THE MAN-ENVIRONMENT INTERFACE IN THE LAKE CHAD BASIN AND THE ISSUES FACING THE COUNTRIES

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Abstract

This study examines the Man-Environment Interface in the Lake Chad basin and the issues facing the countries concerned. The paper utilizes desk study to highlight human and environmental issues in the Chad Basin such as oil exploitation and climate change respectively, as well as their effects in the study area. In conclusion, the study opines that the countries of the Lake Chad Basin have been described as "weak States" characterised by weak political and economic stability, poor institutional capacity, limited information base and knowledge, incomplete development, narratives/strategies, limitation of national policy-making and implementation process etc, (Neiland et al 2005). The region will require international assistance to adapt to climate change and implement necessary mitigation measures. This, as it is suggested, should include assistance to undertake more detailed climate change research that would lead to a greater understanding of patterns of vulnerability in the system in order to develop and prioritise adaptation interventions in the Lake Chad Basin. Some of the recommendations made by the study are that Since there is high evapo-transpiration in the Lake Chad area which involves not only surface but ground water, methods such as injection of surface water from rivers, canals, lakes and reservoirs which will serve as a recovery for over-pumped aquifers should be introduced. Also since the local communities are the primary beneficiaries and victims of the unpredictable occurrences of Lake Chad, there is equally the need to integrate them in the management of the resources of the lake in terms of indulging in more conserving agricultural practices that causes other environmental problems.

Keywords: *Lake Chad Basin, Oil Exploitation, Climate Change, Evapo-transpiration, Aquifers, Canals*

Introduction

One of the major crises facing under-developed countries is that of food production. Throughout the underdeveloped countries the major concern has been how to produce enough food to support the teeming population. This has lead to the creation of various government policies and programmes such as farm settlements, the Green Revolution(GR), Operation Feed the Nation (OFN) and the River Basin Development Authorities (RBDA) (Akindele and Adebo 2004). Several river basin development authorities were created including Chad basin development authority which constitutes seven countries (Niger, Nigeria, Chad, Sudan, Cameroun, Algeria and Central African Republic).

The Lake Chad Basin is a major geographical region in the central part of the Sudan zone of Africa. The northern parts, however, extend into the Sahel and the southern parts of the Sahara desert. It is the largest drainage basin in Africa, centered on Lake Chad. It has no outlet to the sea and contains large areas of desert or semi-arid savanna. It consists of an extensive shallow depression of about 1.536.000 km^2 (600.000 $miles^2$) of which about 10% lies in Nigeria (Udo 1993). The greater part is shared between the three countries of Cameroon, Chad and Niger. Climatically and agriculturally, the Chad Basin lies within the dry or semi-arid zone of Nigeria. It is a marginal area which has experienced severe droughts and considerable environmental changes in recent years. The basin spans seven countries, including most of Chad and a large part of Niger.

Lake Chad basin was created by four member countries in 1964, where the lake Chad basin commission was established with the objective of ensuring the most rational use of water, land and other natural resources and to coordinate regional development. About 20% of the total area of the Lake Chad basin (427,500 $km^{2)}$, is called the Conventional Basin (42% in Chad, 28% in Niger, 21% in Nigeria and 9% in Cameroon), which is under the mandate of the Commission. It covers a total area of 2,381,635km^2 which is 8% of the African continent (UNEP 2004). In the light of these the study therefore, examines the Man-Environment Interface in the Lake Chad basin and the issues facing the countries concerned

Table 1: Showing area covered by Lake Chad Basin within individual countries

Country	Area of the country within the basin (km^2)	% of the total area of the basin	% of the total area of the country
Nigeria	179,282	7.5	19.4
Niger	691,473	29.0	54.6
Algeria	93,451	3.9	3.9
Sudan	101,048	4.2	4.0
Central African Republic	219,410	9.2	35.2
Chad	104,6196	43.9	81.5
Cameroun	50,775	2.1	10.7

Source: FAO, 2009

Location of Lake Chad Basin

The Lake Chad Basin is located between latitude 6^0 and 24^0 N and longitude 7^0 and 24^0 E. it is situated in the central part of north Africa, on the edge of the Sahara desert and provide a vital source of water to human, livestock and wildlife communities. The lake is one of Africa's large fresh water lakes, but has shrunk dramatically over the last forty years (Odada et al 2006).

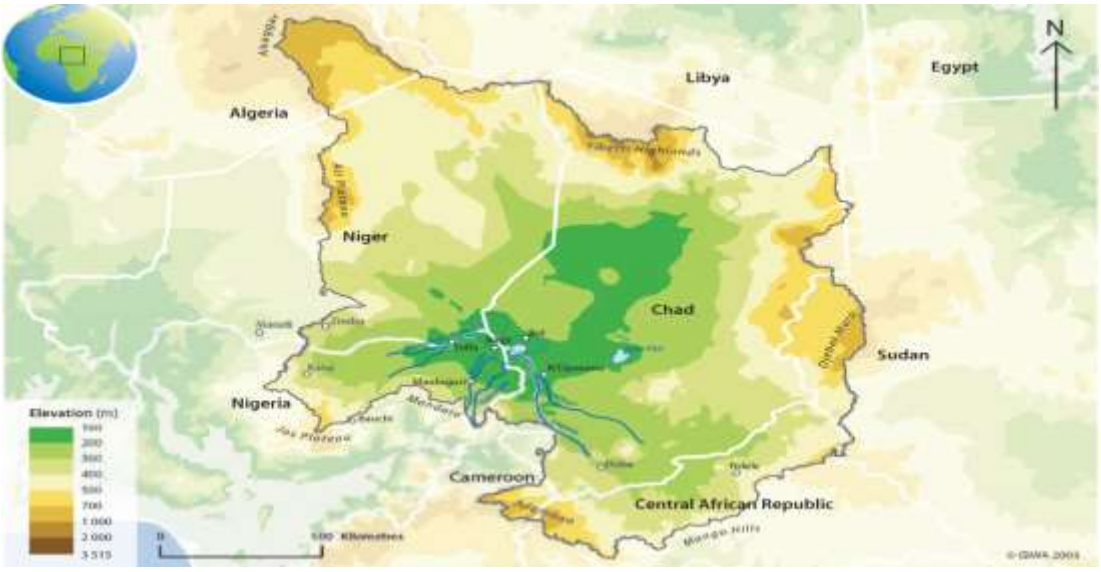

Fig 1: location of Lake Chad Basin (Source: GIWA 2004)

Population

There are over 70 ethnic groups in the lake chard basin who are predominantly Muslims. The natural, political and socioeconomic environments of the Chad Basin in Nigeria have attracted more population and large scale investments in farming during the past thirty years. Refugees from the Republic of Chad, who continues to suffer from political instability and intergroup warfare, and from severe droughts in Niger Republic, have continued to move into Nigeria, especially after the Sahelian droughts of 1972-1974. The demand for suitable agricultural land has therefore increased greatly, since much of the region has itself experienced severe droughts and other environmental hazards during this period.

The Kanuri, numbering about 1.5 million, make up the largest ethnic group in the Nigerian part of the Chad Basin. Kanuri make up the ruling group in Borno, and most of the original indigenous groups that they had conquered have since adopted the Kanuri language. In turn, the Kanuri have become gradually merged with these groups. Small pockets of pure Kanembu people are still found in the Kukawa and Monguno districts. Arabs, whom the Kanuri call Shuwa, make up the second largest group, and are found in the eastern part of Borno.

During the past five hundred years of their settlement in the Chad Basin, the Shuwa Arabs have lost most of their ethnic traits, except their language. The Shuwa Arabs who arrived over 500 years ago have remarkably switched from their camel rearing to cattle rearing since it doesn't suit it. A combination of recurring drought and cattle diseases later resulted in the decimation of the cattle population. Thereafter, the Shuwa adjusted further and settled down as hoe cultivators; and have since become well known for practicing a rudimentary form of mixed farming.

In the western and southern part of the Chad Basin, lies the Hausa who form the predominant indigenous population. They are also settled hoe cultivators who own cattle which they put under the care of the nomadic cattle Fulani.

Other indigenous groups include the Gamargu, a small group in the middle Yedzeram valley who rear cattle and horses and the Mobbar of the lower Yobe valley. Smaller groups including the Margi, and the Kilba, occupying the hilly country west of the Mandara mountains where many hill settlements still exist. The most ubiquitous ethnic group in the Chad Basin are the Fulani, who are relatively new comers to the region. The greatest concentration of the Fulani are

in the Hadejia-Nguru wetlands, the Yobe valley and parts of Bauchi State. Other groups are the Mousgoun in Yaere in Cameroon and the Sara and Kotoko in the Chari Delta in Chad. This population is predominantly rural, thriving on climate-sensitive agriculture-related activities.

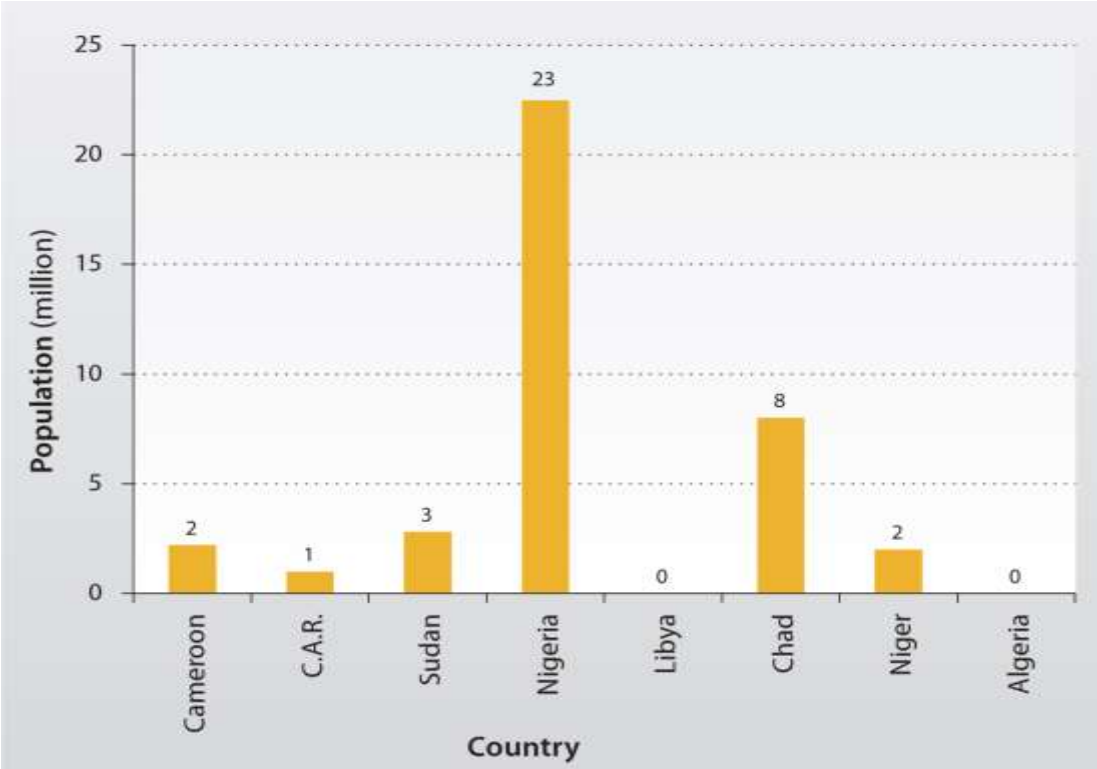

Fig. 2: Estimated population in the Lake Chad Basin by countries in 2002 (Source: GIWA 2004)

Ecological System of the Lake Chad Basin

Climate

The northern half of the basin is desert, containing the Ténéré desert, Erg of Bilma and Djurab Desert. The Basin is predominantly located in the transition zone between the Sahara desert and savannah grasslands called the Sahel, characterised by dry savanna and thorny shrubs (GIWA 2003). The main rivers include riparian forests, flooding savannas and wetland areas. In the far south there are dry forests. Lake Chad Basin is characterized by three different zones: hyper-arid to arid in the north, semi-arid in the centre and subtropical in the south. The climate of Lake Chad basin is characterised by 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 evapo-transpiration of around 2,200 mm (Carmouze, 1976 & FAO, 2009). Annual rainfall varies spatially from nearly 1,400 mm along the southern pools to less than 150mm near the northern end (Odada et al., 2006). The history of drought in the basin is defined by its changing rainfall patterns. From the middle of the 1960s, rainfall started to drop intermittently until the droughts of 1972-1975 which coincided with the shrinking of the basin to 10,700 km^2 from its initial level of 25,000 km^2 in 1963. Another drought of 1982-1985 resulted in a drop in basin area to 1,410 km^2 (GIWA, 2004), the lowest basin surface level recorded over the past 100 years.

Fig 3: Rainfall Distribution in the Chad Basin (Source: GIWA 2004)

Table 2: Rainfall for individual countries in the Chad basin

Country	Average rainfall in the basin area (mm)
Nigeria	670
Niger	105
Algeria	20
Sudan	585
Central African republic	1215
Chad	400
Cameroun	1010

Source: FAO, 2009

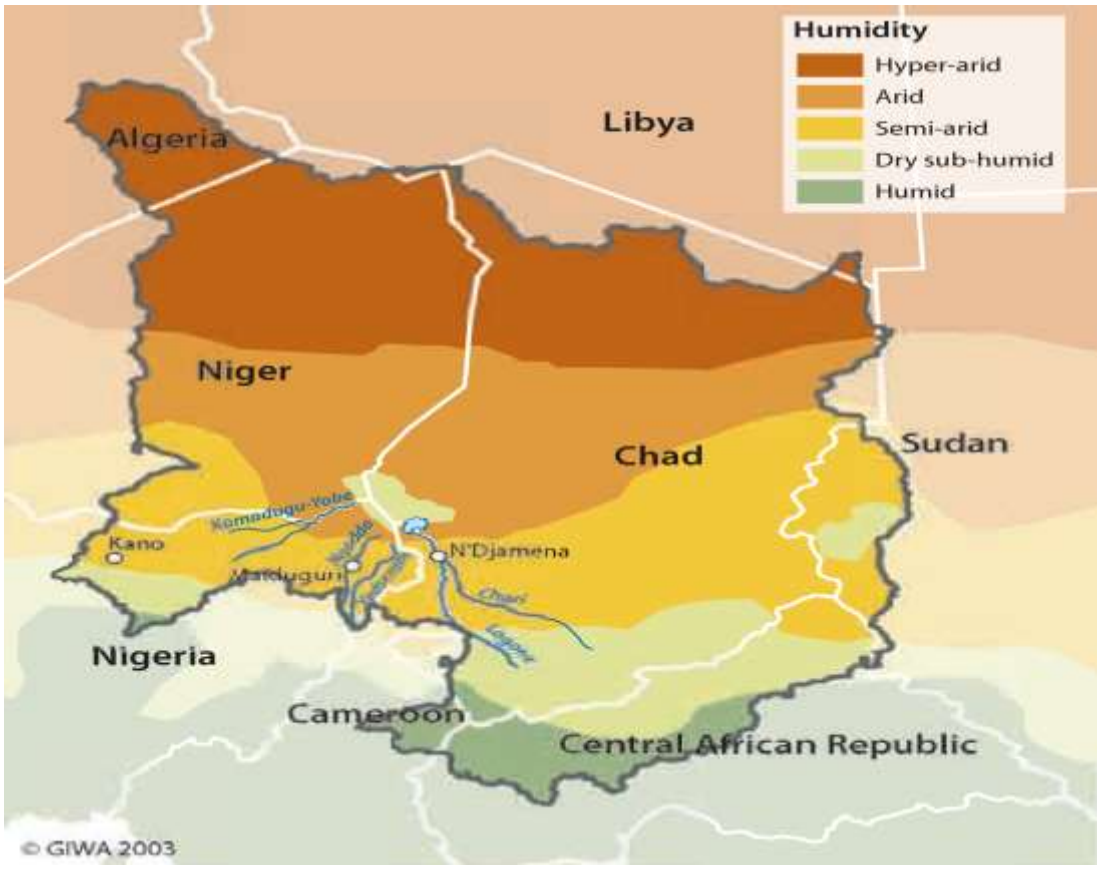

Fig. 4: Five main climatic zones in the Lake Chad Basin region (Source: GIWA 2004)

Vegetation and wildlife

Most of the Lake Chad Basin falls in Sahel savanna. The major wetland plant communities present in the basin comprises three broad categories: floating "sudd" communities, permanent reed swamps and seasonal herbaceous swamps (edaphic grassland). The Lake Chad is separated into the northern and southern pool by a swamp belt. Vegetation in the south pool consist of cyperus papyrus, phragmites mauritanus, vassia cuspidate and other wetland plants. Grassland community dominates where flooding is extensive because most tree species cannot tolerate extensive flooding conditions. Woody communities dominated by acacia species, grow interspersed with the grassland. These woody communities vary in density ranging from scattered trees and bush grasslands to woodlands and thickets. Xeric woodland species found in the basin especially

around Lake Chad include Baobab, Desert Date Palms, African myrrh and Indian Jujube (Mockrin and Thieme 2001).

The basin has remained home to large populations of wildlife. Sahelian large mammal species that used to be common in the ecological region include: Antelopes such as the addax and dama gazelle, and in the savannah there are korrigum and red-fronted gazelle. The black-crowned crane and other water-birds are found in the wetlands. There are populations of elephants, giraffes, and lions. The western black rhinoceros was once common but is now extinct. Elephants almost became extinct by the end of the nineteenth century due to European and American demand for ivory, but stocks have since recovered. The Sitatunga is considered extinct in Niger while only a few declining population remain in the Lake Chad region of Nigeria. A reduced Hippopotamus population is still present and Otters remain common. Up to a million wintering birds congregate on the Lake Chad making it one of the third most important area for migratory water-birds in West Africa (Odada et al 2006).

Topography

The basin is an extended plain mostly covered by medium to fine-grained sands except on its borders. The surface height varies from 3,300metres above mean sea level in the north (Tibesti Mountains); 3,000metres in the NW (Ahaggar Mountains) and 3,300metres in the SW (Adamawa Plateau) to 180metres above mean sea level in the Pays Bas (lowlands). The area with heights below 320metres above mean sea level in 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 characterised 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% of the annual volume of water that reaches the lake and the Komadugu-Yobe that provides about 3% of the annual inflow into the lake. The precipitation over the lake surface completes the remaining 2%. 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.

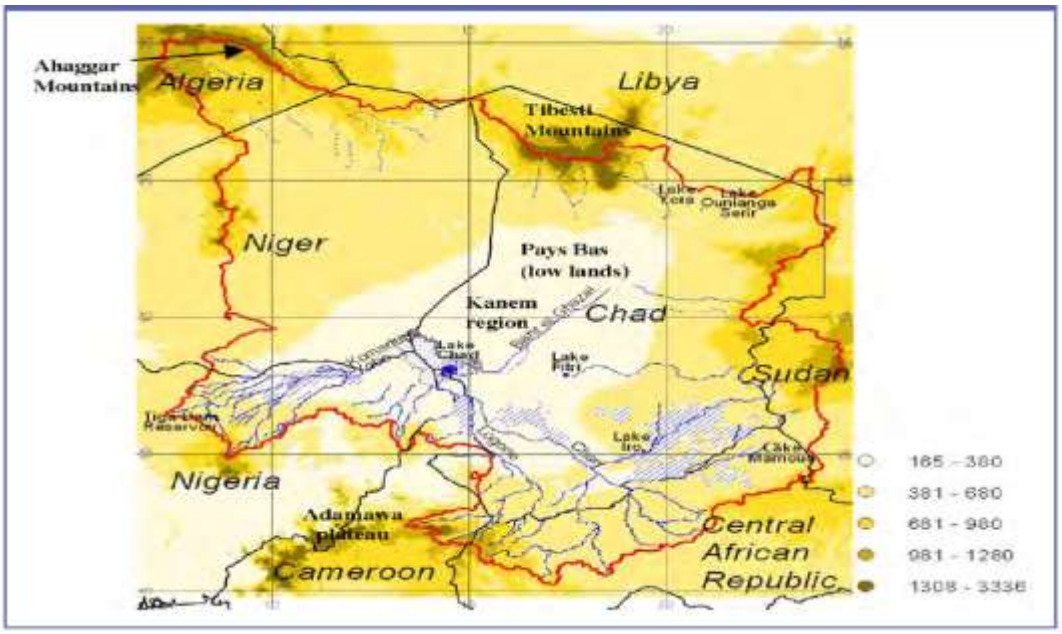

Fig. 5: Topography of the Lake Chad region (Source: FAO 2009)

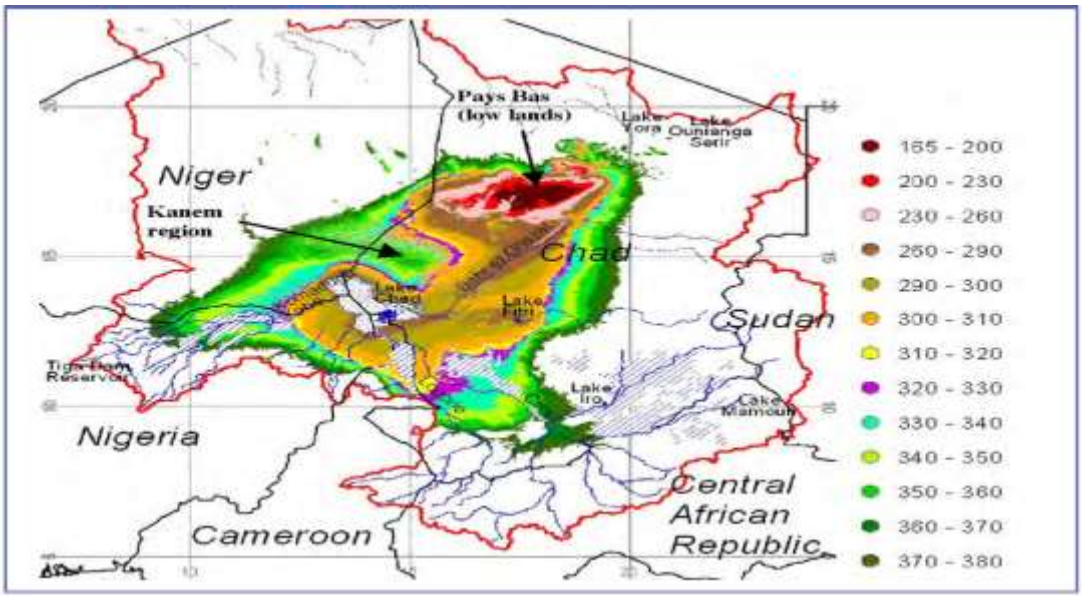

Fig.6: Detailed Topography of the Lake Chad region showing lowest and highest points Geology (Source: FAO 2009)

Most of the Lake Chad Basin is covered by Quaternary sands 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 75metres appears a thick layer of some 280metres of clay from the Upper Pliocene age. 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 30metres, underlain by the sandstones of the Continental Terminal (Tertiary) with a thickness of some 150metres. 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 (Odada et al 2006)

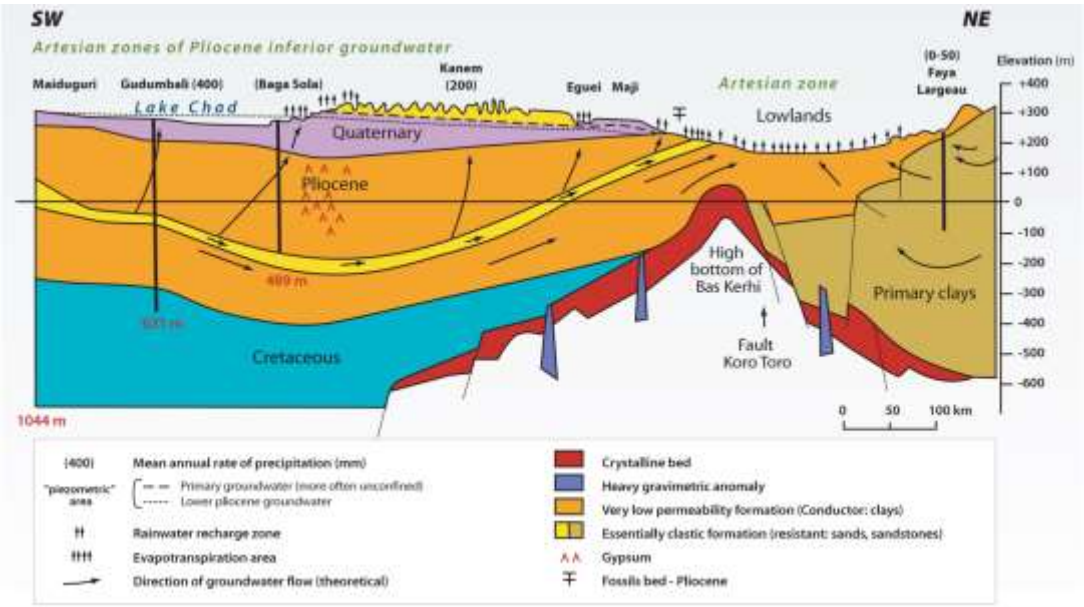

Fig. 7: Cross-section of the geology in depth drawn between Maiduguri (Nigeria) and Faye Largeau (Chad) (Source: GIWA 2004)

Rivers and discharges in the Chad basin

Lake Chad is a terminal depression with the seven basin countries grouped around it, of which four are in direct contact with the lake: Nigeria, Niger, Chad and Cameroon. In Nigeria, two sub-basins which are the Yedseram/Ngadda sub-basin to the south and the Hadejia/Jama'are-Komadougou/Yobe sub-basin to the north, drain into the lake:

The Yedseram River and its tributaries rise in the Mandara hills and it 'loses' most of its water while flowing northwards through a 7km-wide flood plain.

Further downstream, together with the Ngadda River it forms an 80-km^2 swamp and does not maintain a definable water course to the lake.

The Komadougou/Yobe River is the border between Nigeria and Niger over the last 300 km. Upstream of the confluence of the Hadejia and Jama'are rivers the Hadejia-Nguru wetlands (fadamas) start. These cover a total area of about 6000 km^2 and a water surface area of about 2000 km^2, but dam construction and increasing water abstraction for irrigation purposes upstream since the 1980s contribute to the fact that large areas of the floodplains are becoming increasingly drier. All rivers crossing this area lose flow as a result of evaporation and evapo-transpiration and infiltration to recharge the groundwater. The inflow varies between 1 and 1.8 km /year, the outflow between 0.6 and 0.7 km /year. When the inflow is more than 2 km^3/year, the outflow gradually increases to 1.2 km^3/year. Upstream the peak flow is at the end of August and rises and falls rapidly reflecting the sporadic nature of heavy rainfall and the largely impermeable strata. Downstream the peak flow is in January. The flow into Lake Chad is about 0.5 km^3/year. In Niger, in addition to the border Komadugu-Yobe River, there are the Koramas in the south of the country close to the border with Nigeria. These are seasonal rivers and their flow does not reach Lake Chad.

In the north, far away from Lake Chad, is Algeria. The country possesses few renewable water resources. To the east is Sudan with Wadi Kaya and Wadi Azum, both of them are seasonal rivers with spate flows that originate on the western slopes of the Jebel Marra. Their alluvial aquifers could deliver about 0.08 km /year of water of excellent quality.

To the south is the Central African Republic, a humid country with enormous water resources. The sources of the Chari-Logone Rivers are located in the Central African Republic and the quantity of water leaving the country to Chad was about 33 km^3/year in the period before the 1970s, but fell to 17 km^3/year during the 1980s.

The amount of water crossing the border from Cameroon to Chad varies between 3 and 7 km/year. More to the north, the Logone River forms the border between Cameroon and Chad until N'Djamena where it flows together with the Chari River which then continues north to the lake. These rivers have a tropical regime with a single flood occurring at the end of the rainy season, which lasts from August to November. They are characterized by irregular inter-annual

flows and by their large water 'losses', estimated at about 5 km^3/year, due to flooding of the adjacent Yaéré lowlands in Chad and Cameroon. The largest area flooded covers about 8000 km^2 and is used for pasture, fishing, flooded rice production and flood recession cropping. In order to expand the Yaéré area, two sites for regulatory dams have been identified on upstream branches of the Logone in Cameroon and Chad. However, this would be to the detriment of water uses for hydro-electric power generation and for irrigation outside these Yaéré lowlands.

The rivers outside the Chari-Logone basin in Chad have flash floods during heavy rains and negligible flows in other times, like the Batha River. This regime seriously limits irrigation development.

The Chari-Logone rivers, with 38.5 km^3/year, contribute for about 95% of the total inflow into Lake Chad. In recent history the area of Lake Chad has varied between 3000 and 25000 km^2, with a variation in its level of over 8metres and a variation in volume of between 20 and 100 km^3. The total inflow in recent times has varied between 7 km^3/year (1984/85) and 54 km^3/year (1955/56). Due to the lowering of the lake level, ideas have been put forward to replenish the lake with water from the Congo/Zaire basin through the construction of a 2400 km-long canal, but for the time being this is impractical on technical, economic and political grounds.

Human Activities Systems in the Chad Basin

Farming and animal rearing are the two main economic activities in the Chad Basin. Arable farming and livestock grazing along with the high and increasing demand for fuel wood have contributed greatly to environmental degradation. Population movements into the region from drought stricken areas of Niger and Chad Republic have created greater demand for farmland and grazing, particularly along the fadamas. Urban centres, notably Maiduguri and the newer state capitals of Damaturu and Hadejia make considerable demands on both the surface and ground water resources. Indeed, the construction of surface dams to provide water for people in these and other towns has resulted in loss of dry season farmland to the people living downstream. Road construction using large earth moving machinery has created large scars on the landscape, often deliberately to serve as rain water collecting ponds for use by cattle. In many localities, such scars are the starting points of gully erosion.

The land use practices that affect the environment are cultivation, bush burning, grazing, deforestation and irrigation. The changes caused by these land use practices, especially cultivation is often positive because of careful adaptation by the inhabitants who have a vested interest in preserving their homesteads. It is the recent capital intensive irrigation projects that have created more dramatic changes on, and damage to the natural environment.

Mining

Although the Basin contains many minerals they are poorly utilised. Chad's minerals for example, have been relatively unexplored, although it is believed to have many mineral deposits. The principal mineral resource is natron (a complex sodium carbonate), which is dug up in the Lake Chad area and is used as salt and in the preparation of soap and medicines. Annual production is a few thousand tonnes. There is also gold mining development in the Chari-Logone River Basin in southern Chad and CAR.

Oil exploitation

In Chad, oil extraction began in July 2003 and is expected to account for 45-50% of Chad's national budget. The project is exploiting the oil fields at Doba in southern Chad (at a cost of 1.5 billion USD) and has constructed a 1070km pipeline to offshore oil-loading facilities on Cameroon's Atlantic coast (at a cost of 2.2 billion USD). Figure 22 shows the Doba oil field in Chad and the pipeline in Cameroon. The sponsors are ExxonMobil of the U.S. (the operator, with 40% of the private equity), Petronas of Malaysia (35%), and ChevronTexaco of the U.S. (25%). The project could result in nearly 2billion USD in revenues for Chad (averaging 80 million USD per year) and 500 million USD for Cameroon (averaging 20 million USD per year) over the 25-year production period (World Bank 2003).

Farming

Farming involves the killing of some few scarcely populated trees during land clearance and bush burning. Firewood obtained during the clearing is needed for fuel. Land clearance when preparing farm land, exposes the surface soil to water and wind erosion and there is an increase in wind speeds. In localised areas of permanent cultivation, such as the closed-farmed Kano districts,

intensive application of manure produces more stabilized soil conditions. Shade trees planted around homesteads help to conserve the soils around villages, and so do the 'wind belts' planted near villages in the drier areas. However, repeated trampling by livestock and uncontrolled grazing by goats prevent ready regeneration vegetation in the fallows around settlements. Further, foot paths to water points have often initiated erosion gullies which may expand over the years to cause much damage.

The Chad Basin is a very sparsely settled area, and it appears that in some localities the degraded state of the environment is due more to lack of use of the land rather than over use. Effective use of limited water resources in the Kano region and in Israel shows clearly, how concentration of population can improve the state of the environment (Udoh 1993). Further, evidence from densely settled localities in the Chad Basin confirms that permanent cultivation encourages the protection rather than the destruction of trees. It is man that builds wells, plants and burn trees including fruit trees, wind breaks and fuel wood plantations. At the same time, a sparsely settled area permits the time-old system of shifting cultivation which pays little attention to conservation measures that allow the production potential to be maintained (Boserup 1965).

Bush burning

Mortimore (1989) states that bush burning is rare in the drier semi-arid zone of the Chad Basin owing to sparse vegetation cover. This is not correct because burning to encourage regeneration of succulent grass for cattle goes on every year. There are, however, hardly any trees or shrubs to destroy in many areas. In the more wooded areas further south, burning is carried-out in the process of preparing farmland, during hunting and for regeneration of grass shoots. In all cases, burning works to prevent the survival of dense woodland vegetation and thereby exposes the soil to desiccation and erosion.

Grazing activities

The vegetation is scanty and the grass cover is seasonal, while patches and in some districts, extensive areas, remain bare of vegetation even during the rainy season. The natural environment is disturbed by premature grazing, whereby animals eat-up plants before they reach seed producing stage. Indeed during the dry season, bush burning takes place so as to induce regeneration of fresh grass

to feed the cattle. Goats do more damage since they eat up the branches and shoots of plants, and even the barks in some cases. Trampling by livestock destroy vegetation and loosen the soils for the winds to blow away.

Deforestation

Clearance of woodland for farming is a major cause of deforestation in the southern parts of the Chad Basin. In the drier northern parts, there is no woodland to clear. Traditional agriculture is less destructive to woodland, compared to mechanised farming which an increasing number of retired senior civil servants and army officers have established during the past twenty years. Clear felling involving the uprooting of most trees by machinery precedes the preparation of land for cultivation in these mechanised farms, some of which cover several thousand hectares. The more prevalent causes of deforestation are wood cutting, lopping and burning. In the rural areas, virtually every family depends on firewood and charcoal as the main source of fuel; while 90% of urban families also depend on firewood for cooking (Udoh 1993). The shortage of firewood in the region is evidenced by the high prices for wood, especially in the towns and the use of animal waste as fuel for cooking food, instead as manures for producing food. Firewood is obtained mostly from farmlands and fallow bush. But in many districts, trees and shrubs on such land have largely disappeared such that local inhabitants are forced to poach for firewood in protected forest and game reserves. There is clearly a fuelwood energy crisis in many areas including the Local Government Areas of Geidam, Kukawa, Monguno and Nguru where woody stems are few and scattered. Surprisingly, Mortimore (1989), considers the concern expressed over deforestation in an area as arid as the Manga Grasslands along the Nigeria-Niger border as alarming. He states that up to 1986, wood for construction or fuel was still not considered to be scarce in the Manga area of the Hausa-Borno borderlands between Matsena and Dagaceri. His argument is that rural fuelwood in the area is usually harvested from living trees, rather than by clear felling. He therefore concludes that those who talk about 'indiscriminate deforestation' are over-dramatising.

Deforestation caused by farmers and cattle rearers has certainly contributed to increased surface run-off which is responsible for increased deposition and silting up of river-beds. The rather broad river-valleys thus developed often

give-rise to extensive floods which like droughts, are destructive to crops. Deforestation is also considered to be the cause of a dramatic development affecting the surface hydrology of the area between Potiskum and Damagum in Yobe State, where a rise in water table has resulted in the appearance of many new streams. This shows that the level of the water table is independent of the fluctuations in the rainfall, but related to extensive deforestation and cultivation of large areas. Deforestation and cultivation increase run-off, while reducing evapo-transpiration. Since the terrain is almost flat, loss of water by run-off is minimal and does not cause a significant fall in the water table. Rather the run-off enters the river systems which, being influent, are able to supply more water to the permanent ground water.

Irrigation

Irrigation brings considerable modifications in the ecosystems of semi-arid and arid areas. Environmental changes are associated with irrigation schemes in which large dams are constructed to create artificial lakes. Often many settlements have to be relocated.

The large scale irrigation projects in the Chad Basin include the Kano River Project, which relies on water impounded by the Tiga dam. This gravity-fed scheme for developing 24,000 hectares has made permanent cultivation of small farms (1-2 hectares) possible, which are serviced by centrally located tractor hire units. Cultivation is carried out during the rainy season as well as during the dry season. The Hadejia valley irrigation project depends on the release of water from Tiga dam and when fully operational will irrigate 84,000 hectares. But the Tiga dam is largely responsible for the drying up of a branch of the Yobe river. Today the river bed that provided water to irrigate the fadama farmland and fish for local fishermen has been taken over by sand dunes.

The South Chad Irrigation Project at Baga was commissioned in 1983 using water from Lake Chad via a 29km long intake canal. By 1990 most of the canals had become derelict because of the continuous fall in the level of Lake Chad starting from 1972-74. The original supply canal was extended by 24km into the lake in 1979, but by 1986 the lake had dried up so much that the nearest water to the supply canal was 70 km away (Adams and Hollis 1987).

Other important irrigation projects in the Chad Basin include the Yobe irrigation scheme and the Hadejia-Nguru wetlands schemes. There are also many smaller

schemes which rely on water from rivers or pools in the river beds as well as on water obtained from wells. Some of the advantages of large scale irrigation projects are offset by considerable loss of fadama agricultural land to water storage in artificial lakes. In the Kano River Project, the extensive areas of lush fields of wheat and vegetables during the dry season, especially when the non-irrigated areas consist of bare brown fallows, are remarkable evidence of the change that irrigation has brought to the cultural landscape of this part of the Chad Basin. In the area of the Chad Basin irrigation scheme, drought and the recession of Lake Chad have stultified the scheme, thereby creating what has recently been described as 'one of the outstanding monuments of the folly of big irrigation projects in Africa' (The Guardian 1992).

Table 4: Irrigation potential and water requirements

Country	Irrigation potential in whole lake Chad basin	Irrigation water requirements (Km^3/year)
Nigeria	502000	5.020
Niger	48000	0.936
Algeria	0	0
Sudan	4000	0.030
Central African republic	500000	8.250
Chad	835000	12.525
Cameroun	100000	1.250
Total	1989000	28.011

Source: FAO, 2009

Dam construction

Stream flow modification and water diversion, associated with the construction of large irrigation and water development projects along the Chari-Logone River and Komadugu-Yobe River, are also identified as contributory factors in the shrinkage of the basin over the period 1970-2013 (US Geological Survey, 2014). The construction (between 1979 and 1990) of Yaguou-Tekele Dyke and Maga Dam beside the Chari-Logone River in Chad, and a series of other dams, such as the Alau dam, Tiga dam, and the Yeders dam at the Nigerian end of the Kamadugu-Yobe River have impacted greatly on the Lake's waters (Onuoha,

2008). Between 1970 and 1990, the average water discharge from the Chari-Logone River to the basin was 55% of the average of the period 1950-1970 (Olivry et al., 1996). It is estimated that about one-third of the water flow (since the 1980s) is diverted from the Chari-Logone River in Central African Republic before it reaches the Lake Basin (Glantz, 2004). Water diversion for irrigation and hydropower generation increased greatly between 1981 and 1990 (GIWA, 2004). About 50% of the depletion in the Lake's size since the late 1970s to 2000 was attributed to unsustainable water diversion and use for human activities (Coe and Foley, 2001). The current state of the Lake is one of acute water shortage. In 2000 water supply was less than $500m^3$ per person per year (Henninger et al 2000); this has not changed to date, though, population has continued to increase. A change from cultivation of low water intensity food crops (such as wheat) to high water intensity food crops (such as rice) has added to the water scarcity (Odada et al 2006). Reduced water levels have caused increased alkalinity, increased anoxic conditions and worsened the effects of eutrophication (Ovie and Emma, 2011). Because the Lake region is generally and historically exposed to intense drought events, water scarcity is increasingly associated with the myriad of socioeconomic and livelihood shifts around the Lake, for which climate variability acts as an amplifier.

Fishing

Fishing on Lake Chad is a very lucrative activity, between Doron Baga market in the south of Nigeria and the market of N'Djamena in Chad. Between 1960 and 2001, average catches of fish per year in Lake Chad varied between 50,000 and 80,000 tonnes without any risk of stock depletion in normal hydrological periods (Jolley et al 2002 and FAO 2009). The riparian population of Lake Chad is estimated at 20 million inhabitants. This number may increase to 35 million in 2010.

With production levels of hundreds of millions of tonnes per year, fishing is practiced in the Lake Chad basin by thousands of artisanal fishermen and many households. They use relatively unsophisticated techniques such as traditional boats and fishing gear on the lake, rivers and floodplains (GIWA, 2004).

The fishers catch a wide variety of fish; an estimated 176 species, according to a study conducted by *Office de la Recherche Scientifique Technique d'Outre Mer (ORSTOM)* in the 60s, a significant portion of the catch is either dried or

smoked. These are then fed into a well-organized marketing network that extends to the urban markets of southern Nigeria such as Lagos, Ibadan, Onitsha, Enugu, where smoked and dried fish are in high demand. It is currently estimated that the fishery industry annually generates more than 24 million (USD) or about 12 billion FCFA. Indeed, this activity provides employment, income and food for more than 10 million people.

Fishing in the Lake Chad basin is tied to hydrological regimes and water distribution. These parameters depend on the climate, but also on human activities such as irrigation, dyke construction, deforestation, etc. which currently expose the sector to huge challenges.

Environmental Problems in the Chad Basin

Climate change

Climate change or fluctuation is one major factor in the drying up of the lake. The impact of climate change and fluctuations on Lake Chad hacks back to many decades. Early study on the hydrological history of the lake has found that the balance between water intake and evaporation is continually fluctuating, with the result that, due to the shallow nature of the lake, is continually changing its size and shape. These fluctuations may be seen as of three different kinds: long-term, short-term and seasonal. They reflect variations in rainfall not only in the area of the lake itself but particularly in the watershed areas of the feeder rivers.

Fluctuations in the lake are thus, a fairly sensitive indicator of climatic change over a substantial area of Africa (Connah 1981). The impact of climatic variability, particularly the significant decrease in rainfall in the basin since the 1960s, has adversely affected the lake.

There has been a decrease in the number of large rainfall events and in river inflows into the lake. Over the last 40 years, the discharge from the Chari-Logone river system at the city of N'Djamena in Chad has decreased by almost 75%, drastically reducing the inflow into the lake.

Desertification

A large proportion of the Lake Chad Basin has been identified as being vulnerable to desertification, defined as land degradation in arid, semi-arid, and dry sub-humid areas resulting from different factors in each country vulnerable

to desertification and the level of risk it faces. Nigeria and Central African Republic have the largest percentage area of land vulnerable to desertification, but Chad, Niger and Sudan have the largest percentage of areas at very high risk.

Consequently, Chad is currently experiencing the greatest vulnerability to desertification, with 58% of the area already classified as desert, and 30% classified as highly or extremely vulnerable (Reich et al 2001). In Niger, 250,000 hectares of land are being lost each year through desertification (Eden Foundation 2000). Degradation of natural resources such as water, farmland, pastureland and forests has gone a long way toward making populations more vulnerable. All of these factors have led to the near pervasive impoverishment of land capital, the dwindling or disappearance of fallow land, overexploitation of wood resources and overgrazing which have accelerated the process of desertification (Government of Niger 2002).

In Nigeria, desertification (together with soil erosion) accounts for about 73% of the estimated total cost of 5.1 billion USD per year the country is losing from environmental degradation. In the northern states, located in the Lake Chad Basin, it is considered as the "most pressing environmental problem" (Federal Government of Nigeria 2002). Desertification has been indicated by the gradual shift in vegetation from grasses, bushes and occasional trees, to grass and bushes, and in the final stages, expansive areas of desert-like sand. It has been estimated that between 50% and 75% of Bauchi, Borno, Jigawa, Kano and Yobe states in northern Nigeria are being affected by desertification. The country is currently losing an estimated 351,000 hectares of its landmass to desert-like conditions annually, and such conditions are estimated to be advancing southwards at the rate of 0.6 km per year (Federal Government of Nigeria 2002). The situation is being aggravated by the increase in human population, which appears to be stressing the natural support system. The increasing pressure on the limited natural resources of the desertification prone zone, is exacerbated by the southward migration of people and livestock which results in overgrazing and continuous overexploitation of the marginal lands (Federal Government of Nigeria 2002).

The Central African Republic and northern Cameroon have also been experiencing desertification since the severe drought of 1972-1973 (AEO 2002). In northern Cameroon the renewable resource base is being rapidly

degraded due to urbanisation, resettlement due to population pressure, and the search for alternative income sources from wood cutting, commercial grazing and fishing (LCBC 2002).

Drought

The region has experienced a series of back-to-back droughts in the 1970s and the 1980s which left serious adverse effects on the lake such as decreased flows in the major rivers that feed into the lake; falling of groundwater tables; disappearance of specific plant species and reduction of canopy cover; loss of wildlife populations; and increased soil erosion and/or loss of fertility. Within a decade the lake had shrunk to about one-tenth of its normal area. The lake water receded for more than 150km from its northern and eastern shores, and by more than 80km from its western shoreline. This lead to the disappearance of flora and fauna while sand dunes took over the dry lake bed.

All economic activities such as fishing, livestock rearing and farming were adversely affected and the population had to migrate as environmental refugees. People whose economic activities depended on the receding water kept following the water across boundaries without consideration of the national borders. This phenomenon started a major trans-boundary crisis in the lake Chad drainage basin. Migrants found themselves in other countries without realizing the change, as the lake has no boundary markers (Odada et al 2006).

Fig. 8: Chronology of Lake Chad variability: 1963 to 2001, (Source: GIWA 2004)

Water shortage

The Lake with its rich biodiversity also provides a source of fishery, pastoral and agricultural activities for the inhabitants in the basin. However, the lake has continued to shrink owing to natural and anthropogenic forces. It is estimated that between 1963 and 2007, the surface area of the lake has shrunk from 25,000 km^2 to less than 3,000 km^2 (Musa et al 2008).

Erosion

Wind erosion is a normal phenomenon to the north and east of Lake Chad in Niger and Chad, but is intensified by poor land use practices. Overgrazing and cultivation have resulted in the loss of the vegetation that held the dunes in place (LCBC 2002). The area north of Lake Chad has virtually no surface flow and consists of moving sands and recent "ergs". The change in rainfall patterns has moved the limits of wind erosion to the south. The changing rainfall patterns have also concentrated grazing pressure on the remaining rangeland, moving the pattern of transhumance southwards (LCBC 2002).

Pollution

Pollution of existing water supplies has a slight effect on the freshwater shortage facing the Lake Chad region. Though this is not rampant but still require further scientific justification (GIWA, 2004). Water quantity and quality play a significant role in the determination of availability and access to freshwater resources, especially in Sub-Saharan Africa where water quality is a major problem (AEO 2002). Access to safe water however is an option most households in the basin do not have. For example, in the far north provinces of Cameroon in the Lake Chad Basin sector of Cameroon, only 5% of households have access to safe water (Amin and Dubois 1999). According to World Bank Development indicators for the countries of the Lake Chad Basin, access to an improved water resource has remained static or only increased slightly between 1990 and 2000 (GIWA 2004).

Though there is inadequate information regarding the pollution of water supplies in the basin, there is relatively little industrial or mining activity in the region and the impact on water supplies appears to be minimal. Effluent discharges in the upstream parts of the basin (particularly in Kano, Nigeria) from tanneries and textile production have led to localised fish kills. It is likely that untreated domestic wastes are also being discharged into the rivers of the Basin, with negative effects on water quality (GIWA 2004).

Water contamination and reduced stream flows has also caused the proliferation of weeds, mainly Kachalla grass (Typha spp.) that have encroached into reservoirs and clogged channels near Madachi, Krikasamma and Nguru on the Hadejia River (IUCN 1998), and hampered freshwater use. There have also been further reports expressing concern for water quality in the Hadejia River, as salinity has been increasing (World Bank,2002b).
Although, farmers in the region use predominantly traditional methods, the production of crops such as cotton and rice that require high doses of chemical sprays suggest that water supplies are being contaminated (GIWA 2004).

Conclusion

The Lake Chad Basin which is shared by seven countries represent a huge reservoir of natural resources. This has been viewed by many as a natural blessing. The estimated 200 million population of the region are heavily dependent and inextricably linked to the natural resources of the basin for their livelihoods (Neiland et al 2005 & Béné et al 2003). Despite this blessing, other problems have arose and are still on-going due to the harmful agricultural practices and migration. Climate change on the other hand has seriously contributed to the disappearance of the Lake Chad which has triggered inter-boundary crises between beneficial countries.
The countries of the Lake Chad Basin have been described as "weak States" characterised by weak political and economic stability, poor institutional capacity, limited information base and knowledge, incomplete development, narratives/strategies, limitation of national policy-making and implementation process etc, (Neiland et al 2005). The region will require international assistance to adapt to climate change and implement necessary mitigation measures. This, as it is suggested, should include assistance to undertake more detailed climate change research that would lead to a greater understanding of patterns of vulnerability in the system in order to develop and prioritise adaptation interventions in the Lake Chad Basin. The Lake Chad Basin commission (LCBC), NGOs and CBOs has tried in recent times and the past to mitigate the problems in the basin and alleviate poverty in the region which is geared towards sustainability.

Recommendations

1. Effective water management practices should be imbibed for the basin. One is the achievement of more efficient use of rain water by increasing ground water recharge, increasing soil water holding-capacity and reducing evaporation loses from lakes, flood plains, reservoir surface as well as irrigation fields. The water conservation practices should also

include the installation of valves on the free-flowing artesian boreholes draining the draining the regional confined aquifers of the basin.

2. Since there is high evapo-transpiration in the Lake Chad area which involves not only surface but ground water, methods such as injection of surface water from rivers, canals, lakes and reservoirs which will serve as a recovery for over-pumped aquifers should be introduced. This can also store water during periods of water surplus to allow extraction when water is needed using the same well (Pyne 1995 and Gale 2005). Surface infiltration can also be used to restore water by harvesting rain water, storage of river water in a dam reservoir and Diversion of flush flows into secondary channels or basins to enhance the recharge produced by the precipitation.
3. Another solution is for the governments to spearhead the implementation of the proposal by the Lake Chad Basin Commission (LCBC). The Lake Chad Replenishment Project which requires the damming of the Oubangui River at Palambo in the CAR and channelling some of its water through a navigable channel to Lake Chad, with the objective of rehabilitating the lake, rebuilding its ecosystem, reconstituting its biodiversity, and safeguarding it for present and future generations.
4. Since the local communities are the primary beneficiaries and victims of the unpredictable occurrences of Lake Chad, there is equally the need to integrate them in the management of the resources of the lake in terms of indulging in more conserving agricultural practices that causes other environmental problems. This will enable them to play a strong role in articulating their needs in relation to their livelihood priorities as well as to work with local governments, environmental NGOs, the LCBC and donor agencies to achieve the overall objective of reviving and conserving the lake through sustainable exploitation.
5. In mitigating impacts and devising adaptive strategies for climate change, other bodies such as NGO's, community based organizations, adaptation planners and donor agencies should all be included as suggested by FAO (2006).
6. It is also pertinent to strengthen disaster and risk management agencies in riparian countries to cope with potential adverse effects on climate change on fishery reduction and drought whenever they occur.

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