridges** (furrows or bunds): Contour ridges is a micro catchment technique, sometimes called contour furrows or micro watersheds. Ridges follow the contour at a spacing of usually 1 to 2 metres. Runoff is collected from the uncultivated strip between ridges and stored in a furrow just above the ridges. Crops are planted on both sides of the furrow. The system is simple to construct - by hand or by machine - and can be even less labour intensive than the conventional tilling of a plot. The yield of runoff from the very short catchment lengths is extremely efficient and when designed and constructed correctly there should be no loss of runoff out of the system. The main crop (usually a cereal) is seeded into the upslope side of the ridge between the top of the ridge and the furrow. At this point, the plants have a greater depth of topsoil. An intercrop, usually a legume, can be planted in front of the furrow. It is recommended that the plant population of the cereal crop be reduced to approximately 65 percent of the standard for conventional rainfed cultivation. The reduced number of plants thus has more moisture available in years of low rainfall. Contour bunds with larger spacing (5-10 m) are useful for growing trees. The tied contour ridging system is used for crop production (crops are planted on the ridges as well as in the furrows) and tree planting (with a wider distance between ridges). The technology is being used in a variety of climatic and soil conditions and can be adapted to rainfall by adjusting the distance between contours and also the area of cropping. Contour ridges for crops are not a widespread technique in Africa, but have been adopted in Kenya, Niger and Zimbabwe, amongst others.

- **Runoff farming or micro-catchment system:** runoff water and silt from small watersheds are captured by small dams in seasonal streambeds or are diverted to agricultural fields. In front of these dams the silt builds terraces which are used for agriculture. The infiltrated water makes crop production possible.

- **Earth dams and weirs:** A small earth dam is usually constructed to retain flood runoff during the rainy season, on a watercourse which may be a perennial river or a dry river bed. The dam wall normally does not exceed 2 to 5 metres in height and has clay core, stone apron and spillway to discharge excess runoff. The maximum volume of water ranges from hundreds to tens of thousands of cubic metres. Earth dams can provide adequate water for irrigation as well as livestock watering.

- **Spate irrigation**: it is a type of water management unique to arid regions bordering highlands. It is common in South Asia, the Middle East, North Africa and the Horn of Africa. It is also a traditional practice in the Lake Chad Basin and Sahel. Sudden floods, or spates, originate from sporadic rainfall in macro catchments. After the land is inundated, crops are sown – sometimes immediately, but often the moisture is stored in the soil profile and used later – usually cereals or cotton. There is a large untapped potential to improve food production and livelihoods in spate-irrigated areas. Uncertainty is a defining characteristic. The number and sequence of floods vary from one year to another. So do yields which, however, can be high. A second important characteristic is that sedimentation is as important as water management. Rivers in spate lift and deposit huge quantities of sediment. As a result there is constant change in bed levels, in both the river system and the distribution network.

4-2. Conservation agriculture

Conservation agriculture is being promoted as a potential solution to the production problems faced by smallholder farming families in sub-Saharan Africa. Broadly, it is a suite of land, water and crop management practices that aim to improve productivity, profitability and sustainability. The primary principles promoted for hand-based and draught animal powered cropping systems are:

- Disturb the soil as little as possible.
- Timely implement operations, particularly planting, fertilization and weeding.
- Keep the soil covered with organic materials (crop residues or growing crops) as much as possible.
- Do not burn crop residues.
- Rotate crops.

CA/F has multiple benefits for the farmer, the environment and the population in general. The field benefits of the technologies are summarized as follows:

- Reduced traction and labour requirements for land preparation, and thus savings in labour and, where applicable, fuel costs.
- Reduced water runoff and soil erosion due to the increased water infiltration and the effect of residues.
- Increased soil water infiltration due to the protection of soil surface structure by residues and the maintenance of continuous pores with the absence of tillage.
- Reduced evaporation of moisture from the soil surface as the residues protect the surface from solar radiation.
- Increased and more stable crop yields (Note: yield increases may be immediate under the poor fertility conditions of many smallholders fields).
- Increased soil organic matter (SOM) resulting in better soil structure, higher cation exchange capacity and nutrient availability, and greater water-holding capacity.
- Increased biological activity in both the soil and the aerial environment leading to improved soil fertility and pest control.

Conservative agriculture is very little known in West and Central Africa. It can be difficult for many people to accept it because it goes against many of their cherished beliefs. How can crops be grown without ploughing the land? Overcoming this mind-set of the need for ploughing is a major step in achieving successful conservative agriculture systems. It is more difficult to accept in arid and semi-arid regions where livestock is a dominant activity and crop residues are used to feed animals.

Consideration for Expanding the Potential and Up-Scaling

The presentation above shows that there is a wide range of established water management technologies (irrigation and rainfed agriculture) that are water saving as well as having a good potential to allow a large number of small farm households to escape poverty. These technologies are easy to operate and maintain locally and appropriate to poor rural households. However, the key is to adapt them to local circumstances and to plan and implement them within the much broader framework of agricultural and rural development, in ways that yield optimal returns for poverty reduction.

Some countries in the region such as Niger, Nigeria and Chad and other countries in sub-Saharan Africa are already experiencing all these issues and are struggling to find ways to expand these technologies. Lessons learned from their experience can be the base for elaboration of up-scaling small-scale water management strategy through these technologies in LCB. Some of these lessons are described as follows:

- *Small-scale irrigation has greatly benefited from the provision of a package of support:* The success of the "Private small-scale irrigation project" in Niger lies not only in the direct investment in irrigation technologies but also in the package approach, supporting institutional development that provides productivity advisory services, input supply, access to finance and market development, promotes the development of farmers' organizations at several levels, and sets up local level fabrication and repair services.

- *Self-sustaining Agriculture Water Users Associations (AWUA) are needed to promote and service small-scale irrigation (including technologies), in the long run without project support:* Given the necessity to create Agriculture Water Users Associations or the weakness of existing ones, some support is essential to establish a sustainable institutional basis for small irrigated farming in the country.

- *Market creation is needed for wide and sustainable dissemination of affordable water technologies:* Many development organizations and programmes working in rural areas distribute useful technologies to poor families, free of cost, through credit or subsidies, and train them in its use. However, such strategies – as well intended they may be – are neither sustainable nor do they have the outreach needed. Only technologies that are commonly available in local markets have a real chance of being widely and sustainably accessible to smallholders. This requires an economically viable, profitable supply chain in the private sector, which covers all the steps from raw materials over manufacturing and assembly to distributors and spare part dealers who sell the equipment to the users. For low-cost technologies such supply chains often do not develop by themselves, but their establishment can be fostered through market creation approaches. International Development Enterprises, an NGO with headquarters in North America and Europe, has successfully developed such an approach, based on its experience gathered since 1984 in India, Nepal and Bangladesh. With this approach, IDE has achieved a high rate of sales and adoption among farmers. This approach has also succeeded in establishing the private enterprise networks in rural areas necessary for ensuring the availability of the technology to farmers at an affordable price, on a sustainable basis.

- *Partnership between smallholder farmers and commercial farmers can boost small scale agriculture:* The Zambia Agribusiness Technical Assistance Centre (ZATAC) has promoted outgrower horticulture schemes directly linked to ready markets through agribusinesses. Irrigated smallholders benefit from credit for irrigation equipment and become partners in the value chain. Agribusinesses benefit from a chance to increase their supply base and benefit from economies of scale without the associated capital investment. For the first time in the history of Zambia, smallholders now grow fresh vegetables for markets in Europe in an alliance between smallholder producers and agribusinesses (C. Ward, 2007).

- *Moving to a model less dependent on subsidy is essential for small-scale irrigation development:* Subsidy to investments may be needed during an initial period, but the goal is a sustainable financial model for further expansion that could take place without project support. International experience shows that when subsidies continue beyond an initial pilot phase they can undermine the very development they are designed to promote. Drip and sprinkler technologies have been aggressively promoted in India since the mid-1980s; yet, today, the area under them is only 60 000 hectares. A big part of the problem is subsidies that, instead of stimulating the adoption of these technologies have actually stifled their market. Subsidies have been directed at branded, quality-assured systems, but in the process have not allowed viable, market-based solutions to mature. Subsidies are channelled through the big irrigation equipment companies. Their equipment typically costs US$1 750/ha, which puts it out of reach for most farmers - apart from the few that manage to access the subsidy programmes. Fortunately, a grey market of unbranded products began to offer drip systems at US$350/ha. Then, one innovative manufacturer introduced a new product labelled 'Pepsi'- basically a disposable drip irrigation system consisting of a lateral with holes. At US$90/ha, Pepsi costs a fraction of all other systems. (DID: 136, van Steenbergen 2004).

- *Support to water harvesting techniques could help reduce poverty:* In considering public support for watershed management and water harvesting, not only the direct production benefits and the natural resource conservation benefits need to be considered, but also the distribution of the benefits, which will typically accrue to the poorest. In addition, these actions can be highly geared in their effects: irrigable lands are very limited, but there are millions of hectares of farmed rainfed lands in region. Small investments over a large area could benefit very many people.

- *The major issue that has arisen from field assessments regarding the viability and sustainability of water harvesting investments and measures is the question of ownership*: Often government and/or projects step in and provide assistance irrespective of beneficiary performance or adherence to agreements thus creating a culture or attitude of dependence. Political pressure, spending pressures or time restraints makes it difficult to avoid, but without effective adoption by the beneficiaries, the investments will soon be lost.

- *Communication and community consultation during planning and implementation are key for success of projects*: Communities emphasized that if given the opportunity to identify and decide the types of project in line with their expectations, they will mobilize and their participation will be high at all stages of the project. There is ample evidence from the region that most of the failed projects are those implemented without sufficient and effective beneficiary consultation and participation.

- *Support to promote the development of sustainable and accessible financing mechanisms is essential:* supporting the development of rural finance, with a savings first approach and ensuring that any support measures (or subsidies) do not "crowd out" the development of a sustainable rural financial market is essential. Market-based mechanisms for investment financing like suppliers' credit and leasing could be explored.

- *Improvement in land tenure security and the development of efficient land markets could help the process of development:* Access to bank financing, incentives to invest, and transfer of land to the most active and productive farmers would all be eased by land tenure improvement. Clearly, given the limitations of the land titling system, this has to be focussed in priority on specific areas of concentrated commercial agriculture.

Summary and Conclusions

The seminar "Adaptive Water Management in the Lake Chad Basin: Addressing Current Challenges and Adapting to Future Needs", convened by the Lake Chad Basin Commission (LCBC) and the Food and Agriculture Organization of the United Nations (FAO), took place as part of the World Water Week 09 in Stockholm which put a special focus on transboundary waters, with sessions on the Jordan, Tigris–Euphrates, Nile, Zambezi and Mekong rivers and Lake Chad Basin. It was attended by more than 50 participants representing riparian countries, donors and other institutes.

The seminar addressed the current challenges in the Basin and explored opportunities for an Adaptive Water Management and possible future strategies to be adopted to replenish the Lake and to safeguard surrounding livelihoods.

Led by the conviction that there cannot be much water saving from efficient management only, due to the high evaporation, a call was made for the adoption of measures beyond the convention of the available water resources in the Basin. The seminar concluded that adaptation is important to the Lake Chad current situation. As reported in the LCBC Vision 2025, based on an analysis of the current situation and challenges to integrated management of the basin's natural resources, identified the causes of the current environmental degradation to be mainly global climate change, unsustainable decisions, lack of good policy and political will on the part of member states, poor coordination mechanisms, poverty and fragile economic situation of the region.

The effect of climate change, coupled with several anthropogenic effects, is considered as one of the main causes of the severe depletion of the Lake. Inadequate observation of climatic data limits the regional diagnostic analysis and the dearth of information on climatic change forecasting hinders the capability to detect the negative effects of climate change on non adapted human communities. Therefore, it is urgent to enhance the traditional climate change adaptation strategies already put in place in the Lake Chad Basin through the development of effective climate predictability systems and broad integrated programmes to observe, predict and model changes brought by climate.

Despite all analysis, it was, nonetheless, apparent that the causes of the shrinking of the Lake are multiple and still debatable. It was, thus, emphasized that there is still a need to better investigate the source of inflow into the lake and hence better identify the causes of the shrinking.

The common history of the countries sharing Lake Chad can be considered as a precious asset to foster the sustainable management of the basin. Successful experiences from other regions sharing similar challenges should be collected and used as examples and benchmarks. A common information system at basin level is thus crucially needed as well as a stocktaking of the consolidated knowledge. The information already available is massive but a great effort is to be carried out to help the uptake of the available knowledge.

The water transfer project, which aims at constructing a navigable channel using some inflows from the Oubangui to supply Lake Chad with water, will have multiple goals: to ensure river transportation in order to transfer goods from east to west across Africa; to produce electricity; and to develop irrigation and agro-industry in the region. Socio-economic and environmental benefits are also clearly demonstrated: extending and creating water supply; promotion of trade; and irrigation and agro-industry development. The transfer project is an example of integration project in Africa: it will connect regions and even tribes beyond borders and frontiers. The principle of "benefit sharing" amongst the riparian countries appears to be the case that justifies the project.

However, the seminar stressed the importance to look at the water transfer as a solution to stabilize situation for food production/human needs/socio-economic needs and to anticipate progressive but reversible action to recover the lake and its surrounding livelihood. It also emphasized the need to conduct profound and detailed social and environmental impact assessment studies, particularly considering the negative impacts that the project could have on both the Lake Chad Basin and the Congo Basin. A concern was also expressed on how more open water bodies will increase the evaporation. In particular, attention should be paid to the final quality of the water that results from the mixing of the waters of the Lake Chad Basin and the Oubangui and the effect this will have on the ecosystems. There are also often public health impacts associated with water transfer canals that can serve as water-borne disease vectors as well as severe impacts on the socio-economic activities (fisheries, animal husbandry, agriculture, etc.). Moreover, the reduction in the flow of the Oubangui, as also a result of climate change, is of great concern to the riparian states when thinking about a possible transfer of part of such a volume of water into another basin.

Looking for a sustainable solution is vital – an example was made of the effect on the Inga. Because of this concern and since the degree of interdependency goes beyond the Lake Chad, there is a need for wider dialogue with the downstream basins before embarking on such an intervention.

The African leaders are strongly committed to saving Lake Chad and to enhance the adaptive and sustainable management of the natural resources and biodiversity of the Lake Chad Basin for the benefit of present and future generations. This political commitment has to be sustained and made as an agenda, thus assuring that good governance and, eventually, focused intervention will also be sustained. However, political commitment has necessarily to be accompanied by a strong participation of all stakeholders in decision making: the interests of all stakeholders have to be taken into consideration in a wide participatory process and grass-root mobilization has to be pursued.

Optimism for the lake is in short supply, but there is hope that the partnership between the Lake Chad Basin Commission and the FAO may bear fruit. At the FAO World Food Summit this autumn the dialogue continues, but this is a challenge that will require a great deal of solidarity and cooperation to resolve. Support and assistance from all development partners and indeed the international community is required to save Lake Chad: the conservation of the global value of the largest, freshwater reservoir in the Sahel region of Africa is a mission which is the role and responsibility of all.