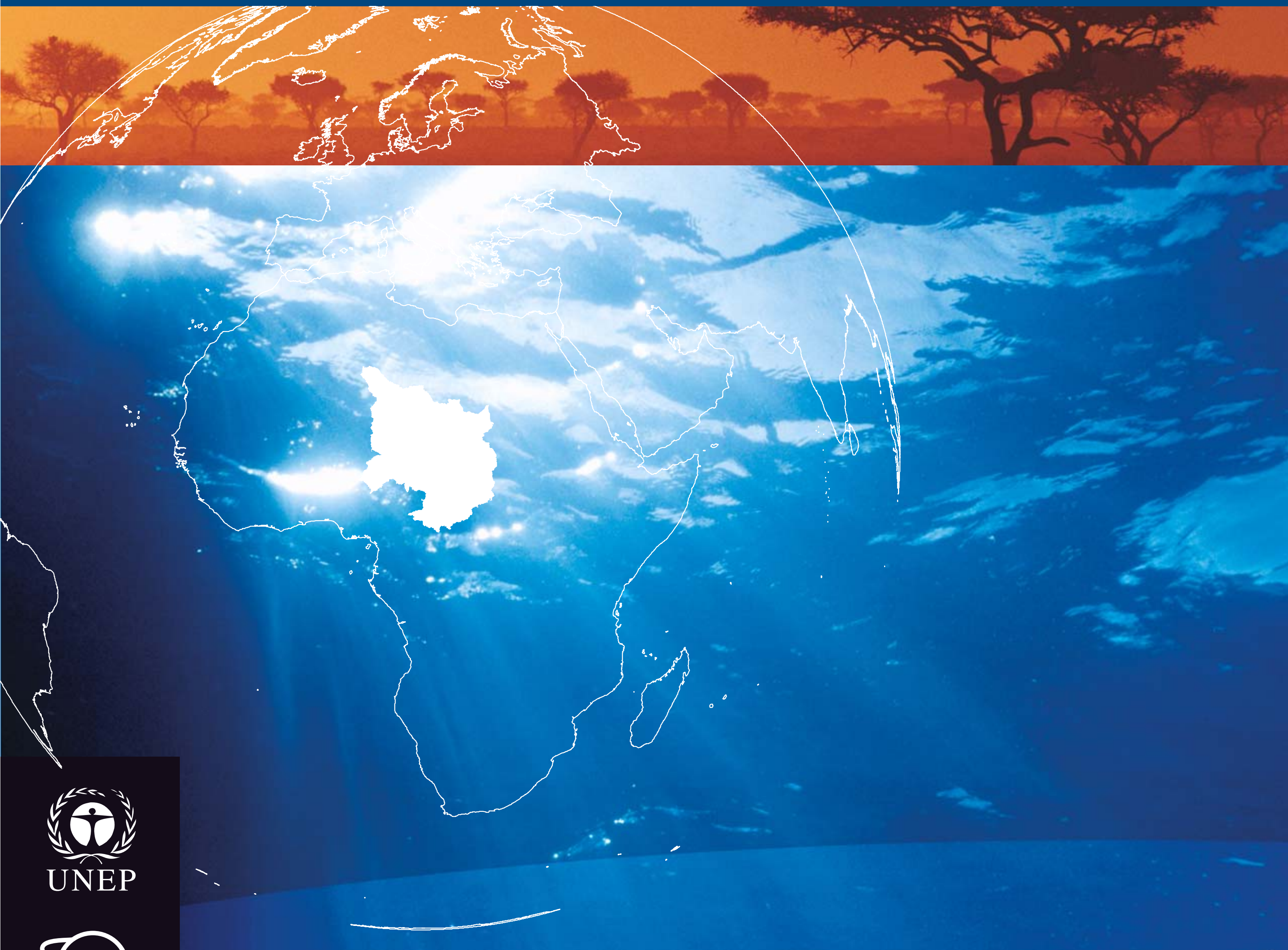
Global International Waters Assessment



Lake Chad Basin

GIWA Regional assessment 43

Global International Waters Assessment

Regional assessments

Global International Waters Assessment

Regional assessment 43
Lake Chad Basin

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The Global International Waters Assessment

This report presents the results of the Global International Waters Assessment (GIWA) of the transboundary waters of the Lake Chad Basin. This and the subsequent chapter offer a background that describes the impetus behind the establishment of GIWA, its objectives and how the GIWA was implemented.

The need for a global international waters assessment

Globally, people are becoming increasingly aware of the degradation of the world's water bodies. Disasters from floods and droughts, frequently reported in the media, are considered to be linked with ongoing global climate change (IPCC 2001), accidents involving large ships pollute public beaches and threaten marine life and almost every commercial fish stock is exploited beyond sustainable limits - it is estimated that the global stocks of large predatory fish have declined to less that 10% of pre-industrial fishing levels (Myers & Worm 2003). Further, more than 1 billion people worldwide lack access to safe drinking water and 2 billion people lack proper sanitation which causes approximately 4 billion cases of diarrhoea each year and results in the death of 2.2 million people, mostly children younger than five (WHO-UNICEF 2002). Moreover, freshwater and marine habitats are destroyed by infrastructure developments, dams, roads, ports and human settlements (Brinson & Malvárez 2002, Kennish 2002). As a consequence, there is growing public concern regarding the declining quality and quantity of the world's aquatic resources because of human activities, which has resulted in mounting pressure on governments and decision makers to institute new and innovative policies to manage those resources in a sustainable way ensuring their availability for future generations.

Adequately managing the world's aquatic resources for the benefit of all is, for a variety of reasons, a very complex task. The liquid state of the most of the world's water means that, without the construction of reservoirs, dams and canals it is free to flow wherever the laws of nature dictate. Water is, therefore, a vector transporting not only a wide variety of valuable resources but also problems from one area to another. The effluents emanating from environmentally destructive activities in upstream drainage areas are propagated downstream and can affect other areas considerable distances away. In the case of transboundary river basins, such as the Nile, Amazon and Niger, the impacts are transported across national borders and can be observed in the numerous countries situated within their catchments. In the case of large oceanic currents, the impacts can even be propagated between continents (AMAP 1998). Therefore, the inextricable linkages within and between both freshwater and marine environments dictates that management of aquatic resources ought to be implemented through a drainage basin approach.

In addition, there is growing appreciation of the incongruence between the transboundary nature of many aquatic resources and the traditional introspective nationally focused approaches to managing those resources. Water, unlike laws and management plans, does not respect national borders and, as a consequence, if future management of water and aquatic resources is to be successful, then a shift in focus towards international cooperation and intergovernmental agreements is required (UN 1972). Furthermore, the complexity of managing the world's water resources is exacerbated by the dependence of a great variety of domestic and industrial activities on those resources. As a consequence, cross-sectoral multidisciplinary approaches that integrate environmental, socio-economic and development aspects into management must be adopted. Unfortunately however, the scientific information or capacity within each discipline is often not available or is inadequately translated for use by managers, decision makers and policy developers. These inadequacies constitute a serious impediment to the implementation of urgently needed innovative policies.

Continual assessment of the prevailing and future threats to aquatic ecosystems and their implications for human populations is essential if governments and decision makers are going to be able to make strategic policy and management decisions that promote the sustainable use of those resources and respond to the growing concerns of the general public. Although many assessments of aquatic resources are being conducted by local, national, regional and international bodies, past assessments have often concentrated on specific themes, such as biodiversity or persistent toxic substances, or have focused only on marine or freshwaters. A globally coherent, drainage basin based assessment that embraces the inextricable links between transboundary freshwater and marine systems, and between environmental and societal issues, has never been conducted previously.

The Global Environment Facility (GEF)

The Global Environment Facility forges international co-operation and finances actions to address six critical threats to the global environment: biodiversity loss, climate change, degradation of international waters, ozone depletion, land degradation, and persistent organic pollutants (POPs).

The overall strategic thrust of GEF-funded international waters activities is to meet the incremental costs of: (a) assisting groups of countries to better understand the environmental concerns of their international waters and work collaboratively to address them; (b) building the capacity of existing institutions to utilise a more comprehensive approach for addressing transboundary water-related environmental concerns; and (c) implementing measures that address the priority transboundary environmental concerns. The goal is to assist countries to utilise the full range of technical, economic, financial, regulatory, and institutional measures needed to operationalise sustainable development strategies for international waters.

United Nations Environment Programme (UNEP)

United Nations Environment Programme, established in 1972, is the voice for the environment within the United Nations system. The mission of UNEP is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

UNEP work encompasses:

- Assessing global, regional and national environmental conditions and trends;
- Developing international and national environmental instruments;
- Strengthening institutions for the wise management of the environment;
- Facilitating the transfer of knowledge and technology for sustainable development;
- Encouraging new partnerships and mind-sets within civil society and the private sector.

University of Kalmar

University of Kalmar hosts the GIWA Co-ordination Office and provides scientific advice and administrative and technical assistance to GIWA. University of Kalmar is situated on the coast of the Baltic Sea. The city has a long tradition of higher education; teachers and marine officers have been educated in Kalmar since the middle of the 19th century. Today, natural science is a priority area which gives Kalmar a unique educational and research profile compared with other smaller universities in Sweden. Of particular relevance for GIWA is the established research in aquatic and environmental science. Issues linked to the concept of sustainable development are implemented by the research programme Natural Resources Management and Agenda 21 Research School.

Since its establishment GIWA has grown to become an integral part of University activities. The GIWA Co-ordination office and GIWA Core team are located at the Kalmarsund Laboratory, the university centre for water-related research. Senior scientists appointed by the University are actively involved in the GIWA peer-review and steering groups. As a result of the cooperation the University can offer courses and seminars related to GIWA objectives and international water issues.

International call for action

The need for a holistic assessment of transboundary waters in order to respond to growing public concerns and provide advice to governments and decision makers regarding the management of aquatic resources was recognised by several international bodies focusing on the global environment. In particular, the Global Environment Facility (GEF) observed that the International Waters (IW) component of the GEF suffered from the lack of a global assessment which made it difficult to prioritise international water projects, particularly considering the inadequate understanding of the nature and root causes of environmental problems. In 1996, at its fourth meeting in Nairobi, the GEF Scientific and Technical Advisory Panel (STAP), noted that: *"Lack of an International Waters Assessment comparable with that of the IPCC, the Global Biodiversity Assessment, and the Stratospheric Ozone Assessment, was a unique and serious impediment to the implementation of the International Waters Component of the GEF"*.

The urgent need for an assessment of the causes of environmental degradation was also highlighted at the UN Special Session on the Environment (UNGASS) in 1997, where commitments were made regarding the work of the UN Commission on Sustainable Development (UNCSD) on freshwater in 1998 and seas in 1999. Also in 1997, two international Declarations, the Potomac Declaration: Towards enhanced ocean security into the third millennium, and the Stockholm Statement on interaction of land activities, freshwater and enclosed seas, specifically emphasised the need for an investigation of the root causes of degradation of the transboundary aquatic environment and options for addressing them. These processes led to the development of the Global International Waters Assessment (GIWA) that would be implemented by the United Nations Environment Programme (UNEP) in conjunction with the University of Kalmar, Sweden, on behalf of the GEF. The GIWA was inaugurated in Kalmar in October 1999 by the Executive Director of UNEP, Dr. Klaus Töpfer, and the late Swedish Minister of the Environment, Kjell Larsson. On this occasion Dr. Töpfer stated: *"GIWA is the framework of UNEP´s global water assessment strategy and will enable us to record and report on critical water resources for the planet for consideration of sustainable development management practices as part of our responsibilities under Agenda 21 agreements of the Rio conference*".

The importance of the GIWA has been further underpinned by the UN Millennium Development Goals adopted by the UN General Assembly in 2000 and the Declaration from the World Summit on Sustainable

Development in 2002. The development goals aimed to halve the proportion of people without access to safe drinking water and basic sanitation by the year 2015 (United Nations Millennium Declaration 2000). The WSSD also calls for integrated management of land, water and living resources (WSSD 2002) and, by 2010, the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem should be implemented by all countries that are party to the declaration (FAO 2001).

International waters and transboundary issues

The term "international waters", as used for the purposes of the GEF Operational Strategy, includes the oceans, large marine ecosystems, enclosed or semi-enclosed seas and estuaries, as well as rivers, lakes, groundwater systems, and wetlands with transboundary drainage basins or common borders. The water-related ecosystems associated with these waters are considered integral parts of the systems.

The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and actions are inadequate in order to cope with these challenges and this makes them transboundary in nature.

The international waters area includes numerous international conventions, treaties, and agreements. The architecture of marine agreements is especially complex, and a large number of bilateral and multilateral agreements exist for transboundary freshwater basins. Related conventions and agreements in other areas increase the complexity. These initiatives provide a new opportunity for cooperating nations to link many different programmes and instruments into regional comprehensive approaches to address international waters.

The conceptual framework and objectives

Considering the general decline in the condition of the world's aquatic resources and the internationally recognised need for a globally coherent assessment of transboundary waters, the primary objectives of the GIWA are:

- To provide a prioritising mechanism that allows the GEF to focus their resources so that they are used in the most cost effective manner to achieve significant environmental benefits, at national, regional and global levels; and
- To highlight areas in which governments can develop and implement strategic policies to reduce environmental degradation and improve the management of aquatic resources.

In order to meet these objectives and address some of the current inadequacies in international aquatic resources management, the GIWA has incorporated four essential elements into its design:

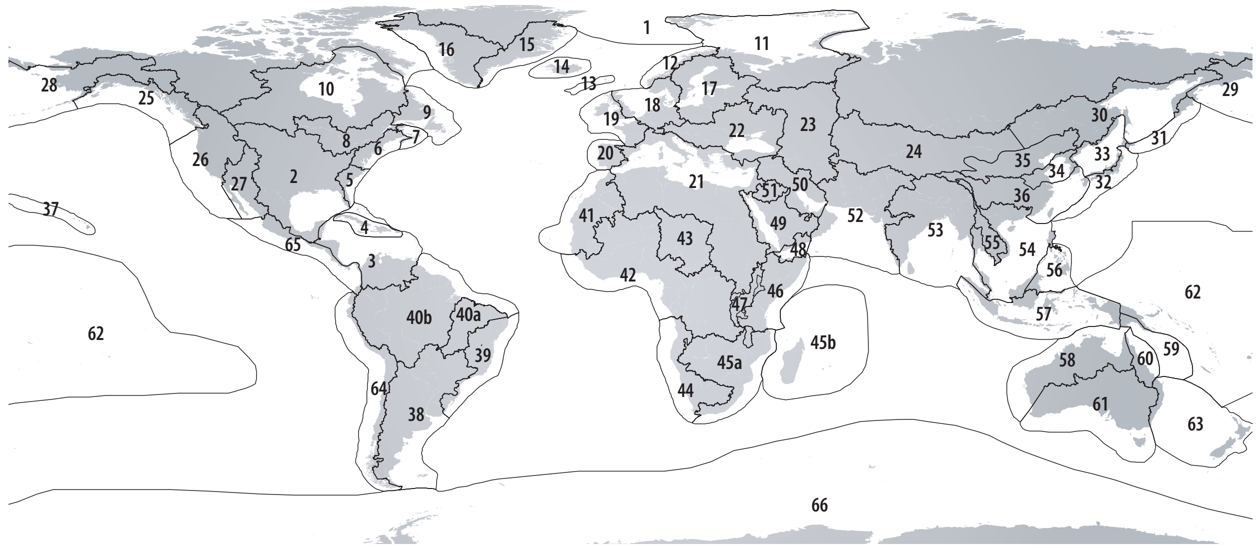
- A broad transboundary approach that generates a truly regional perspective through the incorporation of expertise and existing information from all nations in the region and the assessment of all factors that influence the aquatic resources of the region;
- A drainage basin approach integrating freshwater and marine systems;
- A multidisciplinary approach integrating environmental and socio-economic information and expertise; and
- A coherent assessment that enables global comparison of the results.

The GIWA builds on previous assessments implemented within the GEF International Waters portfolio but has developed and adopted a broader definition of transboundary waters to include factors that influence the quality and quantity of global aquatic resources. For example, due to globalisation and international trade, the market for penaeid shrimps has widened and the prices soared. This, in turn, has encouraged entrepreneurs in South East Asia to expand aquaculture resulting in the large-scale deforestation of mangroves for ponds (Primavera 1997). Within the GIWA, these "non-hydrological" factors constitute as large a transboundary influence as more traditionally recognised problems, such as the construction of dams that regulate the flow of water into a neighbouring country, and are considered equally important. In addition, the GIWA recognises the importance of hydrological units that would not normally be considered transboundary but exert a significant influence on transboundary waters, such as the Yangtze River in China which discharges into the East China Sea (Daoji & Daler 2004) and the Volga River in Russia which is largely responsible for the condition of the Caspian Sea (Barannik et al. 2004). Furthermore, the GIWA is a truly regional assessment that has incorporated data from a wide range of sources and included expert knowledge and information from a wide range of sectors and from each country in the region. Therefore, the transboundary concept adopted by the GIWA extends to include impacts caused by globalisation, international trade, demographic changes and technological advances and recognises the need for international cooperation to address them.

The organisational structure and implementation of the GIWA

The scale of the assessment

Initially, the scope of the GIWA was confined to transboundary waters in areas that included countries eligible to receive funds from the GEF. However, it was recognised that a truly global perspective would only be achieved if industrialised, GEF-ineligible regions of the world were also assessed. Financial resources to assess the GEF-eligible countries were obtained primarily from the GEF (68%), the Swedish International Development Cooperation Agency (Sida) (18%), and the Finnish Department for International Development Cooperation (FINNIDA)



1 Arctic
2 Gulf of Mexico (LME)
3 Caribbean Sea (LME)
4 Caribbean Islands
5 Southeast Shelf (LME)
6 Northeast Shelf (LME)
7 Scotian Shelf (LME)
8 Gulf of St Lawrence
9 Newfoundland Shelf (LME)
10 Baffin Bay, Labrador Sea, Canadian Archipelago
11 Barents Sea (LME)
12 Norwegian Sea (LME)
13 Faroe plateau
14 Iceland Shelf (LME)
15 East Greenland Shelf (LME)
16 West Greenland Shelf (LME)
17 Baltic Sea (LME)
18 North Sea (LME)
19 Celtic-Biscay Shelf (LME)
20 Iberian Coastal (LME)
21 Mediterranean Sea (LME)
22 Black Sea (LME)
23 Caspian Sea
24 Aral Sea
25 Gulf of Alaska (LME)
26 California Current (LME)
27 Gulf of California (LME)
28 East Bering Sea (LME)
29 West Bering Sea (LME)
30 Sea of Okhotsk (LME)
31 Oyashio Current (LME)
32 Kuroshio Current (LME)
33 Sea of Japan/East Sea (LME)
34 Yellow Sea (LME)
35 Bohai Sea
36 East-China Sea (LME)
37 Hawaiian Archipelago (LME)
38 Patagonian Shelf (LME)
39 Brazil Current (LME)
40a Brazilian Northeast (LME)
40b Amazon
41 Canary Current (LME)
42 Guinea Current (LME)
43 Lake Chad
44 Benguela Current (LME)
45a Agulhas Current (LME)
45b Indian Ocean Islands
46 Somali Coastal Current (LME)
47 East African Rift Valley Lakes
48 Gulf of Aden
49 Red Sea (LME)
50 The Gulf
51 Jordan
52 Arabian Sea (LME)
53 Bay of Bengal S.E.
54 South China Sea (LME)
55 Mekong River
56 Sulu-Celebes Sea (LME)
57 Indonesian Seas (LME)
58 North Australian Shelf (LME)
59 Coral Sea Basin
60 Great Barrier Reef (LME)
61 Great Australian Bight
62 Small Island States
63 Tasman Sea
64 Humboldt Current (LME)
65 Eastern Equatorial Pacific
66 Antarctic (LME)

Figure 1 The 66 transboundary regions assessed within the GIWA project.

(10%). Other contributions were made by Kalmar Municipality, the University of Kalmar and the Norwegian Government. The assessment of regions ineligible for GEF funds was conducted by various international and national organisations as in-kind contributions to the GIWA.

In order to be consistent with the transboundary nature of many of the world's aquatic resources and the focus of the GIWA, the geographical units being assessed have been designed according to the watersheds of discrete hydrographic systems rather than political borders (Figure 1). The geographic units of the assessment were determined during the preparatory phase of the project and resulted in the division of the world into 66 regions defined by the entire area of one or more catchments areas that drains into a single designated marine system. These marine systems often correspond to Large Marine Ecosystems (LMEs) (Sherman 1994, IOC 2002).

Large Marine Ecocsystems (LMEs)

Large Marine Ecosystems (LMEs) are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margin of the major current systems. They are relatively large regions on the order of 200 000 km^2 or greater, characterised by distinct: (1) bathymetry, (2) hydrography, (3) productivity, and (4) trophically dependent populations.

The Large Marine Ecosystems strategy is a global effort for the assessment and management of international coastal waters. It developed in direct response to a declaration at the 1992 Rio Summit. As part of the strategy, the World Conservation Union (IUCN) and National Oceanic and Atmospheric Administration (NOAA) have joined in an action program to assist developing countries in planning and implementing an ecosystem-based strategy that is focused on LMEs as the principal assessment and management units for coastal ocean resources. The LME concept is also adopted by GEF that recommends the use of LMEs and their contributing freshwater basins as the geographic area for integrating changes in sectoral economic activities.

Considering the objectives of the GIWA and the elements incorporated into its design, a new methodology for the implementation of the assessment was developed during the initial phase of the project. The methodology focuses on five major environmental concerns which constitute the foundation of the GIWA assessment; Freshwater shortage, Pollution, Habitat and community modification, Overexploitation of fish and other living resources, and Global change. The GIWA methodology is outlined in the following chapter.

The global network

In each of the 66 regions, the assessment is conducted by a team of local experts that is headed by a Focal Point (Figure 2). The Focal Point can be an individual, institution or organisation that has been selected on the basis of their scientific reputation and experience implementing international assessment projects. The Focal Point is responsible for assembling members of the team and ensuring that it has the necessary expertise and experience in a variety of environmental and socio-economic disciplines to successfully conduct the regional assessment. The selection of team members is one of the most critical elements for the success of GIWA and, in order to ensure that the most relevant information is incorporated into the assessment, team members were selected from a wide variety of institutions such as universities, research institutes, government agencies, and the private sector. In addition, in order to ensure that the assessment produces a truly regional perspective, the teams should include representatives from each country that shares the region.

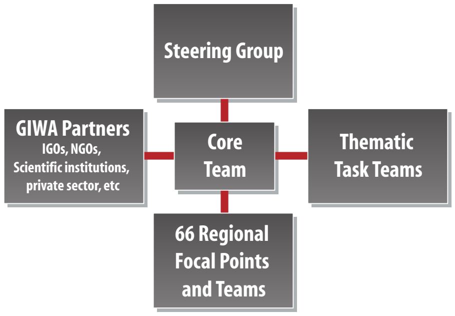


Figure 2 The organisation of the GIWA project.

In total, more than 1 000 experts have contributed to the implementation of the GIWA illustrating that the GIWA is a participatory exercise that relies on regional expertise. This participatory approach is essential because it instils a sense of local ownership of the project, which ensures the credibility of the findings and moreover, it has created a global network of experts and institutions that can collaborate and exchange experiences and expertise to help mitigate the continued degradation of the world's aquatic resources.

GIWA Regional reports

The GIWA was established in response to growing concern among the general public regarding the quality of the world's aquatic resources and the recognition of governments and the international community concerning the absence of a globally coherent international waters assessment. However, because a holistic, region-by-region, assessment of the condition of the world's transboundary water resources had never been undertaken, a methodology guiding the implementation of such an assessment did not exist. Therefore, in order to implement the GIWA, a new methodology that adopted a multidisciplinary, multi-sectoral, multi-national approach was developed and is now available for the implementation of future international assessments of aquatic resources.

UNEP Water Policy and Strategy

The primary goals of the UNEP water policy and strategy are:

(a) Achieving greater global understanding of freshwater, coastal and marine environments by conducting environmental assessments in priority areas;

(b) Raising awareness of the importance and consequences of unsustainable water use;

(c) Supporting the efforts of Governments in the preparation and implementation of integrated management of freshwater systems and their related coastal and marine environments;

(d) Providing support for the preparation of integrated management plans and programmes for aquatic environmental hot spots, based on the assessment results;

(e) Promoting the application by stakeholders of precautionary, preventive and anticipatory approaches.

The GIWA is comprised of a logical sequence of four integrated components. The first stage of the GIWA is called Scaling and is a process by which the geographic area examined in the assessment is defined and all the transboundary waters within that area are identified. Once the geographic scale of the assessment has been defined, the assessment teams conduct a process known as Scoping in which the magnitude of environmental and associated socio-economic impacts of Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, and Global change is assessed in order to identify and prioritise the concerns that require the most urgent intervention. The assessment of these predefined concerns incorporates the best available information and the knowledge and experience of the multidisciplinary, multi-national assessment teams formed in each region. Once the priority concerns have been identified, the root causes of these concerns are identified during the third component of the GIWA, Causal chain analysis. The root causes are determined through a sequential process that identifies, in turn, the most significant immediate causes followed by the economic sectors that are primarily responsible for the immediate causes and finally, the societal root causes. At each stage in the Causal chain analysis, the most significant contributors are identified through an analysis of the best available information which is augmented by the expertise of the assessment team. The final component of the GIWA is the development of Policy options that focus on mitigating the impacts of the root causes identified by the Causal chain analysis.

The results of the GIWA assessment in each region are reported in regional reports that are published by UNEP. These reports are designed to provide a brief physical and socio-economic description of the most important features of the region against which the results of the assessment can be cast. The remaining sections of the report present the results of each stage of the assessment in an easily digestible form. Each regional report is reviewed by at least two independent external reviewers in order to ensure the scientific validity and applicability of each report. The 66 regional assessments of the GIWA will serve UNEP as an essential complement to the UNEP Water Policy and Strategy and UNEP's activities in the hydrosphere.

Global International Waters Assessment

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The GIWA methodology

The specific objectives of the GIWA were to conduct a holistic and globally comparable assessment of the world's transboundary aquatic resources that incorporated both environmental and socio-economic factors and recognised the inextricable links between freshwater and marine environments, in order to enable the GEF to focus their resources and to provide guidance and advice to governments and decision makers. The coalition of all these elements into a single coherent methodology that produces an assessment that achieves each of these objectives had not previously been done and posed a significant challenge.

The integration of each of these elements into the GIWA methodology was achieved through an iterative process guided by a specially convened Methods task team that was comprised of a number of international assessment and water experts. Before the final version of the methodology was adopted, preliminary versions underwent an extensive external peer review and were subjected to preliminary testing in selected regions. Advice obtained from the Methods task team and other international experts and the lessons learnt from preliminary testing were incorporated into the final version that was used to conduct each of the GIWA regional assessments.

Considering the enormous differences between regions in terms of the quality, quantity and availability of data, socio-economic setting and environmental conditions, the achievement of global comparability required an innovative approach. This was facilitated by focusing the assessment on the impacts of five pre-defined concerns namely; Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources and Global change, in transboundary waters. Considering the diverse range of elements encompassed by each concern, assessing the magnitude of the impacts caused by these concerns was facilitated by evaluating the impacts of 22 specific issues that were grouped within these concerns (see Table 1).

The assessment integrates environmental and socio-economic data from each country in the region to determine the severity of the impacts of each of the five concerns and their constituent issues on the entire region. The integration of this information was facilitated by implementing the assessment during two participatory workshops that typically involved 10 to 15 environmental and socio-economic experts from each country in the region. During these workshops, the regional teams performed preliminary analyses based on the collective knowledge and experience of these local experts. The results of these analyses were substantiated with the best available information to be presented in a regional report.

Table 1 Pre-defined GIWA concerns and their constituent issues addressed within the assessment.

Environmental issues	Major concerns
1. Modification of stream flow 2. Pollution of existing supplies 3. Changes in the water table	**I Freshwater shortage**
4. Microbiological 5. Eutrophication 6. Chemical 7. Suspended solids 8. Solid wastes 9. Thermal 10. Radionuclide 11. Spills	**II Pollution**
12. Loss of ecosystems 13. Modification of ecosystems or ecotones, including community structure and/or species composition	**III Habitat and community modification**
14. Overexploitation 15. Excessive by-catch and discards 16. Destructive fishing practices 17. Decreased viability of stock through pollution and disease 18. Impact on biological and genetic diversity	**IV Unsustainable exploitation of fish and other living resources**
19. Changes in hydrological cycle 20. Sea level change 21. Increased uv-b radiation as a result of ozone depletion 22. Changes in ocean CO_2 source/sink function	**V Global change**

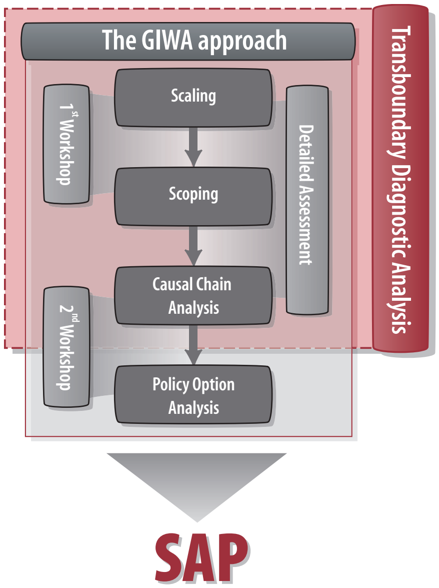

Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

The GIWA is a logical contiguous process that defines the geographic region to be assessed, identifies and prioritises particularly problems based on the magnitude of their impacts on the environment and human societies in the region, determines the root causes of those problems and, finally, assesses various policy options that addresses those root causes in order to reverse negative trends in the condition of the aquatic environment. These four steps, referred to as Scaling, Scoping, Causal chain analysis and Policy options analysis, are summarised below and are described in their entirety in two volumes: *GIWA Methodology Stage 1: Scaling and Scoping*; and *GIWA Methodology: Detailed Assessment, Causal Chain Analysis and Policy Options Analysis*. Generally, the components of the GIWA methodology are aligned with the framework adopted by the GEF for Transboundary Diagnostic Analyses (TDAs) and Strategic Action Programmes (SAPs) (Figure 1) and assume a broad spectrum of transboundary influences in addition to those associated with the physical movement of water across national borders.

Scaling – Defining the geographic extent of the region

Scaling is the first stage of the assessment and is the process by which the geographic scale of the assessment is defined. In order to facilitate the implementation of the GIWA, the globe was divided during the design phase of the project into 66 contiguous regions. Considering the transboundary nature of many aquatic resources and the transboundary focus of the GIWA, the boundaries of the regions did not comply with political boundaries but were instead, generally defined by a large but discrete drainage basin that also included the coastal marine waters into which the basin discharges. In many cases, the marine areas examined during the assessment coincided with the Large Marine Ecosystems (LMEs) defined by the US National Atmospheric and Oceanographic Administration (NOAA). As a consequence, scaling should be a relatively straight-forward task that involves the inspection of the boundaries that were proposed for the region during the preparatory phase of GIWA to ensure that they are appropriate and that there are no important overlaps or gaps with neighbouring regions. When the proposed boundaries were found to be inadequate, the boundaries of the region were revised according to the recommendations of experts from both within the region and from adjacent regions so as to ensure that any changes did not result in the exclusion of areas from the GIWA. Once the regional boundary was defined, regional teams identified all the transboundary elements of the aquatic environment within the region and determined if these elements could be assessed as a single coherent aquatic system or if there were two or more independent systems that should be assessed separately.

Scoping – Assessing the GIWA concerns

Scoping is an assessment of the severity of environmental and socio-economic impacts caused by each of the five pre-defined GIWA concerns and their constituent issues (Table 1). It is not designed to provide an exhaustive review of water-related problems that exist within each region, but rather it is a mechanism to identify the most urgent problems in the region and prioritise those for remedial actions. The priorities determined by Scoping are therefore one of the main outputs of the GIWA project.

Focusing the assessment on pre-defined concerns and issues ensured the comparability of the results between different regions. In addition, to ensure the long-term applicability of the options that are developed to mitigate these problems, Scoping not only assesses the current impacts of these concerns and issues but also the probable future impacts according to the "most likely scenario" which considered demographic, economic, technological and other relevant changes that will potentially influence the aquatic environment within the region by 2020.

The magnitude of the impacts caused by each issue on the environment and socio-economic indicators was assessed over the entire region using the best available information from a wide range of sources and the knowledge and experience of the each of the experts comprising the regional team. In order to enhance the comparability of the assessment between different regions and remove biases in the assessment caused by different perceptions of and ways to communicate the severity of impacts caused by particular issues, the results were distilled and reported as standardised scores according to the following four point scale:

- 0 = no known impact
- 1 = slight impact
- 2 = moderate impact
- 3 = severe impact

The attributes of each score for each issue were described by a detailed set of pre-defined criteria that were used to guide experts in reporting the results of the assessment. For example, the criterion for assigning a score of 3 to the issue Loss of ecosystems or ecotones is: "*Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.*" The full list of criteria is presented at the end of the chapter, Table 5a-e. Although the scoring inevitably includes an arbitrary component, the use of predefined criteria facilitates comparison of impacts on a global scale and also encouraged consensus of opinion among experts.

The trade-off associated with assessing the impacts of each concern and their constituent issues at the scale of the entire region is that spatial resolution was sometimes low. Although the assessment provides a score indicating the severity of impacts of a particular issue or concern on the entire region, it does not mean that the entire region suffers the impacts of that problem. For example, eutrophication could be identified as a severe problem in a region, but this does not imply that all waters in the region suffer from severe eutrophication. It simply means that when the degree of eutrophication, the size of the area affected, the socio-economic impacts and the number of people affected is considered, the magnitude of the overall impacts meets the criteria defining a severe problem and that a regional action should be initiated in order to mitigate the impacts of the problem.

When each issue has been scored, it was weighted according to the relative contribution it made to the overall environmental impacts of the concern and a weighted average score for each of the five concerns was calculated (Table 2). Of course, if each issue was deemed to make equal contributions, then the score describing the overall impacts of the concern was simply the arithmetic mean of the scores allocated to each issue within the concern. In addition, the socio-economic impacts of each of the five major concerns were assessed for the entire region. The socio-economic impacts were grouped into three categories; Economic impacts, Health impacts and Other social and community impacts (Table 3). For each category, an evaluation of the size, degree and frequency of the impact was performed and, once completed, a weighted average score describing the overall socio-economic impacts of each concern was calculated in the same manner as the overall environmental score.

Table 2 Example of environmental impact assessment of Freshwater shortage.

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
1. Modification of stream flow	1	20	Freshwater shortage	1.50
2. Pollution of existing supplies	2	50		
3. Changes in the water table	1	30		

Table 3 Example of Health impacts assessment linked to one of the GIWA concerns.

Criteria for Health impacts	Raw score	Score	Weight %
Number of people affected	Very small (0) … Very large (3)	2	50
Degree of severity	Minimum (0) … Severe (3)	2	30
Frequency/Duration	Occasion/Short (0) … Continuous (3)	2	20
Weight average score for Health impacts		**2**	

After all 22 issues and associated socio-economic impacts have been scored, weighted and averaged, the magnitude of likely future changes in the environmental and socio-economic impacts of each of the five concerns on the entire region is assessed according to the most likely scenario which describes the demographic, economic, technological and other relevant changes that might influence the aquatic environment within the region by 2020.

In order to prioritise among GIWA concerns within the region and identify those that will be subjected to causal chain and policy options analysis in the subsequent stages of the GIWA, the present and future scores of the environmental and socio-economic impacts of each concern are tabulated and an overall score calculated. In the example presented in Table 4, the scoping assessment indicated that concern III, Habitat and community modification, was the priority concern in this region. The outcome of this mathematic process was reconciled against the knowledge of experts and the best available information in order to ensure the validity of the conclusion.

In some cases however, this process and the subsequent participatory discussion did not yield consensus among the regional experts regarding the ranking of priorities. As a consequence, further analysis was required. In such cases, expert teams continued by assessing the relative importance of present and potential future impacts and assign weights to each. Afterwards, the teams assign weights indicating the relative contribution made by environmental and socio-economic factors to the overall impacts of the concern. The weighted average score for each concern is then recalculated taking into account

Table 4 Example of comparative environmental and socio-economic impacts of each major concern, presently and likely in year 2020.

Concern	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community score		
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	1.3	2.3	2.7	2.8	2.6	3.0	1.8	2.2	**2.3**
Pollution	1.5	2.0	2.0	2.3	1.8	2.3	2.0	2.3	**2.0**
Habitat and community modification	2.0	3.0	2.4	3.0	2.4	2.8	2.3	2.7	**2.6**
Unsustainable exploitation of fish and other living resources	1.8	2.2	2.0	2.1	2.0	2.1	2.4	2.5	**2.1**
Global change	0.8	1.0	1.5	1.7	1.5	1.5	1.0	1.0	**1.2**

the relative contributions of both present and future impacts and environmental and socio-economic factors. The outcome of these additional analyses was subjected to further discussion to identify overall priorities for the region.

Finally, the assessment recognises that each of the five GIWA concerns are not discrete but often interact. For example, pollution can destroy aquatic habitats that are essential for fish reproduction which, in turn, can cause declines in fish stocks and subsequent overexploitation. Once teams have ranked each of the concerns and determined the priorities for the region, the links between the concerns are highlighted in order to identify places where strategic interventions could be applied to yield the greatest benefits for the environment and human societies in the region.

Causal chain analysis

Causal Chain Analysis (CCA) traces the cause-effect pathways from the socio-economic and environmental impacts back to their root causes. The GIWA CCA aims to identify the most important causes of each concern prioritised during the scoping assessment in order to direct policy measures at the most appropriate target in order to prevent further degradation of the regional aquatic environment.

Root causes are not always easy to identify because they are often spatially or temporally separated from the actual problems they cause. The GIWA CCA was developed to help identify and understand the root causes of environmental and socio-economic problems in international waters and is conducted by identifying the human activities that cause the problem and then the factors that determine the ways in which these activities are undertaken. However, because there is no universal theory describing how root causes interact to create natural resource management problems and due to the great variation of local circumstances under which the methodology will be applied, the GIWA CCA is not a rigidly structured assessment but should be regarded as a framework to guide the analysis, rather than as a set of detailed instructions. Secondly, in an ideal setting, a causal chain would be produced by a multidisciplinary group of specialists that would statistically examine each successive cause and study its links to the problem and to other causes. However, this approach (even if feasible) would use far more resources and time than those available to GIWA[1]. For this reason, it has been necessary to develop a relatively simple and practical analytical model for gathering information to assemble meaningful causal chains.

Conceptual model

A causal chain is a series of statements that link the causes of a problem with its effects. Recognising the great diversity of local settings and the resulting difficulty in developing broadly applicable policy strategies, the GIWA CCA focuses on a particular system and then only on those issues that were prioritised during the scoping assessment. The starting point of a particular causal chain is one of the issues selected during the Scaling and Scoping stages and its related environmental and socio-economic impacts. The next element in the GIWA chain is the immediate cause; defined as the physical, biological or chemical variable that produces the GIWA issue. For example, for the issue of eutrophication the immediate causes may be, inter alia:

- Enhanced nutrient inputs;
- Increased recycling/mobilisation;
- Trapping of nutrients (e.g. in river impoundments);
- Run-off and stormwaters

Once the relevant immediate cause(s) for the particular system has (have) been identified, the sectors of human activity that contribute most significantly to the immediate cause have to be determined. Assuming that the most important immediate cause in our example had been increased nutrient concentrations, then it is logical that the most likely sources of those nutrients would be the agricultural, urban or industrial sectors. After identifying the sectors that are primarily

[1] This does not mean that the methodology ignores statistical or quantitative studies; as has already been pointed out, the available evidence that justifies the assumption of causal links should be provided in the assessment.

responsible for the immediate causes, the root causes acting on those sectors must be determined. For example, if agriculture was found to be primarily responsible for the increased nutrient concentrations, the root causes could potentially be:

- Economic (e.g. subsidies to fertilisers and agricultural products);
- Legal (e.g. inadequate regulation);
- Failures in governance (e.g. poor enforcement); or
- Technology or knowledge related (e.g. lack of affordable substitutes for fertilisers or lack of knowledge as to their application).

Once the most relevant root causes have been identified, an explanation, which includes available data and information, of how they are responsible for the primary environmental and socio-economic problems in the region should be provided.

Policy option analysis

Despite considerable effort of many Governments and other organisations to address transboundary water problems, the evidence indicates that there is still much to be done in this endeavour. An important characteristic of GIWA's Policy Option Analysis (POA) is that its recommendations are firmly based on a better understanding of the root causes of the problems. Freshwater scarcity, water pollution, overexploitation of living resources and habitat destruction are very complex phenomena. Policy options that are grounded on a better understanding of these phenomena will contribute to create more effective societal responses to the extremely complex water related transboundary problems. The core of POA in the assessment consists of two tasks:

Construct policy options

Policy options are simply different courses of action, which are not always mutually exclusive, to solve or mitigate environmental and socio-economic problems in the region. Although a multitude of different policy options could be constructed to address each root cause identified in the CCA, only those few policy options that have the greatest likelihood of success were analysed in the GIWA.

Select and apply the criteria on which the policy options will be evaluated

Although there are many criteria that could be used to evaluate any policy option, GIWA focuses on:

- Effectiveness (certainty of result)
- Efficiency (maximisation of net benefits)
- Equity (fairness of distributional impacts)
- Practical criteria (political acceptability, implementation feasibility).

The policy options recommended by the GIWA are only contributions to the larger policy process and, as such, the GIWA methodology developed to test the performance of various options under the different circumstances has been kept simple and broadly applicable.

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Table 5a: Scoring criteria for environmental impacts of Freshwater shortage

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 1: Modification of stream flow "An increase or decrease in the discharge of streams and rivers as a result of human interventions on a local/ regional scale (see Issue 19 for flow alterations resulting from global change) over the last 3-4 decades."	■ No evidence of modification of stream flow.	■ There is a measurably changing trend in annual river discharge at gauging stations in a major river or tributary (basin > 40 000 km^2); or ■ There is a measurable decrease in the area of wetlands (other than as a consequence of conversion or embankment construction); or ■ There is a measurable change in the interannual mean salinity of estuaries or coastal lagoons and/or change in the mean position of estuarine salt wedge or mixing zone; or ■ Change in the occurrence of exceptional discharges (e.g. due to upstream damming.	■ Significant downward or upward trend (more than 20% of the long term mean) in annual discharges in a major river or tributary draining a basin of >250 000 km^2; or ■ Loss of >20% of flood plain or deltaic wetlands through causes other than conversion or artificial embankments; or ■ Significant loss of riparian vegetation (e.g. trees, flood plain vegetation); or ■ Significant saline intrusion into previously freshwater rivers or lagoons.	■ Annual discharge of a river altered by more than 50% of long term mean; or ■ Loss of >50% of riparian or deltaic wetlands over a period of not less than 40 years (through causes other than conversion or artificial embankment); or ■ Significant increased siltation or erosion due to changing in flow regime (other than normal fluctuations in flood plain rivers); or ■ Loss of one or more anadromous or catadromous fish species for reasons other than physical barriers to migration, pollution or overfishing.
Issue 2: Pollution of existing supplies "Pollution of surface and ground fresh waters supplies as a result of point or diffuse sources"	■ No evidence of pollution of surface and ground waters.	■ Any monitored water in the region does not meet WHO or national drinking water criteria, other than for natural reasons; or ■ There have been reports of one or more fish kills in the system due to pollution within the past five years.	■ Water supplies does not meet WHO or national drinking water standards in more than 30% of the region; or ■ There are one or more reports of fish kills due to pollution in any river draining a basin of >250 000 km^2 .	■ River draining more than 10% of the basin have suffered polysaprobic conditions, no longer support fish, or have suffered severe oxygen depletion ■ Severe pollution of other sources of freshwater (e.g. groundwater)
Issue 3: Changes in the water table "Changes in aquifers as a direct or indirect consequence of human activity"	■ No evidence that abstraction of water from aquifers exceeds natural replenishment.	■ Several wells have been deepened because of excessive aquifer draw-down; or ■ Several springs have dried up; or ■ Several wells show some salinisation.	■ Clear evidence of declining base flow in rivers in semi-arid areas; or ■ Loss of plant species in the past decade, that depend on the presence of ground water; or ■ Wells have been deepened over areas of hundreds of km^2;or ■ Salinisation over significant areas of the region.	■ Aquifers are suffering salinisation over regional scale; or ■ Perennial springs have dried up over regionally significant areas; or ■ Some aquifers have become exhausted

Table 5b: Scoring criteria for environmental impacts of Pollution

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 4: Microbiological pollution "The adverse effects of microbial constituents of human sewage released to water bodies."	■ Normal incidence of bacterial related gastroenteric disorders in fisheries product consumers and no fisheries closures or advisories.	■ There is minor increase in incidence of bacterial related gastroenteric disorders in fisheries product consumers but no fisheries closures or advisories.	■ Public health authorities aware of marked increase in the incidence of bacterial related gastroenteric disorders in fisheries product consumers; or ■ There are limited area closures or advisories reducing the exploitation or marketability of fisheries products.	■ There are large closure areas or very restrictive advisories affecting the marketability of fisheries products; or ■ There exists widespread public or tourist awareness of hazards resulting in major reductions in the exploitation or marketability of fisheries products.
Issue 5: Eutrophication "Artificially enhanced primary productivity in receiving water basins related to the increased availability or supply of nutrients, including cultural eutrophication in lakes."	■ No visible effects on the abundance and distributions of natural living resource distributions in the area; and ■ No increased frequency of hypoxia[1] or fish mortality events or harmful algal blooms associated with enhanced primary production; and ■ No evidence of periodically reduced dissolved oxygen or fish and zoobenthos mortality; and ■ No evident abnormality in the frequency of algal blooms.	■ Increased abundance of epiphytic algae; or ■ A statistically significant trend in decreased water transparency associated with algal production as compared with long-term (>20 year) data sets; or ■ Measurable shallowing of the depth range of macrophytes.	■ Increased filamentous algal production resulting in algal mats; or ■ Medium frequency (up to once per year) of large-scale hypoxia and/or fish and zoobenthos mortality events and/or harmful algal blooms.	■ High frequency (>1 event per year), or intensity, or large areas of periodic hypoxic conditions, or high frequencies of fish and zoobenthos mortality events or harmful algal blooms; or ■ Significant changes in the littoral community; or ■ Presence of hydrogen sulphide in historically well oxygenated areas.

Issue 6: Chemical pollution "The adverse effects of chemical contaminants released to standing or marine water bodies as a result of human activities. Chemical contaminants are here defined as compounds that are toxic or persistent or bioaccumulating."	■ No known or historical levels of chemical contaminants except background levels of naturally occurring substances; and ■ No fisheries closures or advisories due to chemical pollution; and ■ No incidence of fisheries product tainting; and ■ No unusual fish mortality events. If there is no available data use the following criteria: ■ No use of pesticides; and ■ No sources of dioxins and furans; and ■ No regional use of PCBs; and ■ No bleached kraft pulp mills using chlorine bleaching; and ■ No use or sources of other contaminants.	■ Some chemical contaminants are detectable but below threshold limits defined for the country or region; or ■ Restricted area advisories regarding chemical contamination of fisheries products. If there is no available data use the following criteria: ■ Some use of pesticides in small areas; or ■ Presence of small sources of dioxins or furans (e.g., small incineration plants or bleached kraft/pulp mills using chlorine); or ■ Some previous and existing use of PCBs and limited amounts of PCB-containing wastes but not in amounts invoking local concerns; or ■ Presence of other contaminants.	■ Some chemical contaminants are above threshold limits defined for the country or region; or ■ Large area advisories by public health authorities concerning fisheries product contamination but without associated catch restrictions or closures; or ■ High mortalities of aquatic species near outfalls. If there is no available data use the following criteria: ■ Large-scale use of pesticides in agriculture and forestry; or ■ Presence of major sources of dioxins or furans such as large municipal or industrial incinerators or large bleached kraft pulp mills; or ■ Considerable quantities of waste PCBs in the area with inadequate regulation or has invoked some public concerns; or ■ Presence of considerable quantities of other contaminants.	■ Chemical contaminants are above threshold limits defined for the country or region; and ■ Public health and public awareness of fisheries contamination problems with associated reductions in the marketability of such products either through the imposition of limited advisories or by area closures of fisheries; or ■ Large-scale mortalities of aquatic species. If there is no available data use the following criteria: ■ Indications of health effects resulting from use of pesticides; or ■ Known emissions of dioxins or furans from incinerators or chlorine bleaching of pulp; or ■ Known contamination of the environment or foodstuffs by PCBs; or ■ Known contamination of the environment or foodstuffs by other contaminants.
Issue 7: Suspended solids "The adverse effects of modified rates of release of suspended particulate matter to water bodies resulting from human activities"	■ No visible reduction in water transparency; and ■ No evidence of turbidity plumes or increased siltation; and ■ No evidence of progressive riverbank, beach, other coastal or deltaic erosion.	■ Evidently increased or reduced turbidity in streams and/or receiving riverine and marine environments but without major changes in associated sedimentation or erosion rates, mortality or diversity of flora and fauna; or ■ Some evidence of changes in benthic or pelagic biodiversity in some areas due to sediment blanketing or increased turbidity.	■ Markedly increased or reduced turbidity in small areas of streams and/or receiving riverine and marine environments; or ■ Extensive evidence of changes in sedimentation or erosion rates; or ■ Changes in benthic or pelagic biodiversity in areas due to sediment blanketing or increased turbidity.	■ Major changes in turbidity over wide or ecologically significant areas resulting in markedly changed biodiversity or mortality in benthic species due to excessive sedimentation with or without concomitant changes in the nature of deposited sediments (i.e., grain-size composition/redox); or ■ Major change in pelagic biodiversity or mortality due to excessive turbidity.
Issue 8: Solid wastes "Adverse effects associated with the introduction of solid waste materials into water bodies or their environs."	■ No noticeable interference with trawling activities; and ■ No noticeable interference with the recreational use of beaches due to litter; and ■ No reported entanglement of aquatic organisms with debris.	■ Some evidence of marine-derived litter on beaches; or ■ Occasional recovery of solid wastes through trawling activities; but ■ Without noticeable interference with trawling and recreational activities in coastal areas.	■ Widespread litter on beaches giving rise to public concerns regarding the recreational use of beaches; or ■ High frequencies of benthic litter recovery and interference with trawling activities; or ■ Frequent reports of entanglement/suffocation of species by litter.	■ Incidence of litter on beaches sufficient to deter the public from recreational activities; or ■ Trawling activities untenable because of benthic litter and gear entanglement; or ■ Widespread entanglement and/or suffocation of aquatic species by litter.
Issue 9: Thermal "The adverse effects of the release of aqueous effluents at temperatures exceeding ambient temperature in the receiving water body."	■ No thermal discharges or evidence of thermal effluent effects.	■ Presence of thermal discharges but without noticeable effects beyond the mixing zone and no significant interference with migration of species.	■ Presence of thermal discharges with large mixing zones having reduced productivity or altered biodiversity; or ■ Evidence of reduced migration of species due to thermal plume.	■ Presence of thermal discharges with large mixing zones with associated mortalities, substantially reduced productivity or noticeable changes in biodiversity; or ■ Marked reduction in the migration of species due to thermal plumes.
Issue 10: Radionuclide "The adverse effects of the release of radioactive contaminants and wastes into the aquatic environment from human activities."	■ No radionuclide discharges or nuclear activities in the region.	■ Minor releases or fallout of radionuclides but with well regulated or well-managed conditions complying with the Basic Safety Standards.	■ Minor releases or fallout of radionuclides under poorly regulated conditions that do not provide an adequate basis for public health assurance or the protection of aquatic organisms but without situations or levels likely to warrant large scale intervention by a national or international authority.	■ Substantial releases or fallout of radionuclides resulting in excessive exposures to humans or animals in relation to those recommended under the Basic Safety Standards; or ■ Some indication of situations or exposures warranting intervention by a national or international authority.
Issue 11: Spills "The adverse effects of accidental episodic releases of contaminants and materials to the aquatic environment as a result of human activities."	■ No evidence of present or previous spills of hazardous material; or ■ No evidence of increased aquatic or avian species mortality due to spills.	■ Some evidence of minor spills of hazardous materials in small areas with insignificant small-scale adverse effects one aquatic or avian species.	■ Evidence of widespread contamination by hazardous or aesthetically displeasing materials assumed to be from spillage (e.g. oil slicks) but with limited evidence of widespread adverse effects on resources or amenities; or ■ Some evidence of aquatic or avian species mortality through increased presence of contaminated or poisoned carcasses on beaches.	■ Widespread contamination by hazardous or aesthetically displeasing materials from frequent spills resulting in major interference with aquatic resource exploitation or coastal recreational amenities; or ■ Significant mortality of aquatic or avian species as evidenced by large numbers of contaminated carcasses on beaches.

Table 5c: Scoring criteria for environmental impacts of Habitat and community modification

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 12: Loss of ecosystems or ecotones "The complete destruction of aquatic habitats. For the purpose of GIWA methodology, recent loss will be measured as a loss of pre-defined habitats over the last 2-3 decades."	■ There is no evidence of loss of ecosystems or habitats.	■ There are indications of fragmentation of at least one of the habitats.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by up to 30 % during the last 2-3 decades.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.
Issue 13: Modification of ecosystems or ecotones, including community structure and/or species composition "Modification of pre-defined habitats in terms of extinction of native species, occurrence of introduced species and changing in ecosystem function and services over the last 2-3 decades."	■ No evidence of change in species complement due to species extinction or introduction; and ■ No changing in ecosystem function and services.	■ Evidence of change in species complement due to species extinction or introduction	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure; and ■ Evidence of change in ecosystem services[2].

[2] Constanza, R. et al. (1997). The value of the world ecosystem services and natural capital, Nature 387:253-260.

Table 5d: Scoring criteria for environmental impacts of Unsustainable exploitation of fish and other living resources

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 14: Overexploitation "The capture of fish, shellfish or marine invertebrates at a level that exceeds the maximum sustainable yield of the stock."	■ No harvesting exists catching fish (with commercial gear for sale or subsistence).	■ Commercial harvesting exists but there is no evidence of over-exploitation.	■ One stock is exploited beyond MSY (maximum sustainable yield) or is outside safe biological limits.	■ More than one stock is exploited beyond MSY or is outside safe biological limits.
Issue 15: Excessive by-catch and discards "By-catch refers to the incidental capture of fish or other animals that are not the target of the fisheries. Discards refers to dead fish or other animals that are returned to the sea."	■ Current harvesting practices show no evidence of excessive by-catch and/or discards.	■ Up to 30% of the fisheries yield (by weight) consists of by-catch and/or discards.	■ 30-60% of the fisheries yield consists of by-catch and/or discards.	■ Over 60% of the fisheries yield is by-catch and/or discards; or ■ Noticeable incidence of capture of endangered species.
Issue 16: Destructive fishing practices "Fishing practices that are deemed to produce significant harm to marine, lacustrine or coastal habitats and communities."	■ No evidence of habitat destruction due to fisheries practices.	■ Habitat destruction resulting in changes in distribution of fish or shellfish stocks; or ■ Trawling of any one area of the seabed is occurring less than once per year.	■ Habitat destruction resulting in moderate reduction of stocks or moderate changes of the environment; or ■ Trawling of any one area of the seabed is occurring 1-10 times per year; or ■ Incidental use of explosives or poisons for fishing.	■ Habitat destruction resulting in complete collapse of a stock or far reaching changes in the environment; or ■ Trawling of any one area of the seabed is occurring more than 10 times per year; or ■ Widespread use of explosives or poisons for fishing.
Issue 17: Decreased viability of stocks through contamination and disease "Contamination or diseases of feral (wild) stocks of fish or invertebrates that are a direct or indirect consequence of human action."	■ No evidence of increased incidence of fish or shellfish diseases.	■ Increased reports of diseases without major impacts on the stock.	■ Declining populations of one or more species as a result of diseases or contamination.	■ Collapse of stocks as a result of diseases or contamination.
Issue 18: Impact on biological and genetic diversity "Changes in genetic and species diversity of aquatic environments resulting from the introduction of alien or genetically modified species as an intentional or unintentional result of human activities including aquaculture and restocking."	■ No evidence of deliberate or accidental introductions of alien species; and ■ No evidence of deliberate or accidental introductions of alien stocks; and ■ No evidence of deliberate or accidental introductions of genetically modified species.	■ Alien species introduced intentionally or accidentally without major changes in the community structure; or ■ Alien stocks introduced intentionally or accidentally without major changes in the community structure; or ■ Genetically modified species introduced intentionally or accidentally without major changes in the community structure.	■ Measurable decline in the population of native species or local stocks as a result of introductions (intentional or accidental); or ■ Some changes in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).	■ Extinction of native species or local stocks as a result of introductions (intentional or accidental); or ■ Major changes (>20%) in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).

Table 5e: Scoring criteria for environmental impacts of Global change

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 19: Changes in hydrological cycle and ocean circulation "Changes in the local/regional water balance and changes in ocean and coastal circulation or current regime over the last 2-3 decades arising from the wider problem of global change including ENSO."	■ No evidence of changes in hydrological cycle and ocean/coastal current due to global change.	■ Change in hydrological cycles due to global change causing changes in the distribution and density of riparian terrestrial or aquatic plants without influencing overall levels of productivity; or ■ Some evidence of changes in ocean or coastal currents due to global change but without a strong effect on ecosystem diversity or productivity.	■ Significant trend in changing terrestrial or sea ice cover (by comparison with a long-term time series) without major downstream effects on river/ocean circulation or biological diversity; or ■ Extreme events such as flood and drought are increasing; or ■ Aquatic productivity has been altered as a result of global phenomena such as ENSO events.	■ Loss of an entire habitat through desiccation or submergence as a result of global change; or ■ Change in the tree or lichen lines; or ■ Major impacts on habitats or biodiversity as the result of increasing frequency of extreme events; or ■ Changing in ocean or coastal currents or upwelling regimes such that plant or animal populations are unable to recover to their historical or stable levels; or ■ Significant changes in thermohaline circulation.
Issue 20: Sea level change "Changes in the last 2-3 decades in the annual/seasonal mean sea level as a result of global change."	■ No evidence of sea level change.	■ Some evidences of sea level change without major loss of populations of organisms.	■ Changed pattern of coastal erosion due to sea level rise has became evident; or ■ Increase in coastal flooding events partly attributed to sea-level rise or changing prevailing atmospheric forcing such as atmospheric pressure or wind field (other than storm surges).	■ Major loss of coastal land areas due to sea-level change or sea-level induced erosion; or ■ Major loss of coastal or intertidal populations due to sea-level change or sea level induced erosion.
Issue 21: Increased UV-B radiation as a result of ozone depletion "Increased UV-B flux as a result polar ozone depletion over the last 2-3 decades."	■ No evidence of increasing effects of UV/B radiation on marine or freshwater organisms.	■ Some measurable effects of UV/B radiation on behavior or appearance of some aquatic species without affecting the viability of the population.	■ Aquatic community structure is measurably altered as a consequence of UV/B radiation; or ■ One or more aquatic populations are declining.	■ Measured/assessed effects of UV/B irradiation are leading to massive loss of aquatic communities or a significant change in biological diversity.
Issue 22: Changes in ocean CO_2 source/sink function "Changes in the capacity of aquatic systems, ocean as well as freshwater, to generate or absorb atmospheric CO_2 as a direct or indirect consequence of global change over the last 2-3 decades."	■ No measurable or assessed changes in CO_2 source/sink function of aquatic system.	■ Some reasonable suspicions that current global change is impacting the aquatic system sufficiently to alter its source/sink function for CO_2.	■ Some evidences that the impacts of global change have altered the source/sink function for CO_2 of aquatic systems in the region by at least 10%.	■ Evidences that the changes in source/sink function of the aquatic systems in the region are sufficient to cause measurable change in global CO_2 balance.

Preface

The Lake Chad Basin Commission (LCBC) has been the Focal Point for the regional GIWA Assessment of the Lake Chad Basin. Established by the Fort Lamy (now N'Djamena) Convention signed on 22 May 1964 by the Heads of States of the four countries that share the Lake Chad, LCBC now represents five member States, namely: Cameroon, Central African Republic, Chad, Niger and Nigeria. Sudan was admitted in 2000 but is yet to ratify the convention. LCBC has its executive secretariat based in N'Djamena, Chad, and is governed by the Summit of Heads of States that meets every two years, and the Council of Ministers (two Commissioners represent each member State) that meets at least once every year.

The report presents the results of two workshops, desk research, information development and policy analysis. The GIWA Methodology examines the environmental concerns of Freshwater shortage, Pollution, Habitat and community modification, the Unsustainable exploitation of fish and other living resources, and Global change. During the GIWA workshops, hosted by the LCBC in N'Djamena, Chad, for the Scaling and Scoping (28 to 31 January 2002) and the Causal chain and Policy option analyses (26 to 28 September 2003), the transboundary issues of these concerns were ranked, the priority concerns were traced back to their root causes, and a policy analysis was performed.

The scoring procedure for the assessment, as well as Causal chain analysis and Policy options analysis was based on:
(i) expert opinion obtained during the workshops, where experts from the Lake Chad Basin participated, with different specialist backgrounds from several institutions and geographical regions of the Lake Chad Basin; (ii) expert advice from individuals, and regional, national and international organisations; and (iii) information and data gathered from different sources. The review of the preliminary scores (detailed assessment) was based on information collected from local, regional, national and international documentation and scientific publications. The final scores presented in this report resulted from a revision of the preliminary scores, based on further scientific justification collected during a detailed assessment.

The GIWA region 43 Task team, consisted of experts from the LCBC member states, such as from SODELAC in Chad, Chad Basin Development Authority in Nigeria, Government of Cameroon, Government of Niger, Government of the Republic of Chad, ONU-SIDA and IRAD, a research institute based in Cameroon. One of the two workshops was also attended by representatives of the GEF project and UNECA. The LCBC coordinator for the GIWA Assessment, Dr. Johnson Oguntola and an external consultant, Matthew Fortnam, compiled the Detailed Assessment component of the GIWA Assessment.

The assessment makes use of the work of others throughout the report, drawing on the expertise of regional and international organisations, and individuals with experience and interest in the region. The organisations included the LCBC, WWF International, WWF-US, the IUCN West Africa Bureau, EU-INCO Project, USGS and UNEP.

The information herein is believed to be reliable, but the assessors and their institutions do not guarantee its completeness or accuracy. Opinions and estimates are the judgements of the work team. The sole purpose of this work is to provide information to the many stakeholders of the region regarding issues, strategic planning choices and their possible consequences related to the sharing of international waters.

Muhammad Sani Adamu
Executive Secretary of the Lake Chad Basin Commission

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FAO – Food and Agriculture Organization of the United Nations

GEF – Global Environment Facility
Government of Cameroon
Government of Niger
ILEC – International Lake Environment Committee
IRAD – Institute of Agronomic Research
IUCN – World Conservation Union
LCBC – Lake Chad Basin Commission
ONU-SIDA – Organisme des Nations Unies por la lutte contre le SIDA
The Ramsar Convention on Wetlands
Republic of Chad – Meteorological Office
SODELAC – Société de Development du Lac
UNECA – United Nations Economic Commission for Africa
UNEP – United Nations Environment Programme
UNESCO – United Nations Educational, Scientific and Cultural Organization
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USGS – United States Geological Survey
WWF – World Wide Fund For Nature (also known as World Wildlife Fund)

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Executive summary

The Lake Chad Basin (GIWA region 43) is located in central Africa covering 8% of the surface area of Africa, shared between the countries of Algeria, Cameroon, Central African Republic (CAR), Chad, Libya, Niger, Nigeria and Sudan. The Basin comprises a number of transboundary waters that include three main aquifers and a network of catchment rivers. The Lake Chad itself experiences a close interaction between rainfall, evaporation, the generation of lateral inflow, groundwater leakage under the body of the Lake and human abstraction. Its water supply is primarily from the Chari-Logone River, which provides approximately 95% of the total input and empties into the southern pool, and the Komadugu-Yobe River, which contributes less than 2.5% and is the only river flowing into the northern pool. The water balance of the Lake is highly variable resulting in fluctuating open surface waters that have exhibited dramatic expansion and contraction over geologic and recent history (Servant & Servant 1983). In the last decades the open water surface has reduced from approximately 25 000 km^2 in 1973, to less than 2 000 km^2 in the 1990s (Olivry et al. 1996, Grove 1996, Coe & Foley 2001). The northern pool has not contained permanent open waters for more than 25 years although recently there has been some flooding observed, associated with wet years in 1994 and 1999 (Diouf 2000).

The Komadugu-Yobe River Basin is located in Nigeria and Niger and is formed by various tributaries, in particular the Hadejia, Jama'are and Misau rivers that flow from the Jos Plateau (northern Nigeria). The Chari-Logone River Basin is located in CAR, Cameroon and Chad and contains various rivers that flow from the Mongos Hills (CAR), as well as the Adamawa Plateau and Mandara Mountains (Cameroon). The major tributaries are the Pende, which become the Logone oriental on entering Chad, and the Chari. There is seasonal flooding in both the Chari-Logone and Komadugu-Yobe basins, which feeds the extensive Waza-Logone floodplains and Hadejia-Nguru wetlands, respectively. These are used extensively for pasture, fishing, flooded rice production and flood recession cropping (FAO 1997). The Yedseram and Ngadda sub-system and its tributaries rise in the Mandara Hills and 'loses' most of its water while flowing northwards through a floodplain. From Sudan in the east flow seasonal wadis (Wadi Kaya and Wadi Azum), whereas from the north there is virtually no surface flow.

The Lake Chad Basin contains numerous ethnic groups, whose language, legal and administrative systems are based upon traditional pre-colonial culture and the English and French colonial powers. The population of the Lake Chad Basin has experienced rapid growth in the last decades (2.5 to 3 %) and is currently estimated to be over 37 million (based on ORNL 2003). The people are involved in production activities dominated by the primary and tertiary sector with a predominance of informal, low productivity activities such as agriculture, livestock rearing and fisheries. Industry, mining and manufacturing are less prominent although oil abstraction has recently begun in Chad.

The countries are among the poorest in the world and are characterised by extremely slow and variable economic growth. For example Chad, was ranked 155th out of 162 countries in the United Nations 2001 Human Development Index, with annual per capita income of only 200 USD and GDP growing by barely 1.4% per year over 20 years (IMF 2003). Poverty is widespread and is particularly acute in the countries in the south of the Basin. This is reflected in the poor standard of health: excluding Algeria and Libya, the life expectancy of the Basin ranges from only 43 years in CAR to 56 years in Sudan (World Bank 2002c). Illiteracy is a major hindrance to development in the region, with Niger having the lowest literacy rates in the world (World Bank 2002c).

The bulk of water resources is used in agriculture followed by domestic use. Access to safe drinking water in the Basin for domestic use is very limited and water is mainly obtained using traditional methods. Sanitary conditions for rural dwellers are particularly poor with severely limited waste disposal facilities. Traditional agriculture in the Basin is generally rain-fed, although farmers in the downstream regions rely on flood farming and recessional farming. In the last 40 years there have been many large irrigation projects developed located predominantly in the Komadugu-Yobe Basin. There were also projects around the Lake Chad, but except for the farming of the polders, these projects are not functioning.

The Lake Chad Basin Commission (LCBC), an Inter Governmental Agency, has a responsibility to regulate and control the utilisation of water and other natural resources in the Basin. There are now five member countries: Chad, Niger, Nigeria, Cameroon, and CAR. Sudan was admitted in 2000 but is yet to ratify the convention establishing the commission. Since 1989, in cooperation with the LCBC, there has been a set of initiatives and studies aimed at improving the environmental situation in the region. These have included a Diagnostic study of environmental degradation in 1989, the formulation of a Master Plan and Action Programme in 1992 and a Strategic Action Plan in 1998. As a result a GEF project (UNDP/World Bank implemented) entitled "Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem" was initiated which entered its implementation stage in September 2003.

The GIWA Assessment evaluated the relative importance of the different impacts on the international aquatic system of the Lake Chad Basin. The environmental and socio-economic impacts were assessed for present and future conditions, and overall impacts and priorities were identified. The GIWA Assessment ranked Freshwater shortage as severe and as the priority concern, driving many of the other concerns. All the other concerns except for Pollution have had a moderate impact. Although there has been significant modification of habitats and significant fluctuations in fish production, these are predominantly a function of freshwater shortage, rather than as a consequence of direct habitat modification or unsustainable exploitation of fish.

The concerns for the Lake Chad Basin were ranked in descending order:

1. Freshwater shortage
2. Climate change
3. Habitat and community modification
4. Unsustainable exploitation of fish and other living resources
5. Pollution

Freshwater shortage has the highest severity of impact due to both climatic variability and anthropogenic freshwater shortage issues, namely stream flow modification. Stream diversion, associated with the construction of water infrastructure, has been the immediate cause of anthropogenic stream flow modification. Water resources have been used at an unsustainable level for the climatic scenario of the past 40 years. The Maga Dam located in the Chari-Logone Basin and the numerous dams located in the Komadugu-Yobe Basin have disrupted the timing and extent of the flooding of the Waza-Logone and Hadejia-Nguru wetlands, respectively. There are very prominent indicators of freshwater shortage including the shrinkage of the Lake Chad by 90% in the past four decades (Lemoalle 1991, USGS 2001) and reduced river discharges, for example the mean discharge of the Chari-Logone River between 1970 and 1990 is 55% of the mean for 1950 to 1970 (Olivry et al. 1996). Freshwater shortage has impacted heavily on the Basin's economic activities including the fisheries, agriculture, animal husbandry, fuel wood provision and wetland economic services. There has been consequential food insecurity in the region and combined with a lack of potable water has had implications on the health status of the Basin's population. Social impacts of freshwater shortage have included upstream/downstream conflict over who has the right to use the diminishing water resources. Social tensions have also been further provoked by the increased pressure on resources from the migration of people from the drought stricken northern regions of the Basin into areas surrounding the Lake and associated river basins.

Global change has influenced directly and indirectly all of the GIWA concerns (except for Pollution) that affect the Lake Chad Basin. Climatic variability exerted throughout the history of the Basin is therefore considered as playing a key role in causing the fluctuations in freshwater availability (Servant & Servant 1983). The GIWA Assessment of global change refers to human induced changes. The role of anthropogenic climate change in the recent episode of freshwater shortage is undetermined. Several studies have demonstrated that rainfall events in particular have reduced and in turn led to drought (Nicholson 1988, in Le Barbé & Lebel 1997). A comparison of isohyets of the 1950s, which is regarded as the wettest decade with the driest in the 1980s showed considerable shift towards the south (LCBC 2000b). Changes in precipitation in the Sahel (that includes the Lake Chad Basin) have been linked with Sea Surface Temperature (SST) patterns. These patterns have been attributed to changes in the heat transfer between the southern and northern hemisphere that have been influenced by changes in deep ocean circulation, as well as the reduction in sea ice and an increase in sulphate aerosols (Evans 1996). Land anomalies are also believed to have played a role in the recent trend of climate change. A combination of factors including vegetation cover, soil moisture, monsoon dynamics and SST is thought to best explain the reduction in rainfall in the Lake Chad Basin (Xue & Shukla 1997).

Habitat and community modification of the aquatic ecosystems has been experienced in both the Lake and river environments. Intensive cultivation and large numbers of domestic animals have degraded the wetland ecosystems. The primary reason for the reduction in the extent of the wetlands has been attributed to the changes in the seasonal timing and extent of flooding. Consequently since the 1960s wetland resources in the Basin, such as the Yaérés in Cameroon and Hadejia-Nguru in Nigeria, have been reduced by almost 50% (Barbier et al. 1997). Furthermore, the fish habitat in the Lake has altered from being an open water environment to being a predominantly marshy environment. The fish species composition has changed to reflect this (Benech et al. 1983, Benech & Quensière 1989, Neiland & Béné 2003). However, although there has been significant habitat modification this has been largely a consequence of the freshwater shortage situation.

The unsustainable exploitation of the fish and other living resources was not considered as the primary reason for the fluctuations in fisheries production experienced over the past four decades. It is difficult to talk of fisheries in terms of sustainability in such a naturally fluctuating environment. Freshwater shortage and the consequential habitat modification were regarded as the main influencing factors. Prior to the drought years the fisheries had developed rapidly with fishing effort increasing by 50 times between 1967-1972 (Durand 1973). The contracting lake and wetlands caused fish to be concentrated and more vulnerable to fishing gears and eventually the fisheries collapsed in the northern pool followed by the southern pool fisheries in 1982. The fishing communities migrated eastwards following the receding waters, and they also changed their livelihood strategies to take advantage of the fertile lake recessional floor for agriculture. Since 1982, the fisheries have shown a good recovery, which demonstrates the Lake's ability to regenerate the fish stocks during periods of greater freshwater availability (Neiland & Béné 2003). A major concern regarding the fisheries is that of socio-economic differentiation, as the 'poor' critically do not have access to the fisheries resource (Béné et al. 2002).

Pollution is presumed, due to the lack of industry and relatively limited and localised application of agricultural fertilisers, to have the least impact out of all the GIWA concerns assessed. However, cotton and rice industries are known to use large quantities of agro-chemicals and therefore chemical pollution is not out of the question. The distribution and quantity of these chemicals in the environment is not known. In general it is considered that pollution is discharged in quantities that do not exceed the ecosystem's assimilative capacity. However, further studies are needed to scientifically justify this presumption; there is currently a severe lack of monitoring and information networks regarding pollution.

The GIWA regional experts predict that all of the GIWA concerns will increase in severity by the year 2020. Consequently, the concerns of freshwater shortage, habitat and community modification, unsustainable exploitation of living resources, and global change are predicted to have severe impacts on the ecosystems and population of the Lake Chad Basin. The threat of pollution, which is currently assessed as having a slight impact, is predicted to become increasingly significant in the future. The following are predicted to be major factors in controlling the future severity of the concerns in the region:

- Climate change;
- Further water development projects;
- Increased demographic pressure;
- Increased demand of water;
- Oil development;
- Increased use of agro-chemicals.

The Causal chain analysis determined the root causes of the prioritised freshwater shortage concern, that have resulted in the unsustainable use of freshwater resources in the climatic scenario experienced in the Lake Chad Basin over the past 40 years.

Root causes for Chari-Logone and Lake Chad sub-system

- Demographic: Pressures from rapid population growth and environmental refugees escaping drought in the northern regions of the Basin and from fishermen migrating following the receding lake waters.

- Economic: Poverty in the sub-system is widespread and for their short-term survival communities employ practices which are harmful to the environment.

- Knowledge: There are extreme deficiencies in information availability and public awareness in the Chari-Logone/Lake Chad sub-system and the countries have difficulties cooperating and sharing information. There is also a lack of knowledge predicting the future climate changes and the impact changes will have on the region.

- Legal: There is no water allocation agreement existing between the riparian countries. There are no legal instruments to enforce agreements and there are weaknesses in the Fort Lamy Convention established in 1964. Not all member States of LCBC have water laws in place that uphold the principles of sustainable water management and where there are semblances of law, the provisions are not administered and enforced. Governments of member States do not comply with the Fort Lamy Convention that requires them to give prior notification on their proposed projects; they only notify LCBC of donor-funded projects.

- Governance: There is no integrated management strategy in the sub-system; there are conflicting policies between government departments; a short-term policy focus has resulted in unsustainable management; there has been insufficient account of the impacts of stream flow modification from the Maga Dam and on downstream humans and ecosystems; there was a lack of stakeholder involvement in the initial planning and implementation of and management of the SEMRY project (a large-scale irrigation project); and there is highly inefficient and poor water use management.

Root causes for Komadugu-Yobe sub-system

- Demographic: The sub-system's population has experienced rapid growth and is the most densely populated river basin in the region. It is estimated to represent over 55% of the Lake Chad Basin's total population. This has put increasing pressure on the water resources in the region.

- Economic: Endemic poverty in the region is a catalyst for environmental degradation because for short-term survival natural resources are exploited at an unsustainable level. Upstream water diversion did not take into account the essential income and nutrition benefits for local populations from the Hadejia-Nguru wetlands (Barbier 1997). Large irrigation and water development projects are thought to have provided more negative economic impacts than positive (IUCN 2002).

- Legal: There is no water allocation law between Federal Nigerian States or between Nigeria and Niger. Customary rights established by traditional management systems remain highly influential. The rules and regulations for the administration and enforcement of the Nigerian Water Resources Decree 101 of 1993 has not been published (gazetted).

- Knowledge: There is poor information dissemination, particularly to the traditional communities; weak information sharing networks; and limited pollution monitoring and regulations. Currently, there is a lack of knowledge of future climate changes, which is hindering sound water management planning.

- Governance: There is no overall water management strategy for the Komadugu-Yobe River Basin (Bdliya et al. 1999) and the most acute obstacle in achieving this is the absence of a coordinating mechanism to harmonise the activities of the water users. Water management institutions are only concerned with meeting their water requirements, with minimal or no concern for the impacts of their activities on other users (Bdilya et al. 1999). Management is also fragmented with ill-defined and often conflicting responsibilities between government agencies and stakeholders. The hydro-agricultural schemes were planned with minimal stakeholder involvement and without consideration of the climatic variability of the region and the impact reduced flows would have on downstream communities. Water use by these irrigation projects continues to be inefficient due to poor water use management, which continues to lack measures aimed at conserving water resources. There is no known system in place to monitor return flows from large irrigation schemes in the basin if there are return flows.
- Traditional management systems: The rural population is highly differentiated and the poor, critically, do not have access to fishing and farming resources (Béné et al. 2002).

Despite many of the root causes being identified by the Lake Chad Basin Commission Master Plan (LCBC 1992), and subsequent Strategic Action Plan (SAP) (LCBC 1998), recommendations have not been developed into projects for implementation. Downstream users are still being deprived of adequate water supplies to meet their water requirements. Attempts to mobilise domestic and external resources are not helped by the absence of integrated land and water resources management strategies, investment plans and effective coordination (LCBC 2000b).

Policy options

The policy option analysis aims to describe alternative courses of action that may be taken by policy-makers in the region, and discusses the projected outcomes and trade-offs of each action. These actions should address the root causes identified during the Causal chain analysis. The GIWA Policy option analysis firstly discussed basin wide options followed by projects under discussion for the Chari-Logone and Lake Chad sub-system and Komadugu-Yobe sub-system.

The following options were discussed for the entire Lake Chad Basin:

1. Implementation of the GEF project "Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem".
2. Water allocation agreement.
3. Inter-basin water transfer.

The following projects were discussed for the Chari-Logone and Lake Chad sub-system:

4a. Reinundation of the Waza-Logone floodplains (Chari-Logone sub-system).

4b. Assessment of changing land use in the head waters of the Chari-Logone sub-system.

5. Chad-Niger Transboundary Project to Combat Sand Dunes and Reverse Water Degradation Trends in Lake Chad (Lake Chad sub-system).

The following projects were discussed for the Komadugu-Yobe sub-system:

6. Grant subsidies to irrigation farmers in northern Nigeria for implementing water conservation measures (Komadugu-Yobe sub-system).

7. Maintenance and improvements for the safety and improved efficiency of dams and stream flow in the Komadugu-Yobe Basin.

Following an analysis of the above options it was concluded that the recommendations made by the LCBC Master Plan and SAP (LCBC 1998) addressed many of the root causes identified during the Causal chain analysis. The GEF project entitled "Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem" is beginning to implement prioritised recommendations made by the Master Plan and SAP. Therefore, as a prerequisite, the GIWA Assessment recommends that the GEF project be implemented "to build capacity within the Lake Chad Basin Commission (LCBC) and its national committees so that it can better achieve its mandate of managing land and water resources in the greater conventional basin of Lake Chad" (World Bank 2002a).

As a subsidiary priority to the strengthening of capacity in the LCBC, a water allocation agreement (Option 2) would be a key legal instrument in addressing the inequitable allocation of the water resources in the Lake Chad Basin. A water allocation agreement enforced and coordinated by a strengthened LCBC is necessary if integrated management of the Basin is to be achieved. The implementation of a water allocation agreement will address the root causes: i) lack of coordination; ii) legal - no water allocation law; and iii) lack of capacity to promote compliance. The reinundation of the Waza-Logone floodplains (Option 4a) can be incorporated within the flow rates stipulated by this legal framework, so that increased flooding can restore floodplain economic activities. Dam maintenance and enhancement, and the improvement of stream flow (Option 7) will allow the effective implementation of Option 2 (water allocation agreement) and Option 4a by allowing greater control and efficiency of water conveyance. The GIWA Assessment recommends Option 6 (water conservation) as a possible means of increasing freshwater availability and addressing the root causes of poor water management and the lack of incentives to promote compliance. The implementation of water conservation measures would allow water supplies that are available in the Komadugu-Yobe system to be used more efficiently and would be an effective tool for long-term water demand management as part of the wider allocation of water in the basin.

The GIWA Assessment recommends the following actions in priority order:

1. Continued development of recommendations made by the Master Plan and Strategic Action Plan.
2. Implementation of the GEF project for the "Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem".
3. A draft agreement on the equitable and reasonable allocation of water resources should be negotiated, finalised and ratified by member States (Option 2).
4. The reinundation of the Waza-Logone and Hadejia-Nguru wetlands (Option 4a), according to flow rates stipulated by Option 2.
5. Maintenance and improvements in safety and efficiency of dams and stream flow in both the Chari-Logone and Komadugu-Yobe basins (Option 7), to ensure the effective implementation of the water allocation agreement.
6. Feasibility study of water conservation techniques suitable for selected project sites (related to Option 6).

Abbreviations and acronyms

AEO........................African Environment Outlook
CACID..................Cellule d'Appui a la Conservation et aux Initiatives de Développement Durable
CAR........................Central African Republic
CBD........................Convention on Biodiversity
CBDA....................Chad Basin Development Authority
CCA........................Causal Chain Analysis
CICOS..................Commission Internationale du Bassin du Congo-Ubangi-Sangha
CCNEDD..............National Consultive Committee on the Environment and Sustainable Development (Cameroon)
CNEDD..................National Council for the Environment and Sustainable Development (Niger)
CPUE....................Catch per Unit Effort
DRC........................Democratic Republic of Congo
DSS........................Decision Support System Project
EIA..........................Environmental Impact Assessment
EPP........................Emergency Preparedness Plan
FAO........................Food and Agriculture Organization of the United Nations
FEPA......................Federal Environmental Protection Agency
FEWS....................Famine Early Warning System
FCT........................Federal Capital Territory
FME........................Federal Ministry of Environment
FMWR..................Federal Ministry of Water Resources
GCM......................Global Climate Model
GEF........................Global Environment Facility
GEO......................Global Environment Outlook
GKWS..................Greater Kano Water Supply
GNI........................Gross National Income
HCNE....................National High Committee on the Environment (Chad)
HDI........................Human Development Index
HIA........................Transboundary Health Impact Assessment
HJRBDA..............Hadejia-Jama'are River Basin Development Authority
HNWCP..............Hadejia-Nguru Wetlands Conservation Project
ICB........................International Competitive Bidding
ILEC......................International Lake Environment Committee Foundation
IPCC......................Intergovernmental Panel on Climate Change
ITCZ......................Inter-Tropical Convergence Zone
IUCN......................World Conservation Union
IUCN-BRAO.......IUCN's Regional Office for West Africa
KCWS..................Kano City Water Supply
JEWEL..................Jigawa Enhancement of Wetlands Livelihood project
KRIP......................Kano River Irrigation Project
LCBC......................Lake Chad Basin Commission
NAP........................National Action Plan
NEAZDP..............North East Arid Zone Development Programme
NRBDCC..............National River Basin Development Coordinating Committee
ONG KARKARA..Association Nigérienne pour la Dynamisation des Initiatives locales
OP..........................Operational Policy
ORSTOM..............Institut Français de Recherche Scientifique pour le développement en Coopération
PDRM....................Programme du Développement dans la Région des Monts Mandara
PDRN....................Programme du Développement pour la Région du Nord
PIR..........................Project Implementation Review
PMU......................Project Management Unit
PTF........................Project Task Force
RBDA....................River Basin Development Authority
SAP........................Strategic Action Plan
SCIP......................South Chad Irrigation Project
SECADEV............Le projet de Secours Catholique pour le Développement

SEMRY..................Rice Development Authority (Société pour l'Expansion et la Modernisation de la Riziculture dans la région de Yagoua)
SODELAC............Lake Chad Development Society (Société pour le Développment du Lac)
SST ....Sea Surface Temperatures
STAP ....Scientific and Technical Advisory Program
TDA........................Transboundary Diagnostic Analysis
UNAIDS ....Joint United Nations Programme on HIV/AIDS
UNCCD ....United Nations Convention to Combat Desertification
UNCED...................United Nations Conference on Environment and Development
UNDESA..............United Nations Department of Economic and Social Affairs
UNDP....................United Nations Development Programme
UNECA.................United Nations Economic Commission for Africa
UNESCO..............United Nations Educational, Scientific and Cultural Organization
UNEP.....................United Nations Environment Programme
UNPP ....United Nations Population Division
USGS.....................United States Geological Survey
WEHAB ....Water, Energy, Health, Agriculture and Biodiversity
WFP ....United Nations World Food Programme
WHO ....World Health Organization
WIWO...................Foundation Working Group International Waterbird and Wetland Research
WLP ....Waza-Logone Project
WPI.........................Water Poverty Index
WRI.........................World Resources Institute
WSSD....................World Summit on Sustainable Development

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Regional definition

This section describes the boundaries and the main physical and socio-economic characteristics of the region in order to define the area considered in the regional GIWA Assessment and to provide sufficient background information to establish the context within which the assessment was conducted.

Boundaries of the Lake Chad region

The Lake Chad Basin (GIWA region 43) is situated in Central Africa between 6° to 24° N and 8° to 24° E. It comprises a vast expanse of land made up of several catchments that feed Lake Chad. Figure 1 shows a general map of the Lake Chad Basin with the GIWA region 43 boundaries. The entire geographical basin covers an area of 2 434 000 km²

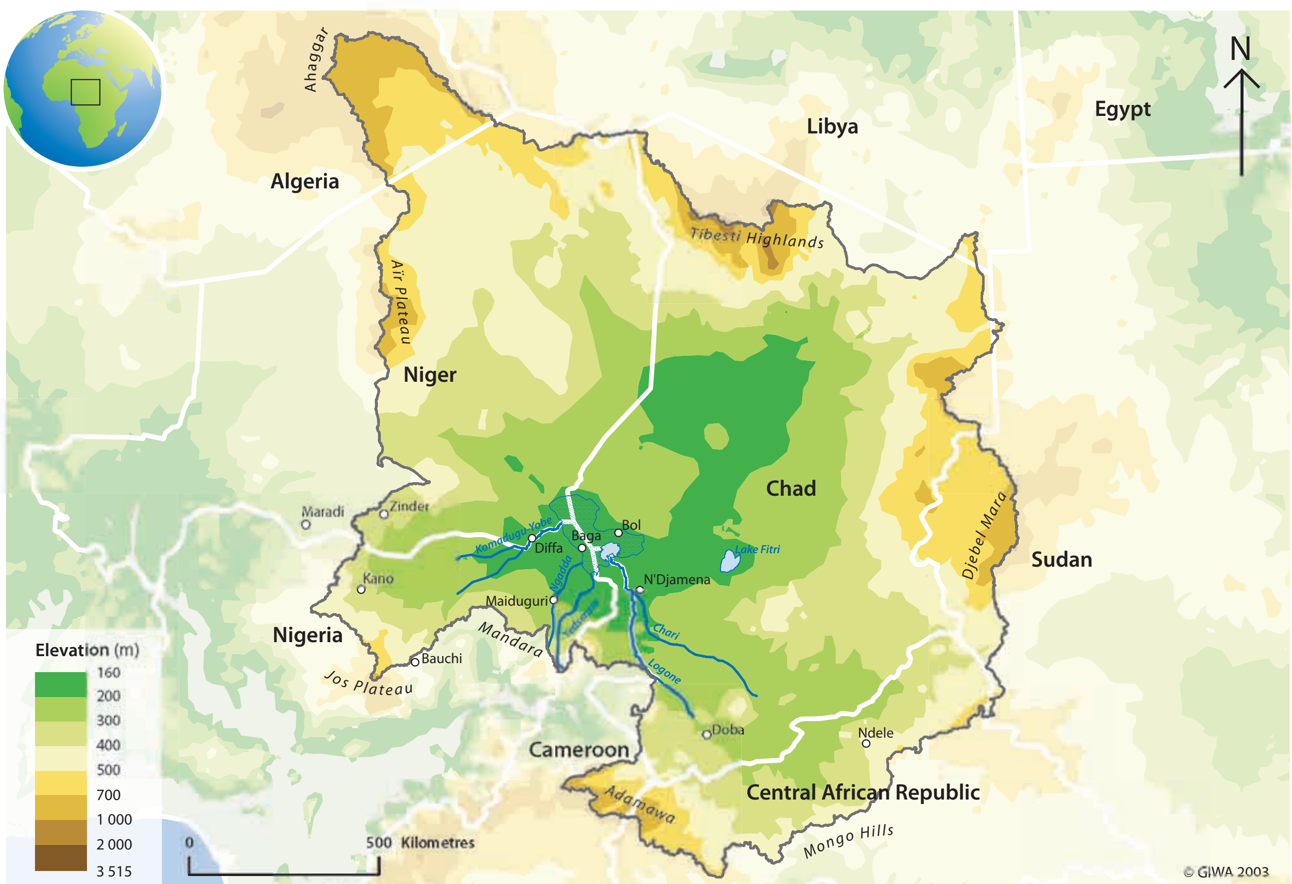


Figure 1 The Lake Chad Basin.

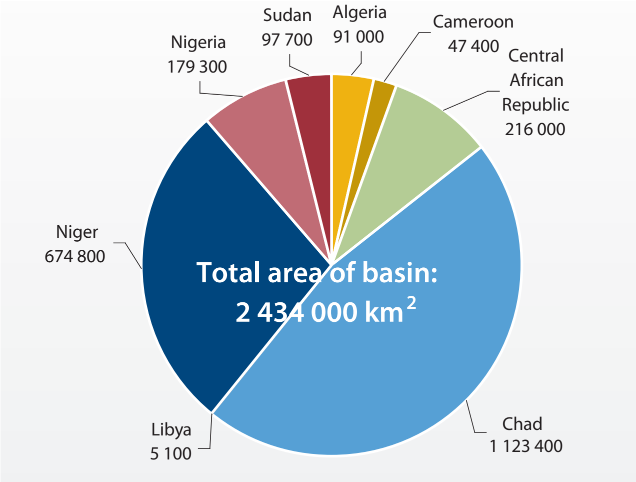


Figure 2 Area coverage per country within the Lake Chad Basin (km²).
(Source: Based on HYDRO 1K Elevation Derivative Database, EROS Data Center 2002)

(based on EROS Data Center 2002), or 8% of the surface area of the African continent, shared between the countries of Algeria, Cameroon, Central African Republic (CAR), Chad, Libya, Niger, Nigeria and Sudan (Figure 2).

The region is bounded to the north by the Ahaggar Mountains in Algeria. From this summit, the border descends southwards towards the Tibesti Highlands that forms the border between Libya and Chad, and continues to about 19° N near the Djebel Mara volcanic mountains in Sudan. The southern border is defined by the Mongos Hills in CAR and the Adamawa Mountains at about 6° N and further west by the Mandaras in northern Cameroon at approximately 10° N. The Jos Plateau marks the western boundary in the Nigerian sector of the Basin and further north the Aïr Plateau in Niger.

Physical characteristics

Geophysical and geological characteristics

The Tibesti and Ahaggar Highlands in Algeria (see Figure 3) form the highest elevations within the Lake Chad Basin region. Their summits rise to an elevation between 2 500 to 3 400 m above mean sea level. They are built up of basalt and crowned with a series of craters. The Djebel Mara volcanic mountains in western Sudan have an elevation of 3 088 m above mean sea level and these mountains gradually decrease to approximately 300 m above mean sea level towards the Lake Chad tectonic depression. Most of the interior of the region is a depression with heights not more than 500 m above mean sea level in altitude, the lowest point being about 160 m in the Chad lowlands (UNDP/FAO 1972). Figure 1 shows these topographic features.

The Lake Chad Basin was formed by extensional tectonic forces during the Cretaceous Period (Burke 1976 in Isiorho & Nkereuwem 1996) with the geological and geomorphological development of the Basin being conditioned by the slow and 'cool' rifting of the West and Central African Rift System. This has formed a regional hydrological sink (World Bank 2002b) known as the Chad Artesian Basin that consists of the Lake Chad (Chad Syneclise) and the Chari-Logone system (Chari-Logone Artesian Basin) located southwest of the Basin. These sub-systems are underlain by a basement complex in the upper source areas and by a progressively thick sequence of sedimentary deposits towards the Lake (World Bank 2002b).

The Chad Syneclise is part of the major meridional zone of depressions extending from the Gulf of Gabes in the North of Africa to the Karoo aquifer in the south. It borders the Mali-Niger aquifer in the west, the Benue Graben in the southwest, and is surrounded by the Aïr Plateau, the Ahaggar and Tibesti Highlands and the Dahomey-Nigeria and Cameroon massifs. This basin is situated in the intersection of the northeastern and northwestern faults. The water supply of the Chad Basin is drawn from the southern Ahaggar and Tibesti Highlands, the Aïr, Ennedi, Darfour and Ouaddai plateaux and other uplands. In the internal recharge and storage area situated in the Chad Syneclise aquifer, water is present in Paleozoic "Continental Intercalaire", Upper Cretaceous, "Continental Terminal" and Quaternary formations.

Figure 3 Ahaggar Mountains, Algeria.
(Photo: Corbis)

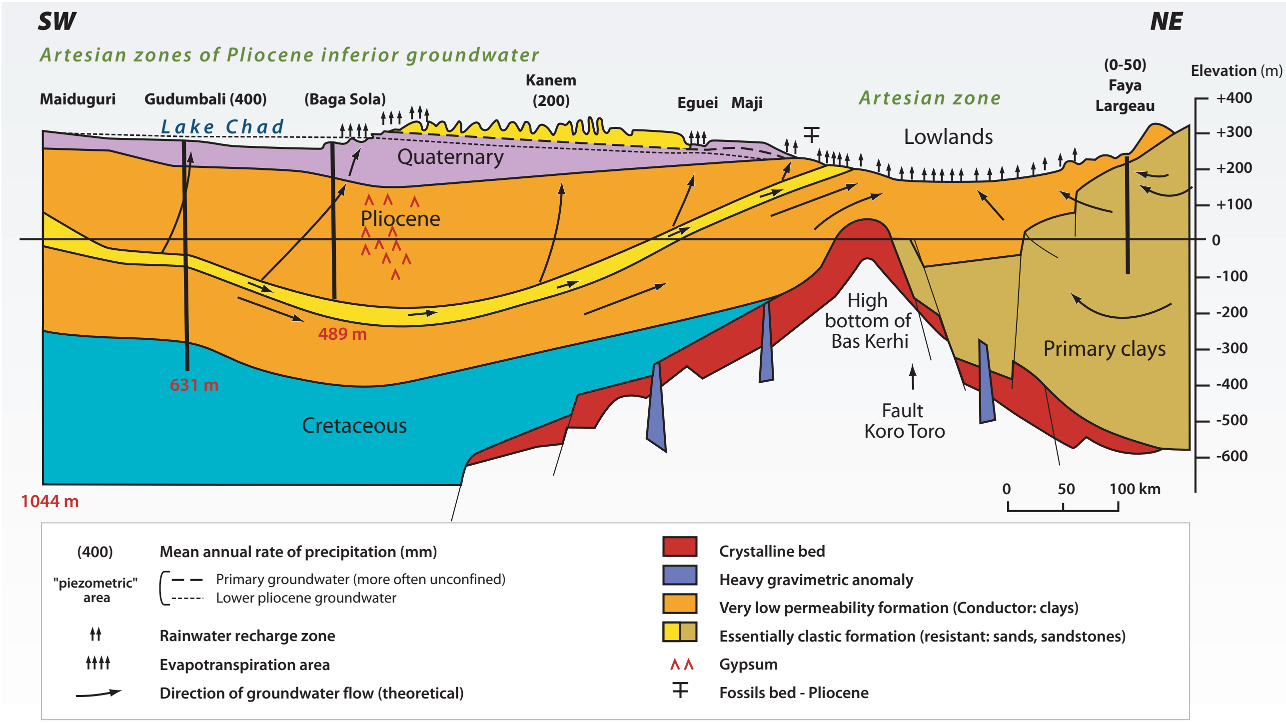


Figure 4 Schematic hydro-geological cross section.
(Source: Redrawn from Schneider 1991)

The Chari-Logone Artesian Basin is situated southeast of the Lake Chad. It includes the extensive Chari-Logone plain, as an inner recharge area, and the Adamawa, Bongas, Ouaddai and other mountains surrounding the plain, as an outer recharge area. Most significant reserves of groundwater in this basin are found in the "Continental Terminal" sequence and in the alluvium of the Chari and Logone valleys. This water is widely used for economic purposes. Much of the soil in the Chari Basin consists of clay particles which swell together when wet, so that water runs off as rapid sheetwash rather than slow percolation (USGS 2001).

Hydrostratigraphy

There is limited knowledge regarding the sedimentary aquifers underlying the Lake, and the hydrodynamics of the groundwater flow into the Lake Chad water body are therefore hypothetical (World Bank 2002b). In the southwest portion of the Basin, the Chad Formation is composed of three aquifers referred to as the upper, middle and lower aquifers shared by the four countries bordering the Lake Chad (Niger, Chad, Cameroon and Nigeria). The systematic hydro-geological cross section in Figure 4 shows the Chad formation, which these aquifers are contained within and also demonstrates the hydrodynamic linkages with the Lake Chad. The formation is overlain by aeolian sands, fluvial, deltaic and lacustrine deposits approximately 1 to 6 m thick. Most of the fluvial deposits occur along stream valleys which are made up of two units: the old alluvium and the young alluvium (Hammand & Abdou 1982 in Isiorho & Nkereuwem 1996). The old alluvium consists of deposits of old rivers, while the young alluvium contains recent riverbeds and flood plains (Isiorho & Nkereuwem 1996).

The upper aquifer consists of a quaternary phreatic aquifer that is made up of fine-grained sediments approximately 30 m thick, and is hydrologically connected to Lake Chad (Isiorho & Matisoff 1990). The phreatic aquifer is not continous all over the basin area, and recharge conditions are poor. Natural recharge occurs primarily by influent seepage from seasonal streams and perennial rivers. The quality of this groundwater is suitable for domestic consumption of the local population and livestock. This aquifer is separated from the underlying middle aquifer by the lower pliocene aquifer found at depths of between 150 and 400 m, and is approximately 200 m of clay-rich sediment (Kindler et al. 1990). In some parts of the Basin, this aquifer is artesian.

The middle aquifer is a continental terminal aquifer that essentially comprises an alternation of sandstone and clay encountered between 450 and 620 m from the surface, extends from Niger and Nigeria into Cameroon and Chad (Kindler et al. 1990). The suitability of this water for irrigation is debatable because of the cost of abstraction, it is essentially used for domestic water supply to the local population and livestock.

Figure 5 Rainfall distribution.
(Source: ESRI 1996)

The lower aquifer is a continental hamadian aquifer that consists of sediments deposited in the cretaceous. There is very little information on this aquifer in the Lake Chad Basin but it is however known to be an important aquifer in the West African region.

Climate

The climate of most parts of the region is hot and dry, with rainfall varying between 1 500 mm per year in the southern parts of the region to less than 100 mm in the northern parts of Chad, Libya and Algeria. Figure 5 shows the distribution of rainfall across the region. In the absence of any specific orographic factors, the reduction in rainfall is about 100 mm for each 100 km of distance (Beauvilain 1996).

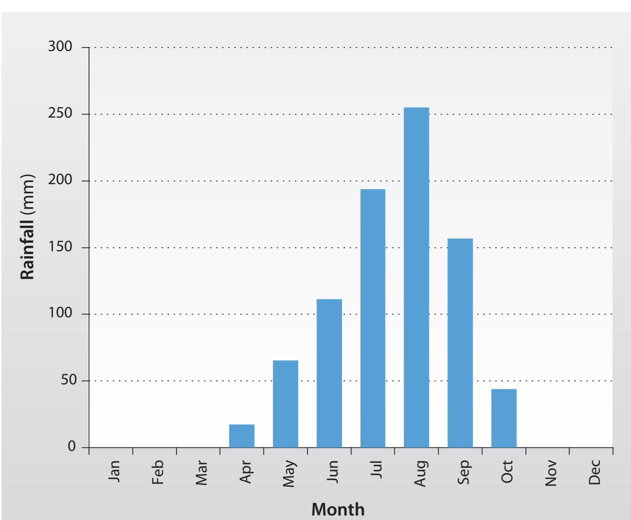


Figure 6 Annual distribution of rainfall in Chad. Readings from eleven meteorological stations (1932-1999).
(Source: Based on Republic of Chad, Meteorological Office)

The Basin is predominantly located in the transition zone between the Sahara desert and savannah grasslands called the Sahel. Rainfall is the single most important factor conditioning the hydrology and the climate in this region. Lake Chad is under the influence of the Inter-Tropical Convergence Zone (ITCZ), which oscillates seasonally between about 15° N and 15° S (Nieuwolf 1977 in Le Barbé & Lebel 1997). North of the ITCZ, high pressure originating from the Sahara prevents rainfall, except during the Boreal winter when occasionally cold air descends from the north. Rain therefore only occurs over the region after the ITCZ has moved past this area towards the north (Le Barbé & Lebel 1997).

From April to October, rainfall occurs but is generally heaviest in August, corresponding with the maximum northward extent of the ITCZ, followed by July and then September. About 90% of the rain falls from June to September (Le Barbé & Lebel 1997). The movement of the ITCZ northern edge is not regular which is often the cause of erratic starts of the rainy season. Even when the rainy season is well established sudden retreats southward of the ITCZ are not uncommon. Figure 6 shows the average annual distribution of rainfall in Chad (1932-1999). Low-rainfall regions are usually also variable-rainfall regions. On the dry, northeast side of Lake Chad, at the town of Bol, rainfall from 1954 to 1972 ranged from 125 to 565 mm per year, averaging 315 mm (USGS 2001).

Annual average rainfall varies from about 500 mm along the southern margins of the actual lake to less than 200 mm near the northern end (Hughes & Hughes 1992). Although rainfall is greatest in July and August the Lake suddenly rises in September. This can be attributed to the fact that rivers provide almost all water supplied to the Lake, so there is a time lag between rain falling in the watershed and reaching the Lake (Holz et al. 1984). Highest lake levels are correspondingly found in December, tapering off slowly for several months (USGS 2001).

The July +30°C isotherm runs across the region. Temperatures are as high as 35-40°C particularly in the northern parts of the region. During the dry season lasting from November to March the basin area is dominated by the Saharan northeasterly winds called the Harmattan. Figure 7 shows dust storms from the Sahara in 2003.

The Lake Chad Basin has a history of drought episodes and in the past 40 years there have been a series of severe drought events. From the middle of the 1960s, rainfall started to drop intermittently but relentlessly until the big drought of 1972-1974. There was then a second occurrence of drought in 1983 and 1984. These droughts have consequently compromised freshwater inputs to the region (see section on Freshwater shortage in Assessment).

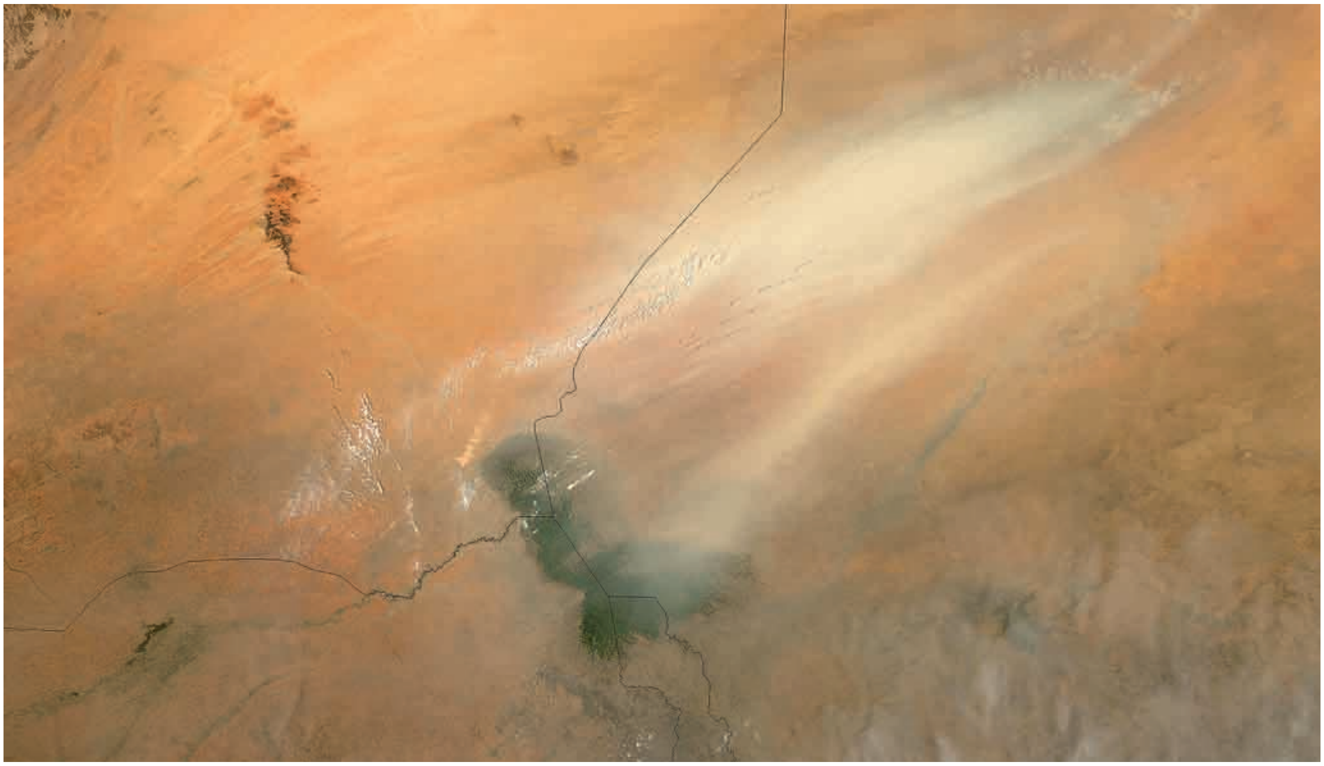


Figure 7 Dust storms from the Sahara regularly whip through central Africa. This image shows Lake Chad (green).
(Photo: Schmaltz, MODIS Sensor Terra satellite, April 2003)

Major climatic zones

According to the UNEP/GRID and UEA/CRU Global Humidity Index (Deichmann & Eklundh 1991) based on a ratio of annual precipitation and potential evapotranspiration (P/PET), the climate of the Lake Chad Basin can be divided broadly into five zones:

- Hyper-arid zone where P/PET < 0.05
- Arid zone where 0.05 <= P/PET < 0.2
- Semi-arid zone where 0.2 <= P/PET < 0.5
- Dry sub-humid zone where 0.5 <= P/PET < 0.65
- Humid zone where 0.65 <= P/PET

The geographic distribution of these climatic zones is illustrated in Figure 8.

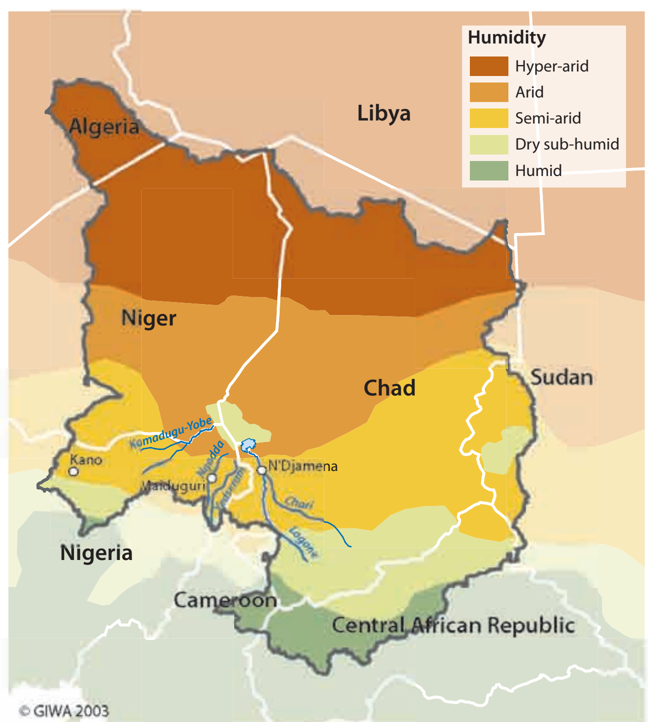


Figure 8 The five main climatic zones found in the Lake Chad region.
(Source: Deichmann & Eklund 1991)

The Lake Chad

Lake Chad is a terminal depression with the eight basin countries grouped around it, of which four are in direct contact with the Lake: Nigeria, Niger, Chad and Cameroon. The Lake occupies less than 1% of the drainage basin (Coe & Foley 2001).

It is extremely shallow, with a mean depth of 4 m (Carmouze & Lemoalle 1983). Therefore any increase in lake volume means a substantial

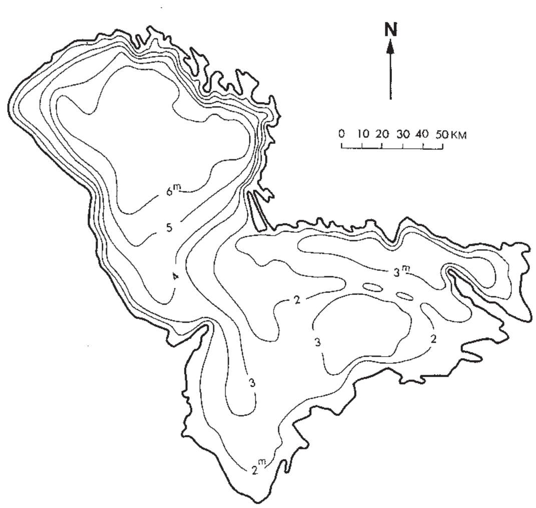


Figure 9 Bathymetric map of Lake Chad 1983.

Note: Although these depths are not applicable for today, it does demonstrate the bathymetry of the Lake.

(Source: Carmouze & Lemoalle 1983)

increase in lake area and shoreline (see review: Burgess et al. In press); seasonal and interannual variations in water level are about 0.5 and 5 m, respectively (Carmouze & Lemoalle 1983).

The bottoms of the northern pool range from 277.5 to 275.5 m above mean sea level and those of the southern pool from 280 to 278.5m (Carmouze & Lemoalle 1983). There is also morphological evidence of a sand ridge between 320 and 330 m of a 'Mega Chad' higher than and 10 times the size of today's Lake Chad (Schneider 1991). Figure 9 is a bathymetry map showing the depths in 1983, demonstrating that the northern pool is deeper than the southern pool.

ORSTOM during the 1970s and early 1980s studied the physical and chemical characteristics of the Lake. The annual average temperature of the Lake Chad water varies between 25.5 and 27.5°C (1956-1975) and is closely related to the annual, seasonal and diurnal variation in air temperature. The water chemistry of the Lake changes throughout the environment and varies seasonally and annually. Wind contributes to the mixing of the shallow, polymictic lake, so that waters are always turbid. Transparency is subsequently low and fluctuates according to water level: in the southern pool transparency decreased from 20 to 100 cm in 1964 when the water level was high, to 25 to 30 cm in 1973 at the time of the Sahelian drought. It is clearest in the southern open waters in December to January, being approximately 100 cm in a 'Normal Chad'[1] hydrological period, and most opaque in August, when it is about 20 cm (Carmouze et al. 1983a). Both pH and salinity become higher with increasing distance from the Chari delta. The pH levels in the Chari are between 7 and 8, and subsequently in the southern pool of the Lake it does not exceed 8, but can reach 9 in the northern pool. In a 'Normal Chad', salinity varies between 40-50 mg/l in the Chari River, 60-120 mg/l in the open waters of the southern pool and 250-400 mg/l in the open waters of the northern pool. Close to the Chari delta, the waters are low in calcium and magnesium carbonates but there is considerable seasonal variation (Carmouze et al. 1983a).

The Lake Chad water balance

There is a close interaction between rainfall, evaporation, the generation of lateral inflow to the Lake, groundwater leakage under the body of the Lake and human abstraction. These factors all influence the overall lake water balance. A distinction has to be made between hydrological and hydro-geological context of each influent tributary, and the aggregate water balance of Lake Chad itself (World Bank 2002b).

By virtue of its location, the Lake Chad region has limited surface and groundwater resources. The water supply is primarily from rainfall and the Chari-Logone and the Komadugu-Yobe rivers. Lake input is seasonal, the majority originating as precipitation on the Adamawa Plateau brought to Lake Chad via the Chari-Logone River (see review: Burgess et al. In press), draining Central African Republic, Cameroon and Chad. The Komadugu-Yobe River and tributaries drain Nigeria and Niger.

The Harmattan winds and dry season aridity contribute to high evaporation that often equals or exceeds water influx and can reach rates of 2 300 mm per year (see review: Thieme et al. In preparation). The annual losses through evaporation from the floodplains (called the Yaéré in Cameroon) are estimated at over 5 billion m^3 per year, or about 30% of the annual run-off from the Logone (see review: Jauro 1998). Despite the high rates of evaporation, Lake Chad has low levels of salinity because the more saline waters sink and leave the Lake through subterranean conduits in the north (see review: Thieme et al. In preparation). This water percolates along the dry bed of the Bahr El Gazal River to feed the oases of the Bodele depression about 40 km to the northeast (ILEC 1999). The surprisingly fresh water is also due to the Chari River putting few dissolved solids into the Lake, as many of its suspended solids settle as sediment onto its wide floodplain. Once in the Lake dissolved solids either precipitate or are absorbed by plants (USGS 2001).

Isiorho et al. (1996) showed that 18 to 32% of the total input to the groundwater system is recharged by Lake Chad. Most of the water is believed to be within the shallow upper aquifer that underlies the Lake. There have been no studies that document the recharge of the deeper aquifers through the lake bed but attempts are being made to identify whether the Lake's water reaches this aquifer.

[1] Normal Chad refers to when the Lake had a open water surface area of about 20 000 km^2. See History of Lake Chad Variability.

Table 1 Tentative illustration of the theoretical water balance of Lake Chad under steady state assumptions for two climatic scenarios.

Type of persistent climatic conditions	Inflow (km³/year)				Direct rainfall inflows (km³/year)	Outflow (km³/year)			Area of Lake and wetlands surface (km²)
	Chari-Logone	Komadugu-Yobe	El Beid and others	Total inflow		Evapotran-spiration	Infiltration (est.)	Total outflow	
Long-term mean rainfall	37.8	1.0	1.2	40.0	6.0	43.0	3.0	46.0	18 000
Mean of period 1971-1990	21.8	0.4	0.2	22.4	2.1	23.1	1.4	24.5	9 400

(Sources: adapted from Olivry, Mott Mac Donald and Pdf-B projects in World Bank 2002b)

The water balance of Lake Chad is highly variable resulting in fluctuating open surface waters that have exhibited dramatic expansion and contraction over geologic and recent history. During the 20th century, an irregular cycle of wet and dry periods occurred due to the climatic regime and to a certain extent by regional hydrological persistence. It has been observed that in general, after five to ten years a new mean level equilibrium is established for each persistent period of "humid", "normal" or "dry" conditions. In an inter-annual balance established in 1984, Table 1 illustrates under steady state assumptions (no change between initial and final levels) the hydrological balance. This illustrative water balance applies to "intermediate conditions" at a level of 281.5 m (surface maximum of 18 000 km²) and also for a small water body at lower levels under much drier conditions (World Bank 2002b).

History of lake level variability[2]

Lake Chad is extremely dynamic. The norm is a variable state of constantly changing size, shape and depth, which occurs both annually and over decades and centuries. Modern Lake Chad is a brackish water remnant of the Pleistocene Lake Mega Chad (10 000-5 000 years ago). Paleo-shoreline studies have shown that Mega Chad covered at least 300 000-350 000 km². Since at least 5 000 years ago, the sub-Sahara zone of Africa known as the Sahel has been progressively desiccated. Paleo-environmental evidence shows conclusively that the Lake completely disappeared several times in the past (Holz et al. 1984). Figure 10 demonstrates how Lake Chad has dried out around year 1450, 1550, 1750, 1850 and 1900.

There is geologic evidence from the Chad Basin of lake level oscillations from the late Pleistocene to the present. From 40 000 to 20 000 years ago, numerous isolated smaller lakes occupied the Chad Basin. From 20 000 to 13 000 years ago, the Basin dried up, allowing the development of dunes on the basin floor, orientated north-northwesterly, south-southeasterly (Nicholson & Flohn 1979 in Holz et al. 1984, Servant & Servant 1983). Dune remnants are still present causing an irregular relief in the Lake Basin, especially along the eastern shore. Dunes are evident on the space imagery taken in 1982, shown in Figure 11 (Holz et al. 1984).

The Basin was occupied by small inter-dunal lakes from 13 000 to 10 000 years ago that also fluctuated in their extent through time (Servant &

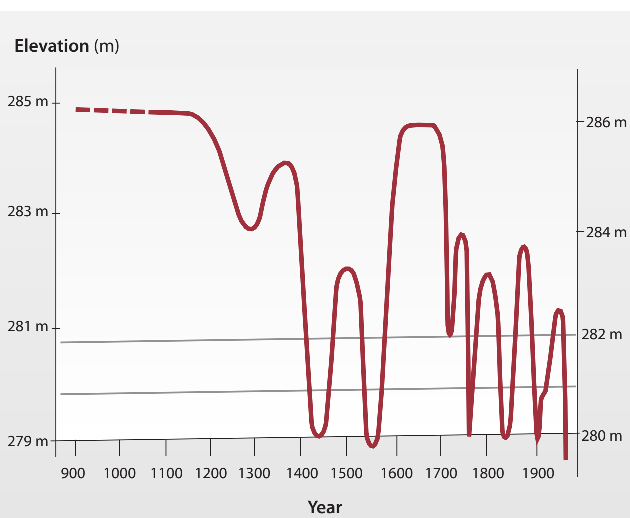


Figure 10 Evolution of Lake Chad in the last millennium. The graph demonstrates the fluctuations in the elevation (above sea level) of the Lake Chad's water level.
(Source: Redrawn from Olivry et al. 1996)

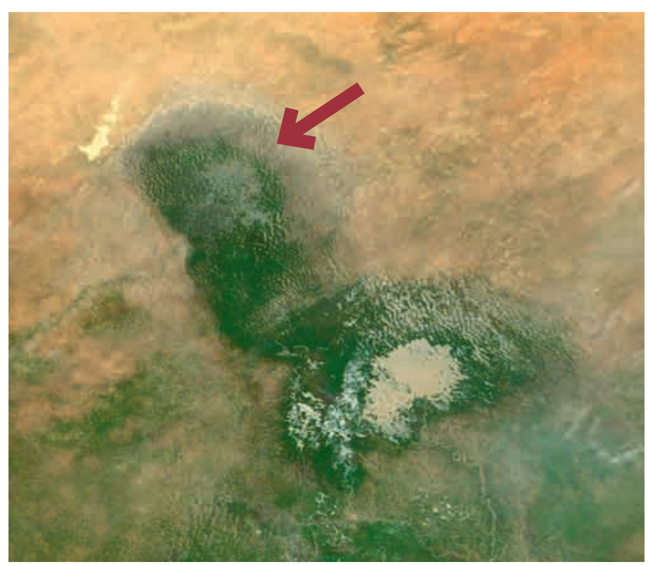


Figure 11 Evidence of sand dunes formed 20 000 to 13 000 years ago (red arrow).
(Photo: Lake Chad, 1982 STS-5 photograph, NASA1982)

[2]*The following section is extracted from Holz et al. 1984.*

Servant 1983). The period from 10 000 to 5 000 years ago is known as Mega Chad (lake area of 300 000-350 000 km^2). At that time the Lake is thought to have approached the area and volume of the Caspian Sea; presently the largest lake in the world. A strandline ridge that represents the old shoreline of Mega Chad can be traced through Borno, Nigeria, and to the northeast of the present lake. The ridge also extends 130 km further southwest than the present shoreline. When Mega Chad stood at its maximum, its waters over-flowed from the Basin into the Benue river valley reaching the Atlantic Ocean through Niger (Grove and Pullam 1963).

In the 19^{th} century, reports of early explorers suggest that the Lake may have reached a higher water level than that during the present century (Tilho 1910). Other observations suggest water level of the Lake Chad in the 19^{th} century varied significantly, decreasing up to 50% in depth and extent (Servant & Servant 1983). In the early 20^{th} century, there was a continued decline of the Lake Chad water level until it eventually turned into marshland, unfit for navigation (Servant & Servant 1983).

Four hydrological periods that are characteristic of the trends in the fluctuating water levels of Lake Chad (first three defined by Tilho in 1910 and the fourth by Holz et al. 1984):

- Greater Chad: open water area of 25 000 km^2 or more.
- Normal Chad: open water area of about 20 000 km^2.
- Lesser Chad: open water area between 6 000 and 15 000 km^2.
- Alimnetric Chad: period of no open water (lake has disappeared).

Recent Lake Chad variability

Up until 1960, Lake Chad was the sixth largest lake in the world. In 1973, it covered an area of 23 000 km^2 (Grove 1996) and occupied first place among the endorheic lakes ahead of Lake Balkhash (18 400 km^2) in Kazakhstan (Nami 2002). The volume and area of the Lake decreased between the 1960s and 1990s. Figure 12 shows the decline in the surface area of the Lake between 1960 and 1999.

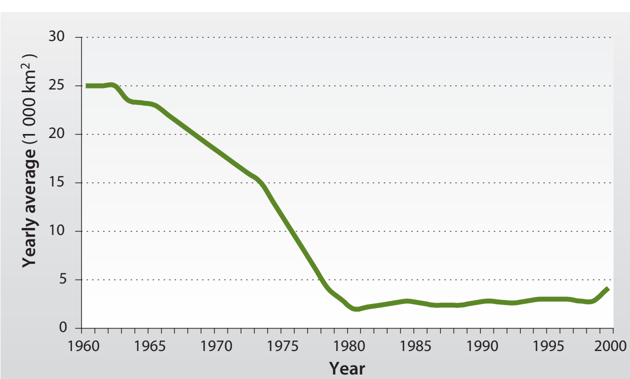


Figure 12 Open surface area of Lake Chad (1960-1999).
(Source: LCBC 2000b)

Lake Chad responds rapidly to precipitation and run-off changes, in part due its shallowness. As a result, Lake Chad has been reduced to a small area covering 1 350 km^2 today (Neiland & Béné 2003) a very significant decrease of around 90% since the 1960s (Lemoalle 1991, USGS 2001) making it now the 15^{th} largest lake in Africa (World Bank 2002a). Receding waters during the 1970s caused Lake Chad to separate into two pools with the "Great Barrier" between them. Since the 1970s the northern pool has only held some temporary waters, and has consequently impeded access for Nigeria and Niger to the open waters of the Lake (Box 1).

Following a wet year in 1999 there were some signs that water flows in the rivers entering Lake Chad were rising, and the floodplains were increasing. The northern pool again began to experience some flooding (Diouf 2000). However the Lake still remains in its Lesser Chad state and wet years are isolated, rather than a sustained upward trend (L'Hôte et al. 2002). It is therefore premature to state whether this most recent cycle is part of a larger climatic trend. Human-based factors in the Basin could also be playing a role in surface water inflows and corresponding aggregate lake levels. Figure 13 shows scientists measuring lake water levels at Kindjeria (centre of the northern pool).

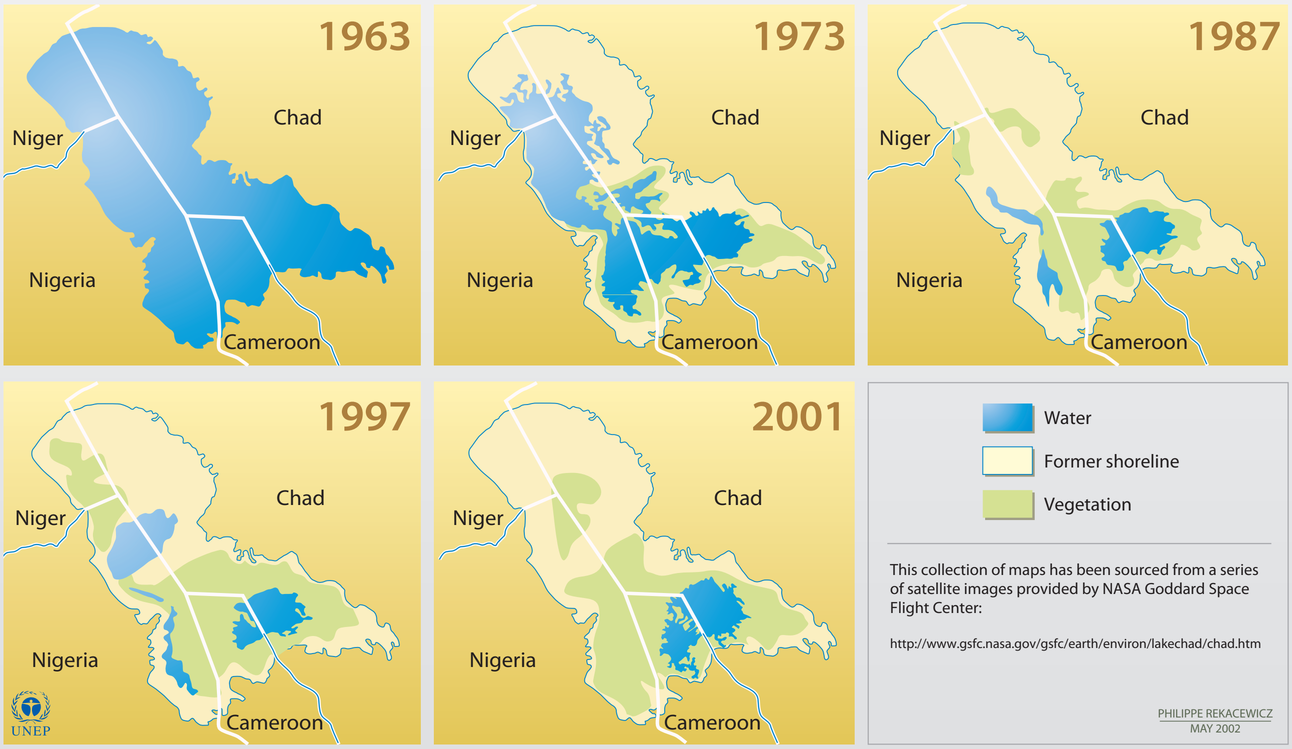
Figure 13 Measuring water levels at Kindjeria (centre of northern pool) in 1975. This gauge is presently not in operation.
(Photo: Chouret in USGS 2001)

Drainage basins of the region

The Chari-Logone sub-system

The Chari-Logone River has a basin area of approximately 650 000 km^2 and the Chari River extends 1 400 km in length (Froese & Pauly 2003). The Chari and Logone rivers have a tropical regime with a single flood occurring at the end of the rainy season, which lasts from August to November (FAO 1997) and feeds the extensive Waza-Logone floodplains and Yaérés. Figure 14 shows the monthly average discharge of the Chari-Logone at N'Djamena. The largest area of the Waza-Logone

Box 1 Chronology of Lake Chad variability: 1960s to present.



A chronology of change - natural and anthropogenic factors affecting Lake Chad.

Note: Images are taken in January each year. (Source: UNEP GRID Arendal 2003)

The figure above shows a time-lapse sequence of maps, sourced from satellite imagery, illustrating the evolution of the Lake 1963 to 2001 (Lemoalle 1991, USGS 2001).

1963: Open water is approximately 23 000 km^2 and each basin is connected by open water.

1973: The beginning of the effects of the 1972-1974 Sahelian droughts separated the northern pool from the southern by exposure of the Basin's inner ridge, the Great Barrier. During this period the northern pool suffered a general drying out period and a change from an open water lake environment to one of an unstable marshy appearance. The open water had totally dried out by 1975 and during the same period the open water areas of the southern pool reduced by 90% (FAO 1986 in Neiland & Béné 2003).

1987: The effect of both the 1972-1974 and 1982 Sahelian droughts has resulted in open water being restricted to the southern pool only.

1997: There was little variation over the previous decade with open water estimated to vary inter-annually in area between 1 500 to 2 000 km^2, plus a larger surrounding area of mixed permanent and temporary swampland of between 2 000 to 4 000 km^2.

2001: The state of open water flooding estimated to be 1 350 km^2 with around 4 000 km^2 of swampland (Neiland & Béné 2003). The expansion in the Lake is masked by the proliferation of floating vegetation.

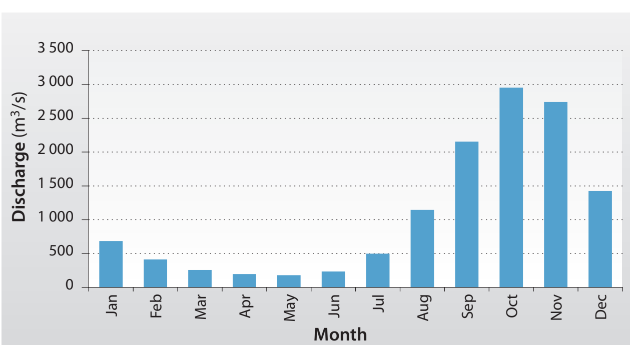


Figure 14 Monthly average discharge from Chari-Logone River at N´Djamena (1933-1991).

(Source: RIVDIS database 1991)

floodplain covers about 8 000 km^2 and is used for pasture, fishing, flooded rice production and flood recession cropping (FAO 1997). The rivers contribute 95% of all riverine inputs into the Lake, an average of 37.8 km^3/year (discharges have been regularly measured at N'Djamena since 1932) (World Bank 2002b).

Water from the Chari-Logone River flow into the Lake at its southern extreme and flows northward and outwards encouraged by the Lake's gradient and prevailing winds (Sarch 2001). These floodwaters take between one and two months to reach the southwest shore. The flow is at its minimum in May/June at the beginning of next year's rainy season.

Various rivers flow in this region, in particular the tributaries of the Chari and the Pende, a tributary of the Logone, which becomes the Logone oriental (eastern branch of the Logone) on entering Chad. Two rivers, the Vina and Mbere, feed the western branch of the Logone from Cameroon. Rainfall reaches 1 400 mm/year in the CAR and on the Adamawa Plateau in Cameroon. The El Beid comes from the Mandara Mountains (northern Cameroon) and forms an overflow for flooding in the Yaérés, which in certain abundant years comes from the Logone. The regime of the El Beid, which forms the frontier between Cameroon and Nigeria and then flows into Lake Chad, depends to a great extent upon the flood levels in the Yaérés when the Logone overflows (LCBC 1998).

Figure 15 The main rivers in the Lake Chad Basin.

The area of the Waza-Logone floodplain inundated in any year depends on over-bank flow from the Logone River, flow from seasonal streams called "mayos" flowing out of adjacent upland areas, direct rainfall onto the floodplain and water released from the Maga Dam, whose reservoir is fed by the same three sources of water (LCBC 2002). However, in the last 40 years the mean Chari discharge has decreased significantly due to the persistent change in rainfall patterns over the contributing catchment.

The Yedseram and Ngadda sub-system

The Yedseram and Ngadda rivers and their tributaries rise in the Mandara Hills (northern Cameroon) and they lose most of their waters while flowing northwards through a 7 km wide flood plain (Figure 15). Further downstream of the Ngadda River (Nigeria) a 80 km^2 swamp is formed from where the river does not maintain a definable water course to the Lake (FAO 1997). The system contains the Alau Dam (162 million m^3 reservoir), which is located southeast of Maiduguri.

The Komadugu-Yobe sub-system

The Komadugu-Yobe River system has a basin area of 148 000 km^2 (World Bank 2002b) but contributes less than 2.5% of the total riverine inflow to Lake Chad (see review: Burgess et al. In press). The Komadugu-Yobe River is the border between Nigeria and Niger over the last 160 km and is the only perennial river system flowing into the northern pool of Lake Chad. The Komadugu-Yobe is formed by various tributaries, in particular the Jama'are River which flows from the Jos Plateau (Nigeria), and the Hadejia River which flows from the area around Kano (Nigeria). The two rivers join to the southwest of Gashua (northeastern Nigeria). The Hadejia River for the first 48 km of its course maintains a gradient of approximately 1 m/km. As it descends the gradient reduces abruptly with the channel diverging forming numerous oxbow lakes. The Jama'are begins with a relatively high gradient from the Jos Plateau before entering the Chad syncline northeast of Foggo (Nigeria). It is also supplied by the Misau, which comes from the north of Bauchi (Nigeria) and joins the Komadugu-Yobe River 120 km from Lake Chad (LCBC 1998). Most of the headwaters carry a high sediment load of silt and fine sands that are deposited downstream, and there are resulting aggraded valleys of poorly defined channels with numerous small oxbow lakes (Oyebande 2001).

Upstream of the confluence of the Hadejia and Jama'are rivers the Hadejia-Nguru wetlands (fadamas) in Nigeria start. Peak inflow to the wetlands occurs in late August, resulting in extensive shallow flooding (see review: Burgess et al. In press). These wetlands cover a total area of about 6 000 km^2, with a water surface area of 2 000 km^2 (FAO 1997). Referred to as an inland delta, the floodplain has a maximum width of 65 km at the confluence of the two rivers, but then diminishes to a 5 km span that continues for several hundred kilometres.

Many patches of higher, unflooded ground are mixed within the floodplain (see review: Burgess et al. In press). Much of the Hadejia-Nguru floodplain is dry for some or all of the year. It provides a wide range of resources including fertile agricultural soils, grazing, non-timber forest products, fuel wood and fisheries. In addition the wetlands are a unique migratory habitat for many wildfowl and wader species (LCBC 2002).

The River Hadejia is controlled by three large dams at Tiga (1 400 million m^3 reservoir), Challawa Gorge (972 million m^3 reservoir), and Hadejia (1 200 million m^3 reservoir), and many small dam structures. The upper basins contribute a total long-term natural yield of approximately 7 km^3/year, the bulk of which is impounded at these reservoirs within the Kano province. More impoundment is anticipated on the Jama'are River, in Bauchi province if the Kafin Zaki Dam (2 700 million m^3 reservoir) is constructed, although presently due to lack of funding and strong opposition it is unclear if, or when, the dam will be completed. Consequently, due to impoundment, siltation and blockage by invasive weeds, the major part of this sub-system has not been able to establish a natural regime through the downstream Yobe River in Nigeria and Niger for more than 20 years.

An analysis of four years of records before the construction of dams (e.g. Tiga) between 1964 and 1967 in the Komadugu-Yobe river system indicates that an average of more than 68% of measured run-off was lost upstream of Gashua. Only 18% of total run-off reached Geidam (Oyebande & Nwa 1980 in Oyebande 2001). A water balance model developed by Adams and Hollis (1988) showed that evaporation from the inundated area and flooded soils represent 64% of the volume of the river inflow to the Hadejia-Nguru wetlands. Along the Misau River the average flow lost between Kari and Dapchi was 68% of the flow at Kari. The river discharge at Gashua, represents only 24% of the rivers original flow. Based upon this research it is estimated that only 10% of the total surface run-off from the Komadugu-Yobe system reached Lake Chad even before the construction of dams (see Assessment, Freshwater shortage, Modification of Komadugu-Yobe River) (Oyebande 2001).

Lake Fitri

Lake Fitri is located in Chad and has a surface area of 300 km^2 and during the dry season is part of a large biosphere reserve covering 1 950 km^2. It is normally a freshwater Sahelian lake, fed by seasonal rainfall and run-off from the seasonal Batha River. Unlike Lake Chad, it is one of the few Sahelian water bodies that has not experienced large-scale hydrological change, although it became desiccated during the 1984-1985 severe drought (World Bank 2002a).

North of Lake Chad

The north of Lake Chad is the largest drainage area of the Basin that encompasses north Chad and the Algerian sector of the Lake Chad Basin. Algeria possesses few renewable water resources and there are virtually no surface flows from the north into the Lake and what little drainage pattern there is flows away from the Lake.

East of Lake Chad

To the east is Sudan with Wadi Kaya and Wadi Azum, both seasonal wadis with spate flows that originate on the western slopes of the Djebel Mara. The Wadi Azum's waters flow onto the Salamat floodplain and fill Lake Iro before finally joining the Chari River. The alluvial aquifers of these wadis have the potential to provide about 0.08 km^3/year of excellent quality freshwater (FAO 1997).

The Lake Chad Basin's ecological regions

The Lake Chad Basin contains a variety of habitats, including deserts, shrub steppes, savannahs, forests, lakes, wetlands and mountains. These terrestrial and aquatic habitats form a unique sanctuary for the diverse fauna of the region that includes ostriches, cheetahs, hyraxes, crocodiles, hippopotamus and elephants. These habitats also have a good stock of water birds, migratory birds and waders that thrive in the river valleys depending primarily on the waters of the numerous small lakes that are formed during periods of receding floods. The humid zones of the Basin and the Lake itself constitute a unique ecosystem in this area of the Sahel, and a preserve of biodiversity of global importance. For example, 140 species of fish (Neiland & Béne 2003) and 372 species of birds, of which one third are migratory species have been listed (see review: Nami 2002). The integrity of the ecosystems is an essential shield against desertification.

Figure 16 shows nine ecological zones in the Basin that have been classified using the WWF Ecoregions (2001). The following text has also been extracted from WWF Ecoregions (Burgess et al. In press) and references therein. The Lake Chad Flooded Savannah Ecoregion also contains additional data extracted from other sources that are cited in text.

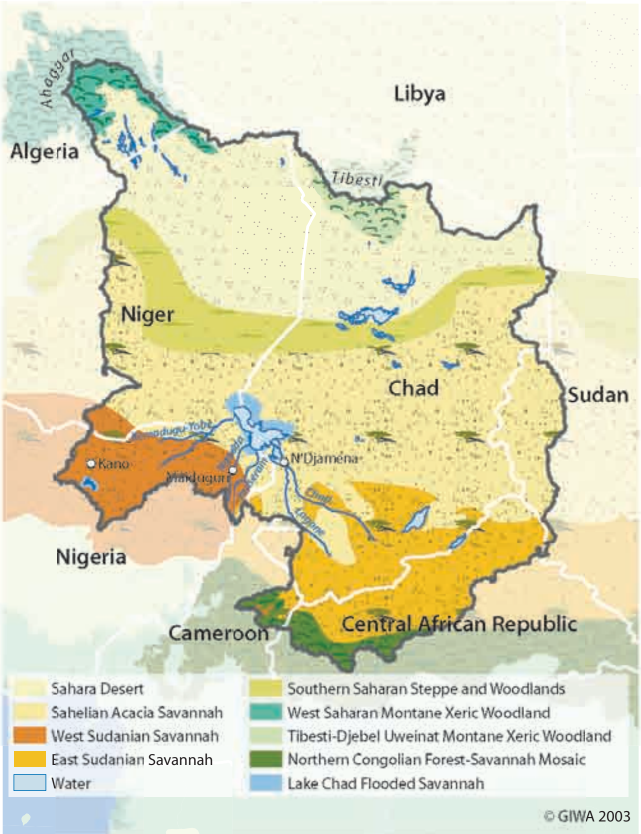


Figure 16 Ecoregions of the Lake Chad Basin.
(Source: WWF 2001)

Sahara Desert

Physical features: The surface of the desert ranges from large areas of sand dunes (Erg, Chech, Raoui), to stone plateaus (hamadas), gravel plains (reg), dry riverbeds (wadis), and salt flats. Vast underground aquifers that underlie much of the region sometimes penetrate the surface, forming oases. Mechanical and chemical weathering of rocks over the past 50 million years has produced the soils that include yemosols (over hamadas and regs), regosols (sandy soils), fluvisols (within non-saline valleys) and solonchaks (within saline depressions). The annual rainfall is below 25 mm and mean annual temperatures are around 25°C. In the hottest months, temperatures can rise over 50°C, and temperatures can fall below freezing in the winter. Figure 17 shows the Sahara desert in Libya.

Flora: The flora of the central Sahara Desert is very poor and estimated to include only 500 species. As many as 162 of the plant species are endemic to the Sahara. The flora of the region shows strictly Sahara-Arabian affinities and exceptional adaptations to aridity. Perennial vegetation is found in wadis, channels, runnels, depressions and hill slopes.

Fauna: The fauna of the central Sahara is richer than earlier believed. Arthropods are numerous, especially ants. Among the Sahara-Sindian biome avifauna are greater hoopoe-lark (*Alaemon alaudipes*) and desert sparrow (*Passer simplex*).

South Saharan Steppe and Woodlands

Physical features: Rainfall is between 100 and 200 mm per year and in the Sahelian portion of the ecoregion temperatures are between 26°C and 30°C. It serves as a transition from the Sahara to the Sahel.

Flora: The northern border of the ecoregion lies several hundred kilometres north of the 100 mm rainfall isohyet, which is the northern limit of summer grassland pasture composed of the grasses *Eragrostis*, *Aristida*, and *Stipagrostis* spp. with the herbs *Tribulus*, *Heliotropium,* and *Pulicharia.* Woody species include *Acacia tortilis* and *Acacia ehrenbergiana*, which mainly grow along wadis. In the south, the vegetation of the ecoregion grades into the Sahelian Acacia Savannah ecoregion, and includes steppes of *Panicum turgidum* perennial tussock grass.

Fauna: Notable animal species that once occurred throughout the ecoregion, but have now been reduced to extremely small and scattered populations include the following: addax (*Addax nasomaculatus*), slender-horned gazelle (*Gazella leptoceros*), dama gazelle (*Gazella dama*), striped hyena (*Hyaena hyaena*), cheetah (*Acinonyx jubatus*), wild dog (*Lycaon pictus*), and ostrich (*Struthio camelus*).

Sahelian Acacia Savannah

Physical: This is the largest ecoregion in the Basin and encompasses the Lake Chad savannah floodplains. Located in the Sahel south of the South Saharan Steppe it represents the transition zone where

Figure 17 Sahara Desert in Libya.
(Photo: R. Pelisson SaharaMet)

savannah meets the Sahara Desert. The topography is mainly flat and the climate is tropical, hot, and strongly seasonal. The monthly mean maximum temperatures vary from 33 to 36°C and monthly mean minimum temperatures are between 18 to 21°C. The annual rainfall is around 600 mm in the south of the ecoregion, but declines rapidly to the north to around 200 mm. The soils of the ecoregion are mainly entisols, with some aridisols, and most are sandy and highly permeable, so that permanent surface water is rare.

Flora: Wooded grassland is widespread on sandy soils in the southern Sahel, with many thorny shrubs and small trees including several Ziziphus species. Grass cover is continuous but often dominated by short annual species such as *Aristida mutabil, Chloris prieurii*, and *Cenchrus biflorus*. In the northern Sahel, short grasslands grow on deep, sandy soils, with widely dispersed shrubs. Most plant species are widespread and fairly common. There are a number of endemic plants such as the *Indigofera sengalenisis* and *Panicum laetum*.

Fauna: This ecoregion host several endemic animals, mainly small rodents adapted to arid conditions. Three bird species are considered near-endemic: the rusty lark (*Mirafra rufa*), the masked shrike (*Lanius nubicus*), and the sennar penduline-tit (*Anthoscopus punctifrons*). For reptiles, endemism is more pronounced, with 10 species regarded as strictly endemic. Prior to the 20th century vast herds of ungulates and other large animals, including elephant, giraffe and ostrich were found in this ecoregion. Most of the large populations have been reduced to scattered remnants due to unregulated hunting with modern firearms. The scimitar-horned oryx (*Oryx dammah*) is presumed to be extinct in the wild. Other species are only found in a handful of protected areas e.g. the western giraffe (*Giraffa camelopardus peralta*). The pronounced dry season signals a significant migration of fauna within the ecoregion. This includes the annual passage of large numbers of migrant birds on the Afrotropical-Palaearctic flyway.

West Sudanian Savannah

Physical features: The ecoregion is mainly flat and the climate is tropical and strongly seasonal. The highest average daily temperatures vary from 35 to 40°C whilst the lowest average daily temperatures are between 15 and 20°C. Mean annual precipitation ranges up to 1 600 mm in the south, but declines to 600 mm per year on the northern border with the Sahelian Acacia Savannah. The rainfall in this northern region of the ecoregion is close to 600 mm. The Mandara Plateau, in northwest Nigeria and northern Cameroon, separates the West and East Sudanian Savannahs. Soil fertility is relatively low in the heavily weathered lateritic soils.

Flora: The vegetation is comprised of woodland with a understory of long grasses, shrubs, and herbs. The northern portion hosts mainly grasslands dominated by numerous short grasses. Shrubland is scattered in patches throughout the ecoregion. Riparian forests occur along many waterways and small areas of adaphic vegetation such as grassy floodplains, or fadamas are found in the Komadugu-Yobe Basin.

Fauna: The West Sudanian Savannah supports a relatively rich fauna, including a number of endemic species. Common large animals are bushbuck (*Tragelaphus scriptus*), warthog (*Phacochoerus africanus*), vervet monkey (*Chlorocebus aethiops*), baboon (*Papio hamadryas papio* and *P.h. anubis*), and savannah monitor lizard (*Varanus exanthematicus*). Most large mammals have been heavily hunted and many species only survive sparsely, mainly in protected areas. The pronounced dry season signals a migration of fauna within the ecoregion. This includes the annual passage of migrant birds on the Afrotropical-Palaearctic flyway.

East Sudanian Savannah

Physical features: This ecoregion lies south of the Sahel and is mainly flat, with a climate that is tropical and highly seasonal. Average high temperatures range from 30 to 33°C and lows fall between 18 to 21°C. Annual rainfall is as high as 1 000 mm in the south. During the rainy season, which lasts from April to October, large areas of southern Chad and northern Central African Republic become totally flooded and inaccessible. During the dry season, however, most of the trees lose their leaves, and the grasses dry up and may burn. The soils are mainly ultisols and alfisols in the south and entisols in the north.

Flora: The vegetation is undifferentiated woodland with trees that are mainly deciduous in the dry season, with an understory of grasses, shrubs and herbs. Typical trees in the Lake Chad Basin sector of this ecoregion include *Anogeissus leiocarpus*, *Kigelia aethiopica*, *Acacia seyal* and species of *Combretum* and *Terminalia*.

Fauna: The East Sudanian Savannah ecoregion closely resembles the West Sudanian Savannah in habitat structure and species composition. The two ecoregions differ somewhat in terms of their species assemblages and the degree to which the habitat and mammal assemblages are intact. The Eastern Sudanian Savannah has low rates of faunal endemism. For example there is only one endemic mammal (a mouse, *Mus goundae*) and two strictly endemic reptiles (*Rhamphiophis maradiensis* and *Panaspis wilsoni*). Threatened mammal species include large herds of elephant (*Loxodonta africana*) in Chad and Central African Republic and wild dog (*Lycaon pictus*), cheetah (*Acinonyx jubatus*) and lion (*Panthera leo*).

West Saharan Montane Xeric Woodlands

Physical: This mountain range is found within the Sahara Desert and is predominantly of volcanic origin. The Aïr in northern Niger is included in this ecoregion. Climatically, it is cold and dry in the winter and hot and dry in the summer. Rainfall is variable, but averages less than 150 mm per year, with most falling at higher elevations. The mean maximum temperature reaches 30°C at the lower elevations and 18 to 12°C at the highest elevations, whereas the mean minimum temperatures are as low as 3°C at the highest elevations. Frosts are common, and snow can be found on the higher peaks in the winter. Throughout the ecoregion permanent water holes, called gueltas, are protected from the sun in narrow gorges, which reduces evaporation and increases the permanence of the pools; it is primarily these areas that give the ecoregion its floral and faunal values.

Flora: Vegetation within this ecoregion varies according to elevation and landscape features. At lower elevations, the vegetation is mapped as regs, hamadas and wadis, but at the highest altitudes there is a transition to saharomontane vegetation. This ecoregion supports an interesting relict flora, with Mediterranean, Sudano-Deccan and Saharo-Sindien affinities and contains a number of endemic and rare species. The most notable of these is Duprey cypress, or tarout (*Cupressus depreziana*), wild olive (*Olea lapperrini*) and myrtle (*Myrtus nivellei*), all of which are relict Saharan-Mediterranean species.

Fauna: The plateaus that comprise this ecoregion are biologically important, and function as one of the last refuges for some species. These include populations of globally threatened antelope, such as dorcas gazelle (*Gazella dorcas*) and dama gazelle (*Gazella dama*). Migratory birds use this ecoregion as a rest area because of the year round water and cooler temperatures. Many reptiles are also present including the snakes *Telescopus obtusus* and *Echis leucogaster.* Amphibians include the European green toad (*Bufo viridis).*

Tibesti-Djebel Uweinat Montane Xeric Woodlands

Physical: Tibesti Mountains consist of seven inactive volcanoes where rainfall is more regular, although still probably under 600 mm per year. Lowland wadis areas receive their water from the mountains down storm channels. The mean maximum temperature is approximately 30°C in the lowlands and falls to 20°C in the highest elevations. Mean minimum temperatures are 12°C in the lowlands, but fall to 9°C over most of the ecoregion and are as low as 0°C at the highest elevations during winter months.

Flora: The Tibesti mountain vegetation varies according to elevation and slope. Large wadis areas radiate from the southwestern slopes supporting tree species such as the doum palm (*Hyphaene thebaica*), *Salvadora persica*, *Tamarix articulata*, and *Acacia albida*, and other tropical herbs in the genera *Abutilon*, *Hibiscus*, and *Tephrosia*. The Saharomontane vegetation of the higher elevations supports the endemic *Ficus teloukat*, which grows on the south and southwestern slopes, *Myrtus nivellei* on the western slopes, and *Tamarix gallica nilotica* on the wetter northern slopes. Remnant tropical and Mediterranean plant species are seen throughout this ecoregion, including palms, *Hibiscus* sp. and *Rhynchosia* sp.

Fauna: The ecoregion supports populations of several important Saharan large mammals including the dorcas gazelle (*Gazella dorcas*), Barbary sheep (*Ammotragus lervia*) and cheetah (*Acinonyx jubatus*). Small mammals and their predators are also abundant, including hyrax (*Procavia capensis*), brown hare (*Lepus capensis*) and spiny mouse (*Acomys* spp.). The reptile and amphibian fauna is poor in this area.

Lake Chad Flooded Savannah

(See review: Burgess et al. In press and references therein, Thieme et al. In preparation, Verhoeye & De Wulf 2001, World Bank 2002b, Carmouze et al. 1983b).

Physical: The physical features of the Lake are discussed in the section on Lake Chad and drainage basins.

Flora: The surface of the Lake is covered with a mixture of island archipelagoes, reed beds, and open water (Iltis & Lemoalle 1983, Dumont 1992 in Thieme et al. In preparation). Separating the Lake into the north and south pools is the Great Barrier, a ridge of land submerged when the Lake is fully inundated. Areas of open water persist in the southern pool, mostly near the Chari River inflow. Swamps are found to the west of this open water. Vegetation in the southern pool consists of *Cyperus papyrus, Phragmites mauritianus, Vossia cuspidata*, and other wetland plants. *Phragmites australis* and *Typha australis* grow in the more saline north pool. Occasionally, the floating plant Nile lettuce (*Pistia stratiotes*) covers large areas of open water (see review: Burgess et al. In press). Normal Chad was classified as a tropical lake rich in phytoplankton and surveys have shown that algal biomass increased as the Lake reduced in size (Compère & Iltis 1983). Over 1 000 species of algae have been described from the Lake (Thieme et al. In preparation).

Seasonal Yaéré grasslands grow on the southern lake shore where flooding is prolonged and water depth reaches 1 to 2 m. Vegetation consists of *Echinochloa pyramidalis, Vetiveria nigritana, Oryza longistaminata* and *Hyparrhenia rufa* (see Figure 18). The Yaéré dries up completely during the dry season. In areas with less prolonged

Figure 18 Sparse and short wetland vegetation (e.g. *Oryza longistaminata*) growing in open water. This type of vegetation can be found at the edges of the wetland. *(Photo: Verhoeye & De Wulf 2001)*

flooding, 'karal' or 'firki' woodland vegetation is present. *Acacia seyal* is the dominant species here, but is replaced by *A. nilotica nilotica* in depressions. Below the trees, a layer of tall herbs and coarse grasses grows to 2 to 3 m in height, including *Caperonia palustris*, *Echinochloa colona*, *Hibiscus asper*, *Hygrophila auriculata*, and *Schoenfeldia gracilis* (see review: Burgess et al. in press).

Historically, the most pronounced feature of the Lake Chad Basin has been its wetlands. Lake Chad itself is the second largest wetland in Africa, and with biodiversity of global significance (World Bank 2002b). There are extensive wetlands and floodplains along the Chari-Logone and Komadugu-Yobe and also around the lake area. In total an estimated surface area of 2.5 million ha of floodplains and wetlands of international significance have been recorded by the Ramsar Convention on Wetlands. The Hadejia-Nguru floodplain in northern Nigeria (Komadugu-Yobe River Basin) contains wetlands that cover a total area of about 6 000 km^2 (see review: Burgess et al. In press). Referred to as an inland delta, the floodplain has a maximum width of 65 km at the confluence of the two rivers, but then diminishes to a 5 km span that continues for several hundred kilometres. Many patches of higher, unflooded ground are mixed within the floodplain.

The major wetland plant communities present in the Lake Chad Basin can be assigned to three broad categories: 1) floating "sudd" communities; 2) permanent reed swamps; and 3) seasonal herbaceous swamps (edaphic grasslands) (Verhoeye & De Wulf 2001).

The term "sudd" is used to describe a floating vegetation mat along the fringes of permanent swamps. The floating islands of Lake Chad are typically formed by *Pycreus mundtii*, with several other plants of minor importance commonly encountered, such as *Echinochloa scabra*, *Ipomoea aquatica*, *Vossia cuspidata*. *Cyperus papyrus* is usually associated with this vegetation type. Permanent reed swamps usually occur in the transition zone between the floating "sudd" communities and the seasonal herbaceous swamps. They are typically dominated by a single reed species, such as *Phragmites*, *Typha* or *Cyperus* (particularly *C. papyrus*) (Verhoeye & De Wulf 2001).

The species composition of seasonal herbaceous swamps is very variable, since it is determined by factors such as rainfall, soil type and salinity, flooding depth and duration. Plant community borders are often indistinct because flood regimes vary from year to year. The most common sequence, from long and deep flooding to short and shallow inundation, is *Vossia*, *Oryza, Echinochloa and Hyparrhenia* (Verhoeye & De Wulf 2001).

The natural dry land vegetation consists of woodland savannah, but is now largely replaced by small-scale agriculture and grassy areas with thorny shrubs. Dependent upon local conditions, this degraded vegetation may vary from sparse and short to dense and tall grasses. Woody vegetation may likewise vary from small (less than 0.5 m) bushes to tall (more than 5 m) trees. Factors that appear to determine the condition of the vegetation are agricultural practice (cultivation of dry season millet), and distance from the nearest village (Verhoeye & De Wulf 2001).

Fauna: This ecoregion has highest biological importance for the large numbers of migrant birds, especially ducks and waders that spend the Palearctic winter period in Africa. Seventeen species of waterfowl and 49 other wetland bird species have been recorded, with varying abundance from year to year. The most abundant bird is the wader ruff (*Philomachus pugnax*), with more than one million seen on the Lake at one time (Keith & Plowes 1997). In the Hadejia-Nguru wetlands the most common waterbirds are white-faced whistling duck (*Dendrocygna viduata*), garganey (*Anas querquedula*), northern pintail (*Anas acuta*), and ruff (*Philomachus pugnax*) (see review: Burgess et al. In press).

Lake Chad also supports two near-endemic bird species, the river prinia (*Prinia fluviatilis*) and the somewhat more widespread rusty lark (*Mirafra rufa*). One other bird of note is the marbled teal (*Marmaronetta angustirostris*), which is occasionally seen on Lake Chad and in northern Chad; it is thought to be declining worldwide (see review: Burgess et al. In press).

Two near-endemic rodent species are found, *Mastomys verheyeni* and the Lake Chad gerbil (*Taterillus lacustris*). The wetlands of Lake Chad and the Hadejia-Nguru wetlands formerly supported herds of large mammals. Savannah species included red-fronted gazelle, dama gazelle, and dorcas gazelle (*Gazella rufifrons, G. dama, G. dorcas*), patas monkey (*Erythrocebus patas)*, striped hyena (*Hyaena hyaena*), cheetah (*Acinonyx jubatus*) and caracal (*Felis caracal*). Species more adapted to the wetland habitats included African Elephant (*Loxodonta africana*) two species of otter (*Lutra maculicollis*, *Aonyx capensis*), hippopotamus (*Hippopotamus amphibius*), sitatunga (*Tragelaphus spekei*) and kob (*Kobus kob*). Most of the large animals have now been hunted and replaced by large numbers of cattle. Nile crocodiles (*Crocodylus niloticus*) are now extremely rare and may have been wiped out (see review: Burgess et al. In press).

Large fish migrations correspond with seasonal inputs, the fish navigating to the rich floodplains to eat and to breed. Flooding brings high periphyton and zooplankton productivity to the floodplains, as well as increased macrophytic growth, creating ideal feeding and spawning habitat (Thieme et al. In preparation). An exceptionally rich fish fauna comes to capitalise on these resources; the inland waters of the Lake Chad Basin harbour a relatively high fish biodiversity and have at times had abundant quantities of fish. There are reported to be 140 species of fish, which can be grouped into 21 major genera or family groups (Neiland & Béné 2003). Migratory species that move to the floodplains include *Alestres baremose*, *A. dentex* and *Districhodus rostratus* (Thieme et al. In preparation). Aquatic vertebrate groups other than fish include the Batrachia, which are abundant in reed islands (Dejoux 1983).

The zooplankton community is particularly diverse, which may be due to the large size of the Lake and abundance of food. In periods of high water the Lake contained nine abundant species (Saint-Jean 1983). The majority of benthic fauna consists of three groups of macroinvertebrates, namely worms e.g. *Alluroides tanganykae*, molluscs e.g. *Melania tuberculata* and insects e.g. *Chironomus formosipennis*. There are no endemic benthic fauna (Lévêque et al. 1983). The major invertebrate groups are found in areas of abundant aquatic vegetation e.g. Chironomidae, Hemiptera and Ostracods (Dejoux 1983).

Northern Congolian Forest-Savannah Mosaic

Physical features: This ecoregion is a narrow transition zone marked by an abrupt habitat discontinuity between the extensive Congolian rainforests and Sudanian/Sahelian grasslands. It contains the northernmost savannah woodlands in Africa. The forest savannah mosaics with their characteristically diverse habitat complexes, support a high proportion of ecotonal habitats, which have high species richness and are possible loci of tropical differentiation and speciation. This ecoregion lies in the tropical savannah climate zone. Mean annual precipitation ranges locally from about 1 200 mm to 1 600 mm per year. This ecoregion experiences small seasonal temperature fluctuations, with rainy season mean daily maximum temperatures of 31 to 34°C and dry season mean daily minimum temperatures of 13 to 18°C. The Lake Chad Basin proportion of this ecoregion consists of western CAR, which is underlain by relatively new and unweathered entisols, and central Cameroon, which consists of a mixture of oxisols and ultisols, highly weathered soils that often contain a fragipan.

Flora: Vegetation common either to the Sudanian or Congolian provinces characterises much of the region. In the relatively arid corners in the northeast Cameroon and northwest portion of the ecoregion, the transitional *Isoberlinia* spp. dominated Sudanian woodlands and wooded savannahs characterise the flora where cultivation has not drastically altered the system.

Fauna: The savannah sub-species of elephant (*Loxodonta africana africana*) occupies the savannah woodlands where it denudes trees and suppresses sapling growth, effectively creating a more fire-prone system. The ecoregion provides a unique set of habitats and resources that supports moderate levels of diversity, including many species with broad distributions in tropical Africa. The red-flanked duiker (*Cephalophus rufilatis*) inhabits forest patches within the savannah matrix across the Guineo-Congolian/Sudanian transition zone. Widespread mammals in these savannah forest mosaics include the black rhinoceros (*Diceros bicornis longipes*) (now however restricted to a few individuals remaining in Cameroon), giant eland (*Taurotragus derbianus*) and in the eastern sector, bongo (*Tragelaphus eurycerus*).

Socio-economic characteristics

Over the centuries the people of this part of Central and West Africa have eked out a living through exploitation of land and its viable resources. Water bodies in the region have not only provided domestic services but have additionally provided access for the people to its aquatic resources such as fish. As droughts and expansion of the Sahel continued, so also has the southward migration mainly of people searching for fundamentals of survival for themselves and for their domesticated animals. The trend has not spared the natural resources from degradation through overexploitation. Drainage systems have been the centres of refuge and at the same time the victim of degradation (Le Barbé & Lebel 1997). Aspects of this nature transcends national borders and in themselves also promote inter ethnic, sectorial and national conflicts. Against this backdrop, it becomes clearer why human settlements are concentrated in the southern parts of the region and not the northern. It also explains why economic developments are centred in these densely settled areas.

The quality of socio-economic data is limited by the fact that data and socio-economic research is country specific rather than basin wide. Regional disparities within the countries must therefore be taken into account. For example Niamey, the capital of Niger, is outside of the Lake Chad Basin but clearly stands apart from other regions in Niger with a higher quality of living, where as Zinder (Niger) is located in the Lake Chad Basin and has the greatest deficit in terms of its peoples poverty and vulnerability, according to infant mortality and child malnutrition indicators (Government of Niger 2002).

Social and cultural aspects

According to Kindler et al. (1990), the Basin exhibits a socio-historical unity based on a history shared by the established population groups some of which straddle national boundaries. Many trading circuits remain controlled by the groups who have long considered them their specialty (e.g. the Hausa and Kanuri).

There are numerous ethnic groups present in the Lake Chad Basin, many of which are present in several countries; altogether, there are more than 70 ethnic groups, each exploiting the natural environment by a range of activities. The majority of the populations speak several local and an official language. The main languages used in the area reflect the political roles exercised during the pre-colonial period: Kanuri (Niger and Nigeria), Fulfulde (Niger, Nigeria, Cameroon), and Arabic (Chad). These include a very diverse range of ethno-linguistic groups; in Nigeria alone there are 394 linguistic units (Otite 1990). The French and English colonial powers have also imposed their languages, and legal and administrative systems, upon the traditional ones; customary laws, regulations, and structures still determine land use systems in large measure.

The old Islamicised states (Kanem, Borno, the Peul Empire of Sokoto, Wadai and Baguirmi) are largely responsible for the present distribution of populations in the Basin, including the small groups that took refuge in the Mandara Mountains and the Mayo Kebbi regions. The Western shore of Lake Chad, where the majority of the Basin's population resides, is under the jurisdiction of Borno (one of the 36 states of Federal Republic of Nigeria) and is dominated by the Kanuri ethnic group. Migration during the latter part of the millennium has brought Shuwa Arabs from the east and Fulani pastoralists from the west and recently during the 1970s Hausa families from across northern Nigeria who were attracted by fishing opportunities at the Lake (Neiland & Verinumbe 1990, Sarch 2001).

Most of the countries of the Lake Chad Basin have experienced considerable political instability and a history of domestic and international conflict since 1960 when they gained their independence from the colonial regimes of the United Kingdom and France. Nigeria has had 11 changes of government, military coups and a civil war, Chad has experienced almost continuous unrest and war, and only Cameroon has had a stable government (Neiland & Béné 2003). Outbreaks of armed clashes and rebel activity on islands in the Lake have persisted since the 1970s and are largely associated with the succession of civil wars in the Republic of Chad and the migration of Nigerian fishermen following the receding lake south eastwards. A multi-national 'Joint Patrol' was created in response to these outbreaks and has been monitoring the Lake to prevent further violence (Sarch 2001).

Population dynamics

Over the last two decades the annual population growth in the region has ranged between 2.5 and 3.0% (World Bank 2002c). The current population within the region is estimated to be approximately 37.2 million people (based on ORNL 2003). The total population has increased by about 11.7 million since 1990 (population estimates for 1990 was 25.5 million people (UNEP 1999). Figure 19 shows how the Basin's population is unevenly distributed between the countries. Nigeria, Africa's most populous country hosts an estimated 22 million people (about 59%) of the total population living in the region. Whereas the northern and eastern peripheral countries, Algeria, Libya and Sudan, only have approximately 2.7 million inhabitants in the Basin (about 7%), as it only represents just over 6% of the land area of the Basin (EROS Data Center 2002). Population densities are greatest in Nigeria and surrounding Lake Chad and decreases in the more arid northern provinces. For example in the Tibesti Highlands the people are primarily nomadic pastoralists, and population densities are as low

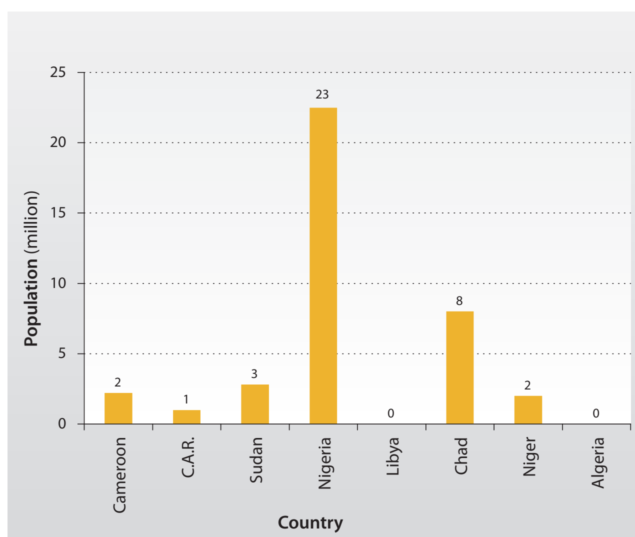


Figure 19 Estimated population in Lake Chad Basin (2002).
(Source: Based on ORNL 2003)

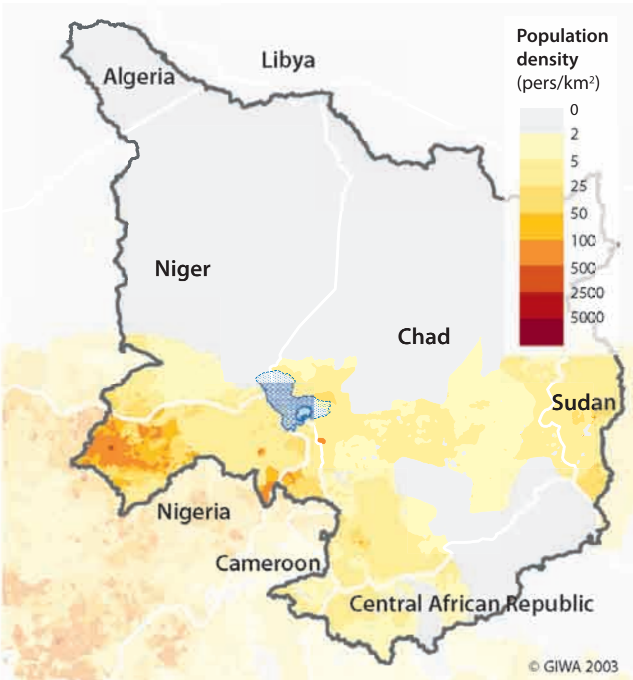


Figure 20 Population density.
(Source: Data from ORNL 2003)

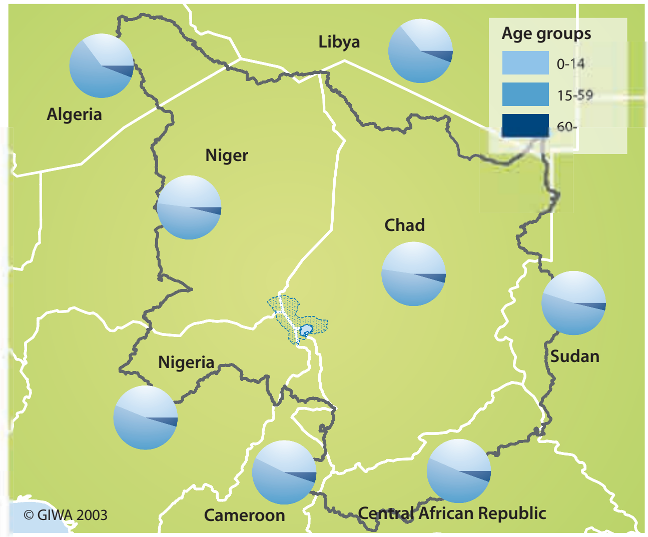


Figure 21 Population structure in the Lake Chad region.
(Source: ESRI 2000)

as 0-1 people/km^2. Figure 20 shows the population density distribution in the region. The region is also experiencing rapid urbanisation, as destitute rural communities search for an improved standard of living in the swelling southern cities such as Kano (Nigeria), Maiduguri (Nigeria) and N'Djamena (Chad). In Cameroon the population of the northern city of Garoua has more than doubled from 122 600 to 287 000 between 1987 and 2003 (World Gazetteer 2003).

Population structure

The Basin's population is characterised by a young age structure, particularly in the southern riparian countries. In Niger for example nearly 50% of the population is under 15 and only 2% is over 65 (World Bank 2002c). The riparian countries of Sudan, Libya and Algeria, located on the periphery of the northern, northwest and northeast borders of the Basin have a larger proportion of over 65 year olds and their population structure is less skewed towards the young. Figure 21 shows the population age structures for the countries of the Basin.

The Basin's population is also predominately rural. In Chad (46% of the Basin's surface area) approximately 80% of the population is rural (IMF 2003).

Economic activities

In the Lake Chad Basin production activities are dominated by the primary sector and tertiary sectors in which technical progress is slow, with a predominance of informal, low productivity activities. In Chad and Niger those working in the primary sector head the poorest households because they make up 78% and 80% respectively of the population but account for only 39% of the GDP (World Bank 2002c, IMF 2003). The primary sector employs more than 80% of the population and comprises primarily of agriculture and livestock rearing (Government of Niger 2002). Table 2 shows the regions sources of income.

Table 2 The region's household sources of income.

Activity	million USD (billion CFA *)
Fishing	45.1 (26.3)
Rain-fed and flood recessional cropping	26.6 (15.5)
Animal husbandry	14.7 (8.6)
Small irrigated areas	10.8 (6.3)
Large irrigated areas	9.4 (5.5)

** CFA=Franc de la Communauté financière africaine.*
(Source: Nami 2002)

The economic activities in the Basin include:

- Mining: e.g. Gold mining in Central African Republic.
- Oil: Exploration and exploitation.
- Agriculture: Cotton, groundnuts, cassava, millet, sorghum, rice, onions. Mixed cropping is widely practiced.
- Fisheries: In dams, rivers, floodplains and the Lake Chad.
- Manufacturing: Cotton ginning, brewing, leather industry, machinery, milling and food industry.

Generally, the Lake Chad region is relatively less industrialised, however the commencement of oil exploitation in southern Chad may trigger industrial development. The number and sizes of industries also differ per country, but generally, there are few industries compared for example with the rest of West Africa. Agro-industries, textiles and tanneries dominate, whereas heavy industries are relatively few (World Bank 2002b). The majority of industry is focused in the urban areas that are disproportionately distributed with the highest concentrations in northern Nigeria and Cameroon, whilst the lowest are in Chad, CAR and Niger.

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 gold mining development in the 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 1 070 km 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 2 billion 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 2003b).

Agriculture

Agriculture is the main activity in 60 % of the administrative units of the Lake Chad Basin. The most commonly grown crops are cotton, groundnuts, cassava, millet, sorghum, rice and onions. Most farming in the Basin is rain-fed, cultivated and harvested by hand, and grown without the use of fertilisers and other agro-chemicals. Mixed cropping is widely practiced and rice is grown by both traditional and modern methods. Cotton is the most important cash crop in the region and is grown in southern Chad, northern Cameroon and Nigeria. Flood recession cropping is a major production system in the Lake Chad Basin (Box 2). Sorghum and berbere are the principal crops produced under this system.

Box 2 Resources available to the Lake Chad Basin's population.

Lake Chad
The Lake is very important to the communities living in the region. It serves as the political barrier between the neighbouring countries of Cameroon, Chad, Niger and Nigeria. It is an important source of potable water (AEO 2002) in a drought prone region and is a source of employment for a variety of professions. Its fisheries resource is particularly significant to the rural populations. The seasonal fluctuations provide excellent feeding grounds for fish through the exposing and submerging of the lake shore (Neiland & Béné 2003). Fish is a major source of protein for the region particularly for the land-locked countries of Chad and Niger. The recessional lake waters also provide very fertile agricultural and pasture land which has been capitalised upon during recent lake retreats. Fertility is then restored during periods of lake expansion. A significant amount of water is stored beneath Lake Chad and is very important for the recharge of the groundwater system (Isiorho et al. 1996), which may be available for future use (Isiorho et al. 2000). The Kanem Lakes (northeast of Lake Chad) contain the blue-green algae *Arthrospira*, which is sun-dried by the local Kanembu tribe to make the cake Dihé.

Rivers and floodplains/wetlands
The floodplains support a significant proportion of the Basin's population. They provide essential income and nutrition benefits in the form of agriculture, grazing lands, non-timber products, fuel wood, drought fall back security, tourism potential and fishing. Ramsar estimated the economic value of the wetlands to be 34 to 51 USD per ha (Barbier et al. 1997), the total economic value of the Hadejia-Nguru wetlands (Nigeria) is estimated to be 15.9 million USD (Schuijt 2002). The table shows the economic values of wetland goods and services in the Hadejia-Nguru wetlands. Like the communities surrounding the Lake Chad, fishing is also a fundamental activity of the floodplains and is practised within a strongly seasonal and flexible matrix of various activities.

Economic values of the Hadejia-Nguru wetlands, valued using market pricing.

Wetland goods or services	Economic value per year (converted to 2002 million USD)
Agriculture	10.7
Fishing	3.5
Fuel wood	1.6
Doum palm	0.1
Potash	<0.1
Total economic value	15.9

(Source: Schuijt 2002)

Mineral resources
The Lake Chad Basin is very rich in mineral resources although mining activity is poorly developed. Mineral resources contained within the Lake Chad Basin include kaolin, natron (soda ash), gravel, diamond, gold and petroleum.

Land and soil resources
Tectonic activity and the fluctuating lake levels over geological time have resulted in the Lake Chad Basin having exceptionally diverse soils and landforms. There are three types of lakes and over 15 landforms ranging from fossil valleys and wadis to active and relict wadis. There is a diverse range of soils numbering over 20. Farmers utilise a variety of soils with different water capacity (dry, drought, wet, very wet) holding properties that allow farmers to ensure some crop production in all types of year. These soils can be found within 10 m of each other and act as a famine prevention technique (LCBC 1992). In general, soil water limits production throughout the Basin. In wet years or, in the southern basin regions, when water is more abundant, nitrogen becomes the limiting factor.

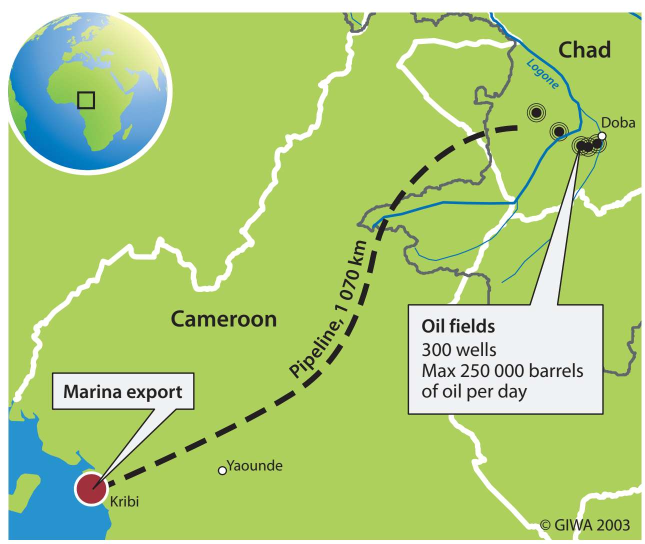


Figure 22 Doba oil field (Chad) and Cameroon pipeline.
(Source: World Bank 2003b)

Farmers are sedentary and the pressure that they put on the quality of the soil grows as their numbers grow (Nami 2002). In Niger, recurrent grain shortages (2 out of 3 years) despite increased overall agricultural production in the last 10 years (1990-1999) and strong demographic growth, has resulted in food production trailing behind actual consumption needs. This has led to food dependence, especially in rural areas, and frequent appeals to foreign aid in emergencies or when facing famine (Government of Niger 2002).

In the 1970s, the irrigated agriculture was seen as a solution to food insecurity in the region and was given priority funding. But the agricultural projects did not yield the results expected, at a time when member States saw it as the appropriate solution to increase agricultural production and improve food security for the people (Nami 2002). However, in Chad irrigated rice accounts for only 4% of national cereal production whereas traditional rice farming accounts for 75%. Figure 23 shows the distribution of irrigation areas, that are mostly located in Nigeria. The reason for growing rice is that it constitutes a cash crop, whereas the market for sorghum is limited (King 1993). However, there are high technical and financial inputs required for the irrigation schemes and net revenues are reported as being negative (King 1993). Furthermore, freshwater shortages have prevented the schemes from functioning. In contrast, traditional flood-recession farming has low inputs, and the scale of outputs compared with other systems has demonstrated the importance of this farming sector (King 1993).

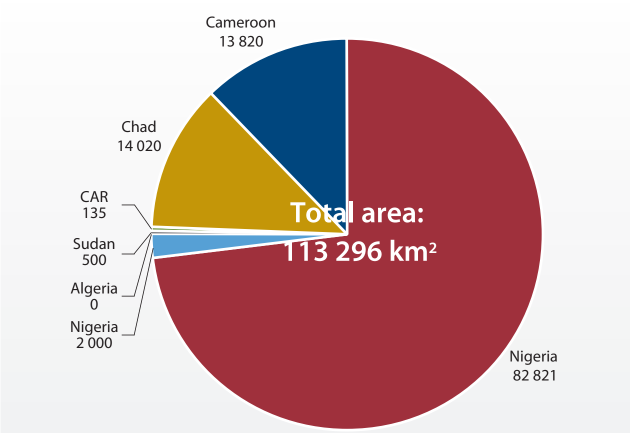


Figure 23 Distribution of irrigated areas.
(Source: FAO 1997)

Animal husbandry

This is an economic activity also very important in the region, particularly for the migrant cattle herders, who undertake large seasonal transhumant migrations. The meat from livestock makes a major contribution to the dietary needs of the population (King 1993). In Chad, 83% of the working population is engaged in the production of crops and livestock, primarily for domestic consumption. Only 25% of Chad's land is cultivated, but about 50% is grazed (Stuart & Adams 1990 in Keith & Plowes 1997). Borno state in Nigeria is the largest livestock centre in West Africa (Everything Nigeria 2002). Figure 24 shows typical Zebru cattle that have been sold to the slaughter house for production of dried meat. Cattle exports mainly to Nigeria are very important to the Chad and Cameroonian economies (King 1993).

Figure 24 Typical Zebru cattle that have been sold to slaughter-house for production of dried meat.
(Photo: FAO R. Faidutti 1987)

Fisheries of the Lake Chad Basin

The inland fisheries of the Lake Chad Basin, and in particular Lake Chad are among the largest and most productive in the whole of Africa. It is estimated that from 1969 to present, an estimated 1.7 million tonnes of fish have been landed, resulting almost entirely from skilled, native fishing operations using relatively unsophisticated techniques (mainly gill nets or longlines from canoes) (Stauch 1977, Durand 1980, Sagua 1986 in Neiland & Béné 2003).

The fishing activities within the Lake Chad Basin are a fundamental element of the livelihoods of over 10 million people living in and around the basin area (Box 2). The system creates a new set of aquatic environments each year, which dictate the local farming and herding production systems. The sustainability of these systems is a key factor of the economic and social stability of the region. Fish from the Lake Chad Basin is traded within all riparian countries and makes an important contribution to the food security of urban centres (Neiland & Béné 2003).

Current research suggests that fish demand is evidently attractive enough to encourage large numbers of fishers (full and part-time), estimated to be more than 170 000, and that the combined trade of riparian countries is worth upwards of 23.5 million USD per year (Neiland & Béné 2003).

Eight different types of fishing grounds are exploited across the Lake Chad Basin. Seasonal ponds and receding channels are the most common type of water bodies used, followed by rivers (Logone and Chari), the open waters of the Lake and the permanent ponds and oxbows. A comparison between areas shows that the Yaéré floodplains offers the largest diversity of exploitable water bodies, followed by the Chari delta and the western shores of the Lake (Neiland & Béné 2003).

The fisheries is largely dictated by the intra-annual flood regime of the Chari-Logone and Komadugu-Yobe sub-systems. Flooding influences the extent of the Lake Chad and its fringing floodplains, as well as the river floodplains. Fish move into the floodplains to feed and to breed, and then retreat with the floods to the main channels and open lake, along well-defined channels and outlets. The seasonal fluctuations in Lake Chad's water level provides excellent feeding grounds for fish through the exposing and submerging of the lake shore. The flooding regime represents an important natural asset, which most households at Lake Chad exploit in one way or another. As the flood peaks and begins to subside, fishers have the option to either fish the area of open water remaining at the centre of the Lake or to fish the pools and channels of residual flood water which remain around the villages (Sarch 2001). Considerable intra- and inter-annual variation in the flooding of the lake shore means that the supply, i.e. the timing, location and amount of resources such as fishing grounds is important determinant of both the productivity of these resources and which groups are able to access them at a given point in time (Sarch 2001). The main fishing season is from October until March (i.e. from the end of the rainy season until halfway into the dry season) while there is a secondary peak in fishing activity at the very end of the dry season when the open water bodies are at their smallest in size and fish are easily caught.

There are six key livelihood groups associated with the fisheries, namely: fishers, fish mongers/processors, fish wholesalers, fish retailers, fish gear dealers and boat builders. A total of 20 different types of fishing gear are used in the Basin (Neiland & Béné 2003). Apart from the seine net (taurow) which is owned almost exclusively by the richer families but operate collectively, all wealth groups, disregarding the area, use the same set of traditional fishing gears, i.e. essentially gill nets, traps (Mali traps or goura), hook-lines, cane trap *(*ndurutu), cast nets, and dip nets (sakama). The diversity and number of each fishing gear used by households declines with poverty. Investments in fishing inputs such as new fishing gears can generate instantaneous surplus, in contrast to farming activities where several months would have to pass before eventual benefits might be returned from the investment (Béné & Neiland 2003).

Figure 25 *Alestes baremoze* (Silversides).
(Drawing: Robbie Cada)

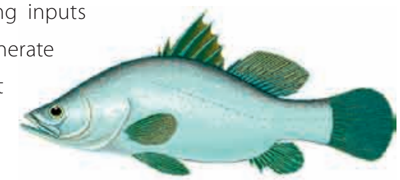


Figure 26 *Lates niloticus* (Nile perch).
(Drawing: Robbie Cada)

The inland waters of the Lake Chad Basin harbour a relatively high fish biodiversity and have at times had abundant quantities of fish. Common fish market species include *Alestes baremoze* (Silversides), *Clarias* (catfish), *Tilapiine cichlids*, *Petrochephalus* and the *Lates niloticus* (Nile perch) (Béné & Neiland 2003). Figure 25 and 26 show the *Alestes baremoze* and *Lates niloticus* respectively.

There have been 21 species of fish identified from Lake Chad that migrate 100 to 150 km up the El Beid and Chari-Logone rivers to the Logomatia marshes to spawn (Bénech & Quensière 1989). Several species, such as *Alestes baremoze*, are known to migrate for breeding over distances up to 650 km from the Lake Chad into the Chari-Logone River as far as Cameroon (Durand 1978).

Fisheries production for the year 2001 in the Lake Chad Basin was estimated at 68 784 tonnes (wet weight) (Jolley et al. 2002 in Neiland & Béné 2003). Fish are an important part of the diet of most people in the Lake Chad Basin, providing an essential supply of protein. The commercial trade of fish originating from the Lake Chad Basin is also very important in the whole of West Africa (Neiland & Béné 2003).

The largest fish market in the Lake Chad Basin is Baga-Kawa in Nigeria, near the lake shore, followed by the much smaller markets of Kinassaram and N´Djamena in Chad and Maroua in Cameroon. The majority of all

Table 3 Market characteristics of fish passing through the three main markets of Lake Chad Basin, June 2000 to May 2001.

Country market	Total volume (tonnes/dry weight) (wet weight conversion factor 4.5)	Total wholesale price		Unit price per kg of fish products (USD)
		Local currency (million)	USD (million)	
Nigeria (Baga Kawa)	10 876 (48 942)	2 487 (NGN)	20.8	0.52
Chad (Kinasserom)	343 (1 546)	551 (XAF)	0.8	0.45
Cameroon (Maroua)	1 518 (6 831)	1 402 (XAF)	1.9	0.79
Total	12 737 (57 319)	-	23.5	0.54

(Source: Neiland & Béné 2003)

Lake Chad Basin fish regardless of country or origin is directed into Nigeria, although some fish is retained and traded locally within the Lake Chad Basin. Table 3 shows the market characteristics of fish passing through the three main markets.

Economic growth

The countries within the region are among the poorest countries in the world. Chad was ranked 155th out of 162 countries on the United Nations' 2001 Human Development Index (HDI), with an annual per capita income of only 200 USD. The Gross National Incomes (GNI) of the countries are extremely low with the exception being Algeria (no data for Libya). Out of 206 countries ranked by the World Bank in terms of GNI per capita; Chad, Niger, CAR and Nigeria are amongst the 23 poorest countries in the world (World Bank 2002c). Figure 27 shows the disparities in GNI between the riparian countries.

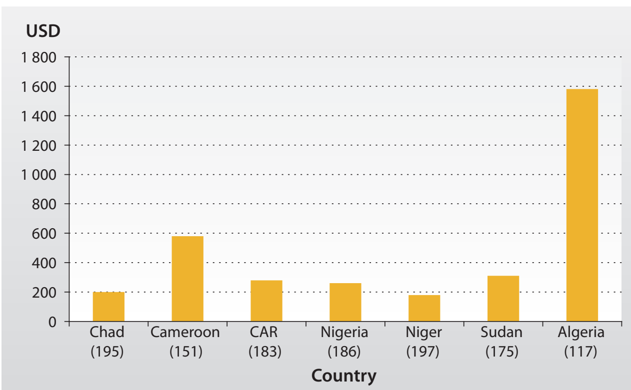


Figure 27 Gross National Income per capita of riparian countries.
Note: No data for Libya. Within parenthesis: GNI ranking by the World Bank.
(Source: World Bank 2002c)

Economic growth is very slow and variable in the region. Overall in the 1980s and 1990s, Chad and Niger's economies are characterised by a practically stagnant standard of living for the populations, with GDP growing in Chad by barely 1.4% per year over 20 years (IMF 2003) and in Niger by 1.9% per year over the decade 1990 to 2000 (Government of Niger 2002). In CAR and Sudan growth rates have declined steadily since 1997. The low growth rates of the Basin's economies are considered as being insufficient to sustain long-term reductions in poverty and bring improvements in the standards of living in the region. In Nigeria, despite vast oil reserves, GDP growth averaged 1.6% between 1980 and 1990, 2.4% between 1990 and 1998, but just 1% in 1999 (Narayan & Petesch 2002).

The economies of the Basin's countries generally suffer from a very low productivity, insufficient infrastructure, poor governance, a lack of a dynamic private sector, an oversized informal sector and a vulnerability to domestic and external shocks. In Sudan and Chad economic progress has also been inhibited by the series of civil war and associated military expenditures, infrastructure deterioration and discouragement of foreign aid and investment (World Bank 2001). The AIDS pandemic has directly impaired economic growth because it mainly affects the economically active population. In Chad, 56% of detected cases are in the 14-49 year old population (IMF 2003).

Poverty

The Lake Chad region is trying to cope with mass poverty. Figure 28 shows how an especially high proportion of the Basin's country populations falls below both the 1 USD and 2 USD international poverty line. The World Development Indicators (World Bank 2002c) does not have data regarding the percentage of Chad's population that is under the international poverty line, and data that is available appears to underestimate the pervasiveness of the problem. The percentage of poor households in the region is likely to be 60% or more (IMF 2003). Nigeria's poverty has steadily grown worse since the 1980s and according to World Bank Development Indicators (World Bank 2002c) in 1997, 90.8% of the population was below the 2 USD per day international poverty line. Based on the poverty line set by the Poverty Profile for Niger prepared in 1994, 63% of the population is poor, and 34% is extremely poor. The extent of poverty in Algeria is not as severe as in the southern region's of the Basin but in recent decades due to economic stagnation the percentage of the population under the poverty line has increased from around 8% to 14% (World Bank 1999).

The burden of poverty is spread unevenly across regional and socio-economic groups.

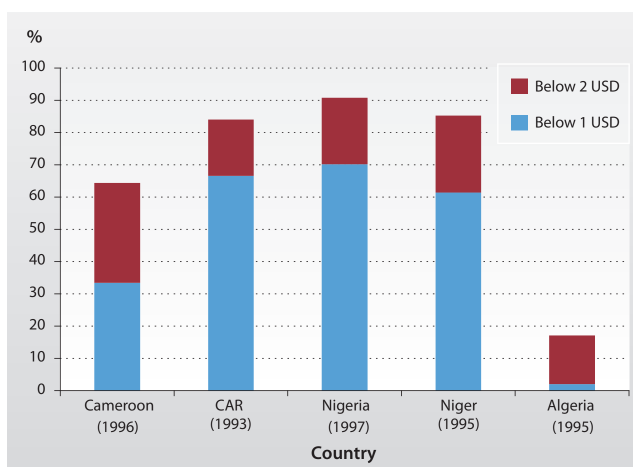


Figure 28 Population below international poverty line.
Note: No data for Chad, Libya and Sudan.
(Source: World Bank 2002c)

Regional inequalities within countries

The severity of poverty in the actual basin is hidden by national figures, as it is often severest in the sector of the country lying within the Lake Chad Basin boundaries. For example, a survey in 1996 estimated 67 million people in Nigeria to be affected by poverty of which the northern region which lies in the Lake Chad Basin accounts for the largest share (40%) of the country's poor people (World Bank 2002c). In Cameroon the situation is similar; in northern and extreme provinces, located in the Lake Chad Basin, there is a particularly significant number of people living in extreme poverty as compared with the rest of the country (World Bank 1999). Surveys have indicated that the poorest segment of the Yaéré floodplains (north Cameroon) is not food self-sufficient (Béné et al. 2000).

Rural-urban inequalities

Poverty is generally more acute and widespread in rural areas. In Niger, 86% of poor people (36% of whom are considered extremely poor) live in the countryside (Government of Niger 2002). In Chad, in both percentage and absolute terms, the problem is also worse in rural areas, since the population of Chad is largely rural (approximately 80%) (IMF 2003). In Algeria 70% of the poor lived in rural areas in 1995 but the share of urban poor is increasing (World Bank 1999).

Gender

Single women and widows are identified as among the most vulnerable and impoverished groups and poverty is more severe in female-headed families than in male-headed families. For example, in Chad households headed by a woman are more prone to poverty than those in which the head of household is a man (54% and 34% respectively). This is partly explained by the fact that most women heads of household are widows or divorcees with dependent children and scant resources (IMF 2003).

Vulnerable groups

Certain socio-economic groups that are at high risk are above all, women and children needing special protection, the disabled, demobilised military personnel, senior citizens, and persons living with HIV (IMF 2003).

Health

Standards of health in the region are overall very poor. However there is a great disparity between the northern countries of Algeria and Libya, which have far higher standards of health than the sub-Saharan nations. Niger, Chad and CAR have the lowest standards of health. The health of the rural populations is inferior to that of the urban populations and it is often the case that these areas of the country are located in the Lake Chad Basin. For example in Niger, child malnutrition is most severe in the regions of Diffa and Zinder contained in the Lake Chad Basin as well as Maradi (Government of Niger 2002). Table 4 shows national statistics for health.

Life expectancy

In Algeria and Libya life expectancy at birth is 71 years and is comparable to the Europe EMU life expectancy of 74 years. However, the life expectancy of the rest and majority of the region reveals a dismal situation, ranging from only 43 in CAR to 56 years in Sudan (World Bank 2002c).

Mortality

Infant mortality is very common in the region. In particular infant mortality in Chad, Niger and CAR is higher than the sub-Saharan average with over 9% of children dying before the age of one. In Niger one out of four children die before their fifth birthday and the country has one of the highest maternal death rates in the world (700 deaths per 100 000 live births) (Government of Niger 2002).

Table 4 Health and education indicators.

Health and education indicators		Chad	CAR	Cameroon	Nigeria	Niger	Sudan	Libya	Algeria	sub-Saharan Africa
Life expectancy (2000)		48	43	50	47	46	56	71	71	47
Infant mortality per 1 000 live births (2000)		101	96	76	84	114	81	26	33	91
Prevalence of under nourishment, % of pop (1996-1998)		38	41	19	8	46	18	ND	5	33
Incidence of tuberculosis per 100 000 people		270	415	335	301	252	195	24	45	339
Physicians per 1 000 people (1990-1999)		<0.05	<0.05	0.1	0.2	<0.05	0.1	1.3	1.0	0.1
Health care expenditure, % of GDP		2.9	3	5	2.8	2.6	3.3	ND	3.6	4.9
Adult illiteracy, % ages 15 and over (2000)	Male	48	40	18	28	76	31	9	24	30
	Female	66	65	31	44	92	54	32	43	47
Gross primary enrolment, % of school-age group (1998)		67	57	90	ND	31	56	153	109	78

Note: ND = No Data.

(Source: World Bank 2002c)

Malnutrition

Excluding Algeria where undernourishment is minimal and Libya (no data), in the rest of the countries of the region, 28% of the population are undernourished. In Cameroon vulnerability to malnutrition is greatest in the northwest and northern provinces that are located in the Lake Chad Basin. Acute malnutrition is experienced by 8% of the people living in these predominantly rural provinces (Amin & Dubois 1999). In Niger, 43% of children under five suffer from malnutrition. The nutritional status in Niger has also been deteriorating; the percentage of children exhibiting stunted growth has risen from 32% in 1992 to 40% in 2000 and is most severe in the regions of Diffa and Zinder located in the Lake Chad Basin (Government of Niger 2002). However, in Nigeria despite there being a low life expectancy (47 years), 92% of the population have sufficient nourishment (World Bank 2002c).

Diseases

Diseases are widespread across the region. The high child mortality can in part be attributable to several diseases, including malaria, various forms of diarrhoea, acute respiratory infections, measles, tetanus, yellow fever, diphtheria and chicken pox (Government of Niger 2002). Tuberculosis incidence in 1999 was greatest in CAR and Cameroon (415 and 335 per 100 000 people). However, vaccination coverage is low (15% in Niger). The highest infant mortality rates are in the region where vaccination coverage is lowest, in Niger this is Zinder (on the fringes of the Lake Chad Basin) and Maradi (Government of Niger 2002). The prevalence rate of the AIDS pandemic continues to increase in the Lake Chad Basin countries. In Chad the number of confirmed cases of AIDS has grown from 10 in 1989 to 1 010 in 1993, to 1 343 in 1996 to over 12 000 cases in 2000 (IMF 2003) and the zero prevalence rate is now between 5 and 10% among adults. In Niger, this rate is over 5% among adults, whereas in Nigeria, Cameroon and CAR the epidemic is from 5% to 14% of zero prevalence among adults (UNAIDS 2001). The AIDS pandemic is far less severe in Algeria, Libya and Sudan. Schistosomiasis (Bilharziasis) is endemic in the Basin and is particularly focused in the Chari-Logone and Komadugu-Yobe river basins and tributaries. Malaria transmission is very high in the region due to the intensity of African mosquito vectors of malaria (ESSO 1999).

Healthcare facilities

The health facilities available to the Basin's population are very poor. The average percentage of GNP spent in the sub-Saharan region is 4.9%; except for Cameroon, all of the Basin's countries spend a smaller percentage of their GNP than this average (World Bank 2002c). In Niger between 1994 and 2000, on average, the government earmarked only 6% of its budget for health, far below the 10% recommended by the WHO (Government of Niger 2002). In Niger, Chad and CAR there is only one physician for more than 20 000 people and only in Algeria and Libya is there one or more physicians per 1 000 people. Nigeria, despite rapid population growth, has doubled the number of physicians it has per 20 000 people from two in 1980 to four in 2000 (World Bank 2002c). In Chad, very few (less than 5%) women from poor households give birth at a health centre primarily due to a shortage of such facilities but also because of the cost of services (IMF 2003).

Education

Illiteracy is a hindrance to development in the region and remains particularly high in Chad, Niger, CAR and Sudan. Niger's primary school enrolment rate is very low (31%) and the literacy rate is the lowest in the world (Table 4). There is a sharp disparity between girls and boys. In Niger, less than one fifth of girls attend school and 92% of females were illiterate in 2000. In CAR net enrolment of girls dropped from 50% in 1995 to 37% in 1998 (Government of CAR 2000). The greatest proportional inequality is found in Libya where only 9% of men are illiterate compared to 32% of women (World Bank 2002c). On a regional scale the Sudan sector of the Lake Chad Basin consists primarily of the region of West Darfur, where literacy in 1993 for the male population stood at 68.4% but for women only 20.2% (World Bank 2003).

Factors that discourage enrolment are the long distances to school, low quality of education, and a low probability of being hired in the modern sector. The children who do attend school have to cope with very little resources. In some of the countries, standards of education are falling. In CAR for example from 1995 to 1998, the net primary enrolment rate fell from 60% to 44% (Government of CAR 2000). However, despite continued economic hardship, in some countries improvements have been made. Nigeria for example has experienced a decline in economic living standards yet illiteracy rates have fallen by almost 30% for both males and females between 1990 and 2000 (World Bank 2002c).

Being poorly educated, many communities are therefore unable to liaise or negotiate effectively with local administrations, central government, NGOs and donors. Another consequence is that farmer organisations, cooperatives, and professional associations are very weak.

Water supply and use

Water uses in the Lake Chad Basin include domestic, industrial, agricultural (flood cropping and small-scale irrigation), large irrigation projects (e.g. Kano River Irrigation Project), livestock, fisheries and ecological. The majority of freshwater consumed in the region is used for agriculture followed by domestic use. The unindustrialised nature of the region results in very little water being used for industrial

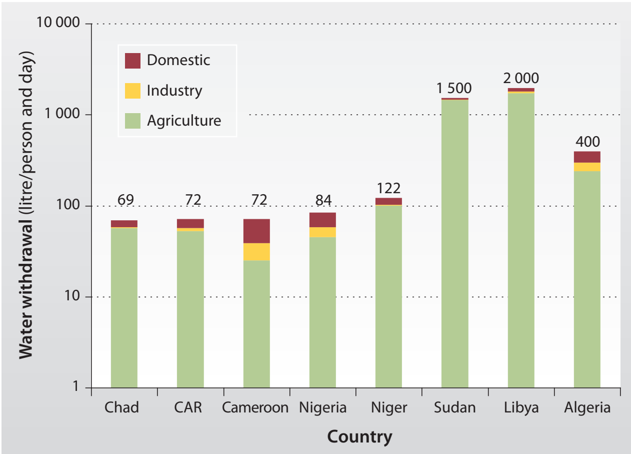


Figure 29 Freshwater withdrawal per person per day by economic sector.
(Source: World Bank 2002c)

processes. In Africa, Nigeria is the sixth largest user of water by volume (4 billion m^3 year) (Revenga & Cassar 2002). Figure 29 shows the percentage water consumption by sector.

Water for domestic use is mainly obtained using traditional methods. In the Sudan sector of the Basin (West Darfur) over 50 % of water is obtained from dug wells with bucket collection (World Bank 2003a). Women have to travel great distances in order to gather water for drinking, cooking and other everyday activities. The Tiga and Challawa Gorge dams through the Kano City Water Supply (KCWS) supply the large Nigerian urban centre of Kano City for domestic and industrial purposes.

Access to safe drinking water in the Basin is very limited. The percentage of people living in rural areas with access to an improved source of water in 2000 ranges from 26% in Chad to 56 % in Niger, excluding Algeria Libya and Sudan (access is above 68%) (World Bank 2002c). In the Niger sector of the Lake Chad Basin (Agadez, Diffa and Zinder Departments), modern water points only cover 53 % of the population's needs. Water shortages are a regular occurrence in this sector of Niger, because of lack of available supplies and the condition of infrastructure (Government of Niger 2002).

Traditional agriculture in the Basin is predominantly rain-fed. The rivers in the Chari-Logone and Komadugu-Yobe sub-systems support flood farming and recessional farming. Farmers in downstream areas therefore depend largely on river flow because rainfall is low and variable. The many large irrigation projects are located predominantly in the Komadugu-Yobe Basin.

Sanitation

Sanitary conditions for rural dwellers are particularly poor with severely limited waste disposal facilities. For example in Niger, the rural sanitation rate was barely 5% in 1996 and has been steadily declining, with the development of disease vectors in swamps and irrigation facilities and the deterioration of drinking water quality as a result of improper transportation and conservation (Government of Niger 2002).

In Chad no town has a functioning wastewater treatment system and collection networks are dilapidated. Less than 2% of the inhabitants of towns and cities have lavatories with running water while lavatories are practically nonexistent in rural areas. As a result, the poor are frequently exposed to chronic diseases related to poor living conditions and lack of access to water and sanitation. Moreover, water-related chores (which take up to four to five hours a day in certain areas) may, among other things, shorten the time spent on more productive and fulfilling activities (IMF 2003). In the Sudan sector of the Basin (West Darfur), over 50% of the population do not have access to any type of toilet facility, and 42% use a traditional pit. There are no sewage systems (World Bank 2003).

Infrastructure related to water

In the last 40 years there has been considerable development of dam infrastructure in the region which have impounded a large proportion of the Lake Chad Basin's water resources. In northern Cameroon, the 30 km earthen Maga Dam was constructed on the upper part of the Waza-Logone floodplain in 1979 to provide water for the SEMRY irrigated rice scheme and for fish farming (LCBC 1998). The Lake Chad supplied freshwater to Nigeria's South Chad Irrigation Project (SCIP), which had a goal of irrigating 67 000 ha of cultivated land, and Baga Polder Project, which had a goal of 20 000 ha. However, by 1996 only 2 200 ha and 1 000 ha were under irrigation respectively and presently they are both not functioning. The Kano River Irrigation project (KRIP), fed by the Tiga Dam (Komadugu-Yobe) was completed in 1974, water is also released from the dam to supply Kano City (northern Nigeria). The Challawa Gorge Dam on the Challawa River (Komadugu-Yobe sub-system) was constructed in 1992 to supply water for the Hadejia Valley Irrigation Project and to provide water for Kano City. Work on the Kafin Zaki Dam on the Jama'are River has been stopped and started many times, and its future is presently unclear. Table 5 shows technical details of the major dams in the Lake Chad Basin. Figure 46 shows a map depicting Lake Maga in the Chari-Logone sub-system and Figure 49 shows those dams located in the Komadugu-Yobe sub-system. The Alau Dam (162 million m^3 reservoir) is located on the Ngadda River system and supplies the city of Maiduguri (Nigeria) to the southeast with 72 million m^3 of water. The irrigation component consisted of 22 km

Table 5 Technical details on major dams in the Lake Chad Basin.

Details of major dams and reservoirs		Tiga Dam 1974-1991	Tiga Dam 1992	Challawa Gorge Dam 1992	Maga Dam
Storage capacity (million m^3)		1 989	1 429	972	680
Active capacity (million m^3)		1 843	1 283	904	ND
Dead storage (million m^3)		ND	146	68	280
Maximum release capacity (m^3/s)		ND	25[1] / 60[2]	86	50
Catchment area (km^2)		ND	6 641	3 859	6 000
Average annual evaporation (m)		ND	2.14	2.31	ND
Average (1964-1985) annual inflow (million m^3)		ND	914	476	ND
Surface area (km^2)	At 100% storage	180	145	100	400
	At 75% storage	ND	117	80	ND
	At 50% storage	ND	85	60	ND
	At 25% storage	ND	52	35	ND
Annual evaporation losses (million m^3)	At 100% storage	385	310	231	ND
	At 75% storage	ND	250	185	ND
	At 50% storage	ND	182	139	ND
	At 25% storage	ND	111	81	ND
Evaporation losses/ average inflow (%)	At 100% storage	42	34	49	ND
	At 75% storage	ND	27	39	ND

Note: ND=No data. [1]Actual maximum capacity of the canal valve is 35 m^3/s. [2]Kano River release gate not provided with control valve and therefore blocked; two smaller release gates not included.

(Source: IUCN 1998, Attewill & Lawerence 2002)

of conveyance canal from Alau Dam to Jere Bowl for development of 2 000 ha of rice cultivation. However this scheme was not completed.

Institutional arrangements - The Lake Chad Basin Commission

The Lake Chad Basin Commission (LCBC), an Inter Governmental Agency was established by the Fort Lamy (now N'Djamena) Convention and Statutes on May 22 1964 by the heads of four countries that share the Lake. This Old Conventional Basin did not include the Central African Republic and excluded the large desert expanses of Algeria, northern Niger, northern Chad and Sudan and, in particular, excluded the upstream part of the active basins of the Chari-Logone and Komadugu-Yobe. In March 1994, Central African Republic was admitted as the fifth member State during the 8th Summit of Heads of State (held in Abuja, Nigeria) leading to the New Conventional Basin thus increasing the conventional area to approximately 987 000 km^2. This has enlarged the conventional basin to include the upper basins of the Chari-Logone and Komadugu-Yobe systems. The New Conventional Basin includes five countries; Chad, Nigeria, Cameroon, Central African Republic and Niger. Sudan was admitted into LCBC in June 2000, but is yet to ratify the Convention establishing the Commission, a necessary precondition for partaking in the activities of LCBC. The admission of Sudan has now increased the conventional area from 427 000 km^2 in 1964 to 1 035 000 km^2 in 2000. This new definition of the conventional Lake Chad Basin thus takes into account almost all the water resources that supply the Lake, the floodplains and the aquifers in the lake area (World Bank 2002b).

The functional system boundary for water, land, forest and wildlife comprise much smaller sub-sets of the Lake Chad Basin Commission's geographic limit. This is because the hydrologically active area of the Basin is much smaller (966 955 km^2) than the topographic limits of the Basin (2 434 000 km^2) which cover a large part of desert areas in Niger and Chad and are hydrologically de-coupled from the Lake (World Bank 2002b).

The primary responsibilities of the LCBC are: to regulate and control the utilisation of water and other natural resources in the Basin; to initiate, promote and coordinate natural resources development projects and research within the basin area; to examine complaints; and to promote the settlement of disputes, thereby promoting regional cooperation and integration. The Fort Lamy Convention recognises the sovereign rights of the member States over the water resources in the Basin, but forbids any unilateral exploitation of the lake water, especially when such use has a negative effect on the interests of the other states. It also recognises the right of the member States to plan projects, provided that they consult the LCBC beforehand. The member States were also supposed to refrain from adopting any measures likely to alter the Lake's water balance, its exploitation by other riparian states, the quality of its water and the biological characteristics of the fauna and flora in the Basin. Lastly, the member States must inform the LCBC of all projects planned within the Conventional Basin. National, sectoral and environmental plans exist in each country. National institutions are officially in charge of coordinating the implementation of Action Programme 21 in Chad, Cameroon, Niger and Nigeria.

At national level, the relevant environmental institutions are:

- Cameroon: National Consultative Committee on the Environment and Sustainable Development (CCNEDD), which includes the Prime Minister, various ministers, professional associations and NGOs.
- Central African Republic: Ministry of Meterorology and Ministry of Mines and Energy.
- Chad: National High Committee on the Environment (HCNE) which includes the Prime Minister and various ministers.
- Niger: National Council for the Environment and Sustainable Development (CNEDD) which includes the Cabinet leader, ministers, civil society, university and NGOs.
- Nigeria: Federal Environmental Protection Agency (coordination of ministries) backed by the National Advisory Council (governmental

organisations, private sector, NGOs, community organisations, university) and by the National Council on the Environment (States). Almost all the States in the Federation have prepared a long-term Environmental Action Plan.

Chronology of recent projects executed in the Lake Chad Basin

Diagnostic Study of Environmental Degradation in the Lake Chad Conventional Basin 1989

The study was undertaken by specialist consultants in cooperation with LCBC member States with funding and support from UNEP. The study gave a synopsis of environmental degradation in the diagnostic basins of the Lake Chad Basin. The goals of the report were to identify the symptoms, causes, and also to set priorities for strategic action. In November 1989, a report was submitted to the Environmental Ministers of the LCBC member States with a number of recommendations (see Kindler et al. 1990). The diagnostic study identified causes of environmental degradation and recognised defining "type years" according to rainfall, channel flow, lake levels and flooding as a necessity for a flexible development policy which can adjust rapidly to water supply changes. The study recommended: (i) integration of irrigated cropping with food storage and famine prevention programmes; (ii) improving water and soil conservation through incorporation of tree regeneration, forage production and other agro-forestry techniques in irrigated agriculture; (iii) imposing a moratorium on large-scale water projects; (iv) undertaking a review of existing water projects; (v) correcting the environmental impact of specific projects to downstream and floodplain users; and (vi) according priorities to downstream users (fishery, recession agriculture, pasture, groundwater recharge) and to multiple use of wetlands (wildlife, tourism and economic production).

Master Plan for the Development and Environmentally Sound Management of the Natural Resources of the Lake Chad Conventional Basin 1992

The Master Plan, compiled in cooperation with UNEP, UNSO, National Experts, the LCBC Secretariat and Consultants, was drawn up on the basis of the recommendations of the Diagnostic Study. The Master Plan supplemented by a programme of action for sustainable agricultural development was prepared with the assistance of the FAO. A prioritised Master Plan was produced from these two documents, for the environmentally sound management and development of the conventional basin. The document consists of 36 projects relating to water resources, agriculture, forestry, biodiversity management, and livestock and fishery development within the Lake Chad Basin (see LCBC 1992).

Decision Support System Project

The Decision Support System Project (DSS) funded by UNEP with contributions from the LCBC in 1995 was intended to support the implementation of the Master Plan. Expected outputs were a DSS and a donors' conference. The donor conference was not undertaken as the Planning Committee decided on first preparing a Strategic Action Plan (see below).

Planning and Management of Water Resources of the Lake Chad RAF/88/029, 1990-1993

A project financed by UNDP. Objectives included the evaluation of water resources, strengthening of data collection and management, model simulations, formulation and evaluation of development strategies. The outcomes from this project were incorporated in the Master Plan and eventually the Strategic Action Plan (see below).

Monitoring and Management of Groundwater Resources in the Lake Chad Basin 1992-1993

Financed by the French Cooperation under convention No98/C88/ITE and executed by the consultancy firm BRGM. The objective of the project was to provide the LCBC with a groundwater resource management model. Insufficient funds resulted in the development of only a pre-model. The project provided remarks and recommendations for the groundwater resources in the Lake Chad Basin, and also identified gaps in knowledge.

Lake Chad Basin PDF-B Strategic Action Plan 1998

Integrated and sustainable management of the international waters of the Lake Chad Basin: A Strategic Action Plan (SAP) was initiated in 1996 following a request from the LCBC made to the GEF (LCBC 1998). The preparation of the SAP facilitated by the United Nations Department responsible for Economic and Social Affairs (UNO-DESA) was supervised, corrected and validated by member States and by LCBC specialists. The objective of the SAP was to prepare a regional framework for protecting the environment and for the sustainable use of the various resources throughout the Lake Chad Basin.

UNESCO-BMZ Management of ground-water resources for sustainable development of the Lake Chad Basin

Within the framework of UNESCO International Hydrological Programme (IHP) particularly its project on "Humid Tropical Zones" and the implementation of LCBC's Master Plan for the Development and Environmentally Sound Management of the Conventional Lake Chad Basin, implementation of the above project commenced in 1997. UNESCO implements the project which is funded by the German Ministry for Economic Co-operation and Development (BMZ). It has the following objectives (UNESCO 1997): (i) knowledge and quantification of the recharge and reserve of the underlying aquifers under three different climatic scenarios of humid, medium and dry years; (ii) evaluation of aquifer recharge from floodplains and surface water; (iii) proposal of regulatory issues for aquifer protection; (iv) proposal of management systems for the quaternary and continental terminal aquifers through the development of a flow simulation model for the three different climatic scenarios; (v) improvement of the efficiency of national agencies for coordinating the development actions through purchased equipment, trained staff, data base and computer simulation; and (vi) contribution to the implementation of the LCBC Master Plan.

The project prepared a hydro-geological synthesis report at the end of 1997 that highlighted data gaps and information that would need to be updated during the project execution. The final hydro-geologic report incorporating all data and analysis done by the project, including the groundwater model developed, is being awaited.

GEF/UNDP and World Bank Project: Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem

GEF initiated a project brief, as well as the SAP. On the basis of the brief 10 million USD was designated for this project. "The development objective is to build capacity within the Lake Chad Basin Commission (LCBC) and its national committees so that it can better achieve its mandate of managing land and water resources in the greater conventional basin of Lake Chad". A Transboundary Diagnostic Analysis and Strategic Action Programme are currently being initiated. See the World Bank Project Appraisal Document (2002a).

Sustainable development of Continental fisheries - A regional study of policy options and policy formulation mechanisms for the Lake Chad Basin EU-INCO Project 1999-2003

Funded by the European Union, the EU-INCO project is a collaboration of both African and European research teams. The project was operated over three years and included a full range of research, knowledge dissemination and capacity-building activities (see Fisheries of the Lake Chad Basin: Using Policy as a basis for future development action) (Neiland & Béne 2003).

Promotion of the Use of Renewable Energy Resources and Conservation of Flora Species in the Drylands of Mega Chad of the West African sub-Region, 2001-2004

The community-based project covers four countries namely Chad, Cameroon, Niger and Nigeria. The project focuses on measures to address loss of biodiversity due to habitat loss as a result of uncontrolled exploitation of vegetal resources, with its negative implications on climate change; and, increasing rate of land degradation, which exacerbates the poverty condition of the inhabitants. Pilot projects include: training and implementation of renewable energy and water conservation technologies, establishment of woodlots of threatened species of community value, and youth and environmental clubs.

Figure 30 Protected wetland in Chad Basin National Park, Nigeria.
(Photo: WWF-2001, canon/Meg GAWLER)

Protection status within the region

Current national protected areas include the Lake Chad Game Reserve on the western shore of Lake Chad in Nigeria (Figure 30), the Manda National Park on the west bank of the Chari in Chad, and the Mandelia Faunal Reserve on the floodplain between the Chari and Logone in Chad. The Hadejia-Nguru Wetlands Conservation Project was started in 1985, as a joint undertaking by the IUCN, BirdLife International and the Nigerian Conservation Foundation (Thieme et al. In preparation). The Aïr and Ténéré National Nature Reserve in Niger and the Ouadi Rimé-Ouadi Achim Faunal Reserve in Chad are the two most important protected areas in the Sahelian sub-desert zone of Africa. They contain many of the last viable populations of many of the larger ungulates of the South Saharan Steppe and Woodlands ecoregion (Burgess et al. In press).

Lake Chad poses a unique challenge for fishing regulations because it lies within four different countries. Systems of regulating access to fishing were recently created. Taking Nigeria as an example, Sarch (2000) shows that regulations are very complicated and haphazardly enforced, with confusion among different administrative agencies over regulation and taxation.

In July 2000, the Lake Chad Basin Commission (LCBC) declared all of Lake Chad a transboundary Ramsar site of international importance. However, only the national governments of Niger and Chad have designated their sections so far, although both Nigeria and Cameroon have promised that they too will designate their sections as Ramsar sites. Currently there are the following Ramsar sites: Nguru Lake (and Marma Channel) complex (Hadejia-Nguru Wetlands, Nigeria); Lake Chad (Chad site); Lake Chad (Niger Site); and Lake Fitri (Chad) (Ramsar 2003). The GEF/World Bank Project has allocated substantial funding for the improved management of the existing and planned Ramsar sites (LCBC 2002). All Lake Chad Basin riparian countries have ratified the Convention on Biodiversity (CBD).

Assessment

Table 6 Scoring table for Lake Chad Basin.

Assessment of GIWA concerns and issues according to scoring criteria (see Methodology chapter)

- 0 No known impacts
- 1 Slight impacts
- 2 Moderate impacts
- 3 Severe impacts

The arrow indicates the likely direction of future changes.

- ↗ Increased impact
- → No changes
- ↘ Decreased impact

Lake Chad Basin	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	2.5* →	3 →	2 ↗	2 ↗	2.8	1
Modification of stream flow	3					
Pollution of existing supplies	1					
Changes in the water table	2					
Pollution	1.0* ↗	1.0 ↗	1.0 ↗	1.0 ↗	1.5	5
Microbiological pollution	0					
Eutrophication	1					
Chemical	1					
Suspended solids	1					
Solid waste	1					
Thermal	0					
Radionucleid	0					
Spills	0					
Habitat and community modification	2.0* ↗	2 ↗	2 ↗	2 →	2.4	3
Loss of ecosystems	2					
Modification of ecosystems	2					
Unsustainable exploitation of fish	2.0* →	2 ↗	2 ↗	1 ↗	2.1	4
Overexploitation	2					
Excessive by-catch and discards	2					
Destructive fishing practices	2					
Decreased viability of stock	0					
Impact on biological and genetic diversity	0					
Global change	2.0* ↗	3 ↘	2 ↗	2 ↗	2.4	2
Changes in hydrological cycle	2					
Sea level change	0					
Increased UV-B radiation	0					
Changes in ocean CO_2 source/sink function	0					

* This value represents an average weighted score of the environmental issues associated to the concern. For further details see Detailed scoring tables (Annex II).

** This value represents the overall score including environmental, socio-economic and likely future impacts. For further details see Detailed scoring tables (Annex II).

*** Priority refers to the ranking of GIWA concerns.

This section presents the results of the assessment of the impacts of each of the five predefined GIWA concerns i.e. Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, Global change, and their constituent issues and the priorities identified during this process. The evaluation of severity of each issue adheres to a set of predefined criteria as provided in the chapter describing the GIWA methodology. In this section, the scoring of GIWA concerns and issues is presented in Table 6.

Freshwater shortage

"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 2001).

Freshwater shortage was considered by the GIWA Assessment to be the most important concern for the Lake Chad Basin. The considerable decline witnessed recently in the Basin's potentially available water resources, can be attributed to both natural and anthropogenic factors. The impact of freshwater shortage was ranked as severe, and it is predicted that the impact of these factors on freshwater scarcity will continue to increase in severity by the year 2020. The concern of freshwater shortage was considered as being the driving force for many of the aquatic environmental concerns and their associated socio-economic impacts.

The World Resources Institute (WRI) estimated that in the Lake Chad Basin the annual water supply per capita was 7 922 m^3 in 1995. However, water supply is unequally distributed. The water supply in 1995 for the Lake Chad Basin excluding the Chari-Logone Basin was less than 500 m^3/person/year (Revenga et al. 2000), which indicates that the majority of the Basin is facing acute water stress. For example Chad and Niger, according to the Water Poverty Index (WPI), are both in the 10 most water impoverished countries in the world, with Niger being rated second lowest (UNEP 2003). However, the fourth and fifth countries with largest volume in annual renewable water resources in Africa are Nigeria (286 km^3/year) and Cameroon (285 km^3/year) (Revenga & Cassar 2002).

The GIWA methodology that usually separates the concerns of freshwater shortage and global change has been adapted to take into account the particularly close relationship of the two concerns in Lake Chad Basin. Presently, the roles and extent of influence of climate change and human induced stream flow modification in causing the freshwater shortage has not been determined. Both climate change and stream flow modification are contributing to the freshwater shortage situation in the region and the ecological and socio-economic impacts are therefore similar. Global and regional climate change has been considered as an issue of freshwater shortage in the GIWA region 43 Lake Chad Basin report, due to the distinct synergies between these concerns.

Lake Chad fluctuations - Natural versus human influence

The most obvious indicator of declining freshwater availability has been the dramatic decrease in the surface area and volume of Lake Chad. This has been attributed to regional and global climate change as well as water management practices. Rainfall over the Chad drainage basin has decreased greatly since the 1960s, largely because of a decrease in the number of large rainfall events (Le Barbé & Lebel 1997). At the same time, water diversion has increased due to the construction of many dams in the hydrologically active sector of the Basin used to supply water for mainly irrigated cultivation.

During the 1960s discharge losses due to irrigation were almost non-existent, however after 1983, precipitation continued to be low, but irrigation withdrawals increased. The FAO (1997) estimated the gross irrigation water requirements for the Basin to be 16.5 km^3/year. A change in cropping strategy from low (e.g. wheat) to high (e.g. rice) water intensive crops was a major factor causing the increase in water use, particularly in Nigeria. Although the reduction in lake size is primarily attributed to reduction in rainfall, in the climatic scenario of the past four decades water use has been unsustainable.

Global change

The GIWA Assessment considers global changes from anthropogenic sources. Overall climatic change has caused considerable changes in the hydrological cycle of the Basin and consequential changes in the level of Lake Chad, but this has been witnessed many times in the history of the Lake as a result of natural processes (see Regional definition, History of lake level variability). It is undetermined to what extent the changes in the hydrological cycle are attributed to this natural variability or to human influences including the emission of greenhouse gases, bush clearing and agriculture. However it is not believed that human activities are the primary cause of the climatic variability and therefore the GIWA Assessment scored global change as moderate, not severe.

There has been no documentation investigating the GIWA issues of sea level change, increased UV-B radiation as a result of ozone depletion and changes in ocean CO_2 source/sink function on the Lake Chad Basin. These issues have therefore not been assessed in this GIWA report.

Regional climate changes

Several studies have shown that the hydrological cycle of the Sahel region which forms almost half of the Lake Chad region has changed over the last half of the last century (Bryson 1973, Gregory 1982, Lamb 1978a and b, Nicholson 1986 in Le Barbé & Lebel 1997). These studies and more recent scientific research by Coe and Foley's climatic data analysis (2001) have demonstrated that rainfall events in particular have reduced and in turn led to drought and increasing desertification (Nicholson 1988 in Le Barbé & Lebel 1997). Figure 31 shows a wet period prior to 1960 followed by a decreasing trend of annual rainfall recorded at N'Djamena (Chad) between 1960 and 1990. In the Sahel, the 1990s was less dry than the 1970s and 1980s and there have been recent wet years in 1994 and 1999 (L'Hôte et al. 2002). However the 1990s were still the third driest decade in the last century and the wet years remain very

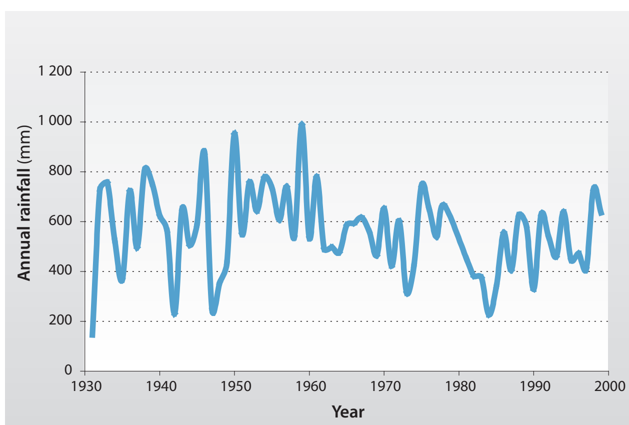


Figure 31 Annual rainfall at N'Djamena.
(Source: Meteorological station at N'Djamena airport)

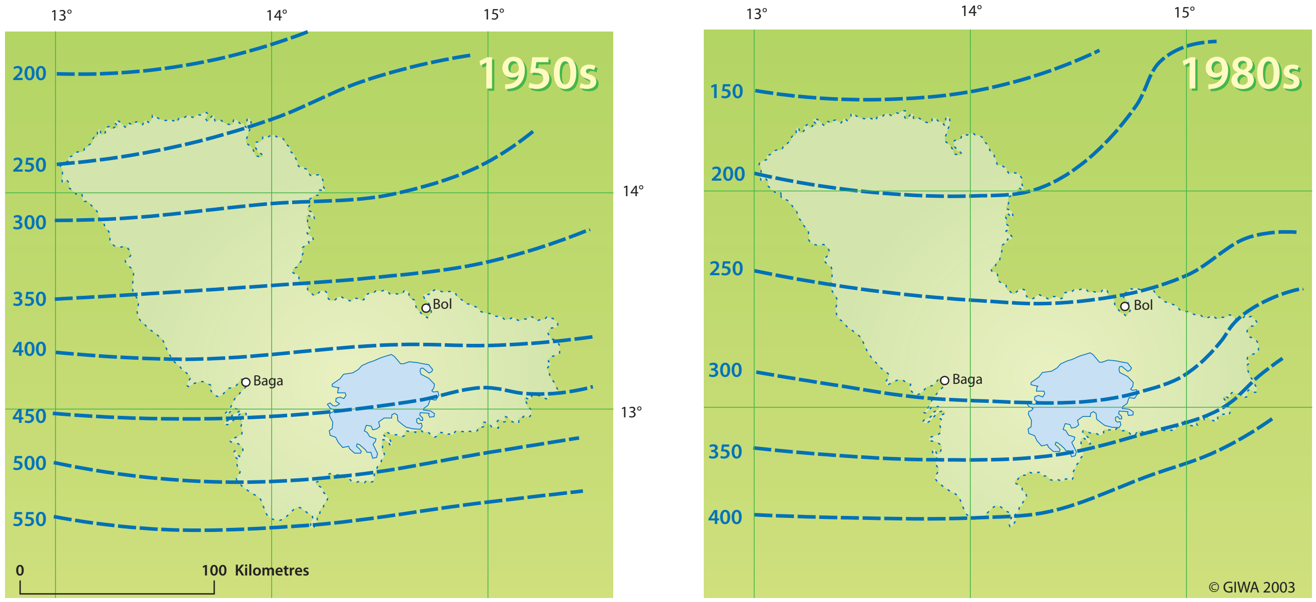


Figure 32 Interannual isohyets.
(Source: Olivry et al. 1996)

isolated from each other. L'Hôte et al. (2002) concluded that the drought since 1970, had not finished by the end of the year 2000.

A comparison of isohyets of the 1950s, which is regarded as the wettest decade, with the driest in the 1980s showed considerable shift towards the south as shown in Figure 32 (Olivry et al. 1996). In particular, the 400 mm isohyet moved 200-250 km towards the south in the west of Lake Chad, 100 km towards the south in the east but only few (10s) of kilometres in Ouaddai (Chad). The 800 mm isohyets shifted by 300 km to the south at the longitude of Guera and by 200 km to the south east of Guera, in Nigeria. The shifts were controlled by orographic effects while effects on the vegetation did not exactly parallel the shift of the isohyets as the soil type also had major effect in maintaining the status quo or in accelerating the rate of degradation as do the effects of man and animals. The reduction in rainfall was about 100 mm for each 100 km of distance apart from the annual and spatial variations (LCBC 2000b). The shift showed that areas that had experienced a mean rainfall of 320 mm (e.g. over the Lake itself) received less than 210 mm (World Bank 2002b).

Gaston (1996) also studied the effects of the 1973 and the 1983-1984 droughts on the Sahelian pasture lands in the Kanem region of Chad. According to the author, the effects of the 1973 drought seen on the ground were spectacular. There were many dead trees and all woody species had disappeared, as had the perennials of the field layer. In many places, sand had been blown and heaped against the dead and fallen trees. A revised 1:500 000 map based on specially flown aerial photographs taken in 1974 showed only eight (out of 20 vegetation types represented on maps of the same scale prior to 1973) vegetation formations. The northern limit of the Sahel had moved 100 km to the south (from latitude 15° 30' N to latitude 14° 30' N). The movement resulted from the significant downward shifts of isohyets widely observed in the Sahel and the progressive desertification ushered in by the desiccation.

According to Le Barbé and Lebel (1997) the lasting drought that has affected the Sahel for more than 20 years is associated with a 30% reduction in the number of rainy events, rather than to a decrease of the mean event rainfall or length of rainy season, and that this decrease is more pronounced for the core of the rainy season (July/August), with a reduction of two-thirds in August. Almost 90% of the annual rainfall

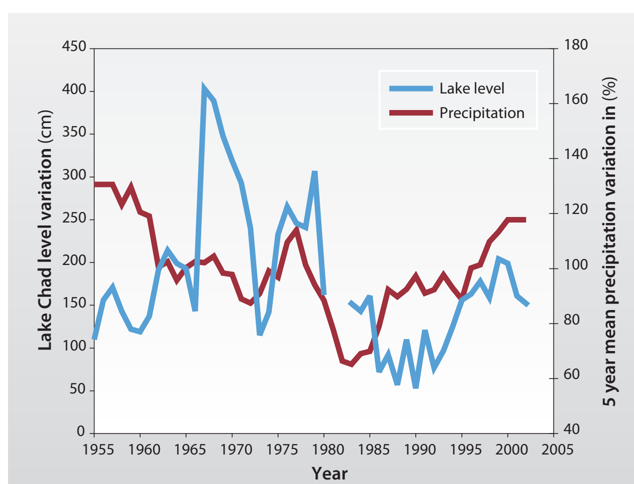


Figure 33 Lake Chad level variation and yearly precipitation at Bol.
(Source: Tschierschke 2002)

decrease between 1970-1989 is explained by the decrease of the mean number of rainfall events during July and August, while both the length of the rainy season and mean event rainfall remained stable (Le Barbé & Lebel 1997). The fact that the length of the rainy season did not change between the wet and dry periods supports the idea that the drought is not primarily linked to a shift in the average position of the Inter-Tropical Convergence Zone (ITCZ). There is a need to identify the factor responsible for the triggering of convection (which may be a consequence of the general atmospheric circulation or of local conditions), which will provide a physical basis for understanding the diminution in the number of rainfall events.

Lake Chad's water level has consequently responded to the variations in the number of rainfall events. In Figure 33, an extrapolation based on the water level comes to a calculated rainfall of 800 mm/year for Maiduguri (Nigeria) in the period 1870-1880 (Tschierschke 2002). This shows how the lake level at Bol (Chad) strongly correlates with the 2-3 years preceding rainfall.

Global climate change

Climate change is regarded as the most important global change relevant to the Lake Chad Basin. In the past 30 years, the Sahel has experienced the most substantial and sustained decline in rainfall recorded anywhere in the world within the period of instrumental measurements (IPCC 2001). Linear regression of 1901-1990 rainfall data from 24 stations in the West African Sahel yields a negative slope amounting to a decline of 1.9 standard deviations in the period 1950-1985 (Nicholson & Palao 1993 in IPCC 2001). Since 1971, the average of all stations fell below the 1989-year average and showed a persistent downward trend since 1951 (IPCC 2001).

Lamb (1978) showed a relationship between variations in Sea Surface Temperature (SST) patterns and rainfall patterns. Several other observational and modelling studies have suggested that the global SST anomalies have a substantial influence in producing rainfall anomalies over the Sahel and the neighbouring regions (Folland et al. 1986, Palmer 1986, Folland et al. 1991, Palmer et al. 1992, Rowell et al. 1995 in Xue & Shukla 1997). Folland et al. (1991) found that relatively minor variations in large-scale patterns of SST have played a significant role in the variability of Sahelian rainfall. They also observed that tropical oceans have a greater influence than extratropical oceans, and that Sahel droughts are associated with a warmer SST in the southern hemisphere than the northern hemisphere (Xue & Shukla 1997).

According to Demarée (1990), western Sahel underwent an abrupt hydroclimatic transition from a "wetter" to a "drier" rainfall state in the second part of the 1960s. This was marked by cooling of the oceans of the northern hemisphere and simultaneous warming in the southern hemisphere being observed. A reversal occurred around 1970, since when temperatures in both hemispheres have increased. A time series plot of SST differences between oceans of the southern hemisphere and those of the northern hemisphere, and rainfall anomalies for the Sahel, shows a strong negative correlation. The correlation between the July-September SST and Sahel rainfall for the period 1901 to 1984 was -0.62, which is significant at the 99.9% probability level. Numerical equilibrium Global Climate Model (GCM) experiments with prescribed sea temperatures were also undertaken by the UK Meteorological Office which were able to replicate rainfall reductions in the Sahel for recent drought years (Evans 1996).

The observed and unexpected warming of the southern oceans at a faster rate was thought to be due to a reduction in the heat transfer from southern to northern hemispheres, although the detailed mechanisms of the transfer are still the subject of much research. Alternative scenarios include increased deep water circulation from 1960 to 1970 in the Atlantic and the effect of sulphate aerosols which are dominant in the northern hemisphere. If, however, the reduction in heat transfer is related to the north-south conveyor system combined with a slowdown in formation of north Atlantic deep water at high latitudes, owing to a reduction in the extent of sea ice (Street-Perrot & Perrot 1990 in Evans 1996), then the Sahelian drought may persist until the greater land mass in the northern hemisphere starts to dominate the effects of a slowdown in ocean transfer and the attenuation effect of sulphate aerosols. However, confirmation will depend on further research developments into detailed coupled transient GCM models, which can be calibrated against recent climate and sea temperatures. It is likely that the results from the equilibrium GCMs will be found wanting once more reliable coupled models have been developed (Evans 1996).

However, the relative importance of these external factors over more local causes (such as vegetation degradation) in changing Sahelian rainfall remains to be determined and understood. A combination of factors including vegetation cover, soil moisture, and SST is thought to best explain the reduction in rainfall in the Sahel. Changes in albedo, soil moisture, land surface roughness, and SST anomalies have been modelled and a rainfall deficit over the Sahel is calculated similar to observed patterns (IPCC 2001). It has been suggested that a meridional distribution of boundary-layer entropy regulates the dynamics of monsoon circulation over West Africa, explaining observed correlations of SST to rainfall and the sensitivity of monsoon circulation to land-cover changes (IPCC 2001). A coupled surface-atmosphere model indicates that, whether anthropogenic factors or natural variation in SST patterns initiated the Sahel drought of 1968-1973, the persistence of drought conditions could be attributed to the permanent loss of Sahel savannah vegetation (IPCC 2001).

Zeng et al. (1999) compared actual rainfall data from the period 1950-1998 with the output of a coupled atmosphere-land-vegetation model incorporating SST, soil moisture, and vegetative cover. Their results indicate that actual rainfall anomalies are only weakly correlated to SST by itself. Only when the model includes variations in vegetative cover and soil moisture does it come close to matching actual rainfall data. Modelling the importance of SST, sea ice, and vegetative cover to the abrupt desertification of the Sahara 4 000 to 6 000 years ago, Claussen et al. (1999 in IPCC 2001) show that changes in vegetative cover best explain changes in temperature and precipitation. Xue and Shukla (1997) concluded that it is likely that both SST and land surface anomalies play a role in simulation of Sahel rainfall.

Modification of stream flow

The GIWA Assessment considered anthropogenic stream flow modification as having a severe impact on freshwater availability. Although the Lake has already dried out several times in the past (Holz et al. 1984) and therefore recent shrinkage is not a new phenomenon, the trend has been severely exacerbated by human stream flow modification.

The hydrological regimes of rivers of inter-tropical Africa are directly influenced by rainfall. In areas of the Lake Chad Basin, despite the relative abundance of water at times, the flow of rivers has been constantly diminishing (Nami 2002) partly due to decreasing rainfall in the hydrologically active upstream basins but also as a consequence of the increased abstraction for human consumption (World Bank 2002b). This abstraction has dramatically modified stream flow through the construction of dams upstream of the catchment, that have not taken sufficient account of the people and ecosystems downstream of the development (Second World Water Forum 2000, LCBC 1998). Stream flow modification has been focused on the two hydrological sub-systems Chari-Logone and Komadugu-Yobe. Detailed maps are provided in Figures 46 and 49.

Modification of the Chari-Logone River

The Chari-Logone Basin has a catchment area of 650 000 km^2, and the annual supply of the Chari River to Lake Chad between 1930 and 1960 represented 95% of the total annual inflow from all the basin rivers. However, the discharge of the Chari-Logone River at N'Djamena has decreased by almost 55% over the last 40 years (Olivry et al. 1996).

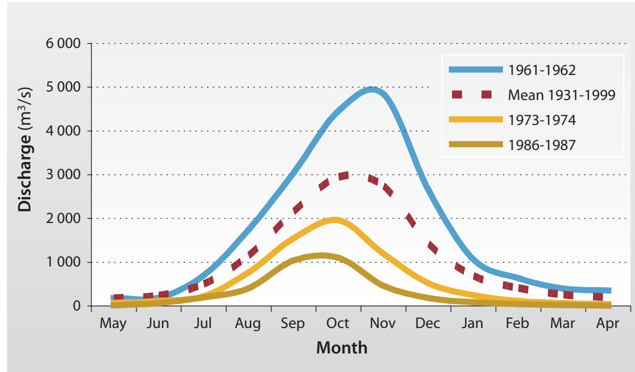


Figure 34 Interannual variations in discharge for the Chari River at N'Djamena.
(Source: Republic of Chad 2003)

Average annual discharge over 59 years covering the period 1932-1992 of the Chari-Logone river system was estimated at 33.3 billion m^3 while the average discharge since 1972 has been estimated at 20.7 billion m^3 in the period between 1972-1991.

Figure 34 shows interannual variations in discharge for the Chari-Logone River at N'Djamena. Birkett (2000) showed that there is a strong correlation between the height of the Chari River during the 1990s (upstream of the major irrigation extractions) and the level of the Lake Chad in one to two months.

The reduction in stream flow of the Chari-Logone River is thought to be due to both natural and anthropogenic causes. Following the Sahelian drought 1982-1984 the total run-off of the Chari River was only an estimated 20% of the long-term mean (Evans 1996), in consequence the level of the Lake fell to its lowest level this century. However, stream flow modification has occurred on the Chari-Logone River through the construction of the Maga Dam, as part of the Company for the Expansion and Modernization of Rice in Yagoua (SEMRY) irrigation project, aimed at utilising the water resources of the region.

SEMRY irrigation project (northern Cameroon): For many years prior to the droughts, it was considered that water overflowing onto the Waza-Logone floodplains from the Chari River was not reaching the Lake Chad and therefore offered no advantage to the people of the region. It was decided that by constructing dams, this freshwater could be used for agriculture and as a fisheries resource. Many development works were carried out to open up large rice growing areas in northern Cameroon as part of the SEMRY irrigation project. The 30 km earthen Maga Dam was constructed on the upper part of the Waza-Logone floodplain in 1979 to provide water for the irrigation scheme and for fish farming. At the same time, some 80 km of dykes were constructed along the bank of the Logone extending 20 km downstream from Maga Dam to prevent

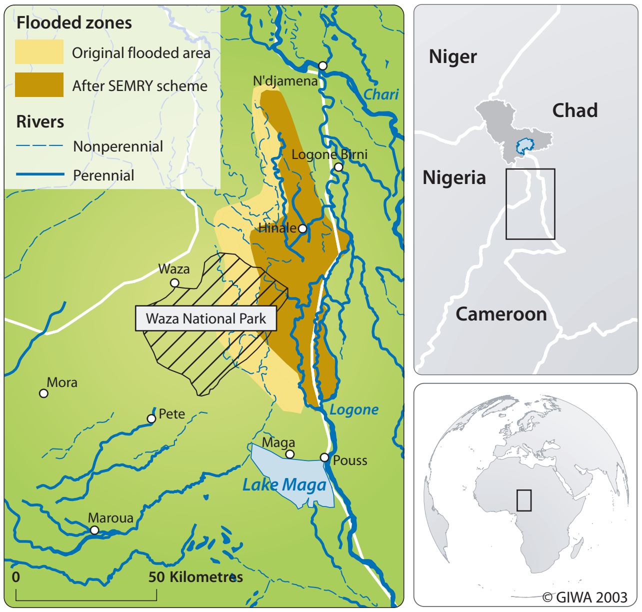


Figure 35 SEMRY project and Waza-Logone floodplain, north Cameroon. The map shows the Maga Lake (SEMRY project) and the reduced flooding of the Waza-Logone floodplains downstream.

the irrigated rice fields from being flooded from over-bank flow from the Logone River (LCBC 1998, Neiland & Béné 2003). Figure 35 shows the project infrastructure and the reductions in flooding of the Waza-Logone floodplains following the construction of the Maga Dam.

An IUCN hydrodynamic study of the floodplain reviewed the impacts of the dam for three scenarios; good years, average years and drought years (Etude du Modele Hydrodynamique du Logone, Mott MacDonald/Project Waza-Logone 1999 in LCBC 2002). The "pre-dam average year" flooded area was estimated at around 3 385 km^2, and following dam construction around 2 420 km^2, a decrease of around 30% (see review: LCBC 2002).

The establishment of embankments blocked breaches of the Logone River and entrances of the tributaries of Mayo Aretékelé and Petit Goroma, and deprived the Logomatya River of its main supply (Wesseling et al. 1994 in IUCN 2003b). The Maga Dam sealed up watercourses entering the Pouss depression, stored water originating from the tributaries of Mayo Boula and Logomatya, and caused the Mayo Gougoulay to dry up. In total these construction works resulted in a 70% reduction of water supply to the floodplain from the Mandara Mountains, and an almost complete curtailment of the water supply from the Logone (IUCN 2003b).

The significantly reduced flows in the Mayo Vrick below the dam (World Bank 2002a) has had negative impacts on part of the Yaérés downstream and on the Waza National Park, drying up an area some 20 km wide and 75 km long i.e. a total of 1 500 km^2 representing about 40% of the floodplain downstream of Maga and less than 20% of the Yaérés (LCBC 1998).

The SEMRY irrigation scheme seriously modified the floodplain regime leading to an acceleration of the degradation of the environment caused by drought. This included the disappearance of many botanical species and the progressive invasion of meadows and natural environments by unwanted ligneous forming plants. These modifications are thought to have eliminated the flooding of some 59 000 ha of floodplain and seriously reduced another 150 000 ha which were important breeding grounds and nursery for fishes. The SEMRY project has been seen as a failure and an IUCN project is currently rehabilitating the region to restore at least part of the flooding (see review: IUCN 2003b).

Studies and experience of both the Waza-Logone floodplains and the Hadejia-Nguru wetlands (Komadugu-Yobe Basin), as well as studies of fishing in the Lake Chad Basin, have led specialists to consider the relationships between the hydrosystem and ecosystem. Instead of viewing overflows from the Logone as a loss of water for the Lake, flooding of the Yaérés is now known to play an important role for the local fauna and flora and for the entire equilibrium of the system. The re-flooding of the Yaérés by making openings in the embankment that prevented water from overflowing into the plain has partly corrected the effects of Maga Dam further downstream, in particular in the Waza National Park (LCBC 1998).

Modification of the Komadugu-Yobe River

The upstream basin of Komadugu-Yobe River contributes a total long-term natural yield of approximately 7 km^3/year. However the River has experienced significant changes in stream flow regime. The modification in stream flow is in part attributed to the human stream diversion and in part due to drought, but it is undetermined what role each of these factors has played. The droughts in both the 1970s and 1980s severely affected northern Nigeria, and in particular the eastern half of the Komadugu-Yobe Basin. For example, annual rainfall decreased by over 40% compared to the long-term mean (1905-1982) in Kano in 1983 and 1984 (Oyebande 1997 in Oyebande 2001). The Ngadda, Yedseram and Komadugu Gana rivers did not flow and the Misau River, which obtains water from the Komadugu Gana was completely dry at Kari (Oyebande 2001).

During the 1970s and early 1980s around 20 reservoir dams were built on the Hadejia river system, which negatively affected the hydrology of the Yobe River, the only inflowing river into Lake Chad's northern pool.

The dams control about 80% of the total run-off of the Hadejia River. The River used to supply large amounts of water to the Lake but has now been reduced to an insignificant flow of 1% since the construction of the dams and pre-drought years (Neiland & Béné 2003). The Komadugu-Yobe River now only flows for six months of the year instead of nine, with a smaller discharge (annual modulus at Diffa: 558 million m^3 from 1965 to 1973 and 379 million m^3 from 1983 to 1996). Figure 49 provides a map with the location of major water constructions.

The largest upstream irrigation scheme at present is the Kano River Irrigation Project (KRIP), fed by the Tiga Dam completed in 1974, which has an active storage capacity of 1 400 million m^3 (Figure 36). Water is also released from this dam to supply Kano City in Nigeria. Before the construction of the Tiga Dam, there was a relatively strong stream flow in the Hadejia River during June-October that accounted for 98-99% of annual flow. After the dam was completed there was a 21-22% reduction in stream flow. In 1992 the height of the Tiga Dam was lowered due to structural instability, which resulted in a 31% reduction in its storage capacity (Oyebande 2001).

The Challawa Gorge Dam (972 million m^3 reservoir) on the Challawa River is designed to release water into the Hadejia River for subsequent storage behind the Hadejia barrage to supply the Hadejia Valley Irrigation Project. The barrage and Challawa Gorge Dam were finished in 1992. Challawa Gorge also provides water for Kano City (World Bank 2002b).

A decrease of flow upstream of Hadejia because of evaporation from the Tiga Reservoir with a rate of 425 million m^3 annually has caused a reduction of flow in Gashua of 56 million m^3 annually. When water used for irrigation and by urban centres is taken into account, the reduction in

Figure 36 The Tiga Dam (Hadejia river system, north Nigeria).
(Photo: Oguntola 2003)

flow at Gashua is 60 million m^3. If all the dams located in this sub-system were operating at their designed capacity the total reduction would be 76 million m^3. Since the mid-1970s, dry season flood releases from the Tiga Dam during the dry season modified stream flow from zero flows during the season to a perennial regime (Oyebande & Uwa 1980 in Oyebande 2001). However, these releases did not appear to benefit the ecological systems downstream of Gashua (Oyebande 2001). Consequently the major part of this water resource has not been able to establish a natural regime through the downstream Yobe River in Nigeria and Niger for almost 30 years. The absence of an integrated river basin management strategy in the basin has further given rise to a host of other problems, such as uncoordinated operation of dams, growth of weeds and silt blockages in the Old Hadejia River preventing its contribution to the Komadugu-Yobe River, among others.

So far there has been little development on the Jama'are River with only one small dam across one of its tributaries. However, plans for a major dam at Kafin Zaki have been in existence for many years to provide water for irrigated area of around 84 000 ha. Work on the Kafin Zaki Dam has been started and stopped a number of times, most recently in 1994, and its future is at present unclear (World Bank 2002b). The water demand in the sub-basin has been estimated to be about 2.6 times the available water resources (DIYAM Consultants 1996) and according to Oyebande (2001) if the development of the Jama'are and Hadejia basins goes ahead as planned there will be reduction in flow at Gashua of at least 1 275 million m^3 per year, or the equivalent total flow at Gashua over an average year.

In addition, the development of large irrigation areas has not followed construction of dams so far. If all the irrigation projects of the various agencies were to be implemented, more water would be used in the upper basin, to the detriment of the downstream basin (LCBC 1998). For example in the Nigerian part of the Basin at present, 20 dams have been built or are under construction and nine more are contemplated (with reservoirs of 1 076 million m^3), whereas only 36 620 ha have in fact been irrigated out of the intended 188 780 ha. Much water is therefore unused or lost through evaporation in the reservoirs or silted up beds on the plateau. The various dam and irrigation projects were planned without any environmental impact study and in particular without taking into account the effects on people downstream (LCBC 1998).

Reduced stream flows and the absence of large flood events have reduced the ability of the system to clear river channels of silt blockages and caused a proliferation of weeds. Flows have consequently been diverted onto the floodplains and stopped the flow in the Old Hadejia River, so that Marma Channel has received more water since the 1970s.

Due to these weed blockages the Hadejia and Burum Gana now only have a limited contribution to the flow of the Komadugu-Yobe River (Oyebande 2001).

Prior to impoundment, large volumes of floodwater nourished an extensive sub-system of floodplains and wetlands (World Bank 2002b). These upstream developments have diverted surface or groundwater for irrigation and altered the timing and size of flood flows. Downstream, increasing demand for irrigated agriculture has led to the diversion of water past wetlands through bypass channels. This sub-system presently provides 1.5 km^3 water per year when exiting the upper basin at Gashua and only 0.45 km^3 when arriving at Lake Chad. Below Gashua, flows maintain Hadejia-Nguru wetlands, where effluent flow from the watercourse recharges alluvial aquifers and pumping and diversions for small irrigation schemes. Development of irrigation by pumping has exacerbated the existing water-stress imposed by upstream impoundment. Irrigation developments coupled with decreases in precipitation have caused the maximum extent of flooding of the Hadejia-Nguru to decline from between 250 000 and 300 000 ha in the 1960s and 1970s, to 70 000 to 100 000 ha more recently (World Bank 2002b). The current contribution of the Komadugu-Yobe River to the northern part of the Lake Chad wetlands is minor in terms of the overall balance (World bank 2002b).

The stream flow modification of the Komadugu-Yobe River has impacted on the ecology of the Basin. The decline in wetland extent has proportionately decreased the fish abundance in the wetlands and in addition perhaps more than five species are no longer found in different parts of the floodplain (Oyebande 2001). The decline in fish species diversity is blamed on the reduced flooding and changes in the timing, depth and extent of flooding. Fish species that have been particularly affected include *Alestres* sp. and *Schilbe* sp. that depend on the flood regime for their migration and spawning patterns (Drijver & Van Wetten 1992 in Oyebande 2001). The number of birds in the Hadejia-Nguru wetlands is highly correlated with the extent of the wetlands. The abundance of birdlife has consequently been reduced.

Figure 37 New town on the Cameroon shore, 1989.
(Photo: USGS 2001)

Direct modification of Lake Chad

The South Chad Irrigation Project (SCIP) is an example of a Lake Chad development scheme that has failed due to poor management, civil strife and by the Lake's rise and fall. SCIP is the largest irrigation project in Nigeria, with a goal of irrigating 67 000 ha with an average cropping intensity of 130% (200% would be two crops per year). The project aimed to resettle 55 000 farming families onto the irrigated land. Nigerians had already practised resettlement as a drought strategy (Figure 37); the number of villages in the Nigerian portion of Lake Chad rose from 40 to 100 between 1975 and 1988 (USGS 2001).

SCIP planning started in 1962-1963 at the very peak of the wet years. A successful 1966 pilot project irrigated 1 000 ha. The major project started in 1974, and was commissioned at 23 000 ha in 1979. A system of pumps and canals was to carry water from the lake shore intake point to farmers' inland fields. But the plans were dependent on the lake's level. When the Lake fell below 279.9 m (about 2 m above the baseline) no irrigation could take place. The system operated only six of the first 10 years, with a maximum of 7 000 ha irrigated. Few of the farmers got water, few crops were produced, and water efficiency was low. The canals were unlined, so water seeped into the ground, and only about half reached farmers. When water did come, many farmers overcompensated by breaching or siphoning the canals to get more water, thereby wasting water and waterlogging their fields. Some fields were also poorly prepared for irrigation (USGS 2001).

The Baga Polder Project, had a goal of irrigating 20 000 ha to produce 26 000 tonnes of wheat, 28 000 tonnes of maize and 14 000 tonnes of groundnuts annually. However, by 1996 only 1 000 ha were under irrigation and now the project concentrates on farming the receding lake waters. The original polder that was constructed for irrigation purposes is now several kilometres from the lake shore.

The farmers surrounding the Lake have adapted to the fluctuating lake levels using both traditional and improved technologies. Farmers in Lac Prefecture (Chad), to the north of the Lake, have planted in the depressions between the sand dunes exposed by the receding waters that are known as polders. The polders are fertile from alluvial deposits and source water from rainfall, residual moisture and irrigation. Rice, wheat, maize, and vegetables are grown. The Government of Chad created the Lake Chad Development Company (SODELAC) in 1967 to enhance the socio-economic development of the Lac Prefecture, which resulted in the establishment of the Lake Chad Polders Project. This project promoted the development of the polders, and improved the technologies used by the farmers. Farmers of traditional polders produce one crop per year, using residual moisture as lake waters recede each season. In the improved polders, farmers use small dams and pumps which allow them to produce as many as three crops each year. SODELAC believe that the agricultural potential of the Lac Prefecture has not been utilised and with improved water management, production could increase to meet national wheat and rice consumption needs (FEWS 1997).

Pollution of existing supplies

The GIWA Assessment regarded the pollution of existing water supplies as only having a slight effect on the freshwater shortage facing the region, although further scientific justification is needed. Water quantity and quality play a significant role in the determination of availability and access to freshwater resources. In sub-Saharan Africa in general, water quality is a major problem (AEO 2002, GEO 3 2002). People may reside in an area with plenty of water and yet still not have access to it freely because of its status of purity and suitability for human consumption. 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 (ECAM 1996 in Amin & 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.

Presently there is a lack of information regarding the pollution of existing water supplies in the Lake Chad 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.

Water contamination and reduced stream flows has also caused the proliferation of weeds, mainly Kachalla grass (*Typha* sp.) that have encroached into reservoirs and clogged channels near Madachi, Kirikasama 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 agriculture uses 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. There is a lack of studies on the distribution of these agro-chemicals in the environment.

Changes in the water table

The GIWA Assessment considered that there are moderate changes in the water table due to reductions in aquifer recharge and the increased sinking of boreholes. There is little information concerning groundwater, but it is considered to be abundant, which does not necessarily mean that it is always easy to exploit. However, it may be stated that the cumulative rainfall shortages and virtually generalised decline in low flows has led to a reduction in groundwater reserves in the river basins, and in particular the phreatic aquifers. The reduced flooding of the plains has negatively impacted on the important role wetlands play in recharging the underground aquifers, in both the Yaérés in Cameroon and the Hadejia-Nguru plain in Nigeria (LCBC 1998). According to Hollis et al. (1993) groundwater storage beneath the Hadejia-Nguru floodplain was largely stable between 1964-1971 and 1975-1982 but diminished by an estimated aggregate of 5 000 billion m^3 as a result of the drought years and reduced flooding in the early 1970s and particularly in the 1980s. However, a study in southwest Niger by Favreau et al. (2001) concluded that the clearing of native vegetation increased the rate of groundwater recharge. Therefore, the decrease in vegetation cover experienced in the Lake Chad Basin may also influence the rate of groundwater recharge. As shown by Gaston (1996) in Chad, the northern limit of the Sahel moved 100 km to the south as a result of the 1973 drought. The dead and fallen trees were a result of inadequate soil moisture to sustain the vegetation. A net decrease in groundwater reserves would have potential impacts on the drinking water supply of a large proportion of the Basin's population who dig wells to obtain groundwater reserves (Figure 38).

Figure 38 Women fetching water from a well in southern Niger.
(Photo: FAO P. Cenini 1995)

Although reserves are abundant in the region, due to the recent declines in their recharge, aquifers are currently vulnerable to over-extraction exceeding their safe yield. Surface water scarcity during the drought as well as adaptation strategy increased the abstraction of groundwater for human, agricultural and pastoral purposes (Thieme et al. In preparation). It is known that there has been indiscriminate sinking of boreholes that have led to a decrease in groundwater reserves. Groundwater drawdowns of several tens of metres have been reported in the Maiduguri area of Nigeria due to the over-pumping of water. Isiorho et al. (2000), estimated that 10-25% of water in the region is utilised inefficiently and attempts to improve the situation have achieved little. The droughts of the 1980s triggered the mass drilling of 537 wash boreholes between 1985 and 1989 (CBDA 1990 in Isiorho et al. 2000). This rapid development resulted in unsatisfactory logging of wells by several contractors who were not supervised and did not use hydro-geological data when locating the wells. Most of these deep boreholes are uncapped and freeflowing. Normally the local authorities cap artesian wells, but local people uncap them and allow the water to flow out and cool so that their animals can use it. This free flow of water is very inefficient and results in vast amounts of water being lost due to the high rates of evaporation in the region (Isiorho et al. 2000). Water points at Ala near Marte (Nigeria) monitored on a routine basis by the Lake Chad Basin Commission, have shown a sharp decline of about 4.5 m within a period of one year attributable to the general decline in the artesian pressure within the Basin. Most desert species have also disappeared due to the declining water table.

Economic impacts

The GIWA Assessment considered freshwater shortage caused by both anthropogenic and climatic changes as having severe economic impacts. Over-abstraction of water by upstream users at unsustainable levels in a period when there has been a substantial decrease in precipitation in the watershed, has led to a reduction of the supplies for downstream users. This has essentially, had a direct negative impact on the economic activities of agricultural production (crops, livestock), forestry, fisheries, agro-processing industries, tourism and wildlife. Declining freshwater availability also impacts on the general downstream ecology thus reducing the environment's capacity to support economic activities. The irrigation developments have taken place without consideration of impacts on the floodplain or the loss of economic benefits previously provided by the floodplain (Barbier et al. 1991 in Schuijt 2002).

Declining freshwater has impacted on water-related infrastructure. The lower recharge rates of aquifers have facilitated the need to deepen wells and increase pumping to reach the lower water table. This has been time consuming and a further financial burden in a poverty stricken region. The decrease in volume and flow of the Komadugu-Yobe River has encouraged the growth of weeds in the main river courses, causing flooding in the villages along the river banks as flow can no longer take place normally towards the downstream part of the River (LCBC 1998). The Lake's ever-fluctuating shores are preventing the installation of permanent infrastructure and reduced river flows are reducing the accessibility for inland transport. Freshwater shortage is therefore compromising significant development and contributing to economic destitution faced by the riparian countries.

Freshwater shortage is directly impacting on the following economic activities:

Impacts on agriculture

Agriculture in the drier downstream regions and around Lake Chad is more dependent on water level as low precipitation limits rain-fed agriculture. Water level is strictly dependent on the hydrology of the rivers and thus has suffered from water deficits. This bedrock economic activity is considered as being the most affected by freshwater shortages. Large irrigation projects undertaken with a view to agricultural intensification on large areas along the Chari River in Chad (SONASUT at Banda, 4 000 ha), the Logone River in Cameroon (SEMRY projects in Yagoua, Maga and Kousseri), and in Chad (Casier A, B, C at Billiam Oursi, Bongor, 7 120 ha, and Laï) the Komadugu-Yobe River (e.g. Kano River Irrigation Project and Hadejia Valley Project), and the SCIP project on the lake shore (northeast Nigeria), have not produced the expected results. Rather than stimulating increased agricultural production, they have reduced the flooding of large areas of farmland that was previously very productive for flood and recessional farming. The Maga Dam constructed as part of the SEMRY project (north Cameroon) abstracted water from almost 700 km^2 of the Yaéré floodplains that small farmers cultivated during the dry season after a good humid year. The supply of water to the floodplains became increasingly deficient due to the persistent drought, and they no longer reached all the Yaéré floodplains that are favourable to dry season agriculture (Nami 2002). A reduction in floodplain surface area has consequently led to a decline in agricultural production and has accentuated food insecurity in the region (Nami 2002).

More than 95% of crops in the Basin are traditional and therefore do not rely on the water from the irrigation project but are dependent on the rains. The reduced rainfall has therefore impacted directly on yields of sorghum and millet in the Sahel and the Sudanese zone (see review: Nami 2002). For example, in Chad annual sorghum production was less than 250 000 tonnes during the 1972-1974 droughts and

180 000 tonnes during the 1982-1984 droughts, compared with mean annual production of 328 000 tonnes (1961-2002) (FAOSTAT 2003).

There has been a proliferation of pests due to the droughts and water management practices employed. In Chad between 1986 and 1988, the farmers were plagued with desert locusts (*Schistocerca gregaria*) who were already tackling an economic downturn caused by the succession of droughts, in addition to civil wars, that had depressed cotton prices in 1985 (Keith & Plowes 1997). Box 3 describes how the failure of the South Chad Irrigation Project (SCIP) has resulted in an ecological imbalance in the region.

Box 3 *Typha australis* and *Quelea quelea* pest infestation.

The Nigerian Government, worried about low agricultural production in the Lake Chad Basin, took steps to intervene through the South Chad Irrigation Project (SCIP), in order to stabilise agricultural production. With a goal of irrigating 67 000 ha, the system depended on lake water levels. As these levels fell in the late 1980s, irrigation could not take place.

The irrigation channels, which were not lined, now provide suitable shallow water and marshy habitat for emergent hydrophytes (plants that grow in wet conditions). Plant biodiversity is lost in this way, as the complex variety of plants adapted to the complex rhythm of rising - steady - falling water levels are disadvantaged in favour of emergent rhyzomatous plants that can survive long dry spells. The SCIP channels are clogged with one of these plants, the bulrush *Typha australis*.

The Typha stand is a preferred nesting ground of the avian pest *Quelea quelea*. Quelea infestation is an additional pressure on the already unstable livelihood systems of the Lake Basin. The regular loss of rice and other grain crops to large flocks of feeding quelea is a major concern. The Government has initiated a quelea control effort through massive aerial spraying of toxic chemical control agents. While the effectiveness of this control method is an ongoing debate, the long-term effect of these toxic chemical sprays on other life forms has not been determined.

(Source: http://www.panda.org)

Impacts on animal husbandry

Before the advent of persistent drought, animal production and export was the third largest source of income for families in the Basin. Since the droughts the amount of land suitable for grazing has decreased. For example, in the Hadejia-Nguru wetlands (Komadugu-Yobe River Basin) the receding floods previously allowed fresh grass to grow using the residual moisture. This allowed the wetlands to sustain large numbers of cattle during the dry season due to the high quality grazing land compared with the dry surrounding areas. However, wet season peak flows are necessary to inundate these grazing lands. With reduced peak flows the extent of high grade grazing land has declined. The Yaéré floodplain pastures (Chari-Logone River Basin) are also an important dry season grazing resource. Prior to the loss of floods, it is estimated that some 20 000 to 50 000 sheep and goats spent the dry season on the floodplain (Wesseling et al. 1994 in IUCN 2003b). Most of these formally flooded pastures have now lost their perennial grass cover, leaving only degraded grasslands of inferior quality and decreased area (IUCN 2003b). Reduced grazing land across the entire basin following the droughts of the 1970s, encouraged herders to shift from grazing animals (cattle and camels) to browsing animals (sheep and goats), which affected the area's vegetation through the consumption of woody plants (USGS 2001).

Impacts on fisheries

(See also section on Unsustainable exploitation of fish).

The Sahelian droughts of 1972-1974 and 1982-1984 combined with anthropogenic stream flow modification caused a reduction in the extent of Lake Chad and the wetlands which consequently altered the fish habitat. Fisheries production has experienced large fluctuations due to these environmental changes. Annual production escalated in the early 1970s before falling significantly in the 1980s (Neiland & Verinumbe 1990), and has since increased once again (Neiland & Béné 2003).

The decline in wetlands has caused a proportional decline in the yield of fish in the wetlands (Thomas 1996 in Oyebande 2001). In the Waza-Logone floodplains there has been an estimated 90% reduction in fish yields within flood-fed wetlands (Wesseling et al. 1994 in IUCN 2002b), and a reduction in the capacity of wetlands to provide nursery grounds for fish stocks in the wider river systems of the Logone and Chari. In the Komadugu-Yobe River Basin it has been observed that in the last 20 years the quality of fish in the oxbow lakes has declined due to siltation, from reduced stream flows, making the lakes too shallow (Oyebande 2001). Low flows in rivers also constrained the seasonal fish migrations. Lacustrine species, that are often migratory and more selective in spawning preference, suffered from high mortality and fewer accessible spawning sites (Bénech 1992). Natural selection operating on the fish communities during this dry period favoured marshy species adapted to freshwater shortage conditions (Benech et al. 1983) (see Habitat and community modification, Modification of fish habitats).

The fisheries of the Lake Chad Basin are very important economically to the rural communities (see Regional definition, Fisheries of the Lake Chad Basin) (Neiland & Béne 2003). The fluctuations in fish production therefore have had a significant impact and have contributed to the regional poverty.

Impacts on food security

Freshwater shortages in the Lake Chad Basin have compromised the performance of agriculture, the fishery and livestock. Consequently the people of the Basin have become vulnerable to food insecurity (AEO 2002).

FAO Statistics have shown that the food situation in Niger and particularly Chad are precarious as a result of rainfall deficits, but more so also as a result of regional imbalances of water distribution (FAO/GIEW 2001).

Food shortages have increased significantly in Chad and Niger both of which are downstream of the Komadugu-Yobe and Chari-Logone rivers. In 2000, Niger's food supplies were 25% short of the national requirements leading to high food prices, particularly for millet. In Chad, under normal conditions cereal production only covers 75% of national food requirements and during 1999/2000 this situation was further exacerbated by erratic weather conditions resulting in food insecurity. The World Food Programme in response to food insecurity in Chad distributed emergency food to 252 000 people in 2003 (WFP 2003).

Figure 39 shows the extreme and high vulnerability zones in Africa. It can be seen that in the last 30 years famine has been experienced in the north and Sudan sectors of the Basin and that all of the countries have been subjected to either food shortages or acute malnutrition except for Nigeria, Algeria and Libya.

Health impacts

The GIWA Assessment considered the impact of freshwater shortage on the health of the Basin's population as being moderate in terms of the number of people affected, the degree of severity, and the frequency and duration. Lack or inadequate potable water supplies coupled with poor or lack of proper sanitation are two very significant problems facing more than half of the population of the region. The problem differs from country to country with Niger, Chad and Central African Republic being at the helm of severe impacts. As a consequence of the acute freshwater shortage experienced in 1973, drought killed 100 000 people in the Sahel, and even countries in the humid zone suffered lowered rainfall and reduced crop yields (see review: AEO 2002).

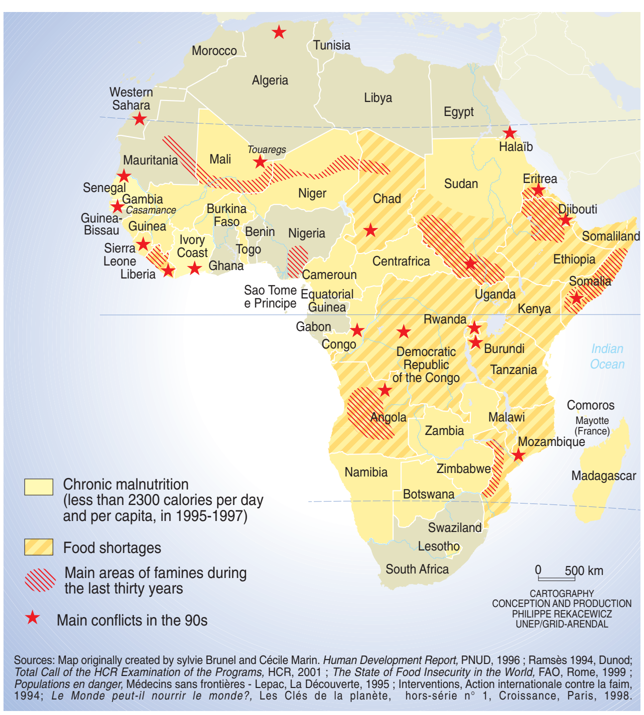


Figure 39 Food security in Africa.
(Source: Atlas du monde diplomatique 2003)

During the wet season, water filters very slowly through the very clayey Karl soil causing floods. Taking into account the low levels of hygiene in riparian villages often without latrines, soiled pits overflow and spill into watercourses during the floods, the contaminated water causes various illnesses such as cholera and malaria to emerge. During periods of drought and due to the absence of plant cover, violent winds transport epidemics such as meningitis, which is permanently rife in the region (Nami 2002).

According to the World Bank (1994), out of eight major diseases or disease groups found in developing countries, four are linked to water supply and sanitation or to vectors (organisms) that breed in water. Furthermore, many water resource projects alter the environment so as to either increase the number of vectors or increase the amount of contact with disease-causing organisms (Tiffen 1989a and b). In Northern Nigeria where irrigation projects have proliferated in recent years, the number of vectors or disease-causing organisms has more than doubled (Tiffen 1989a and b). Ofoezie (2002) classed Bauchi, Kano and Borno States as having hyperendemic prevalence of schistosomiasis. In Kano, the prevalence of the disease rose from 0.8% before 1973 to 37.6 % after 1973 following dam construction. The communities surrounding Tiga Dam have a 46.7% prevalence of schistosomiasis (Imevbore et al. 1988, Ndifon et al. 1988). The artificial lakes, unlike other freshwater bodies such as rivers, lack currents and seasonal ponding, and subsequently provide favourable conditions for year round transmission of vector-borne diseases (Ofoezie 2002).

The reduced river flow caused by these irrigation projects can also reduce the river's waste assimilative capacity resulting in decreases in the level of sanitation. Poor sanitation is a major contributor to the spread of diseases such as diarrhoea, cholera, typhoid, intestinal worms and hepatitus (A and E). In N'Djamena 1 317 cases with 94 deaths were reported in an outbreak of cholera in 1996 (WHO 1996).

Other social and community impacts

The GIWA Assessment evaluated the impact of freshwater shortage on the social and community status as being moderate. Social pressures caused by decreased freshwater availability have aggravated human conflicts. Competition between user groups for shared resources including space has been accentuated e.g. agriculture versus tourism and conservation versus food production.

The freshwater shortages have increased the potential for upstream/downstream conflict. In the Komadugu-Yobe Basin disputes between the downstream riparian states of Borno and Yobe (Nigeria) were fuelled by the lack of adequate water for their needs. They blamed this on the upstream states that they accused of storing all the water from the Tiga and Challawa Gorge dams, and releasing too little for downstream users (Oyebande 2001). Recently there has been pro-active opposition from the downsteam states of Yobe and Borno to the construction of the Kafin Zaki Dam on the Jama'are River (IUCN 2003a).

During the dry seasons, the nomadic pastoralists move their stocks southwards in search of grazing areas. The continuing drought has led to further migration of pastoralists from the increasingly dry northern regions into the southern river basins. This has increased ecological stress on river basin resources and the abandonment of traditional, effective resource management practices (World Bank 2002) and has put greater pressure on the water resources in the southern river basins of the Komadugu-Yobe and Chari-Logone.

The contraction of the Lake is also a potential source of conflict due to disagreements over whether the national borders also migrate with the Lake. The political boundary is normally shifted in favour of the dominant power in the region, and has led to some clashes between neighbouring countries in the region (Isiorho et al. 2000). Fishermen have migrated following the receding lake and thus crossed political borders, notably fishers from Niger and Nigeria. There have consequently been armed clashes with local fishermen from Chad over who had the right to the declining fishing resource.

However, many fishermen in the Basin have tried to adapt their livelihood strategies to compensate for declining fish production caused by the contracting lake. Sarch and Birkett (2000) have compared the livelihood responses of fishermen on the southwestern shore with the lake fluctuations recorded by ground gauges, satellite imagery and radar altimetry. This shows that since 1972, the communities of the western shore have made important responses to the contraction and recent expansion of the Lake. Two of these responses were resettlement and switching livelihood strategies:

As the lake levels dropped during the 1970s and 1980s, the maximum extent reached by the Lake each year receded eastwards towards the centre of the Lake Basin. Communities followed the lake shore and in some cases moved eastwards more than once.

The second response to the contraction of the Lake was to diversify from relying entirely on fishing to farming the lake floor as the floodwater receded. Although each of the village communities described how they had originally set up as fishing settlement during the 1970s and 1980s, in 1993 the majority of the households relied on farming as their main source of income (Sarch 1996 in Sarch & Allison 2000). Many of the Hausa communities that had been attracted by the fishing opportunities of the 1970s, switched to farming as the lake shore contracted and revealed the moist soils of the lake floor around their fishing settlements. Of the 80% of Hausa households who had fished Lake Chad in the past, the majority (58%) now relied on farming for more than a quarter of their annual income (Sarch 1999 in Sarch & Allison 2000).

The mobility and livelihood flexibility of the rural communities making their living on the shore of Lake Chad has enabled them to respond to the extreme fluctuations observed. This ability to react and cope with changing livelihood opportunities and constraints are characteristic of these communities whom have changed livelihood strategies many times in the past and who do not rely solely on fishing. It is not accurate to talk of fish stocks as being sustainable in the context of this level of natural fluctuation. Around Lake Chad people have adapted their livelihoods and are able to exploit the same areas of the Lake Basin in a range of environmental conditions through fishing during the flood and farming after the flood has receded. It is argued that such strategies highlight the importance of enhancing or maintaining the flexibility of lake shore livelihoods rather than constraining it with fixed fisheries production quotas, seasons or areas (Sarch & Allison 2000).

Future outlook

The GIWA Assessment predicts that the magnitude of freshwater shortage is to become increasingly severe by the year 2020. The Basin is set to experience major alterations and developments in the next 20 years that need to be taken into consideration.

Future climate change

The future variability of the climate is critical to future freshwater availability. Future climate change in Central Africa has yet to be determined as there are presently no accurate models for predicting future precipitation rates over the region. During the 1990s there has been evidence of increased precipitation and consequential increases in discharge from the Chari-Logone River. However, the climate remains drier than pre-1970s with only isolated wet years (L'Hôte et al. 2002), and it is too early to state whether this most recent cycle will persist. Some forecasts predict that the scenario between 2003 and 2020, at best, could be similar to the current status from 1973 until now (Republic of Chad 2003). This is based on the scenario of future global warming linked to a weakening in carbon sinks and radiation sinks in the polar regions with reduced deep water formation due to reduced heat transfers from the southern hemisphere to the north. It is postulated that reductions to the radiation and CO_2 sinks could give rise to significant positive feedbacks leading to an increase in global warming (Lewis 1989 in Evans 1996). However the future influence of these global processes on the region's climate over local factors remains a subject of study and debate. Local factors will undoubtedly also continue to play an important role in driving the future climate of the Sahel.

Population growth

Presently, the annual population growth (2000-2005) is estimated to be 2.6%[3] (UN Population Division 2002) and the total population for the Basin in 2020 could be over 56 million (UN Population Division 2002). This significantly enlarged population will depend on the Basin's limited water resources for their survival. If the current trends of urbanisation continue, particularly in Nigeria, there could be an increasing demand for water supply to municipalities.

Increased water use

For the foreseeable future water demands in the Lake Chad drainage basin are expected to increase, as the population becomes more dependent on irrigation agriculture (Hutchinson et al. 1992, FEWS 1997 and 1998 in Coe & Foley 2001). Therefore it is important to learn more about the response of this very sensitive system (Coe & Foley 2001). The population trend of the conventional basin reveals that, from a standpoint of the Malthusian concept (as compared to other schools of thought, such as Virtual water, structural inequality, environmental or social scarcity, lateral pressure, etc.), the per capita renewable water availability which presently places the region in the class of "water stress" (1 263 m^3) could worsen to "acute water shortage" situation (698 m^3) by the year 2025 (LCBC 2000b).

Water development projects

Planned water development projects, particularly those in the Komadugu-Yobe Basin will increase water requirements and outstretch available supplies. The water requirements in the Hadejia River Basin are already at times exceeding the available water resources (Bdilaya et al. 1999) and are at a critical point where further expansion of requirements of one use will deprive other users of water. An IUCN study estimated that the potential water requirements are at least (not taking into account evaporation losses) 2.6 times greater than the mean surface water resources. In the Jama'are and Yobe river basins available water resources presently meet requirements. If the construction of the Kafin Zaki Dam is completed for the proposed Jama'are Valley Irrigation Projects and some smaller irrigation upstream of Katagum, potential water requirements for the Jama'are River Basin could be more than 1.8 times the available water resources in a mean year (Bdilaya et al. 1999).

Petroleum exploitation

The employment opportunities presented by the Chad oil exploitation that began in July 2003, will encourage migrant workers to the area and thus increase and concentrate pressure on water resources. There is a possible risk of polluting existing water supplies from run-off from the oil fields and construction sites although a comprehensive management plan has been implemented to mitigate all environmental risks (ESSO 1999). The Chad-Cameroon pipeline crosses transboundary waters several times; there is always a possibility of an oil spill incident even with stringent safety measures installed. There are six area-specific Oil Spill Response Plans in place to react to any such emergency.

Conclusions

The GIWA Assessment considered the major issues of freshwater shortage as climate change and stream flow modification, which consequently have decreased water table levels. Natural climatic variability has been exerted throughout the history of the Basin and is considered as playing an important role in fluctuations in stream flow and in the level of the Lake Chad (see Regional definition, History of Lake level variability). Recent climatic variability can be primarily attributed to these long-term climatic cycles but may have been exacerbated by recent human induced Sea Surface Temperature (SST) and land surface anomalies. The GIWA Assessment refers to anthropogenic global change and therefore it was considered as having a moderate impact. The GIWA Assessment considered anthropogenic stream flow modification as having a severe impact on freshwater availability. Although the Lake has already dried out several times in the past (Servant & Servant 1983), recent trends have been exacerbated by the diversion of water by dams for irrigation projects such as the SEMRY (north Cameroon) and the KRIP (northeast Nigeria). The level of water use has been unsustainable in the climatic scenario of the past 40 years. Birkett (2000) concluded that the seasonal fluctuations of the lake level are still primarily controlled by climate, not water management practices. Nevertheless, stream diversion is a key factor in the extent of the freshwater shortage downstream of the large dam constructions and is a concern regarding the use of what water supplies that is available in the region during periods of low precipitation.

The issue of the pollution of existing water supplies is considered as having a slight impact due to limited industrial activity in the Basin. However with the onset of petroleum exploitation in Chad, pollution of water supplies either directly from the oil projects activities or by the increased urbanisation in the region could increasingly become a concern. There may also be contamination from agro-chemicals as the production of crops such as cotton requires chemical sprays. Pollution studies will be required to monitor the impact and distribution of these

[3]The estimate of population growth is based on national figures from United Nations Population Division 2002, with the assumption that the population growth is evenly distributed within each country within the Lake Chad Basin.

in the environment, and to assist in the formulation of regulations regarding pollution, which are lacking in the current legislative framework (see Pollution, Agricultural chemical pollution).

The issue of changes in water table was regarded as having a moderate impact due to the reduction in the wetlands and lake and therefore their aquifer recharge function, and due to the indiscriminate sinking of boreholes that are often uncapped and free flowing. There is however a lack of information on groundwater reserves and the impacts of abstraction are not known.

Overall, the concern of freshwater shortage was considered as being severe due to it driving almost all environmental concerns in the Lake Chad Basin. The ecological impacts on the wetlands and lake environment have been severe. For example, since the 1960s wetland resources within the Basin, such as the Yaérés in Cameroon and the Hadijia-Nguru floodplains in northern Nigeria, have been reduced by almost 50% (Barbier et al. 1997) and the Lake Chad was reduced in the 1990s to just 10% of its former extent prior to the 1960s. Freshwater shortage has had severe economic impacts on the fisheries, flood-recessional agriculture, livestock rearing and other wetland industries. There has consequently been severe food insecurity in the region and a proliferation of diseases. Large dam developments in the upstream catchments of the Chari-Logone and Komadugu-Yobe river basins has caused conflicts due to downstream users receiving insufficient amounts of water to meet their requirements. There has also been significant migration from the north of the Basin as "environmental refugees" have fled drought, increasing the pressure on natural resources and inciting social tensions.

Leading up to 2020 the Lake Chad Basin is set to experience some major alterations, namely the large-scale oil developments in Chad and water management projects that have the potential of changing the freshwater shortage situation for better or for worse.

IMPACT Habitat and community modification

Aquatic habitat modification has primarily been a result of the freshwater shortage concern in the region. For example, wetland habitat modification can be mainly attributed to declining stream flows and the diversion of water away from the wetlands. However, the consequences of habitat modification have been severe in the Lake Chad Basin, but although the impacts are being experienced across the region they are generally localised and terrestrial. The GIWA methodology addresses transboundary water issues and therefore the concern was assessed as having only a moderate impact. However to fully understand the wider context regarding habitat modification, terrestrial and non-transboundary issues have also been discussed, but not assessed under this concern.

Modification of aquatic habitats (assessed by GIWA)

The GIWA Assessment identified community modification and habitat loss as having a moderate impact. The wetlands, lakes and rivers have all experienced habitat loss and modification to a certain degree. The most severe habitat modification has been caused by drought and the construction of dams in the Chari-Logone and Komadugu-Yobe river basins. These have altered the seasonal timing of flooding in the floodplains and have thus reduced the size of the wetlands. Stream flow modification has also significantly affected the lake environment as the habitat has changed from predominantly open-water to a marshy environment as the Lake contracted. Vegetation degradation has contributed to regional climate change and consequently the decreased rainfall experienced in the region. The GIWA Assessment predicts that the riparian countries are likely to face increasingly severe problems with the possibility of greater aridity and increased pressure on ecosystems and ecotones to support rapidly increasing populations. For example, Nigeria's population is projected to reach 338 million by the year 2025. This figure is 123 million in excess of its carrying capacity with intermediate inputs (Nana-Sinkam 1995).

Wetland modification

Wetlands play an important role in both biological and socio-economic systems contained in the Lake Chad Basin. Wetlands are an important source of water and nutrients necessary for biological productivity (Thompson 1996 in Schuijt 2002). They provide people with fertile soils for agriculture, fish, fuel wood and raw material for mats and roofs. Wetlands also store water temporarily and recycle nutrients and human waste to improve water quality. It is clear how valuable wetlands are to a considerable portion of the population who survive by exploiting its natural resources (Acreman & Holis 1996).

The floodplains and wetlands have consequently been intensively cultivated, and the wet areas are frequented by domestic animals especially during the dry season when the pastoral groups migrate southwards in search of grazing areas. The Hadejia-Nguru wetlands, in northern Nigeria, host approximately 120 000 cattle in the wet season and 320 000 cattle in the dry season, 370 000 goats and 375 000 sheep (RIMS 1992, using aerial reconnaissance). Although the North East Arid Zone Development Programme (NEAZDP) estimated that there could be twice as many. The wetlands have also experienced intensified agricultural production. These human activities have had significant impacts on wetlands. Wetlands and other protected areas continue to be exploited by the local communities with surveys in the Yaérés (northern Cameroon) recording severe losses. The floodplains and wetlands, particularly in the Hadejia-Nguru and Yaérés have been claimed for settlements, farms, cattle grazing and as bases for fishing (see review: Mockrin & Thieme 2001).

The modification and loss of wetlands is however primarily due to the decreasing stream flows, resulting from persistent droughts and upstream dam impoundment (see section on Stream flow modification). These floodplains were once the second largest wetland in Africa, highly productive, and supporting a diversity of wildlife (USGS 2001). Since the 1960s wetland resources within the Basin, such as the Yaérés in Cameroon and the Hadejia-Nguru in Nigeria, have been reduced by almost 50%. The Hadejia-Nguru floodplains in northern Nigeria at one time covered nearly 300 000 ha, today, these wetlands have shrank to an estimated 70 000 to 90 000 ha (Barbier et al. 1997).

Before the Sahel droughts in the 1970s the southern pool was characterised by *Cyperus papyrus* and the northern pool was dominated by *Typha australis*. As the Lake contracted in the early 1970s, the northern pool became even more saline and the permanent swamps virtually disappeared. In the southern pool in particular the *Cyperus papyrus* communities were badly affected and replaced by *Vossia cuspidata* meadows (Verhoeye & De Wulf 2001).

Kindler et al. (1990), revealed the relationship between freshwater shortage and floristic degradation. Fundamentally, the research showed that freshwater shortage led to:

- Reduced canopy coverage that increases ground temperature, soil water evaporation, and opens up the soil surface to rain drop and wind erosion;
- Change of species from perennials to annuals;
- Reduced biomass of forest products from lowered water tables or overexploitation;
- Loss of root volume that increases soil erosion;
- Reduced numbers of deep-rooted trees that recycle minerals locked in soil.

The bird life has also been threatened by decreasing water levels. Recently there have been concerns over the availability of nesting sites for the endangered West African subspecies of black-crowned crane (*Balearica pavonina pavonina*) and adequate wintering grounds for intercontinental migrants such as the ruff (*Philomachus pugnax*) (see review: Mockrin & Thieme 2001). The abundance of the 17 species of waterfowl and 49 other wetland species recorded on Lake Chad, have correlated with the extent of the water surface of Lake Chad and with wetland conditions elsewhere in West Africa (Keith & Plowes 1997). Although little is known on the range, abundance or status of the listed rare species river prinia (*Prinia fluviatilis*), the contraction of the wetlands is likely to have been detrimental to their populations.

The decreased inundated area of the Waza-Logone floodplain has been a major cause for the reduction in the number of kob, and the complete disappearance of buffalo, waterbuck, bushbuck and common duiker in the Waza National Park (Wesseling et al. 1994 in IUCN 2003b).

Sedimentation has increased in the Hadejia river system due to the reduced stream flows, but also because of the declining wetlands, as they play an important role in trapping sediment and in protecting river banks from erosion in upland wetlands. The riverine wetlands such as the Yaérés also regulate the floods by storing excess water.

Modification of fish habitats

Aquatic habitats have experienced extreme alterations due to the decreasing stream flows and consequential lake shrinkage. As the Lake contracted, it changed from hosting a predominantly open water ecosystem to marshes. The aquatic flora and faunal community structures were modified accordingly. The fisheries market species composition has been a prominent indicator of these changes.

Among the most important commercial fish species recorded in the Nigerian sector of Lake Chad before the 1972-1974 Sahelian drought (recorded 1963-1967) were *Lates, Hydrocunus, Labeo, Citharinus,* and *Distichodus* (Bukar & Gubio 1985 in Neiland & Béné 2003). Following the 1972-1974 drought these species generally disappeared and were replaced by species such as *Clarias*; for example, in 1972 *Clarias* made up 0% and *Lates* 52.7% of fish markets, whereas in 1976 they consisted 89.6% and 0%, respectively. These changes were accelerated by intensive opportunistic fishing effort in the northern pool in which open-water species such as *Lates* were easily caught. Benech et al. (1983) concluded that the natural selection operating on the fish communities during the drying up period (1972-1978) favoured the development of these marsh adapted species endowed with adoptions of diet, reproduction and respiration that allowed them to survive in an unstable environment, at the expense of open-water species that are generally migratory with strict preferences (Neiland & Béné 2003).

Following the total drying of the northern pool in 1975, fishermen migrated south and began to target the southern pool more seriously (Sagua 1986 in Neiland & Béné 2003). This environment, containing both open water and marshes, may explain the slight reappearance of some lacustrine species such as *Lates*, *Hydrocynus*, *Labeo* and *Distichodus* and a decline in mudfish from 1980 onwards. However, current research suggests that the majority of fish moved through the Baga-Kawa market since the Lake has evolved to its present lesser state, originate from the swamp fisheries, which surround the Lake Chad and seasonally extend northwards into the Nigerian sector (Neiland & Béné 2003).

As would be expected, data for Kinnaserum market, Chad, indicates that the species, which disappeared from the Nigerian sector of the Lake, are still found within markets serving the lacustrine environment of the southern pool. Typical examples include *Hydrocynus* and *Lates,* but also swamp species such as *Clarias* (catfish), tilapiine cichlids, *Synodontis*, *Gymnarchus*, *Mormyrus* spp. and *Mormyrops*. One reason for survival of the purely open-water species is the connection between the southern open water and the Chari-Logone river system, which can provide the refuge of deeper and well-oxygenated water. Data from Maroua market, Cameroon, which services mostly the Yaéré floodplains and Maga Reservoir traded in species common to river and floodplain environments, dominant species included *Alestes, Clarias, Petrochephalus* and tilapine cichlids. Although time series data is not available for the Chadian and Cameroonian markets, composition of north Nigerian market species for 2000-2001 was similar to that noted during the early 1980s mid-1990s suggesting a stabilisation in environment of the lesser lake state and the associated species composition (Neiland & Béné 2003).

The change in dominance between open-water and marshy species is very rapid when there are changes in the lake environment, and as no species are restricted only to the Lake, the reconstruction of stocks is possible from river fish communities if a normal lake state reoccurs (Benech et al. 1983 in Neiland & Béné 2002b).

Regional climate change caused by habitat modification

The cyclic behaviour of the climate in the Sahel, where dry and wet periods persist, has been explained by biogeophysical short-term feedback processes named the 'Joseph' and 'Noah' effects; reduced vegetation leads to increased albedos and increased radiation losses, surface cooling and greater atmospheric stability which reduces rainfall and encourages persistence (Charney 1975 in Evans 1996).

According to Coe and Foley (2001) overgrazing of the savannah is a contributing factor in the shrinking of the Lake. As the climate became drier, the vegetation that supported grazing livestock began to disappear. The vegetation has a significant influence, especially in semi-arid regions, in determining weather patterns. The loss of vegetation in itself contributed to a drier climate. Human and animal populations came to rely more and more on water from the Lake. Massive irrigation projects to combat the drier climate diverted water from both the Lake and the main rivers that empty into it. Coe and Foley described this situation as a domino effect; overgrazing reduces vegetation, which in turn reduces the ecosystem's ability to recycle moisture back into the atmosphere, and thus contributes to the retreat of the monsoons. The consequent drought conditions have triggered a huge increase in the use of lake water for irrigation, while the Sahara has gradually edged southward. This is a hypothesis and the domino effect may not necessarily affect the source area, especially in such flat lands widely open to advection/free lateral air flows. Further studies are needed regarding the influence of regional habitat modification on regional climate change.

Economic impacts

The GIWA Assessment regarded the economic activities most affected by habitat loss and modification as the fisheries, agriculture, livestock and wetland industries. These activities were severely impacted but primarily as a result of freshwater shortage. Wetlands provide essential income and nutrition benefits in the form of agriculture, grazing resources, non-timber forest products, fuel wood and fishing for local populations. The wetlands also serve wider regional economic purposes, such as providing dry-season grazing for semi-nomadic pastoralists, agricultural surpluses for neighbouring states, groundwater recharge of the Chad Formation aquifer and insurance resources in times of drought (Barbier 1997).

Several economic activities are severely affected by wetland destruction:

- Agriculture: dryland farming of sorghum and millet, seasonally flooded rice farming, flood retreat farming (mainly cowpeas) and irrigated farming. Rice is the most important crop grown in seasonally flooded areas.
- Fishing: is done at various times of the year with different gear. The reduced flooding of the wetlands due to dams, diversions and climatic change has caused poor fishing revenues.

- Dry season grazing: grazing of sheep, goat, cattle and a few camels. Pastoralists often move into the area as the dry season develops.
- Wild resources: provides materials for utensils and construction. Doum palm is a source of food, materials and income. Dried palm is harvested throughout the year to make a variety of products like mats, baskets and roofing materials. Potash is sold as an industrial raw material first to wholesalers and then to traders from other parts of the country. Households use potash as a food ingredient, a stomach medicine and an appetite stimulant for livestock. Firewood is collected mostly for subsistence by both men and women, but is also a very active trade commodity (Schuijt 2002).

According to the Ramsar Convention on Wetlands, the Hadejia-Nguru wetlands present value of the aggregate stream of agricultural, fishing and fuel wood benefits were estimated to be around 34 to 51 USD per ha (1989/1990 prices based on the maximum flood inputs) (Barbier 1997). The economic importance of the wetlands means that there will be an economic loss associated with any scheme that leads to degradation of the floodplain system, e.g. by diverting water away from them (Barbier 1997). The Hadejia-Nguru wetlands have declined by 210 000 to 230 000 ha. It is therefore estimated that decline in this wetland has had an economic cost of between 7.1 million and 11.7 million USD.

Moreover, this does not take into account perhaps the most important environmental function of the Hadejia-Nguru wetlands as its role in recharging the groundwater aquifers of the Chad Formation. Evidence presented by Hollis et al. (1993) shows that a reduction in floodplain inundation leads to a lower rate of groundwater recharge. Since 1983, when the extent of flooding dropped appreciably, groundwater recharge fell by an estimated aggregate amount of 5 000 km^3. Continual loss of groundwater storage and recharge will have a significant impact on the numerous small villages throughout the region that depend on well water from the aquifer for domestic use and agricultural activities (Barbier 1997).

The wetlands and lake host an array of habitats for a wide range of fauna and flora. Future tourist markets attracted by this wildlife might establish if political stability increases in the region, this however could be jeopardised by habitat loss and destruction. These ecosystems also provide a unique and important educational resource for local, regional and international education institutes and the scientific community.

Health impacts

The GIWA Assessment considered the impact from habitat loss and modification as to have a moderate impact on the health of the Basin's population. In a region where poverty is widespread and access to safe water and sanitation is very limited, the habitats in the region provide vital resources to sustain the population. As these resources have become scarcer, greater effort has been required to subsist, which will ultimately impact on health.

Other social and community impacts

The GIWA Assessment also identified moderate social and community impacts. The drying up of the northern pool resulted in fishing communities migrating eastwards several times to follow the contracting lake. They also changed their livelihood strategy to adapt to the decreases in fish production by farming the Lake's fertile recessional lands. This has caused social unrest with communities competing for the diminishing aquatic resources (Sarch & Allison 2000).

Future outlook

The GIWA Assessment predicted that in a future scenario it is likely that the impacts from habitat modification will become severe. The following factors are predicted to occur and will thus facilitate the increased severity of habitat loss and modification.

Population increase

Population increases will place further pressure on wetland, river and lake ecosystem resources and thus lead to increased habitat and community loss and modification. Desertification in the arid northern regions of the Basin will continue to cause a southward migration towards the Lake and the southern river basins, and consequently increase the pressure placed on these habitats.

Freshwater availability

The rate of habitat loss and modification is largely dependent on future variations in freshwater availability, which in turn, is dependent on the amount of human water abstraction and climatic variability. There are presently no accurate forecasts of future climate change (see Freshwater shortage, Future outlook). Greater aridity could lead to further desiccation of the wetlands and the persistence of a marshy lake environment. There is also the concern of future water management plans that do not take sufficient account of their impacts on the Basin's habitats. Freshwater shortages could be aggravated further by proposed developments that include the construction of more dams that will further alter the wetland, lake, and fisheries habitats accordingly.

Livelihood strategies

The fishing communities of the Lake have changed their economic profiles to adapt to the fluctuating lake levels in the past. This has included reducing fishing effort, in order to allocate time and effort to farm the fertile recessional lake floor. The relationship between habitat resources and livelihood strategy is twofold; changes in the community's profile of economic activities is often caused by the changes in the availability of the habitat's resources, but changes in livelihood strategy also alters the distribution of pressure placed on these resources. For example if future fish production declines once again, then more pressure will be placed on the wetlands for agricultural and grazing purposes.

Conclusions

The GIWA Assessment regarded the overall impacts of habitat and community loss and modification as moderate, but it is predicted that this could worsen to severe by the year 2020. The modification of habitats has been primarily a function of freshwater shortage rather than a result of direct habitat modification by humans. The wetlands have been the aquatic ecosystem most affected by habitat modification with a reduction by 50% in their surface area (Barbier et al. 1997). This has been a result of stream flow modification, but high levels of agriculture and livestock activity has also increased the pressure on wetland resources. Stream flow modification has also modified the open-water habitats to a predominantly marshy environment. This has consequently changed the community structure of this region. The economic impacts were regarded as moderate, as habitat modification was primarily a result of freshwater shortage. Overgrazing may have contributed to regional climate change by reducing the Basin's moisture recycling capacity and thus decreasing rainfall in the region.

Modification of terrestrial habitats (not assessed by GIWA)

Terrestrial habitat modification has had a significant impact on a large proportion of the Basin's population. Although terrestrial and non-transboundary concerns are not included in the GIWA Assessment, to understand the wider context and linkages, it is necessary to discuss these issues.

In the past four decades there has been habitat and community loss and modification due to a combination of anthropogenic and climatic induced pressures. The persistent droughts have had a dramatic effect on ecosystem structure and combined with land use practices such as deforestation and unsustainable agricultural practices, have resulted in the exacerbation of land degradation and desertification. The intensification of land use has thus reduced diversity and the extent of habitats for wildlife (Keith & Plowes 1997).

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, including climatic variations and human activities. Land degradation is the deterioration in the quality and productive capacity of land and has been identified as one of the major environmental challenges facing Central Africa (see review: AEO 2002). For example, Nigeria's 2002 Interim Strategy Update cites land degradation as the most serious environmental problem facing Nigeria (World Bank 2002a). The desert is said to be moving at an annual rate of 5 km in these semi-arid areas (Nana-Sinkam 1995). Human induced desertification has occurred as a result of unsustainable land use practices arising from rapidly increasing population and intensive economic activities. Figure 40 demonstrates the risk from human induced desertification in Africa; a large proportion of the Lake Chad Basin is at very high risk.

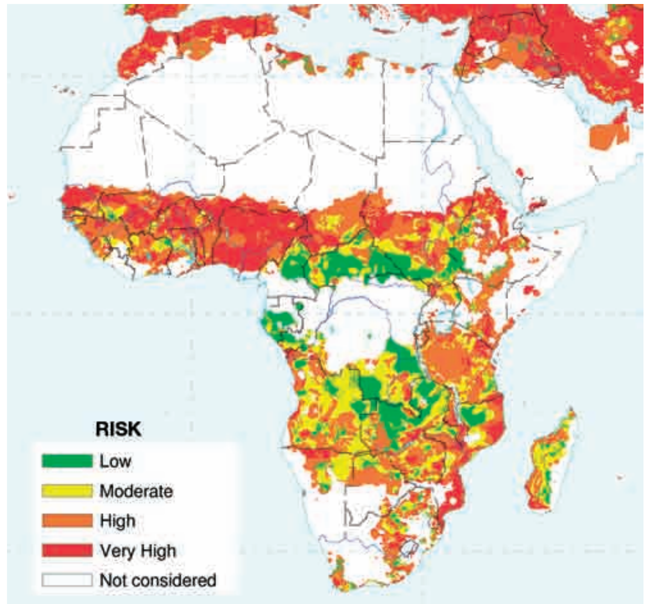


Figure 40 Risk of human-induced desertification in Africa.
(Source: Reich et al. 2001)

Although the countries of the Lake Chad Basin all experience desertification to some degree, there are disparities between the riparian countries. Figure 41 gives a breakdown of the total area of land

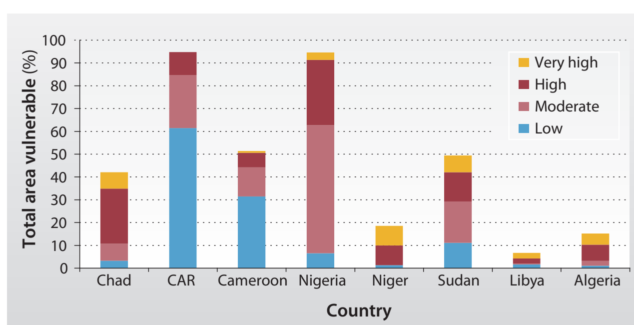


Figure 41 Vulnerability to desertification.
(Source: Reich et al. 2001)

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.

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). 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 ha 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 ha 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. In many areas, the sustainable yield threshold of the vegetation and soils is being breached (Federal Government of Nigeria 2002). Over 37 million people depend for their livelihood on activities carried out in the Lake Chad Basin with the Nigerian Sector of the Basin supporting two thirds of this population (based on ORNL 2003).

The increasing pressure on the limited natural resources of the desertification prone zone, is exacerbated by the southward migration of people and livestock, results in overgrazing and continuous overexploitation of the marginal lands (Federal Government of Nigeria 2002). In Nigeria this pressure is being absorbed by states such as Benue, Kaduna, Kwara, Niger, Plateau, Taraba and the Federal Capital Territory (FCT). This action leads to an intensive use of fragile lands and marginal ecosystems resulting in further degradation even during years of normal rainfall. The steady deterioration in northern Nigeria has continued largely ineffectively challenged for several years (Federal Government of Nigeria 2002).

The Central African Republic and northern Cameroon have also been experiencing desertification since the severe drought of 1972-1973 (see review: 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).

Several techniques have been developed to fight against desertification or to minimise the impacts of factors that exacerbate the processes of desertification (Ahmed 2000) which can be adapted to the Basin. These techniques include the plantation of shelter belts, replication of sustainable agricultural practices and agro-forestry. There are also many other ideas for local action in water management practised in other parts of the world. Within the Lake Chad Basin, some of these innovative ideas are currently practiced by the UNEP-Belgium government Mega Chad Project, as well as NGOs including the North East Arid Zone Development Project (NEAZDP) and JEWEL in Nigeria, ONG KARKARA at Diffa in Niger, SECADEV in Chad, PDRM in Cameroon and PDRN in CAR. These techniques if widely applied in the Basin are capable of reversing some of the presently observed degradation trends in future.

Overgrazing

Overgrazing is considered as a major cause of desertification in the Lake Chad Basin, as grazing animals remove vegetation cover and expose the soil to processes of wind and soil erosion. Large quantities of soil can be moved by these processes and future productivity of the land limited or rendered useless for future regenerations.

Traditional animal husbandry is not very important economically but its impact on the environment constitutes a significant threat of desertification in times of drought as one third of the 300 000 km^2

available to man, livestock and fauna is dedicated to animal husbandry (Nami 2002). It was estimated in 1995 that there were more than 404 000 pastoralists in Chad (about 15% of the country's population), with pasture areas covering about 55% of the national territory (FEWS 1995 in AEO 2002).

Nomadic pastoralists have been encouraged by the sinking of boreholes to settle in locations that they previously only grazed for relatively short periods of time. This has been detrimental to wildlife that was previously allowed to regenerate (Newby 1980 in Keith & Plowes 1997).

Kindler et al. (1990) drew up a transhumance map which shows that the migration routes of herds move towards the south and towards the Lake in the dry season, thus confirming the desert's advance to the south, and the decline of animal husbandry in the Lake Chad Basin (Nami 2002). The migration of livestock from the Sahelian zone could trigger overgrazing and a shortage of pasture in the Sudanian zone nearer to Lake Chad (FAO/GIEWS 2001). Population pressures on the land have also resulted in diminishing pastureland and, in some cases, to the narrowing or even disappearance of transit corridors for animals. This has led to a decrease in feed crop production, and at the same time livestock population has increased and placed more of a burden on plant cover than can be normally sustained (Government of Niger 2002).

Overcultivation

Overcultivation can lead to desertification due to the unsustainable consumption of nutrients from soil resources. Nutrients are not replaced as agricultural products are removed and the soil replanted without sufficient fallow time. This increasingly degrades the soil resulting in lower crop yields, which consequently forces farmers to plant on larger areas of land to receive the same return on their agricultural investment. Land degradation eventually becomes so severe that the land turns to desert like conditions (desertification).

The pressure exerted on the quality of soil increases with the number of farmers in an area (Nami 2002). The semi arid zone of Nigeria located in the Lake Chad Basin, constitutes the largest grain producing area of the country and most of the livestock are concentrated here as well. In years of abundant rainfall, the region provides high yields and profitable livestock production. Conversely, in periods of poor rainfall, there is increasing pressure, which sometimes results in a food deficit and associated unfavourable consequences (Federal Government of Nigeria 2002).

Agriculture has been forced to expand due to the climate constraints, intense population pressures, reduced soil fertility, and difficult access to inputs and farming equipment. In Niger the acreage under cultivation has doubled and farming has shifted towards "marginal" lands in the north (Government of Niger 2002).

Figure 42 A millet field during the dry season, after the farmer has cleared it from remaining millet stalks. The picture is from Dalli, 1990 (north of Tanout, Niger).
(Photo: Eden Foundation Sweden 2000)

Millet, the staple food crop of Niger, is widely grown in the sandy soil of valley bottoms. After some years of millet agriculture the land is left to fallow and the natural vegetation is allowed to regenerate. Fallow periods of 6-10 years are typical but, as pressure on the land has increased, less land is being left to fallow and rotation times are reduced. Land used for millet cultivation in east Niger and northeast Nigeria has consequently become barren sand dunes. Land that has been allowed to fallow for four years or more, increases in value for wildlife, with improved biodiversity. Shorter fallow cycles will result in a decreased biodiversity and abundance on these fallow lands (Keith & Plowes 1997). Figure 42 shows the vulnerability of fields to wind erosion once the millet crops have been removed.

The land in some areas is insufficient to support communities and to supplement crop production particularly during periods of food insecurity, herds of wildlife such as ostriches and bustards, and fish resources are further exploited. This is exacerbated by the ready supply of ammunitions used in combat between rival forces in the succession of civil wars in Chad that allows harvesting of wildlife at a scale not previously possible (Newby 1980 in Keith & Plowes 1997). This has resulted in a decline in animal populations.

Vegetation removal and modification

Extensive removal of vegetation by humans combined with a considerable fall in water level in Lake Chad and the associated aquifers has resulted in a decline in perennial vegetation. This has resulted in soil erosion and soil compacting leading to severe land degradation in the region. When vegetation is removed soil is exposed to heavy rainfall, evaporation and wind action. The main reasons for vegetation removal are commercial logging and tree cutting to provide domestic fuel, clearance of forests for commercial, or subsistence cultivation, as well as livestock browse and bush burning.

Unsustainable forestry practices to meet increased demand for firewood and lumber for local use, has resulted in the overharvesting of the Basin's woodland resources (Keith & Plowes 1997). Deforestation exposes soil to high temperatures, which break down the organic matter, increase evaporation and make the soils vulnerable to erosion (Nana-Sinkam 1995). The removal of vegetation also alters drainage patterns and rates, increasing surface run-off, which again results in further soil erosion. The rate of forest loss in the Basin is a cause for concern in terms of its impacts on biodiversity, atmospheric change and hydrological cycles, in addition to the concerns regarding soil erosion.

Expanding agriculture to meet demand from the rapidly increasing population of the Basin, has led to habitat modification as land is cleared for cultivation, while increased grazing and cutting for firewood will accelerate destruction of wildlife habitat on the remaining non-cultivated areas. This habitat modification can decrease the ecosystem functions and eliminate vegetation essential for specific animals (Keith & Plowes 1997). Expansion of agricultural production will also put increasing pressure on the inadequately enforced parks and reserves as communities search for new land to harness for agriculture, firewood gathering, and grazing (Keith & Plowes 1997). Farming expansion has cleared large areas of greenbelt, such as north of Tanout (Niger), to make way for annual crops. Farmers have attempted to cultivate this land, but later abandon the land, as it is unsuitable for sustainable crop production. By destroying areas of green belt the desert will be able to advance more rapidly (Eden Foundation 2000).

Firewood is the predominant source of fuel for the Lake Chad Basin population. In Niger for example, 95% of households use firewood as the principal source of energy for cooking, regardless of region. This high demand and scanty supplies has resulted in fuel wood becoming a source of conflict. A number of forest reserves have been developed in the area that are being heavily exploited by commercial firewood harvesters for large urban centres (Barbier et al. 1991, Eaton & Sarch 1997).

Deforestation in the Nigerian sector of the Lake Chad Basin

(Source: Neiland & Verinumbe 1990).

In the Nigerian sector of the Lake Chad demand for wood probably exceeds the available supply as shown in Table 7. These figures show that an area of savannah woodland 10% greater than the total area of Nigerian sector of the Chad Basin cropped at the sustainable level of 50 tonnes/km^2/year. However the relationship between supply and demand for wood is complicated by a number of factors.

Table 7 Wood supply and demand in the Lake Chad Basin (Nigerian sector) for 1989.

Wood supply and demand in the Lake Chad Basin 1989 (Nigerian sector)	
Total area of Chad Basin – Nigerian section (km^2)	136 000
Human population	22 million
Annual domestic wood demand (tonnes)	7.5 million
Annual sustainable wood extraction (savannah) (tonnes/km^2)	50
Area required to meet present demand (km^2)	150 000

Note: Figures based on best reliable estimates of wood supply and demand.
(Source: Neiland & Verinumbe 1990)

There is an estimated population of almost 22 million (based on ORNL 2003) residing in the Nigerian Lake Chad Basin sector with a national population growth rate of 2.9% (World Bank 2002c, estimated population growth rate for Nigeria 1980-2000). This increasingly populous region uses fuel wood and other traditional fuels (charcoal, animal and vegetable wastes) as their major fuel source, representing 67.8% (1997) of the total energy consumed by Nigeria (World Bank 2002c).

This extreme demand has to be supported by an area of woodland available for exploitation as low as 50% of the total area (due to overexploitation and agricultural clearance). The relatively slow growing savannah woodland will require time to recover from the drought conditions, and it is expected that annual sustainable yield will remain below 50 tonnes/km^2 for some years. This area of woodland also has to support the considerably large population of domestic animals (cattle, sheep, and goats) who depend almost entirely on fodder trees for their dry season food. Consequently, the FAO has identified northern Nigeria in general as being an area where there are acute shortages of fuel wood. In Baga (north Nigeria), easily accessible supplies close to the Lake have already been overexploited and large areas close to the Lake have been cleared for agriculture, both by local villagers and as a result of government development intitiatives. The South Chad Irrigation Project (SCIP) has also cleared an area of 670 km^2. Disruptions during its construction led to large areas of land being devoid of vegetation and left exposed to wind erosion (Neiland & Vernumbe 1990).

Neiland and Verinumbe (1990) stated that almost certainly demand for wood products and in particular fuel wood far exceeds the available local sustainable supply. Productivity of the woodlands has also been impaired by the water shortages and severe drought over the past four decades. The inevitable result of this imbalance is overexploitation beyond the sustainable yield, leading to the destruction of the resource base (deforestation).

Economic impacts

Economic impacts of desertification

The consequences of land degradation, and of soil erosion and compaction, are manifest as a result of the declining ability to support natural or domesticated plant and animal production. Ultimately, this translates to reduced nutritional status of the population and to reduced export revenues. In addition, communities that are dependent on wild produce (such as fruits, nuts, animals, mushrooms, and fuel wood) have to search further and further a field to meet their needs, and may experience food shortages or even famine during drought years. Extreme reductions in productivity may result in people abandoning their farms and migrating to urban centres, in search of improved security (AEO 2002).

In Nigeria due to desertification entire villages and major access roads are being buried under sand dunes in the extreme northern parts of Borno, Jigawa, and Yobe states in the Nigerian sector of the Lake Chad Basin (Federal Government of Nigeria 2002) causing social and economic disruption. An agricultural survey of Niger, which constitutes the basis for calculating changes in rural poverty, indicates that farming output has declined steadily since 1992. At the same time, livestock production, which accounted for more than 35% of agricultural GDP, has been declining at nearly 2% per year (Government of Niger 2002).

Economic impacts of deforestation

The shortfall in supplies of local wood to meet demand has had three main economic effects in North Nigeria (Neiland & Vernumbe 1990):

- The average price of a wood bundle is significantly higher compared with areas further south.
- The demand for wood stimulated a vigorous trade in wood bundles and logs. The market demand encouraged further heavy exploitation of wood resources.
- Due to common wood shortages the people have been forced into using readily available alternatives, other than the expensive paraffin and gas. These alternative fuels include dried woody shrubs such as *Calotropis procera*, the papyrus sedges and grasses of the Lake, and the stalks of crops such as sorghum. Unfortunately both are of a much lighter density than acacia wood, for example, and burn very quickly, so that a large volume is required to maintain a cooking fire. This is leading to further land degradation.

Health impacts

Habitat and community modification has significantly contributed to the poor standards of health found in the region. The declining fertility of land has effectively decreased crop yields in an area vulnerable to food insecurity from climatic fluctuations. Scarcity of woodland is forcing villagers to have to travel further to obtain enough supplies to sustain their families, with implications on their health and also on food security for their family as their efforts are diverted away from productive activities.

Other social and community impacts

Desertification is creating "environmental refugees" in increasing numbers, as people are forced to abandon their land because it can no longer sustain them and migrate to other regions or to urban slums (Darkoh 1993). The southward advance of the desert is causing a southward movement of the Basin's population and further increases the pressure on the resources of the receiving regions. Transboundary migrations are a source of conflict causing ethnic tensions, social upheavals and changes in traditions in an already volatile region. In addition, civil unrest or conflict can result in vast movements of refugees, many of whom are settled in marginal or fragile areas. Such social and environmental pressures were clearly demonstrated in 1997, when Central African Republic (having to cope with internal disputes) received more than 50 000 refugees from Sudan and Chad (AEO 2002).

Future outlook

Future climate change

The influence of future climate change on the Central African region has yet to be determined as there are presently no accurate models for predicting future precipitation rates over the region (see Freshwater shortage, Future outlook). If there is greater aridity there could be a greater vulnerability to land degradation, which may result in a food security crisis and even famine as food production is already at a critical level. The riparian countries cannot afford to lose further productive land to desertification.

Population growth

Future population growth rates for the Basin are predicted to be high (2.6%). A larger population will increase demand for land resources and fuel wood supplies. Further desertification will result in a large influx of migrants from the rural communities into the swelling urban slums. This will result in social upheaval in the urban centres of the south of the Basin and other large urban areas in Central and West Africa.

Habitat and community modification from oil development

An oil project on the scale of the Chad-Cameroon Project will ultimately result in a degree of habitat and community modification. The pipeline is set to traverse areas of dense jungle inhabited by the Bagyeli ethnic group, or Pygmies, as they are popularly known (ESSO 2002). The pipeline route, as originally proposed, transacted the core area of the Mbere Rift Valley, and there was concern that induced access rights would disturb sensitive habitats. Environmental assessments on Cameroon raised this concern, as the construction of the pipeline route would have a negative impact on habitat and would have failed to meet World Bank directives for the protection of natural habitats. Biological field research has identified a need to protect some IUCN-listed species that are known or have the potential to occur in some areas of the Wooded Savannah in northern Cameroon. These species include elephant, hippopotamus, bushback, kob, waterbuck, reedbuck, red-flanked duiker and oribi. Faunal and floral species could also be threatened by the upgrading of existing seasonal roads that will increase the accessibility for illegal poaching and logging of habitats previously protected by the area's remoteness (ESSO 2002).

The habitat and faunal communities will be further altered by increased land use pressure by the large numbers of transboundary migrants attracted by employment opportunities presented directly and indirectly by the oil project. These populations concentrated on the oil fields will have severe impacts on wildlife and fishstocks through increased fishing and hunting activity. This transboundary migration could cause ethnic tensions, social upheaval, and disruption of rural farmer's traditions. Environmental pressure groups have also expressed concerns over whether Chad's current political situation after 30 years of civil war is too unstable to accommodate such a large-scale oil project.

These potential environmental and social concerns have prompted the consortium to make adjustments and apply a comprehensive set of mitigation measures to limit the impact of the project. To avoid environmentally sensitive areas such as the Mbere Valley numerous adjustments have been made to the route of the pipeline. The pipeline will run entirely underground (ESSO 2002) and techniques are being employed to answer concerns over rehabilitation after construction due to the disturbance of top soil. To date, all local ethnic groups have been compensated for land they lost to the pipeline project (ESSO 1999). The pipeline route has been sited to avoid/minimise impacts on the Bagyeli pygmies and a compensation mechanism is in place for those who may suffer any losses to crops or housing structures. The Indigenuous People Plan, in addition, provides for a 25-year programme of support for the Bakola, which should result in improving their living conditions and their empowerment as full citizens of Cameroon.

The threat of habitat modification from oil development could become increasingly severe as the existing agreement between the consortium and Chad allows for oil exploration not only in the Doba region, but in four other regions (Lake Chad, Salamat, Bongor and Doseo) covering a surface area of 104 223 km^2. The proposed pipeline, whose capacity exceeds the oil flow that can be provided by the Doba fields, could be the first step of further oil development projects in the region.

Conclusions

The Lake Chad Basin has experienced severe terrestrial habitat and community loss and modification. The persistent drought has been the catalyst for land degradation but has been exacerbated by unsustainable land use practices. Agriculture and livestock rearing are the predominant economic activity; 60% of the administrative units of the Lake Chad Basin depend on agriculture as their main activity (Nami 2002) and livestock covers extensive areas of the Basin (50% of Chad's National territory). Unsustainable forestry practices to meet increased demand for firewood and lumber for local use, has resulted in the overharvesting of the Basin's woodland resources (Keith & Plowes 1997). These activities have encouraged deterioration in soil structure and quality, and thus enhanced the vulnerability to erosion. Desertification has consequently become a serious threat to the diversity and extent of habitats, and the livelihood and survival of many of the agricultural and pastoral dependent communities.

Poverty and environmental degradation are closely correlated in the Lake Chad Basin with agriculture forced increasingly on marginal lands. Measures to tackle the environmental issues are severely limited by this regional poverty (World Bank 2002a). Villages traditionally have values and restrictions for the sharing of resources common to people within a village and neighbouring villages. Civil strife, herder-villager conflicts as well as the endemic poverty have compromised the rules for use of common resources and contributed to the overexploitation of these resources (Keith & Plowes 1997).

Habitat and community loss and modification could increase in severity in future years. Greater aridity and increased pressure on diminishing biotic and abiotic resources will further encourage desertification and the southward advance of the Sahara.

IMPACT Unsustainable exploitation of fish and other living resources

The GIWA Assessment identified Unsustainable exploitation of fish and other living resources as having a moderate impact. Although fish production has fluctuated greatly over the past 50 years, this has primarily been attributed to climatic variability and poor water governance, and the associated environmental changes, rather than unsustainable exploitation of fish. Present data does not suggest that the viability of fish stocks is affected by pollution and disease, or that biological or genetic diversity has been modified. Excessive by-catch and discards is not thought to be a significant issue because, although there has been increased juvenile catch due to use of smaller mesh, all of the catch is used and not discarded.

Within the arid and difficult environment of the Sahelian region, the Lake Chad has always played an extremely important role in the livelihoods of the thousands of people living in its vicinities. However due to the remoteness, poor continuity of information systems, recent political instability of the region and limited funding for research and management, the whole basin is now suffering an important information deficit. FAO for instance considers the national statistics for this region to be unreliable and incomplete (FAO 1995). Currently, it is extremely difficult to make any accurate and up-to-date assessment of the economic status of the inland fisheries activities within the Basin (Neiland & Béné 2003) because there is very little time series data on fisheries (Jolley 2001). Small-scale fishermen in and around the wetlands and floodplains do not document their catches thus making it difficult to provide precise figures. In the past there has been comparatively few international studies of the Lake Chad Basin, despite the fact that most fisheries straddle international borders and their characteristics and dynamics are transboundary, determined by factors within the Basin as a whole (e.g. supply of water and movements of fish stocks).

Faced with this lack of information, national policy makers and planners but also international development agencies are severely constrained in their ability to generate and implement rural development policies appropriate and adapted to this area (Neiland & Béné 2003).

Overexploitation

The GIWA Assessment considered overexploitation of fish resources to have a moderate impact, as the primary reason for the fluctuations in fish production witnessed in the Basin over the past 40 years has been caused by fluctuations in water levels in the Lake Chad and in the timing and extent of flooding, rather than due to unsustainable exploitation of the fish resources. The term overexploitation is difficult to apply to the Lake Chad Basin fisheries due to difficulties in defining a measurement level in such a large dynamic system.

Figure 43 shows how fisheries production has fluctuated between 1969 and 2001. The increases in production from 1969 to 1972 was attributable in part to the rapid development of the fishery pre-droughts years (1960-1972), from decreased competition from fish imports, increased fishing effort, and increased Catch per Unit Effort

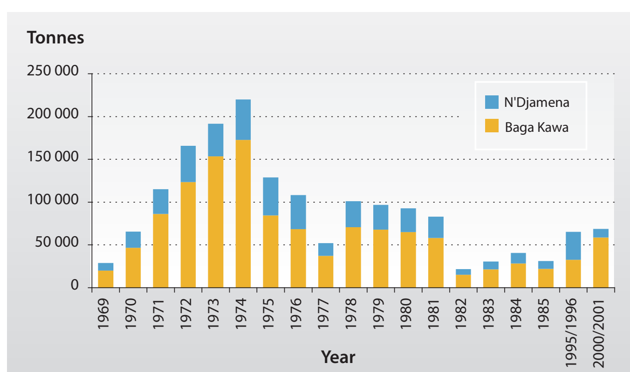


Figure 43 Fish production from Lake Chad obtained from road traffic census of dried fish at entry to Maiduguri from Baga Kawa (Nigeria) and N'Djamena (Chad).

(Source: 1969-1985: Sagua 1986, 1995-1996: Neiland & Bené 2003 (conversion factors to wet (fresh) weight x 4.5), 2000-2001: Neiland & Béné 2003)

(CPUE) facilitated by the introduction of nylon gill nets and outboard engines used on canoes (Sagua 1986, Neiland & Verinumbe 1990, Neiland & Béné 2003). Durand (1973) estimated that fishing effort increased by 50 times in the northern pool between 1967-1972 and fisheries production by five times. Trade in Lake Chad fish was also encouraged significantly in the early 1970s with the extension of tarmac roads practically throughout Nigeria, and eventually to the lake shore at Baga. The dramatic improvements in communications significantly reduced the travelling time between the Lake and large urban fish markets in the south of Nigeria, in particular Lagos, Enugu, Onitsha and Benin. The fish merchants were quick to take advantage of the high demand for fish products from those markets, to which at times over 80% of the total Lake Chad Basin fish production was exported (Stauch 1977 in Neiland & Verinumbe 1990). The total fishing effort during this period of rapid development accordingly escalated to meet the demand (Neiland & Verinumbe 1990).

The severe Sahelian droughts of 1972 and 1973 led to a drastic reduction of open water in both the northern and southern pools resulting in concentrations of fish with greater vulnerability to fishing gears. This explains the largest production estimate recorded of more than 200 000 tonnes in 1974. The fall in production noted during 1975 was the result of the drying of the northern pool and very low water levels found within the southern pool during the same period. Reduced water levels lead to scarcity of space for fishes, oxygen depletion and increased organic pollution. As the northern pool dried out, fishermen migrated with the receding waters and fish production stabilised between 90 000 and 100 000 tonnes up until 1982 (Durand 1979 and 1980, Sagua 1986). In 1982 the fisheries collapsed with production estimated at only 21 704 tonnes, there are believed to be two reasons for this; firstly as a result of decreased inflow from the Chari-Logone River Basin (see Freshwater shortage, Modification of the Chari-Logone River) due to the Sahelian droughts of 1982 and 1984, which adversely affected fish recruitment due to reduced flooding of the floodplain, an important nursery ground and breeding ground for the Lake Chad; and secondly because of reduced fishing activity due to the Chadian Civil War. Overall production has steadily recovered since then to an estimated 68 783 tonnes in 1996 (Neiland et al. 1997) and is presently estimated to be over 60 000 tonnes.

This would suggest that the Chad Basin fisheries have specific characteristics, which makes them exceptional production systems retaining a relatively large and important biomass of fish (Neiland & Béné 2003). Therefore it can be concluded that overexploitation is not the primary threat to the aquatic ecosystems and the fisheries industry.

Destructive fishing practices

In general, traditional gears are used for fishing in the Basin, however increasingly modern materials such as nylon twine or rope for nets are being manufactured locally or imported from elsewhere (Neiland & Béné 2003). According to Quensière (1990), studies around N'Djamena, on the Logone and around the Chari delta have allowed a comparison of the fishing techniques used in 1989 with those being used during the 1970s. There was a marked reduction in the mesh size of nets during the period and an increase in the use of cast-nets. Modern casting nets, in particular, have many advantages over the heavy traditional nets. Fishermen are able to exploit new ecosystem niches, such as the deep parts of the Logone River, with these lighter more mobile nets. These new fishing grounds are not controlled by the traditional restrictions upheld by the Kotoko ethnic group in the Logone floodplain so fishers have unlimited access (Van Est 1999).

Among other new techniques is the increasing use of baits. In addition to baits placed in basket traps, balls of bait comprising bran and mud are used to lure fish to gather together. They are then easier to catch by the use, for example, of a cast-net. The major development is however the use of boats. Prior to the end of the 1970s, the traditional dug-out canoe was the only type of boat used by local fishermen. Currently, the traditional canoe has almost disappeared and been replaced by much more stable boats made from plywood. This innovation has allowed much better exploitation of the whole lake area. The use of outboard engines has also developed very rapidly for both transport and fishing. The intensified use of modern equipment has decreased the access of the poorer fishers who are left with the remaining fish that have escaped dragnets (Van Est 1999).

During the recession season in the Yaéré floodplains (north Cameroon and south Chad), a large number of fishing fences are set up across channels connecting the floodplain areas to the Logone River and its tributaries (Logomatia or Petit Goroma in Cameroon, Salamat in Chad). These fences catch migratory fish leaving the floodplains especially *Alestres* spp. An example of this type of fishing technique is the "malan" fences used on the Bahr lli tributary of the Logone River in Chad. The local fishermen from Kotoko ethnic group set up a dam made of wooden fences across a channel or shallow part of the River. In front of this fence, on its upstream side, many "kotoko" traps are attached to tall wooden sticks fixed in the riverbed. The traps have their mouth orientated downstream and catch fish as they turn back to try and escape the fences. Few fish are able to escape the traps and those that do are often caught downstream. The yield from this fishing method is very high and can be several tonnes per day in the peak season.

The contraction of the Lake has encouraged the "dumba" method of fishing to become increasingly popular, particularly along the western shore of Lake Chad, in Nigeria. A dumba is a row of Malian fish traps that are placed across a channel of receding lake water. The traps are linked by small meshed netting, which forces the fish into the traps. The dumba is especially effective, as fish retreating the flood cannot escape them, and they do not need to be baited (Sarch 2001).

In 1992 the Federal Government of Nigeria promulgated the Inland Fisheries Decree, which charged the Commissioner for Agriculture in each state with the responsibility for licensing and regulating inland fishing (Federal Government of Nigeria 1992). The aim of the decree was to "give maximum protection to our precious inland fisheries resource … [and] enhance the optimum productivity and utilisation of the inland fisheries resources …" (Ita 1993 in Sarch 2001). A key implication of the decree for fishing at Lake Chad was the ban on fishing techniques that obstructed the free movement of fish. In effect, this has prohibited the use of barrages of fish traps dumba set across channels of receding lake water (Sarch & Allison 2000). The Lake Chad Basin Commission's Joint Regulations on Flora and Fauna also effectively ban dumbas (Sarch 2001).

Although both federal and local governments have tried to manage fishing at Lake Chad, compliance with measures such as this is limited by the inability of fisheries staff to reach the most productive fishing areas on the Lake and enforce them. Although broadly benevolent and similar in their aims to sustain fish stocks, the efforts of the federal Fisheries Department and local government have conflicted and resulted in failure. Illegal fishing persists and local government have little direct control over it (Krings 1998, Sarch 2000).

Economics impacts

The GIWA Assessment rated impacts on the economic and public sectors as moderate as although the economic impacts of the decreased fish production experienced at times during the last 40 years has had a severe affect on the fisheries, fish production has increased once again more recently. These economic impacts have also been primarily a result of environmental changes caused by the freshwater concern in the region rather than as a result of overexploitation of fish.

The fisheries of the Lake Chad Basin are very important economically with current lands of about 60 000 to 100 000 tonnes per year contributing over 24 million USD to national, regional riparian economies (Neiland & Béné 2003). The industry provides employment for the majority of rural households on a seasonal and part-time basis for fishermen and also in associated fish processing and trading industries. Fluctuations in fish production therefore have a significant impact on the rural community. The fisheries collapse following the Sahelian droughts of the 1970s and 1980s, occurred at a time when all economic activities were significantly affected by the droughts. The situation was further exacerbated by the numerous people hoping to capitalise from fishing as well as by later arrivals from the outlying Sahel who were trying to escape from drought and famine. The poorest households of the Lake Chad Basin felt the impact of the decreased fish production greatest. For example, a survey by Béné et al. (2000) noted that dwindling fish stocks in the Yaéré floodplains of northern Cameroon impacted most severely on the poorest households. In part, the survey stated, "the richest fishers are those with ownership and access rights, whereas the poorest fishers are marginalized or excluded entirely from the most productive fisheries".

However, given that such a high percentage of the community are involved in fishing, the fluctuations did not have as severe effect as would be expected. This can be explained by the long history of climatic variability forcing the local communities to adopt a diversification strategy to minimise risks imposed by fluctuating environmental and economic conditions, with so called fishing households earning most of their income from a combination of fishing, farming and other occupations (Neiland & Béné 2003).

Health impacts

The GIWA Assessment considered the impacts on health from the Unsustainable exploitation of fish to be moderate regarding the number of people affected but only having a slight impact in terms of severity, duration and frequency. Fisheries production has fluctuated dramatically and at times contributed to food insecurity and caused economic hardship, which has in turn contributed to the poor health in the region.

Other social and community impacts

The GIWA Assessment regarded social and community impacts of the Unsustainable exploitation of fish to be slight. The contracting Lake Chad induced the fishing communities to migrate to follow the receding waters and also to make a number of livelihood strategy changes to adapt to the changing environment (see Freshwater shortage, Other social and community impacts).

The collapse of the fisheries in the northern pool followed by the southern in the end forced many fishermen to emigrate elsewhere in search of a living, mainly to the south, or to the larger towns and cities of Nigeria, Chad and Cameroon (Neiland & Verinumbe 1990). This migration has contributed to the rapid urbanisation that has been experienced in the southern urban centres of the Lake Chad Basin.

Future outlook

The GIWA Assessment predicted that the Unsustainable exploitation of fish and other living resources could be severe by the year 2020.

Future climatic and environmental change

The future size and composition of fish stocks will be integrally linked to the size, duration and timing of the annual floods in the Basin, thus future fish production will largely depend on the discharge rates of the Basin's rivers. In recent years rainfall has increased again, which could lead to the rejuvenation of the floodplains and their standing stock of fish and increase the potential fish production. Overall production estimates have indicated that overall production is moving back towards levels noted following the collapse of the fishery in 1982. However the persistence of this recovery will be determined by future climate change, which is yet to be determined for the region. Some forecasts predict higher aridity, which could again lead to a decline in the fisheries (see Freshwater shortage, Future outlook). If current environmental conditions remain stable then the dominance of small-sized and hardy fish such as *Clarias* and tilapine cichlids is likely to continue as long as the flood levels remain restricted and fishing effort remains relatively high (Neiland & Béné 2003).

Population growth

The average population growth for the Basin is predicted to be 2.6% (UN Population Division 2002). The fisheries resource will consequently be under increasing pressure as food demand increases and greater competition and possible conflict is provoked over rights to access fishing grounds. The well-developed markets particularly in Nigeria continue to grow and trade in Lake Chad processed fish is expected to expand as fishing redevelops. This market growth is associated with a population growth rate of 2.9% (World Bank 2002c: 1980-2000 growth rate), the high rate of urbanisation in southern Nigeria, and the increasing demand for protein foods such as fish. The urban population of Nigeria has increased from 19.1 million to 55.8 million between 1980 and 2000 (World Bank 2002c), it is to these large urban areas that an estimated 80% of fish production from Lake Chad is sent (Neiland & Verinumbe 1990). This increase in demand will have to be met by the Lake Chad fisheries, as well as from the other sources of fish production that includes large dam reservoirs, aquaculture and ocean/lagoon fisheries.

Further desertification in the northern regions of the Basin will lead to greater numbers of environmental refugees migrating to the south of the Basin. Traditional management systems may not be sufficient in managing the increased fishermen population. There are presently no restrictions on the number of fishers, as long as a designated fee is paid to the village leaders. Migrant fishermen are therefore often welcomed as they pay higher fees than local fishermen. Traditional authorities may therefore inadequately control the quantity of fish extracted from the fisheries resource. It is likely that the poor households will face further poverty as they are marginalised by their inability to afford access rights to the fisheries resource.

Development plans

Ongoing water management plans for the Basin such as the construction of more dams, continue to not take sufficient account of their impact on fish and other natural resources (Neiland & Béné 2003). Further stream flow modification and associated habitat modification could jeopardise the redevelopment of the fisheries. For example if construction of the Kafin Zaki Dam (Jama'are River) in the Komadugu-Yobe River is completed it could lead to a reduction at Gashua of at least 1 275 million m^3 per year (Oyebande 2001) with consequential impacts on the fish stocks of the Hadejia-Nguru floodplains.

Fishing method developments

The increasing use of modern fishing methods such as more stable boats, the use of outboard engines and new fishing gears, will allow further fishing grounds to be exploited. These may be out of the jurisdiction of the traditional management systems, and are therefore not subject to regulation.

Conclusions

The GIWA Assessment regarded the Unsustainable exploitation of fish and other living resources as having a moderate impact. There have been substantial changes in the taxonomic composition, distribution, diversity and production of the fisheries over the past 40 years in the Lake Chad Basin. However, this can be primarily attributed to climatic variability and anthropogenic stream flow modification and the associated environmental changes, rather than unsustainable exploitation of fish. The Sahelian droughts and human water diversion reduced stream flow, which changed the distribution of aquatic habitats of both the floodplains and Lake Chad environment. Fisheries production fluctuated accordingly and fisheries species composition changed from predominantly open water species to predominantly marshy species (see Modification of fish habitats). The fishing methods presently employed by the fishermen do not pose a significant threat to the health of the aquatic ecosystems, when compared with the large-scale habitat modifications caused by stream flow modification (climatic and human).

Despite climatic and environmental fluctuations, a naturally high productivity of the lake system results from complex and diverse mechanisms bound by particular environmental characteristics. In comparison to other continental fluvio-lake systems, the Lake Chad displays exceptional performance in terms of productive capacity and resources available to fishermen (estimated 170 000 full and part time fishers) (Neiland & Béné 2003). Overall, there is no need to be over-pessimistic about the level of exploitation in the Chad Basin. Recent production estimates have indicated a significant recovery of the fishery since the collapse of 1982, which demonstrates the Basin's natural ability to regenerate. The fish fauna of Lake Chad and its basin consists of about 140 species, with about 84 species in the Lake itself with only three species endemic to the Lake. The reconstruction of stocks is always possible from river fish communities if a "normal" lake state reoccurs.

The significant issue regarding the fisheries in the Lake Chad Basin is that of governance. Fisheries management cannot operate effectively because there is confusion over which agencies have jurisdictions over which areas, the formulation of regulations cannot keep up with dynamics of the Lake, and the organisations charged with enforcement are so poorly resourced that their staff are rarely in a position to enforce a regulation (Sarch & Allison 2000). There are weaknesses in all of the riparian states, as well as in the Lake Chad Basin Commission (LCBC), in institutional capacity and enforcement of fisheries regulations. Traditional management systems, enforced by village leaders are still the predominant fisheries regulators in the Basin, and analysis suggests that these traditional authorities only tolerate central authorities, rather than fully integrate them in the process of fisheries management (Neiland & Béné 2003). The present lack of fisheries governance can be attributed, in part, to the attempt to centralise fisheries management away from the local communities, and by central authorities trying to control, rather than cooperate with, traditional systems.

Although the fisheries are very productive and generate significant wealth, at least 40% of the rural population remain impoverished and the poorest households face chronic food shortages. While the traditional management systems function very effectively in regulating fishing activity, they create socio-economic differentiation in the communities. Open access rights are seldom found and to the contrary access is usually under regulation. The predominance of traditional management systems at a local level, and the absence of strong modern systems, has resulted in the majority of the benefits from the fisheries being retained by a powerful elite minority, including local leaders, their extended families, and other prominent people and their associates. It can therefore be concluded that the poverty associated with the fisheries in the Basin, is more a result of limited access to fishing opportunities and to the benefits which might be realised from fisheries activities including fishing, fish processing and fish trading, than a function of the catch level. The question has to be asked whether traditional management systems are a significant barrier to the future social and economic development of the Lake Chad Basin (Benech et al. 1983 in Neiland & Béné 2003).

IMPACT Pollution

Pollution was assessed by GIWA as having a slight impact under present conditions but has a potential to escalate to moderate by the year 2020. There is however an extreme lack of scientific data regarding pollution and therefore ranking was primarily made using expert opinion. There is presently no evidence of impacts from radionuclide pollution and spills in the Basin. It is important to note that the Lake Chad Basin as an inland drainage basin with no outlet to the sea, the Lake Chad itself is the final receptacle of any pollution admitted into the Basin's hydrological sub-systems (LCBC 2000b).

Chemical pollution

The Lake Chad Basin has very limited industrial development; however oil exploitation in Chad, which began in July 2003, may generate opportunities encouraging industrial development (Republic of Chad 2003). Chemical pollution may therefore be an increasing concern for the Basin.

Industrial chemical pollution

The Lake Chad Basin has a proliferation of textiles and tanneries in the upstream parts of the Basin (particularly in Kano and Maroua). These industries contribute to pollution of surface water supplies and in severe but rare cases cause localised fish kills. Wastewater discharges from settlements along the Chari-Logone and Komadugu-Yobe River courses particularly from abattoirs, hotels and hospitals are also thought to contribute to microbial and chemical pollution.

It is believed that industrial discharges are in low enough quantities to not severely affect water quality, although studies are needed to confirm this. For example, the refinement and processing of sugar cane in Banda (Chad) discharges sodium carbonate and dissolved organic matter in unknown quantities into the surrounding rivers. The sodium carbonate, rejected by this factory and by a brewery at Moundou, is however dissipated in surrounding waters dissolving as it reacts with CO_2, thus causing limited long-term consequences. The effects of these industries are therefore considered as minimal (Republic of Chad 2003).

Chemical pollution from mining

Mining activity, excluding oil production is still very limited in the Lake Chad Basin and is concentrated primarily in the CAR and southern Chad. Diamonds are essentially the main mineral exploited in Chad, with mining activity on the border with the CAR and gold mining in the regions of Tandjile and Mayo Kebi (Republic of Chad 2003). Mining in the CAR has the potential for chemical pollution, but the current levels of contamination are not known. There have however been reports of chemical pollution around the mining areas in the headwater regions of the Chari-Logone River Basin lying in the CAR.

Gold mining in Chad in the regions of Tandjile and Mayo-Kebbi uses mercury to agglomerate the dusts of gold. Mercury is highly toxic and when exposed to the atmosphere or water can form complexes with organic matter (organic mercury). Although there is less polluting gold extraction techniques, mercury is still used in Tandjile and Mayo-Kebbi. Assessments evaluating the effect of these mercury concentrations are needed to determine the impact they have had on the local and downstream ecosystems (Republic of Chad 2003).

Agricultural chemical pollution

There is a lack of data on agricultural pollution in the Lake Chad Basin, however, the LCBC Strategic Action Plan (LCBC 1998) recognised that there is a possible pollution threat to water by pesticides used in agriculture, especially during periods of low flow and high temperatures. In Chad, the quantities of pesticides used are between 500 to 1 000 m^3 per year. The cotton industry uses the largest amounts of insecticides, in 1999 and 2000 4.5 m^3 were used (Republic of Chad 2003). The type of insecticides currently used in Chad are considered as highly toxic and if in high enough concentrations can lead to mortalities, thus reducing the abundance and diversity of vertebrate and invertebrate organisms as well as the flora of wetlands. The organophosphate insecticide, monocrotophos, has been banned in other regions of the world due to it killing birds, and although there are alternatives available, it is still used extensively in the cotton industries of Chad (Keith & Plowes 1997). Herbicides can kill non-intended plants after entering aquatic systems decreasing the diversity of wetland flora. Pesticides can be potentially detrimental to migratory birds and there have been studies expressing concern for species in West Africa (Balk & Koeman 1984, Mullie et al. 1991 in Keith & Plowes 1997).

In the upper parts of the Logone Basin upstream of Bongor, there are also significant amounts of pesticides used in the cotton industries. The quantities are unknown and there needs to be an assessment of their possible impact on the environment (Lemoalle 1997). Lemoalle (1997) identified the transfer and degradation of pesticides in the Logone upstream of Bongor (CAR) originating from the cotton industry as one of the main risks to the area. Generally, there is a lack of studies in the Lake Chad Basin that analyse the distribution of pesticides in the aquatic environment (Lemoalle 1997).

Rice farmers use large quantities of fertilisers and apply illegal insecticides including deltamethrine, malathion, fenitrothion and an organochlorine, lindane (Keith & Plowes 1997). Nearby lakes and streams can be contaminated by agro-chemicals by the return flow of waters and also run-off and percolation from the irrigated fields (Richards & Baker 1992 in Keith & Plowes 1997). The SCIP project in northern Nigeria extracts water from Lake Chad, which is applied to the irrigated fields with agro-chemicals. Surface and ground flows carry these chemicals directly into the Lake. There is an inadequate pollution regulatory framework in the Basin and the region is therefore vulnerable to increases in agro-chemical contamination. For example in Chad, there is no legislation regarding pesticides in terms of their registration, food residue tolerances or pesticide safety. There also appears to be a lack of information available for pesticide application and recommendations for pest control on crops other than cotton.

In southern Chad the rich alluvial soils by the rivers and lake provide conditions suitable for vegetable gardens. The produce from these markets are sold in local markets and provide a relatively profitable source of income. They therefore justify investment in fertilisers and pesticides that consequently contaminate streams, rivers and lakes (Keith & Plowes 1997).

Chemical degradation also occurs, because of intensive cultivation of marginal areas without sufficient fallowing and through salinisation from irrigation with poor quality water (AEO 2002), these impacts are however again mainly localised. Lack of data makes it impossible to determine the exact impact of agricultural chemical pollution, but the predominance of cotton and rice crops that require high doses of chemical sprays on the irrigated farms, suggests that contamination of water supplies could be occurring.

Eutrophication

Production of crops such as cotton and rice require high doses of fertiliser, nutrient loading of water supplies is therefore not out of the question. Environmental impacts of nutrient loading from upstream developments (irrigated and urban discharges) directly impact on downstream cities and populations. Eutrophication cases have been identified in small sections of the Hadejia-Jama'are-Komadugu-Yobe River Basin (Madachi, Kirikasama and Nguru) as well as the edges of Lake Chad. The numerous irrigation projects along the Komadugu-Yobe River have been identified as sources of nutrient loading with subsequent impacts on water quality.

Industries within the Basin have been reported as discharging organic wastes into the streams. The slaughterhouse of Farcha (Chad) ejects about 4 m^3 of organic matter per day resulting from the slaughtering of 800 ruminants (cattle, goats and sheep) per day (Republic of Chad 2003).

These activities can cause nutrient loading due to the high nitrogen content of wastes and should therefore be monitored. However, in order to limit this sedimentation processes are used to extract waste solids before the wastewater is discharged and the nitrogen rich wastes are then utilised in agricultural activities (Republic of Chad 2003). There are reports of organic pollution in areas where recession agriculture is practised around the Lake and other wetlands, where crops are left after harvest; this however is not considered as posing a major threat to water quality.

Water enrichment can support heavy growth of algae that during the summer forms thick algal mats over extensive areas of open water. Both algal mats and suspended sediments in water can restrict penetration of sunlight and the production of plants rooted to the bottoms of marshes and lakes. Decay of algae reduces the dissolved oxygen content of water and, over time, most fish species and other aquatic organisms that require high levels of dissolved oxygen can be eliminated. On Lake Chad, there is an abundance of macrophytes, phytoplankton and also blue-green algae (cyanobacteria), known to be a rich source of proteins. *Arthrospira* sp. (*Spirulina*) is blue-green algae, found on ponds surrounding the Lake Chad, which possesses practically all the amino acids. It has been described as one of the only few environments worldwide where this type of blue-green algae thrives due to the very narrow range of pH values that the species survives in.

Fertilisers can increase the growth of emergent plants, and therefore reduce areas of open water (Keith & Plowes 1997). Parts of the Lake are reported to have emerging macrophytes (*Phragmites australis aubsp. Altissimus, Typha australis, Vossia cuspidata, Cyperus papyrus, C. laevigtus, Leersia hexandra, Echinochloa* sp.); floating macrophytes (*Pistia stratiotes, Lemna perpusilla, Spirodela polyrhiza, Azolla africana, Nymphaea* spp., *Ipomoea aquatica, Neptunai Oleracea*); submerged macrophyte (*Potamogeton* spp. *Valliseneria* spp. *Ceratophyllum demersum, Utricularia* spp.); and phytoplankton (*Closterium aciculare, Pediastrum, Botryoccus, Microcystis, Anabaena, Melosira granulata* and *Surirella muelleri*). Proliferation of these water weeds may clearly signify an increasing amount of nutrients in the lake waters. During periods when there is insufficient flows from the Komadugu-Yobe River to support the northern pool eutrophication is exacerbated and all areas see the exposure of more paleo-dunes which are rapidly colonised by vegetation (primary acacia and papyrus), and aquatic weeds. Navigation is impeded if not made impossible by shallow depths and floating islands of vegetation (Holz et al. 1984).

Suspended solids

The northern sector of the region is naturally prone to wind erosion that significantly leads to deposition of sand into the Lake and rivers. However declining productivity and soil structure in the Sahelian zones of Chad and Cameroon combined with unpredictable rainfall and drought has resulted in extreme degradation and desertification. Desertification has lead to sandstorms from increased wind erosion that deposits huge amounts of debris in the Lake and rivers causing greater turbidity.

Land degradation in the Basin has been caused by many years of inappropriate agricultural practices, commercial logging, soil compacting as a result of extensive removal of vegetation and bush burning. These factors have exposed the soils to heavy rainfall, increased evaporation and wind erosion which has consequently increased the sediment load of rivers causing siltation on the lake bottom and has thus reduced the effective lake volume. This has been exacerbated by the growth of rhyzomatous hydrophytes that encourage soil accretion and increases water loss through increased evapotranspiration (see review: Obot 2000). The problem of siltation has increased along river channels due to upstream reservoirs and reduced peak flows downstream.

Migratory fish spawning grounds such as those in the extensive Logomatia marshes reached through the El Beid and Chari-Logone river systems could be altered and degraded with the intensification of agriculture. This is occurring as a consequence of increased sediment and agro-chemical pollution carried by the rivers (Keith & Plowes 1997).

In Chad and Central African Republic, the exploitation of diamonds and gold mining, in the regions of Tandjile and Mayo Kebbi and along the Aouak River in the upper Chari Basin, has increased the load of suspended solids in the surrounding rivers, with unknown impacts on river ecology and possibly disrupting the migration and reproduction cycles of fish in the seasonal rivers of southeast Chad (Lemoalle 1997, Republic of Chad 2003).

Microbiological pollution

There is no relevant documentation on the extent of microbiological pollution; this issue was therefore unable to be ranked by the GIWA Assessment. However, water-borne diseases are rampant in the region as a whole, indicating that there could be possible cause for concern.

Waste management facilities are very poorly developed in the Basin. In Niger for example, rural and urban sanitation is grossly inadequate, due to accelerating urban growth and the depletion of municipal resources. Enormous quantities of waste are consequently produced and with most neighbourhoods having no sewerage system, the accumulated household waste represents a vector for many diseases. In Chad no town (except the Doba oil well site) has a functioning wastewater evacuation system and collection networks are dilapidated (IMF 2003).

Microbiological pollution is suspected of being prominent around settlements and on riverbanks of major waterways, where population densities are highest. The heavily concentrated numbers of settlements surrounding the Lake Chad are a particular focus of pollution, where there are occurrences of direct discharges of industrial and domestic waste. Factories and other unhealthy installations in urban areas also constitute sources of pollution of surface and groundwaters (Government of Niger 2002). Lemoalle (1997) identified the increased discharge of sewage into the rivers upstream of Bongor in Logone River Basin and the upper Chari River Basin in the Central African Republic and from increased urbanisation as one of the major environmental risks in the region, especially at times of low flow when effluent discharges are poorly diluted.

Socio-economic impacts

The economic, health and social impacts of pollution were all considered as slight. There is a lack of data outlining the impacts of pollution in the Basin and scores were assigned based on expert opinion. A significant number of people are at risk from water quality problems but this is influenced not specifically by pollution but by a combination of other concerns including freshwater, global change and habitat modification. In the basin water-borne epidemics are resurgent, particularly among young children. Several diseases are rampant in the region including malaria, various forms of diarrhoea, acute respiratory infections, measles, tetanus, yellow fever, diphtheria and chicken pox. However, there are no studies identifying the role water pollution plays in the proliferation of these diseases.

Future outlook

With the start of oil exploitation in the region and the increased application of fertilisers and pesticides due to the expansion of large-scale irrigation, pollution could become moderate by the year 2020. This scenario is likely in the current environmental legislative framework, where there are limited constraints on industry. Although presently pesticides are not extensively used, as irrigated and shoreline agriculture increases, larger amounts of agro-chemicals will be utilised as they become increasingly affordable and available. Insecticide use will most likely be used primarily for high value crops and therefore its effect of toxicity to fish and wildlife will be localised rather than widespread (Keith & Plowes 1997). The Lake would be highly vulnerable to increases in pollution as it is the final recipient of the Basin's rivers and in its current 'lesser' size has a limited dissimilative capacity (LCBC 2000b).

Petroleum exploitation in the region has presented itself as a solution to the poverty situation. The project has the potential to transform the economic status and structure of the region. It is likely that industrial activity will become increasingly significant with the expected increased foreign capital injected into the economies of Chad and Cameroon from oil revenues and associated industries. The actual oil project and the increased industrial activity will subsequently pose a pollution threat. The World Bank project documents and non-governmental organisations have identified the following possible pollution impacts of the oil project and an action plan has been prepared and implemented to mitigate all of these risks (ESSO 1999):

Chemical pollution: Recent oil development in Chad and Cameroon could result in chemical pollution through the discharge of industrial and domestic effluents, and contamination from site run-off.

Environmental assessments for the Doba oil well site identified that there were possible risks from domestic and industrial effluents from extraction site during and after construction (Republic of Chad 2003). The exploitation of the oil field of Sedigui, north of Kanem, will also pose a threat from extraction effluents. In Sedigui however, further caution is needed due to the relationship between groundwater and surface waters in this region, which are particularly vulnerable to contamination (Republic of Chad 2003).

Oil in the Doba Basin will contain a significant percentage of water that must be extracted from the crude oil before shipment. This water will need to be disposed of safely, so that there is no contamination of local water supplies (ESSO 1999).

However, mitigation measures have been applied to minimise the risk of possible pollution incidents to comply with World Bank specifications. The exploitation of oil in the region has been presented by project sponsors as having no effect on the aquatic environment (Republic of Chad 2003).

Oil spill/leakage: Oil development in Chad has a potential risk of pipeline leakage, groundwater contamination and freshwater pollution. Although mitigation measures have been installed, there is always a risk of an oil spill event (ESSO 1999), even if the best available technology is adopted. The pipeline traverses several major rivers contained in the Lake Chad Basin including the Nya, Loule, Lim and Mba rivers and crosses the Mbere River twice. The Mbere River, forms part of the boundary between Cameroon and Chad, and Cameroon and the Central African Republic and the area contains tributaries to Lake Chad. A spill incident would have international implications (ESSO 1999) with even one leak endangering communities all along the pipeline as they rely on surface water systems for most of their water needs. Leak prevention measures have included the pipe being buried at a safe depth and reinforced pipe walls at river crossings. An emergency response plan has been formulated in compliance with World Bank specifications although it has been criticised for not going far enough in being site-specific. Concerns raised during public consultations resulted in the oil pipeline being constructed to pass around Lake Chad, to avoid risks of pollution incidents (spills) into the Lake (Republic of Chad 2003).

Suspended solids: Environmental assessments at the Doba oil well identified that there could be possible risks of erosion resulting from landscape modification during construction of the pipeline and sediment could subsequently run-off into the surrounding streams. However, mitigation measures have been employed to minimise the effect of particulate pollution before it is able to reach the rivers (Republic of Chad 2003).

Conclusions

The GIWA Assessment considered pollution as having the least impact on the Lake Chad Basin. Although there is very little current scientific data to confirm this assumption, it is presumed that due to the current lack of industrial development and limited application of fertilisers in agriculture because of financial constraints, that pollution is slight. The pollution that is occurring is released in insignificant quantities that do not exceed the ecosystems' carrying capacity and the impacts are generally localised. Studies are needed to identify the status and distribution of pollution in the environment. With the increasing use of agro-chemicals and the exploitation of oil in the region and associated industrial growth, mitigation measures need to be installed in an adequate environmental legislative framework.

Priority concerns

Freshwater shortage was ranked severe and was considered the priority concern in the GIWA region 43, Lake Chad Basin. All of the other concerns except for pollution have had a moderate impact. Although there has been significant modification of habitats and significant fluctuations in fish production, these are a function of freshwater shortage, rather than a consequence of direct habitat modification or unsustainable exploitation of fish. Table 8 shows the overall rating and justification for each concern.

Table 8 The overall rating and justification for the GIWA assessed concerns.

Concern	Overall severity	Justification/Indicators for current severity	Future severity
Freshwater shortage	Severe	Lake Chad shrinkage: A 90% reduction in surface area. Stream flow modification: the Chari-Logone River discharges 75% less water into the Lake Chad (Olivry et al. 1996).	Severe
Habitat and community modification	Moderate	Wetland modification: Wetlands resources have been decreased by 50% (Barbier et al. 1997). Fisheries habitat modification: Open-water species previously made up approximately 52% of the fish market species composition, currently they make up less than 1% (Neiland & Béné 2003).	Severe
Unsustainable exploitation of living resources	Moderate	The terms overexploitation and unsustainable are difficult to apply to such a dynamic system. Large fluctations in fish production have been more a funcation of environmental changes than overexploitation. Fisheries governance and its relationship with socio-economic differentiation within the communities are the significant issues affecting the fisheries sector.	Severe
Pollution	Slight	There is a lack of industrial and mining activity and there is moderate application of agricultural fertilisers, although there is an extreme lack of data to justify this presumption.	Moderate
Global change	Moderate	Climate change has had a severe impact on freshwater shortage. However the Basin has exhibited a history of climatic variability (Holz et al. 1984). The impact of recent anthropogenically induced climate change is unclear but is considered as playing a role in freshwater shortage.	Severe

The overall scores did not dictate a priority order for all of the concerns. The priorities were assigned on the basis of common judgement built on intense discussion during the GIWA workshop, hosted by the LCBC, and further assessment of the individual scores. The concerns for the Lake Chad Basin were ranked in descending order:

1. Freshwater shortage
2. Global climate change
3. Habitat and community modification
4. Unsustainable exploitation of fish and other living resources
5. Pollution

Freshwater shortage was considered by the GIWA Assessment to have the highest severity of impact. Climatic variability and anthropogenic freshwater shortage issues, namely stream flow modification, were identified as the two immediate causes of the concern. Although climate change has depleted the water resources in the region, it is believed that the level of stream diversion and abstraction has been unsustainable in the climatic scenario of the past four decades. Figure 44 is an illustration of the impacts of the freshwater shortage concern, in the Chari-Logone Basin and Lake Chad. It demonstrates how freshwater availability drives the other GIWA assessed concerns and highlights some of the related ecological and socio-economic impacts. There are very prominent indicators of freshwater shortage including the shrinkage of the Lake Chad by 90% in the past four decades (Lemoalle 1991, USGS 2001) and reduced river discharges, for example the Chari-Logone River now discharges 55% less than in wet years prior to the 1970s (Olivry 1996). Freshwater shortage has impacted heavily on the Basin's economic activities including the fisheries, agriculture, animal husbandry, fuel wood provision, and wetland economic services. There has been consequential food insecurity in the region and combined with a lack of potable water has had implications on the health status of the Basin's population. Social impacts are linked to water supplies not meeting the population's requirements, and have included upstream/downstream conflict over water allocation, due to the construction of dams upstream without sufficient provisions for people and the ecosystems that support these people downstream of the development (Oyebande 2001). Freshwater shortage has caused social tensions from the migration of people from the drought stricken northern regions of the Basin into areas surrounding the Lake and associated river sub-systems (World Bank 2002a).

Global change has influenced directly and indirectly all of the assessed concerns (except for pollution) that affect the Lake Chad Basin. Climatic variability exerted throughout the history of the Basin is therefore considered as playing the most important role in the reduced rainfall in the region. Changes in precipitation in the Sahel (that includes the Lake Chad Basin) have been linked with Sea Surface Temperature (SST) patterns (Lamb 1978). These changes have been attributed to changes in heat transfer between the Southern and Northern hemisphere (Evans 1996). Possible scenarios include increased deep water circulation in the Atlantic affected by the reduction in extent of sea ice, and the effect of sulphate aerosols which are dominant in the Northern hemisphere. It is believed that local land surface anomalies (such as vegetation degradation) have also played a role in the rainfall variability (Evans 1996). A combination of factors including vegetation cover, soil moisture, and SST is thought to best explain the reduction in rainfall in the Sahel (Xue & Shukla 1997). The role of anthropogenic climate change in the recent episode of freshwater shortage is therefore undetermined. Further research developments into detailed coupled transient GCM models may be able to confirm the roles of 'natural' and human influences.

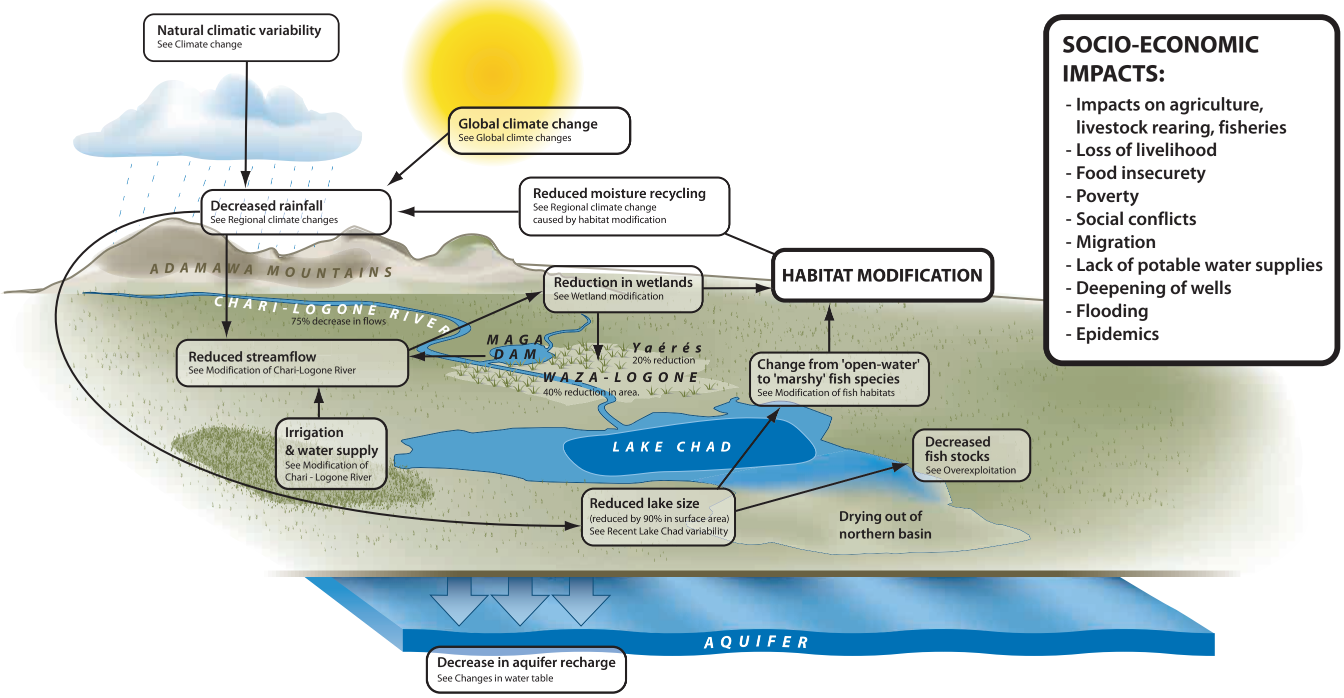


Figure 44 Illustration of the driving influence of the GIWA freshwater shortage concern on the other assessed concerns and the associated environmental and social impacts.

Note: Please see the Causal chain analysis for the root causes of the freshwater shortage concern.

Habitat and community modification of the aquatic ecosystems of the Basin has been primarily focused on the wetland ecosystem that have been intensively cultivated and frequented by large numbers of domestic animals. The wetlands have primarily decreased in extent due to changes in the seasonal timing and extent of flooding (Oyebande 2001). Consequently, since the 1960s, wetland resources in the Basin, such as the Yaérés in Cameroon and Hadejia-Nguru in Nigeria, have been reduced by almost 50% (Barbier et al. 1997). The fish habitat has altered from being an open water environment to being a predominantly marshy environment and the fish species composition has changed to reflect this (Neiland & Bene 2003). Although there has been significant habitat modification this has been largely due to freshwater shortage.

Unsustainable exploitation of fish and other living resources was not considered as the primary reason for the fluctuations in fisheries production over the past four decades. The terms unsustainable exploitation and overexploitation are inappropriate for the Lake Chad Basin fisheries due to difficulties defining a baseline level and due to the dynamic nature of the system. Freshwater shortage and the consequential habitat modification were regarded as the main influencing factors. Annual fish production fell from over 200 000 tonnes in the early 1970s to some 20 000 tonnes in 1987 (Neiland & Verinumbe 1990), and is presently estimated at over 60 000 tonnes (Neiland & Béné 2003). Prior to the drought years the fisheries had developed rapidly with fishing effort increasing by 50 times from 1967-1972 (Durand 1973). The contracting lake and wetlands caused fish to be concentrated and more vulnerable to fishing gears, eventually the fisheries collapsed in the northern pool followed by the southern pool fisheries by 1982. The fishing communities migrated eastwards following the receding waters; they also changed their livelihood strategies to take advantage of the fertile lake recessional floor for agriculture. Since 1982, the fisheries have shown a good recovery, which demonstrates the Lake's ability to regenerate the fisheries as freshwater availability increases once again (Neiland & Béné 2003).

Pollution is presumed due to the lack of industry and limited application of agricultural fertilisers to have the least impact out of all the concerns assessed. It is considered that pollution is discharged in quantities that do not exceed the ecosystem's assimilative capacity. However, further studies are needed to scientifically justify this presumption; there is currently a severe lack of monitoring and information networks regarding pollution.

Future scenarios of priority concerns

All of the concerns assessed are predicted to increase in severity by the year 2020. Consequently, the concerns of Freshwater shortage, Habitat and community modification, Unsustainable exploitation of living resources, and Global change are predicted to have severe impacts on the ecosystems and population of the Lake Chad Basin. The threat of Pollution, which is currently assessed as having a slight impact, is predicted to become increasingly significant in the future.

Future climate change will directly and indirectly play an important role in determining the future severity of freshwater shortage and subsequently the other inter-connected concerns (see Inter-linkages and synergies). The number of rainfall events in the region will be influential in conditioning freshwater inputs and consequently, if water resources continue to be used at an unsustainable level in the Basin, freshwater shortage. However, the influence of future climate change in the Central African region has yet to be determined as there are presently no accurate models for predicting future precipitation rates over the region. There have been several indications that the drought is ending in the Sahel. There have been only three wet years (1975, 1994 and 1999) in the last 30 years, but they were always separated from each other by at least four non-wet years (L'Hôte et al. 2002). The 1990s were indeed less dry than the 1970s and 1980s, and in the wet year of 1999 increases in precipitation led to the flooding of the northern pool once again. However the 1990s was still the third driest decade of the 20th century and the wet years were isolated events (L'Hôte et al. 2002). Consequently there appears to be no sustained upward trend since the 1970s and the Lake remains in its 'lesser state'. According to L'Hôte et al. (2002) the drought had not finished by the end of 2000 and it is therefore premature to state whether recent increases in precipitation are part of a larger climatic trend.

Some predictions have envisaged greater aridity and a scenario between 2001 and 2020 similar to the current status from 1973 until now (Republic of Chad 2003). This is based on a future scenario of increased global warming linked to a weakening in carbon sinks and radiation sinks in the polar regions with reduced deep water formation due to reduced heat transfers from the southern hemisphere to the north. Positve feedbacks from reductions to the radiation and CO_2 sinks could lead to an increase in global warming (Lewis 1989 in Evans 1996).

Available water supplies will be further overexploited if planned water development projects go ahead. An IUCN study estimated that in the Hadejia river system the potential water requirements are at least (not taking into account evaporation losses) 2.6 times greater than the mean surface water resources (Bdilaya et al. 1999). Although currently the water requirements In the Jama'are and Yobe river basins are met by available water resources, if the construction of the Kafin Zaki Dam is completed they could be outstretched. Water will be used for the proposed Jama'are Valley Irrigation Project and some smaller irrigation schemes upstream of Katagum. Potential water requirements for the Jama'are river system could consequently be more than 1.8 times the available water resources in a mean year (Bdilaya et al. 1999).

The average population growth for the Basin is predicted to be 2.6% which could lead to an estimated population of over 56 million by 2020 (UN Population Division 2002). This will increase the pressure on natural resources and therefore increase water use, habitat modification and pressure on the fisheries. A larger population could inflict further economic stress on the countries of the Basin, which may lead to a greater employment of unsustainable practices by communities to allow them to subsist. The further southward advance of the Sahara due to desertification will potentially lead to greater migration from the northern provinces to the south and exacerbate the major concerns faced in the in-taking regions.

The severity of the assessed concerns could increase due to greater demand and use of resources. For the foreseeable future water demands in the Lake Chad drainage basin are expected to increase, as the population becomes more dependent on irrigation agriculture (Hutchinson et al. 1992, FEWS 1997 and 1998 in Coe & Foley 2001). In the southern markets of Nigeria there is increasing demand for protein foods such as fish (Neiland & Verinumbe 1990), which will result in greater pressure on the Lake Chad fisheries as the majority of fish production from the Basin, is sold in these markets. Future technological improvements in the fisheries have also the potential to expand fisheries production.

The recent Chad-Cameroon oil development has the potential to transform the economies of the two countries. It is expected to account for 45 to 50% of Chad's national budget (World Bank 2003b). This could influence the severity of the assessed concerns. Employment opportunities will encourage migration into the Chari-Logone Basin where the Doba oil field is located. This has a potential to enhance the pressure on natural resources due to increased use of water, habitat services and the fisheries resource. The boosted economy is expected to generate opportunities for industrial development that may impact on the pollution concern especially under the current weak environmental legislative framework. Although the project sponsors have installed comprehensive mitigation measures there is always a risk of pipeline leakage, groundwater contamination and freshwater pollution (ESS0 1999). Pollution from the agricultural sector should also be closely monitored, with potential contamination of lakes and rivers from agro-chemicals. The increase in irrigated rice and cotton production which both require large amounts of pesticides and herbicides could increasingly become a threat to ecological systems as well as human health, if mitigation measures are not installed. Pollution is therefore expected to have a moderate impact (rather than its current 'slight'), before the year 2020.

Inter-linkages and synergies between the concerns of the Lake Chad Basin

Freshwater shortage linkages with Habitat modification

Freshwater shortage has significantly modified the habitats and community structure of the Basin's ecosystems. Stream flow modification as a result of decreased rainfall events and upstream dam impoundments primarily in the Chari-Logone and Komadugu-Yobe river systems has impacted on the habitats downstream. Wetlands have been the most affected as a result of changes in the timing and extent of seasonal flooding. The reduction in the stream flow has also caused the Lake Chad to shrink to less than 10% of its former surface area (Lemoalle 1991, USGS 2001). This has significantly altered the Lake from being an open water environment to being a predominantly marshy environment. The fish species composition has correspondingly also been modified. A lowering of water tables has caused a reduction in perennial vegetation.

Freshwater shortage linkages with the Unsustainable exploitation of fish and other living resources

The size and composition of fish stocks is integrally linked to the size, duration and timing of the annual floods and the level of Lake Chad. Changes in stream flows changed the distribution of aquatic habitats of both the floodplains and Lake Chad environment and fisheries production fluctuated accordingly. Recent production estimates have indicated a significant recovery of the fishery since the collapse of 1982, which demonstrates the Basin's capacity to regenerate its fish stocks when water levels increase (Neiland & Béné 2003).

Global change linkage to Freshwater shortage

Climate variability is considered as a key determining factor in freshwater availability in the Basin. In the past four decades there has been a persistent reduction in rainfall over the Lake Chad Basin. Stream flows have consequently decreased and available water supplies have been unable to meet the water requirements of the Basin.

Habitat modification linkages with the fisheries

Aquatic habitats have been altered from being predominantly open water to a marshy ecosystem. Fish species have also modified accordingly from 'open water' species to 'marshy' species. 'Open water' species have therefore been more vulnerable to fishing gears. Wetland habitat modification has also contributed to considerable losses of both riverine and lake fisheries, as they provide habitats for fish in general and spawning in particular.

Habitat modification linkages with global climate change

Climate change can partially be attributed to regional habitat modification. Vegetation in semi-arid regions such as the Lake Chad Basin has a significant influence in determining weather patterns. As the climate became drier over the past 40 years and overgrazing continued, vegetation declined. The ability of the ecosystem to recycle moisture back into the atmosphere was thus reduced, contributing to the retreat of the monsoons (Coe & Foley 2001).

Pollution linkages with other assessed concerns

Although there is limited information regarding the influence of pollution in the Basin, it is presumed due to the lack of industrial activities and limited application of agricultural fertiliser that pollution has had a minimal effect on the four other concerns.

Figure 45 shows a model of the inter-linkages and synergies of the five assessed concerns of the Lake Chad Basin. Thickness of line indicates extent of influence of a concern on another concern assessed.

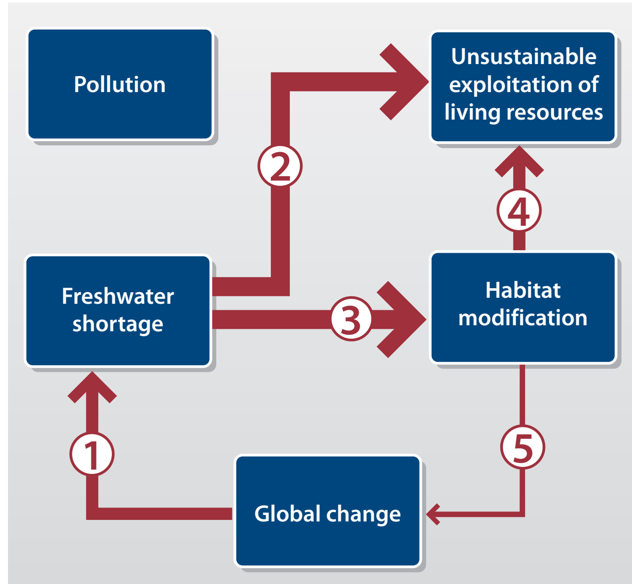


Figure 45 Model indicating the inter-linkage and synergies between the concerns of the Lake Chad Basin.

Causal chain analysis

This section aims to identify the root causes of the environmental and socio-economic impacts resulting from those issues and concerns that were prioritised during the assessment, so that appropriate policy interventions can be developed and focused where they will yield the greatest benefits for the region. In order to achieve this aim, the analysis involves a step-by-step process that identifies the most important causal links between the environmental and socio-economic impacts, their immediate causes, the human activities and economic sectors responsible and, finally, the root causes that determine the behaviour of those sectors. The GIWA Causal chain analysis also recognises that, within each region, there is often enormous variation in capacity and great social, cultural, political and environmental diversity. In order to ensure that the final outcomes of the GIWA are viable options for future remediation, the Causal chain analyses of the GIWA adopt relatively simple and practical analytical models and focus on specific sites within the region. For further details on the methodology, please refer to the GIWA methodology chapter.

Freshwater shortage was selected as GIWA region 43 Lake Chad Basin's priority concern (see Assessment, Priority concerns). The Chari-Logone sub-system and Lake Chad was identified as one hotspot and the Komadugu-Yobe sub-system as another hotspot, and for both the priority issue of stream flow modification was selected. They are both highly transboundary in nature; the Komadugu-Yobe is found in Nigeria and Niger; the Chari-Logone sub-system is located in Central African Republic, Cameroon and Chad, where as the Lake Chad is surrounded by the countries of Chad, Niger, Nigeria and Cameroon. The Chari-Logone and Lake Chad systems will be analysed together as the freshwater shortage in the Lake Chad is largely determined by the discharge of the Chari-Logone River, which supplies 95% of the Lake's total riverine inputs.

The focus of the Causal Chain Analysis (CCA) is to determine the root causes of freshwater shortage in the selected hotspots, so that the driving forces of the issues can be addressed by policy makers rather than the more visible causes. Casual chain analysis traces the cause-effect pathways, associated with the freshwater shortage concern in the Chari-Logone/Lake Chad and the Komadugu-Yobe hotspots, from the socio-economic and environmental impacts back to the root causes. The root causes can then be targeted by appropriate policy measures. Separate analyses were carried out for these two systems.

Chari-Logone and Lake Chad sub-system

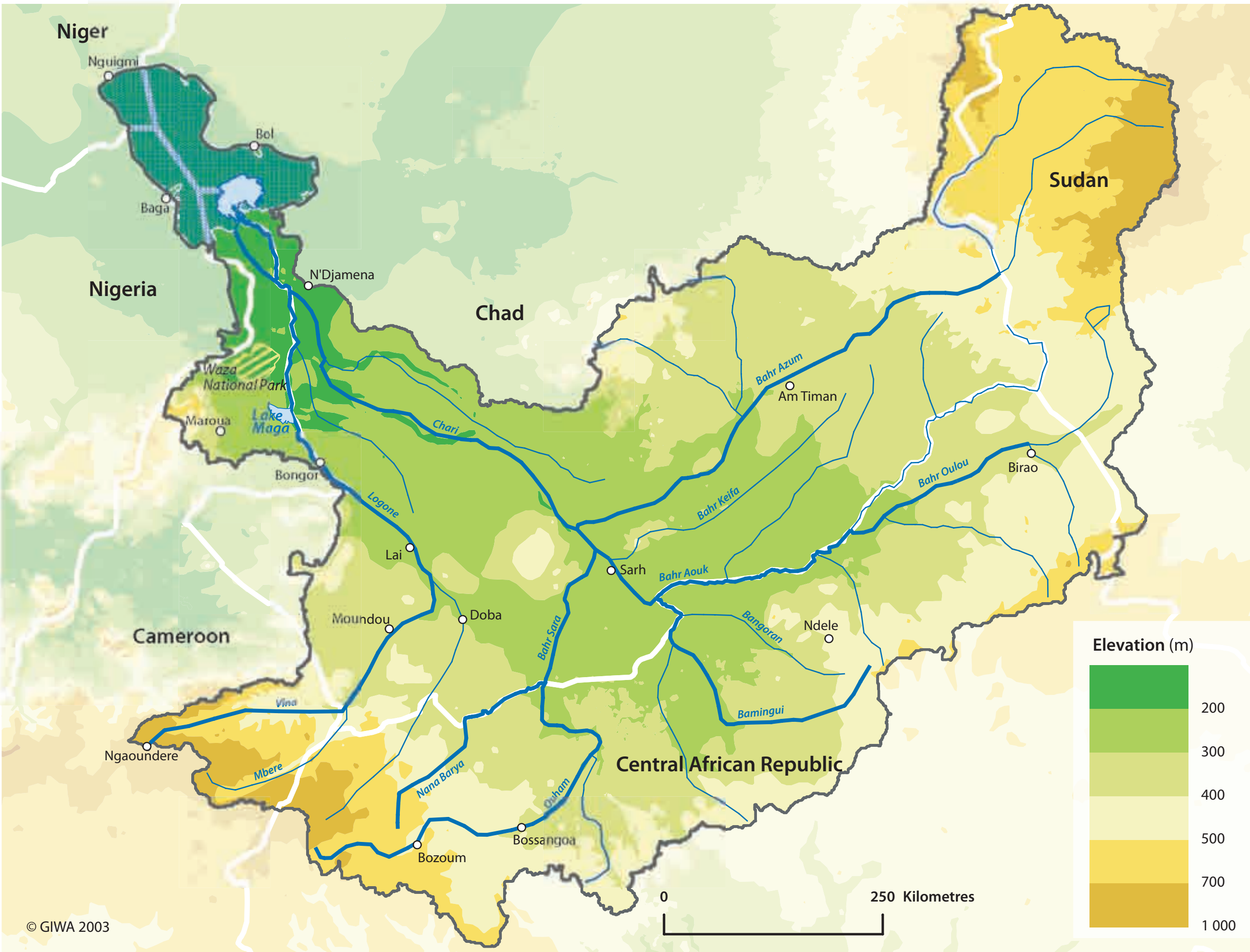


Figure 46 The Chari-Logone and Lake Chad sub-system.

The Chari-Logone sub-system has a basin area of approximately 650 000 km^2 and the Chari River extends 1 400 km in length (Froese & Pauly 2003). The parts of the sub-system lying in Central African Republic constitutes the headwater region. The Ouham in CAR, becoming the Bahr Sara in Chad, is the main tributary of the Chari River with its confluence located at Manda, downstream of Sarh. Its contribution was estimated to be twice that of the Bahr Aouk, despite having a smaller catchment area. The Bahr Aouk drains the entire northeastern part of CAR and together with its tributaries, is a true floodplain river. The Bamingui and Bangoran rivers drain the northern part of CAR and form the transition between the northeast and the more populated northwestern areas. All rivers in the CAR parts of the Basin have their main flow during and following the rainy season from July to September.

The Logone River forms the border between Cameroon and Chad until N'Djamena where it flows together with the Chari River northwards to the Lake Chad. The Chari and Logone rivers have a tropical regime with a single flood occurring at the end of the rainy season, which lasts from August to November (FAO 1997) and feeds the extensive Waza-Logone floodplains in northern Cameroon.

The Waza-Logone floodplain is located in the extreme north of Cameroon and is bordered by Nigeria to the west and Chad to the east (IUCN 2003b). It was previously a vast body of shallow water that contained many species of bird and was surrounded by rich grasslands that hosted a large number of grazing animals. The floodplain contains the 1 700 km^2 Waza National Park which is designated a Biosphere Reserve, and the 45 km^2 Kalamaoué National Park (Ngantou & Braund 1999).

The high productivity of the Waza Logone region depends to a large extent on the overbank flooding of the Logone River and the seasonal rivers Mayo Tsanaga, Mayo Boula and Mayo Vrick. The flooding cycle begins with the first important rainfall in May, which saturates the soil and starts to fill the deepest depressions (Mott MacDonald 1999 in IUCN 2003b). The discharges of the Mayo Tsananga and Mayo Boula reach the floodplain in August, and by September or October the area is inundated by overbank flow from the Logone River, lasting until November or December. The almost total lack of relief in the region means that the flood spreads over a large area: more than 3 000 km^2 of the 8 000 km^2 floodplain. By December, the residual floodwaters are drained back in to the Logone through the Logomatya River, and north to Lake Chad through the El Beid River.

For further physical characteristics of the Chari-Logone sub-system see Regional definition, Chari-Logone sub-system. Figure 46 shows a map of the Chari-Logone and Lake Chad sub-systems.

The population of the Waza Logone region is estimated to be 220 000 people, approximately 60% of whom rely on floodplain and wetland resources for their basic income and subsistence (IUCN 2003b). The Mousgoum and Kotoko are the dominant ethnic groups in the region (Van Est 1999). The inundated plains are highly productive breeding grounds for fish and large numbers of livestock of nomadic, transhumant and sedentary herders are supported during the dry season (Ngantou & Braund 1999). A complex fishery exists in both the main river channels and permanent lakes, and in flood-fed and seasonal creeks, ponds, depressions and wetlands. The SEMRY project and Maga Dam are located to the south of the Waza-Logone floodplain. Irrigated agriculture is minimal now, with most of the project's farmers exploiting the fisheries opportunities in the region or reverting to traditional agriculture.

Lake Chad is a terminal depression occupying less than 1% of the Basin (Coe & Foley 2001) with four countries in direct contact with the Lake: Nigeria, Niger, Chad and Cameroon. The Lake is extremely shallow, with a mean depth of 4 m (Carmouze & Lemoalle 1983), therefore any increase in lake volume means a substantial increase in lake area and shoreline (see review: Thieme et al. In preparation). The Chari-Logone rivers contribute the majority of all freshwater inputs into the Lake (World Bank 2002b) and its level is therefore highly correlated with the river's discharge.

Lake Chad serves as the political border between the riparian countries and provides an important source of potable water (AEO 2002) in an otherwise very dry region. Many economic activities are concentrated around the shores of the Lake including recessional agriculture and fisheries. The South Chad Irrigation Project (SCIP) extracts water from the Lake on the western shores in north Nigeria. For further physical and socio-economic information on Lake Chad see: Regional definition, Lake Chad and Box 2.

Environmental and socio-economic impacts

Figure 47 provides a summary illustrating the main causal links for freshwater shortage in the Chari-Logone Basin and Lake Chad. Stream flow modification in the Chari-Logone sub-system as a result of human induced stream diversion and climatic variability has resulted in the following environmental and socio-economic impacts:

Environmental impacts

- The discharge of the Chari-Logone system at N'Djamena has decreased by almost 75% over the last 40 years as a result of drought and water management practices (Olivry et al. 1996).
- The Maga Dam (SEMRY) sealed up water courses entering the Pouss depression, stored water originating from Mayo Boula and Logomatya, and caused the Mayo Gougoulay to dry up (IUCN 2003b).
- In total these construction works resulted in a 70% reduction of water supply to the floodplain from the Mandara Mountains, and an almost complete curtailment of the water supply from the Logone River (IUCN 2003b).
- The SEMRY project resulted in 30% decrease in the flooded area of the Waza-Logone floodplains (see review: LCBC 2002). Water diversion for the project combined with drought has eliminated the flooding of some 59 000 ha of floodplain and seriously reduced another 150 000 ha (LCBC 1998).
- Reduced flooding has resulted in the disappearance of many botanical species and the progressive invasion of meadows and natural environments by unwanted ligneous forming plants (IUCN 2003b).
- The extent of important breeding and feeding grounds for fish provided by the wetlands has been reduced (Neiland & Béné 2003).
- Lower recharge rates of aquifers (Barbier et al. 1997).
- The Lake Chad has been reduced by 90% in surface area between the 1960s and 1990s (based on satellite imagery, NASA).
- There have been large fluctuations in fisheries production; annual production escalated in the early 1970s, suffered a severe decline in the 1980s (Neiland & Verinumbe 1990) and is currently experiencing a recovery (Neiland & Béné 2003).

Socio-economic impacts

- Over-abstraction of water by upstream users in the Chari-Logone sub-system, at unsustainable levels in a period when there has been a substantial decrease in precipitation in the watershed, has led to a reduction of the supplies for downstream users.

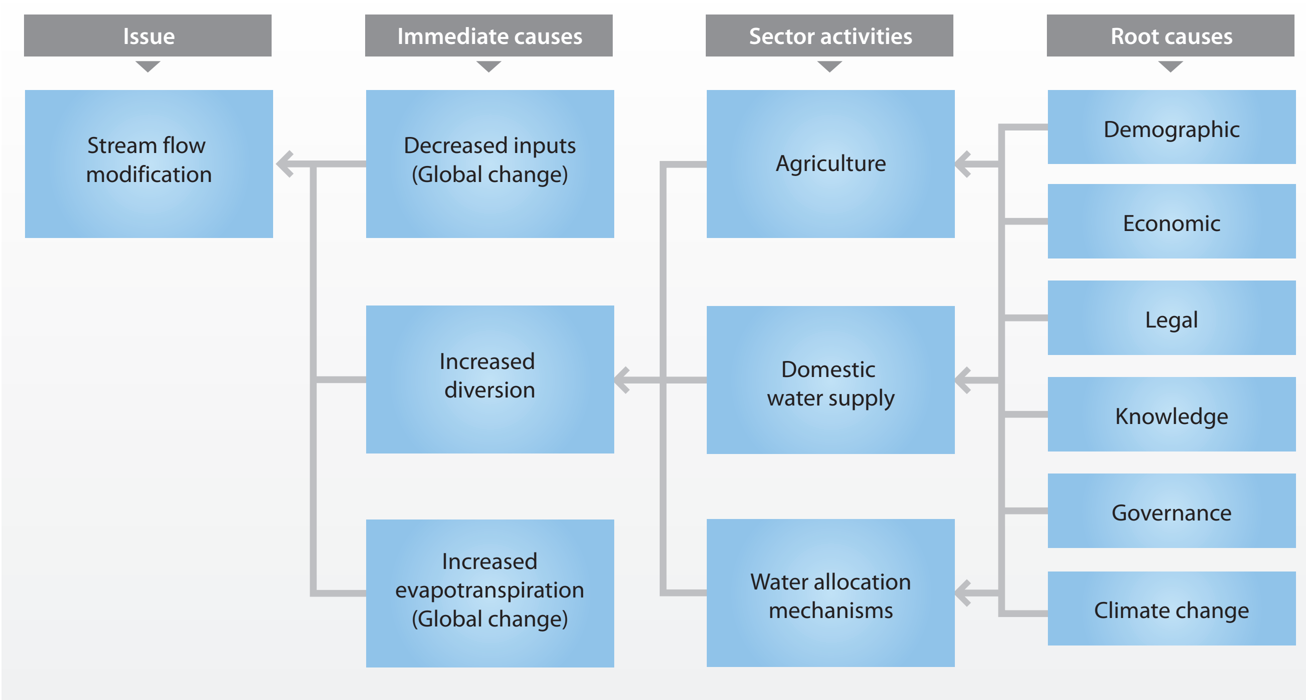


Figure 47 Causal chain analysis model for Chari-Logone/Lake Chad sub-system.

- Costly deepening of wells, and increased use of pumping to reach the lower water table (LCBC 1998).
- A reduction in inundated flood plain surface area has led to a decline in agricultural production and has accentuated food insecurity in the region (Nami 2002). Reduced flooding of Yaéré floodplains reduced the extent of land favourable to dry season agriculture (Nami 2002). In the Waza-Logone floodplains after the reduction in flooding, floating rice, floating sorghum, and flood recession sorghum were unable to be cultivated and the farmer's fields no longer were provided with a natural supply of water (IUCN 2003b). There has been a proliferation of pests as consequence of poor irrigation management.
- There has been a dramatic reduction in the extent of dry season grazing lands that previously supported large numbers of livestock. In the Yaérés perennial grass cover diminished, leaving only degraded grasslands of inferior quality and decreased area (IUCN 2003b).
- The contraction of the Lake Chad and reduced flooding of the wetlands has caused fisheries production to decline, affecting the majority of the rural population.
- There has been severe food insecurity in the downstream sections of the Chari-Logone river system and around the Lake. This has resulted from the decline in agriculture, livestock and fisheries productivity.
- Lack or inadequate access to potable water supplies coupled with poor or lack of proper sanitation has encouraged the proliferation and spread of diseases associated with water. Irrigation canals are also a vector for these diseases such as cholera, schistosomiasis and goiter. Chad in the downstream section of the Chari-Logone and surrounding the Lake Chad is particularly vulnerable to water-borne diseases.
- Upstream/downstream conflicts and migration from north of basin into the case study site, have exacerbated pressure on water resources.
- Fishing communities have migrated southeastwards following receding lake waters.

Immediate causes

Decreased inputs

Over the last half century the hydrological regime of the Lake Chad region has changed. Rainfall events have been reduced which in turn has led to decreased run-off and thus decreased stream flows in the Chari-Logone. At Doba, located on the Logone Pende, in 1955 an annual mean rainfall of 1 475 mm was recorded, which fell to 740 mm during the 1984-1985 drought, but has increased recently to almost 1 130 mm (1999) (Doba weather stations, Republic of Chad Meteorological Office). See Assessment, Freshwater shortage, Regional change, and Global climate change.

Increased diversion

The Maga Dam constructed on the Chari-Logone sub-system aimed at utilising the water resources of the region more efficiently. The water has been used for agriculture. The SEMRY project carried out many development works to open up large rice growing areas in northern Cameroon. A 30 km earthen Maga Dam was constructed on the upper part of the Waza-Logone floodplain in 1979 to provide water for the SEMRY irrigated rice scheme and for fish farming. At the same time, some 80 km of dykes were constructed along the edge of the Logone extending 20 km downstream from Maga Dam to prevent the irrigated rice fields from being flooded from over-bank flow from the Logone (LCBC 1998, Neiland & Béné 2003). The irrigation project aimed to reduce the dependency of local communities on the unpredictable floods and rain patterns, which had occurred during the 1970s (WIWO 2001). This was seen as a solution to the food insecurity in the region and a driving force for developing the economy of the Chari-Logone river system, and was given priority funding. Changes did at first reduce the dependence on natural conditions but at the expense of greater dependence on traders and moneylenders in order to purchase modern farming equipment to cultivate rice, as well as on state officials running the SEMRY project (Van Est 1999). The agricultural projects did not produce the revenues that were anticipated due to the decreased water supplies and lower than expected exports to the Nigerian markets. Since the construction of the Maga Dam and flood embankments the natural hydrological regime of the Waza-Logone floodplains was seriously affected. This diversion of water from the Chari River for agricultural purposes has contributed to the decreasing stream flows and the discharges into, and extent of, the Lake Chad.

Conclusion

The immediate causes of stream flow modification in the River Basin are the decreased rainfall events and increased diversion of water resources. Decreased rainfall events will not be analysed further as the regional and global climate change that has caused this decrease should be addressed by policy at a global forum (IPCC 2001). According to expert opinion the most significant GIWA assessed immediate cause is the increased diversion of rivers and the associated unsustainable use of water resources. The following section will identify the root causes of freshwater shortage in the Chari-Logone Basin.

Root causes

Demographic

Population growth: The population of the sub-system is currently estimated to be 11.1 million (based on ORNL 2003). The World Resources Institute (Revenga et al. 2000) estimated water supply to be 7 900 m^3/person/year in 1995 for the Chari Basin. The Chari-Logone Basin has almost half as many inhabitants as the Komadugu-Yobe sub-system and larger water supplies, and the highest per capita water supply in the Lake Chad Basin. However, an increase in the Basin's population has led to greater pressure on the natural resources of the Chari-Logone sub-system including its water resources.

Migration: There has been a large influx of immigrants from the northern provinces into the Chari-Logone Basin and around the Lake Chad due to drought and desertification forcing communities to leave the increasingly arid northern environment. The migrants were predominantly pastoralists who in the past frequented the Chari-Logone pasturelands and lake peripherial during seasonal transhumant migrations. For example, although population densities are relatively low in the CAR sector of the Chari-Logone sub-system, and have limited pressure on the environment, the Sahelian drought resulted in an important movement of cattle and stockbreeders from the neighbouring countries, encouraged by the National Association of Stockbreeding Development. No special infrastructure was created to cater for the extra cattle and watering took place along the rivers (Lemoalle 1997). The SEMRY project also encouraged migration into the region as it promised employment opportunities. The population of the village of Maga grew from around 50 inhabitants to 20 000 inhabitants in less than five years (Nami 2002). The SEMRY project has been seen as a failure and many of the inhabitants of Maga village now fish instead. Although water resources are more abundant in the Chari-Logone Basin, migrants have increased the stress on water resources and water management systems. This has increased competition and aggravated conflicts between stockbreeders, who are moving southwards, and farmers (LCBC 2000b).

Economic

Poverty: The River Basin suffers from mass poverty, and the people are often forced to degrade the environment in order to survive in the short-term. However more information is needed to verify this presumption in the Chari-Logone Basin.

Inadequate valuation of environmental goods and services: The construction of dam and flood infrastructure as part of the SEMRY irrigation project did not take into account the values placed on the freshwater resources and flooding regimes by fishing communities and pastoralist populations. The upstream diversion of the Logone River at the Maga Dam has had severe economic impacts on the Waza-Logone floodplain (IUCN 2003b). The severity of these economic impacts on the region has outweighed the economic benefits provided by the project. A valuation study conducted by IUCN (2003b) showed that before the construction of the SEMRY scheme, the value contributed by this flooding to the regional economy was over 10 million USD per year, or more than 3 000 USD/km^2 of flooded area. Since then, the inundated area of the Waza-Logone floodplain has been reduced by almost 30%, incurring annual economic costs to the local economy of more than 2 million USD (Table 9). This study has highlighted the economic costs to the poor rural communities of the inadequate valuation of environmental goods and services during planning of the SEMRY project (IUCN 2003b). However, planners did not have accurate forecasts available to them, and did not foresee such a significant decrease in stream flow.

Table 9 The economic costs of flood loss in the Waza-Logone region.

Economic loss	Total loss (USD per year)
Pasture losses	-1 310 000
Fisheries losses	-470 000
Agriculture losses	-320 000
Grass losses	-290 000
Surface water supply losses	-20 000
Net cost	-2 400 000

(Source: IUCN 2003b)

Knowledge

Public awareness: There are extreme deficiencies in information availability and public awareness in the Chari-Logone/Lake Chad sub-system. There are difficulties in information dissemination and communication with the local communities whom predominantly live in rural areas. Given this lack of information availability, the people of the Waza-Logone floodplain lack the expertise they need to organise themselves adequately in the management of the diminishing resources (Ngantou & Braund 1999).

Information sharing: Countries have difficulties cooperating and sharing information. There is no permanent interface between the neighbouring countries of Chad and Cameroon regarding allocation and management of the water resources of the Chari-Logone catchment, with only a few meetings held sporadically. The weak information sharing network amongst the five countries contained in the Chari-Logone/Lake Chad sub-system is also partly attributed to their different colonial experiences and political systems and partly due to the communication infrastructure in the region. The only data exchange is through the Chad-Cameroon Joint Commission with no permanent secretariat and the Lake Chad Basin Commission (LCBC). There is not any information sharing networks such as through the Internet and the application of regional GIS databases.

Identifying and quantifying water abstraction: There is no record of the levels of water abstraction for irrigation, municipalities, traditional activities etc. from the sources of the Chari-Logone to Lake Chad itself. Traditional management systems are dominant in the sub-system and regulate access to water. These systems generally do not monitor water use and abstraction quantities.

An insufficient knowledge of water resources and the functioning of aquatic ecosystem: There is not a comprehensive model that is able to predict the hydrodynamic reactions of proposed water projects. At present the institutions in Cameroon which are responsible for the monitoring of the hydrology and environment can not provide sufficient data, although the IUCN Waza-Logone Project (CACID) can provide data but it is generally limited to the Waza-Logone stretch of the sub-system (Lemoalle 1997). There is presently a lack of knowledge regarding future climate change and the impact possible changes may have on the sub-system.

Scientific resources: Due to the financial difficulties in the region, scientific and technical research does not receive sufficient funding (LCBC 2000b) and has not been perceived as a priority by the Basin's countries. The region contains inadequate professional human resources and there is an absence of performance indicators for monitoring and evaluation. This is not helped by weak logistic support (e.g. supervision, equipment, vehicles and spare parts) and lack of centralised or coordinated national water resource databases (LCBC 2000b).

Legal

The current water laws of Chad, Cameroon and CAR, do not have the necessary elements in order to ascertain integrated water management of the Chari-Logone catchment rivers and tributaries. An important impediment to integrated water management is the absence of any implemented water allocation law between the Chari-Logone and Lake Chad sub-system's riparian states, to enable the equitable use, conservation and sustainable development of the water resources already contained within the Basin. There is no water allocation rule contained in the Fort Lamy (now N'Djamena) Convention of 1964. The FAO submitted a draft agreement at the LCBC's request to the member States at the 13th session of the LCBC, which was to be studied in detail by the legal departments of the member States. However it is believed that due to a lack of experience in dealing with water law the ratification of a water allocation rule never materialised (LCBC 2000a). The equitable use of groundwater supplies is also a further legal gap in national law and the Fort Lamy Convention, and was also not stipulated in the FAO draft agreement.

Figure 48 Chari River at N'Djamena in Chad.
(Photo: Corbis)

The bi-lateral Moundou Agreement between Chad and Cameroon in 1970, established fixed maximum abstraction rates on the Logone River. The Chad-Cameroon Joint Commission was subsequently established. However the commission has no secretariat and there is no monitoring or enforcement of the maximum abstraction rates. The commission is essentially inactive. The maximum abstraction rates have been criticised for not taking into account new low water flows and that the minimum flow is not sufficient to protect fish, water table levels and river bank vegetation (Lemoalle 1997). Without an official water allocation agreement there is confusion about who has the right to the diminishing resource in the Chari-Logone sub-system. The decreased water availability in the region has led to competition and disputes over access and use of water resources that became increasingly scarce.

Another legal weakness in the Fort-Lamey Convention is that member States are only required to consult each other when altering international watercourses. A nation does therefore not need prior agreement from all member States in order to proceed with a development i.e. there is no veto power residing in the Commission or any of its organs (LCBC 2000a).

Governance

Conflicting policies between ministries: The governments active in the Chari-Logone sub-system, namely Cameroon and Chad, have two conflicting policies. The first is to reduce poverty, by increasing economic growth and also by improving food self-sufficiency through the utilisation of irrigated rice cultivation. The other policy is to conserve wildlife through the creation of national parks. The impact of this is clearly shown in the Waza-Logone floodplain where the SEMRY project has decimated the wildlife of the Waza National Park (Van Est 1999). There is a need to recognise that some policies are compatible whereas some are conflicting and identify the trade-offs in order for informed decision making. For example, increased flooding conserves wildlife and at the same time promotes tourism and improves fishing, flood recessional agriculture, pasturelands and other wetland resources. The incompatibility of the current two policies also cause legal confusion regarding land management regarding which use – agriculture or conservation – the land should be used for.

Lack of water resource environmental planning: A short-term policy focus resulted in unsustainable policy decisions. The planners of the SEMRY project did not take sufficient account of the impacts of stream flow modification from the Maga Dam, on downstream humans and ecosystems. The project was undertaken with no environmental planning and little or no resource management (Ngantou & Braund 1999). The vulnerability of the region to climatic variability was not considered during planning, and the impacts this would have on the freshwater availability and consequently the SEMRY project. The unilateral decision to construct the Maga Dam caused conflict with downstream users of the water resource.

Lack of stakeholder participation: Stakeholders were not involved in the initial planning and implementation of and management of the SEMRY project. The project did not attempt to encourage stakeholders to participate. Consultations occurred at a ministerial level, with a lack of involvement of the private sector. The communities of the Waza-Logone floodplains were not consulted even though they were most liable to be affected due to their dependence of the intra-annual flooding for recessional agriculture, fishing etc. There has been a realisation by states of the importance of traditional management systems that govern these communities since the failure of the SEMRY project. The Republic of Chad's Code of Water (LOI No016/PR/99, 18th August 1999, Article 1, paragraph 3) states that local traditional laws should be taken into account during water management.

LCBC institutional weakness and lack of capacity to promote compliance and enforce agreements and policies: The LCBC has no power to enforce the agreements made between the riparian countries, so they are often not complied with. The LCBC founding riparians gave the LCBC a broad mandate relating to prior notification before undertaking projects which may have a transboundary influence on water resources. The Commission was also given the authority to examine complaints and to resolve disputes amongst member States. However the LCBC has often been bypassed when undertaking developments despite these issues falling in the Commissions mandate (World Bank 2002a).

Poor water use efficiency: Water-demand management is ineffective and little attention is paid to adapting production methods to natural resource limitations. There is an absence of measures aimed at conserving the precious water resources of the Basin, and opportunities to increase the availability of potential productive freshwater are not being seized (Isiorho et al. 2000).

The irrigation schemes require large inputs of water and were planned not taking into account the large fluctuations in water availability experienced in the Lake Chad Basin. The farmers receive a low return on the amount of water used in the irrigated fields, at the expense of downstream traditional farmers (King 1993). Originally it was intended to become self-sufficient in wheat production. The Government's failure to guarantee wheat prices among other factors led to farmers converting to using more water intensive crops such as rice and sugar cane. It has to be questioned whether these water intensive crops, grown on the irrigated fields, are appropriate in a region prone to freshwater shortages. King (1993) identified that the rice extraction rates in Chad and Cameroon are very low by modern standards. He attributed this in part to the drying techniques employed where frequently the paddy was too dry and the milled product was of a poor quality resulting in low market prices. In Nigeria par-boiling is adopted which increases the extraction rate and produces a more marketable product. This effectively increases the yield per unit of water (King 1993).

The SEMRY project exposes large amounts of water to extreme evaporative losses from the Maga reservoir surface and the remaining irrigated fields. At 100% storage capacity the Maga Dam exposes a surface area of 400 km^2 (IUCN 1998 in Attewill & Lawrence 2002). Reviews undertaken by an international dam safety expert for the World Bank (within the GEF project "Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem") indicated that the dam is threatened by erosion, wave action, overtopping and seepage. If the dam fails several thousand people are at risk to their lives, and approximately 20 000 are at risk of being flooded (World Bank 2002a). The flood release outlet is partially blocked limiting the control of flood flows making the flooding of the Waza-Logone floodplain difficult during times of peak flow.

The SCIP project (Nigeria, western shore of Lake Chad) utilised the Lake's waters extremely inefficiently through a network of irrigation channels. This leaves the water surface exposed to high evaporation rates resulting in large water losses (Isiorhoet al. 2000). The failure of the large irrigation projects such as SCIP may have been averted if greater efficiency of water had been implemented (Isiorho et al. 2000).

Slow progress in implementing environmental degradation mitigation measures: The aforementioned root causes have long been realised by the governments and international assistance organisations as a result of the studies by GEF and UN organisations (see Regional definition, Chronology of recent projects executed in the Lake Chad Basin). Many of these root causes were identified by the "Diagnostic Study of Environmental Degradation in the Lake Chad Conventional Basin" undertaken by UNEP as early as 1990 (Kindler et al. 1990), and recommendations made in the LCBC Master Plan (LCBC 1992), and subsequent SAP (LCBC 1998). Therefore the question has to be asked: why has there not been more progress in tackling environmental degradation in the Lake Chad Basin and why have not the recommendations made by the LCBC Master Plan (LCBC 1992) and subsequent initiatives been developed and implemented sooner?

The slow progress has been partially attributed to lack of external funding and to the lack of funds riparian governments have available. The recommendations in the Master Plan were not taken up after it was decided by the Planning Committee Decision Support System Project (DSS) to first develop a Strategic Action Plan (SAP) before arranging a donor's conference. Attempts to mobilise domestic and external resources are not helped by the absence of integrated land and water resources management strategies, investment plans and effective coordination (LCBC 2000b). The GEF/World Bank has taken the initiative in establishing the project entitled "Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem". The project is now beginning a Transboundary Diagnostic Analysis (TDA) before implementing projects. The TDA is designed to identify and evaluate the major environmental problems that face, or may face, the region and to determine their root causes. Activities will include the strengthening of groundwater data management tools, surface-groundwater interaction modelling, and risk analysis modelling in the Lake Chad Basin in order to identify and quantify long-term consequences of development alternatives.

Climate change

Changes in precipitation in the Lake Chad Basin have been linked with a combination of factors including vegetation cover, soil moisture, monsoon dynamics and SSTs (see Assessment, Freshwater shortage, Global climate change).

Komadugu-Yobe sub-system

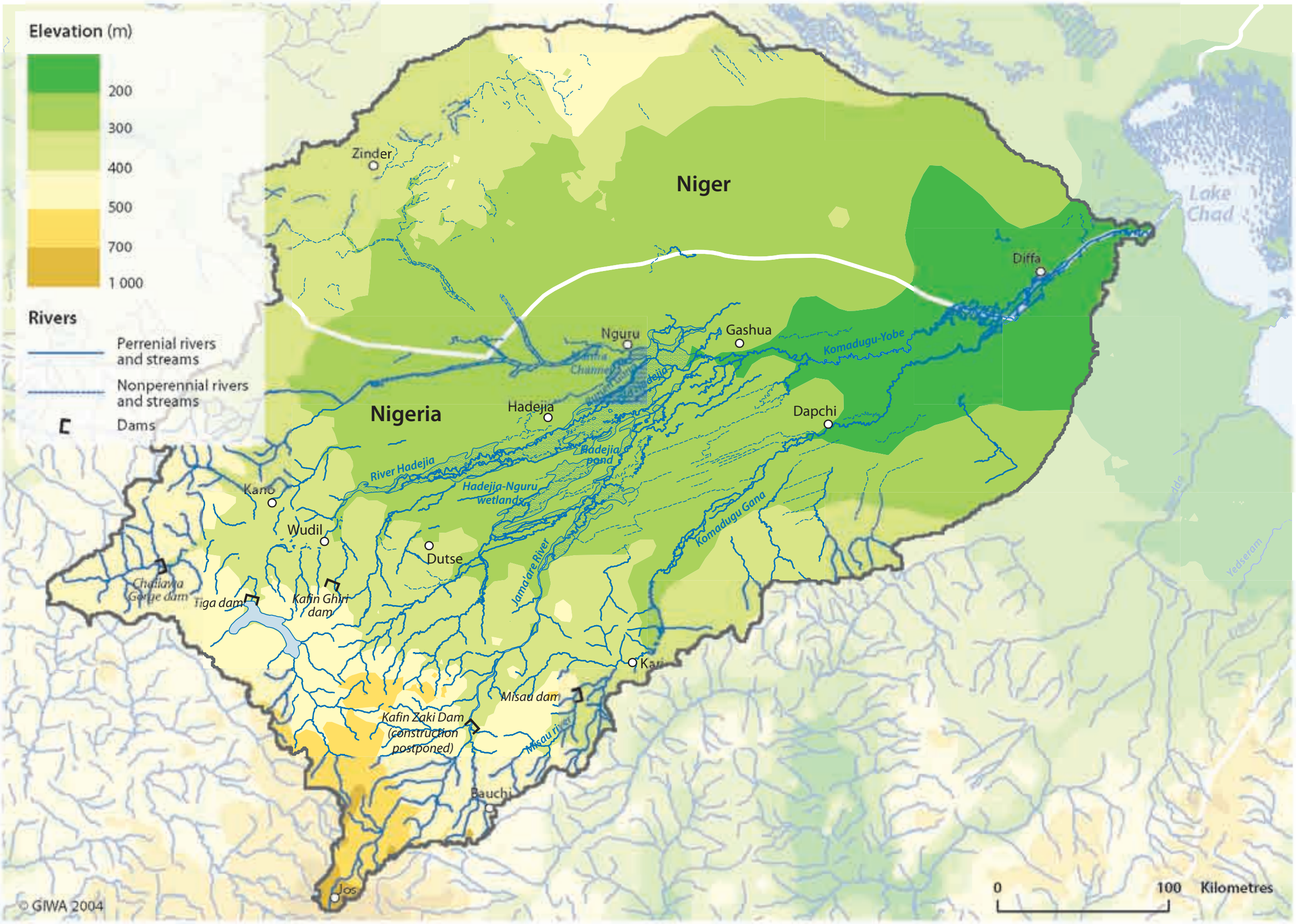


Figure 49 Komadugu-Yobe sub-system.

The Komadugu-Yobe sub-system has a basin area of 148 000 km^2 (World Bank 2002b) but contributes less than 2.5% of the total riverine inflow to Lake Chad (see review: Thieme et al. In preparation). The Komadugu-Yobe River is the border between Nigeria and Niger over the last 160 km and is the only perennial river system flowing into the northern pool of Lake Chad. Figure 49 shows a map of the Komadugu-Yobe sub-system. The Komadugu-Yobe River is formed by various tributaries, in particular the Jama'are River that flows from the Jos Plateau (Nigeria), and the Hadejia River which flows from the area around Kano (Nigeria). The two rivers join to the southwest of Gashua (northeast Nigeria). It is also supplied by the Misau, which comes from the north of Bauchi (Nigeria) and joins the Komadugu-Yobe 120 km from Lake Chad (LCBC 1998). Upstream of the confluence of the Hadejia and Jama'are rivers the Hadejia-Nguru wetlands (fadamas) in Nigeria start. Peak inflow to the wetlands occurs in late August, resulting in extensive shallow flooding (see review: Thieme et al. In preparation). The mean annual rainfall, which falls from June to October, varies from over 1 000 mm in the upstream catchment areas to approximately 500 mm in the Hadejia-Nguru wetlands to less than 300 mm near Lake Chad (Bdliya et al. 1999).

Traditional farming of sorghum, millet and cowpea in the Komadugu-Yobe Basin is predominantly rain-fed. Flood farming (rice) and recession farming (e.g. cassava) is practiced in the Hadejia-Nguru wetlands and along some parts of the Yobe River. Low rainfall in the downstream regions forces farmers to largely depend on the river flows for water requirements. The two major dams in the region (Tiga and Challawa Gorge) feed large irrigation schemes near Kano and Hadejia and supply Kano City. There has been increase in the number of small-scale irrigation schemes that pump water from the ground, river and

Table 10 Current requirements of water uses (domestic, irrigation, traditional flood and recessional farming, and livestock) that have already been developed.

Water use	Hadejia river system upstream of Hadejia Town (million m³ per year)	Hadejia river system downstream of Hadejia Town (million m³ per year)	Jama'are River within Hadejia-Nguru wetlands (million m³ per year)	Jama'are River upstream of Katagum (million m³ per year)	Yobe River (million m³ per year)
Domestic	341 [a]	16.4	5.2	24.1	11.9
Irrigation	586	94.9	42.9	80 [b]	162.1
Flood & recessional farming	-	270.6	180.9 [c]	104.6 [d]	116.7
Livestock	9	1.49	0.5	1.53	13.2

Notes: [a] Domestic and industrial use: other hydrologic units do not have significant industrial water requirements. [b] If planned irrigation development takes place, future water requirements are expected to be 80 million m³/year. [c] Water requirements in a reasonable flooding year. The larger the extent of inundation the larger the area under cultivation and the larger the water requirements. [d]Water i.e. minimum water requirements for water use. (Source: Blidya et al. 1999 (updated))

floodplain since the 1980s. Dry season farming has consequently increased, for example in Hadejia River between Wudil and Hadejia, and Burum Gana River (Bdliya et al. 1999).

The Hadejia-Nguru wetlands support a wide range of economic activities, which provide essential income and nutritional benefits, including agriculture, grazing resources, non-timber forest products, fuel wood and fishing for local populations. The wetlands also serve wider regional economic purposes, such as providing dry-season grazing for semi-nomadic pastoralists, agricultural surpluses for neighbouring states, groundwater recharge of the Chad Formation aquifer and 'insurance' resources in times of drought. The wetlands contain exceptional biodiversity particularly as a habitat for migratory waterfowl, especially wader species from Palaearctic regions, and contain a number of forestry reserves (Barbier et al. 1997).

Water is used for domestic, industrial, agricultural (flood cropping and small-scale irrigation), large irrigation projects (e.g Kano River Irrigation Project), livestock, fisheries and ecological purposes. Agriculture is the largest consumer of water in the Basin. Table 10 gives a breakdown of the gross water requirements for domestic, irrigation, traditional flood and recessional farming, and livestock water use.

Environmental and socio-economic impacts

Figure 50 provides a summary illustrating the main causal links for freshwater shortage in the Komadugu-Yobe sub-system. Stream flow modification from human stream diversion and climatic variability has resulted in the following environmental and socio-economic impacts:

Environmental impacts

- Following the droughts of 1983 and 1984, the Ngadda, Yedseram and Komadugu Gana rivers did not flow and the Misau River, which obtains river water from the Komadugu Gana was completely dry at Kari (Oyebande 2001).
- The River before the construction of dams and pre-drought years used to supply large amounts of water to the Lake but has now been reduced to an insignificant flow of 1% (Neiland & Béné 2003). The Komadugu-Yobe now only flows for six months of the year instead of nine.
- After the Tiga Dam was completed there was a 21 to 22% reduction in stream flow of the Hadejia River (Oyebande 2001).
- The Hadejia-Nguru floodplains in northern Nigeria at one time covered nearly 300 000 ha, today, these wetlands have shrank to an estimated 70 000 to 90 000 ha (Barbier et al.1997).
- Reduced stream flow has caused a proliferation of weeds and siltation. This has consequently limited the contribution from the Hadejia and Burum Gana rivers to the Komadugu-Yobe River (Oyebande 2001).
- The decline in wetland extent has proportionately decreased the fish abundance in the wetlands and in addition perhaps more than five species are no longer found in different parts of the floodplain (Oyebande 2001).
- In the Komadugu-Yobe sub-system it has been observed that in the last 20 years the quality of fish in the oxbow lakes has declined due to siltation from reduced stream flows, making the lakes too shallow (Oyebande 2001).
- The number of birds in the Hadejia-Nguru wetlands has decreased in correlation to the extent of the wetlands (Oyebande 2001). Recently there have been concerns over the availability of nesting sites for the endangered West African subspecies of black-crowned crane (*Balearica pavonina pavonina*) and adequate wintering grounds for intercontinental migrants such as the ruff (*Philomachus pugnax*) (see review: Mockrin & Thieme 2001).

Socio-economic impacts

- Over-abstraction of water by upstream users in the Komadugu-Yobe sub-system, at unsustainable levels in a period when there has been a substantial decrease in precipitation in the watershed, has led to a reduction of the supplies for downstream users.

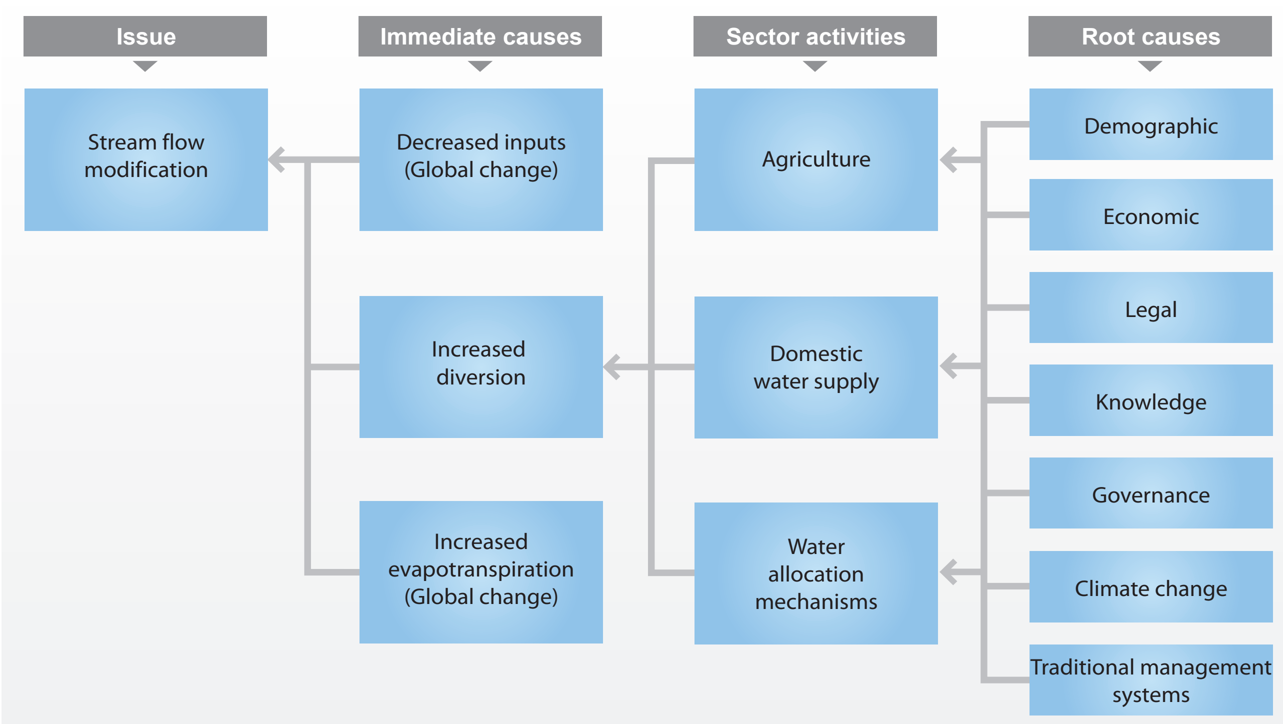


Figure 50 Causal chain analysis model for Komadugu-Yobe sub-system.

- There has been costly deepening of wells and increased use of pumping to reach the lower water table (LCBC 1998).
- Reductions in the Hadejia-Nguru wetlands surface area has led to loss of economic benefits previously provided by the floodplain. It is estimated that the decline in this wetland has had an economic cost of between 7.1 million USD and 11.7 million USD (based on Barbier et al. 1997).
- Reduced flooding has led to a decline in flood recession cropping and the extent of land favourable to dry season agriculture. Food insecurity has consequently been accentuated in the region (Nami 2002). There has been a proliferation of pests as consequence of poor irrigation management.
- There has been a dramatic reduction in the extent of dry season grazing lands that previously supported large numbers of livestock. In the Hadejia-Nguru wetlands perennial grass cover diminished, leaving only degraded grasslands of inferior quality and decreased area.
- The reduction of the Hadejia-Nguru wetlands has reduced the productivity of the fisheries.
- There has been greater vulnerability to food insecurity caused as result of the decline in agriculture, livestock and fisheries productivity.
- The role of the Hadejia-Nguru wetlands in recharging the groundwater aquifer of the Chad Formation, has been diminished (Barbier et al. 1997).
- There is an inadequate supply of potable water coupled with poor or lack of proper sanitation. Irrigation canals are a vector for water-borne diseases such as cholera, goiter and schistosomiasis.
- Upstream and downstream conflicts and disputes between the downstream riparian states of Borno and Yobe were fuelled by the lack of adequate water for their needs.
- Migration from the northern peripheral of the Lake Chad Basin into the case study site has exacerbated pressure on water resources.

Immediate causes

Decreased inputs

Rainfall events have been reduced in the Komadugu-Yobe sub-system which in turn has led to decreased run-off and thus decreased stream flows. For example, annual rainfall decreased by over 40% compared to the long-term mean (1905-1982) in Kano (Nigeria) in 1983 and 1984 (Oyebande 1997 in Oyebande 2001). See Assessment, Freshwater shortage, Regional climate change.

Increased diversion

There have been many dams constructed on the Komadugu-Yobe sub-system aimed at utilising the water resources of the region for agriculture and domestic water supply. During the 1970s and early 1980s around 20 reservoir dams were built on the Hadejia river system, which negatively affected the hydrology of the Yobe River, the only inflowing river into Lake

Chad's northern pool. The largest upstream irrigation scheme at present is the Kano River Irrigation Project, fed by the Tiga Dam completed in 1974. The Hadejia Valley Project is the second major irrigation scheme within the River Basin, and is supplied by the Challawa Gorge Dam (capacity of 972 million m^3). It is estimated that in the Komadugu-Yobe Basin 16 312 ha are used as large irrigation areas (Kindler 1990) and that a water requirement of 380 million m^3 would be needed for optimum management of the irrigated areas (King 1993). The Tiga and Challawa Gorge dams also supply water to Kano City for domestic and industrial purposes. After the Tiga Dam was completed there was a 21 to 22% reduction in stream flow of the Hadejia River (Oyebande 2001). Water use in the Basin is estimated to be 2.6 times higher than available water in the Komadugu-Yobe Basin (IUCN 2003b).

Conclusion

Stream flow modification has been caused by the immediate causes of decreased rainfall events and the diversion of water resources. Reduced rainfall has been caused by changes in the regional and global climate and therefore policy to address this immediate cause needs to be discussed at a global forum (IPCC 2001). According to expert opinion the most significant GIWA assessed immediate cause is the increased diversion of rivers by the large dam developments in the Komadugu-Yobe region. The following section will identify the root causes for the unsustainable use of water resources in the Basin.

Root causes

Demographic

Population growth: Increases in the Basin's population has led to greater pressure on the natural resources of the Komadugu-Yobe sub-system including its water resources. The population of the sub-system is currently estimated to be 20.8 million (ORNL 2003) representing over 55% of the Lake Chad Basin's population. Such a concentration of population has led to extreme pressure on the diminished water resources.

Migration: There has been a large influx of immigrants from the northern provinces into the Komadugu-Yobe Basin due to drought and desertification forcing communities to leave the increasingly arid northern environment. This has increased competition and aggravated conflicts between stockbreeders who are moving southwards and sedentary farmers (LCBC 2000b).

Economic

Poverty: Endemic poverty faced by the population of the Komadugu-Yobe sub-system is a catalyst for environmental degradation. For their short-term survival the population exploits natural resources at an unsustainable level. The people suffer greatly from the effects of freshwater shortage that has prevailed over the past 40 years. The prevalence of poverty in the sub-system requires special attention regarding water allocation.

Inadequate valuation of environmental goods and services: Water diversion as part of the Komadugu-Yobe irrigation projects e.g. the Kano River Irrigation Project supplied by the Tiga Dam, did not take into account the essential income and nutrition benefits in the form of agriculture, grazing resources, non-timber forest products, fuel wood and fishing provided for local populations by the Hadejia-Nguru wetlands. The wetlands also serve wider regional economic purposes, such as providing dry-season grazing for semi-nomadic pastoralists, agricultural surpluses for neighbouring states, groundwater recharge of the Chad Formation aquifer and 'insurance' resources in times of drought (Barbier et al. 1997).

According to the Ramsar Convention on Wetlands the present value of the aggregate stream of agricultural, fishing and fuel wood benefits were estimated to be around 34 to 51 USD per ha (1989/90 prices based on the maximum flood inputs) (Barbier et al. 1997). The Hadejia-Nguru wetlands have declined by 210 000 to 230 000 ha. It is therefore estimated that decline in this wetland has had an economic cost of between 7.1 million and 11.7 million USD. However, it must be noted that this has been a result of both upstream water developments and because of climatic variability. There is little evidence that the large irrigation and water developments provided any economic benefits, and in fact it is thought that they had negative impacts because of the significant implementation costs involved and because of the above mentioned loss of environmental goods and services.

Lack of incentives promoting environmentally sound practices: There is an absence of economic instruments, incentive measures, and specific programmes to promote and support local initiatives (World Bank 2002a). For example farmers have no incentive to conserve water, as they do not pay for the resource. This encourages farmers to grow crops such as rice, which fetch high market prices, yet are water intensive.

Knowledge

Public awareness: Information is only disseminated amongst the scientific community and to ministerial departments. Information does not filter down to the traditional communities such as those in the Hadejia-Nguru wetlands, partially due to poor communication infrastructure and a lack of consideration by policy makers of traditional management systems.

Information sharing: There is weak information sharing networks between the Nigerian Federal States and between the two riparian nations. The Nigeria-Niger Joint Commission has meetings where some information is exchanged verbally; however these meetings primarily resolve disputes rather than being an information dissemination mechanism. Environmental and hydrological data are rarely centralised in the Nigerian Federal ministries and are thus difficult to access (Lemoalle 1997). For instance, the water resources Master Plan is yet to be updated since 1993.

An insufficient knowledge of water resources and the functioning of aquatic ecosystem: The Komadugu-Yobe sub-system has a larger body of scientific information as compared to the Chari-Logone sub-system, and it is the most studied region of the Lake Chad Basin. Hollis et al. (1993) created a model simulation of the maximum flood extent between Hadejia and Gashua, but the region still lacks a comprehensive model that is able to predict the hydrodynamic reactions of proposed water projects. The current model could be significantly improved through the application of remote sensing and GIS. There is a lack of hydrometeorological information to support decision making in the region and monitoring networks have not been operating since the late 1970s (IUCN 2003b). Information networks on sediment loads are particularly weak. There is presently a lack of knowledge regarding future climate changes and its impact on water infrastructure, ecology and socio-economic status of the Komadugu-Yobe sub-system.

Scientific resources: Nigeria and Niger place inadequate importance on scientific and technical research, which can be partly blamed on financial difficulties. The region lacks professional human resources and monitoring and evaluation facilities. Although there is a greater wealth of information than in the Chari-Logone Basin, the Federal ministries do not centralise or coordinate research efforts.

Legal

Although in the Komadugu-Yobe River Basin there is some legislation related to water resources managment, it does not enable integrated management of the entire sub-system. The Federal Government of Nigeria Decree No. 101 of 1993 (National Water Resources Legislation) does relate to this, but the regulations for and rules for administration and enforcement have not been published (see next paragraph Governance: Capacity to promote compliance and enforce agreements). There is also a policy of the National Water Resources Council, which stipulates releases of water from the Federal Government/River Basin Authority dams at a prescribed charge per m^3 to State Water Agencies downstream of such dams. For example, releases from the Tiga and Challawa Gorge dams to Kano State Water Corporation. There is however no water allocation law between Nigerian States or between Nigeria and Niger. The inadequate water for the downstream states has fuelled disputes between the downstream states of Borno and Yobe about who has the right to this diminishing resource. With no water allocation law for the entire basin, the uncertainty over water rights also transcends national boundaries. It has been argued that since Nigeria uses a large share of Lake Chad's water for irrigation, they have special responsibility in insuring the long-term sustainability of water use for all riparian countries (Isiorho et al. 2000).

Prior to the Decree No. 101 of 1993, water users in northern Nigeria had customary rights, which had the force of law, permitting anyone to make use of water where available for his personal needs and for his livestock and agriculture. This inadequately regulated the use of inter-state waters, and prevented the effective management of the growing demand for water resources (Bdilya et al. 1999).

Governance

No integrated management strategy: There is no overall water management strategy for the Komadugu-Yobe sub-system (Bdliya et al. 1999). The Nigeria-Niger Joint Commission brokered an agreement on the equitable sharing of the water resources common to the two countries in 1989 and, unlike the Chari-Logone equivalent, there are regular meetings between the two states. The Commission provides an interface between the two countries that enables concerns to be discussed and conflicts to be resolved. However, this only tackles issues concerning the last 160 km stretch of the Komadugu-Yobe that forms the border between Niger and Nigeria. The major water developments, which are located in the upstream states are not represented at these meetings. The Commission therefore does not enable integrated management of the entire Komadugu-Yobe sub-system. The meetings are a forum to discuss problems, rather than long-term solutions for the water problems that face the entire region. The most acute obstacle in the management of water is the absence of a coordinating mechanism to harmonise the activities of the water users.

Institutional weakness: Out of the six government organisations and over 14 non-government organisations in the Komadugu-Yobe Basin that have interest in the management of water resources in the sub-system, only two governmental institutions, namely the Federal Ministry of Water Resources (FMWR) and the Federal Ministry of Environment (FME), and two non-government organisation, the Hadejia-Nguru Wetlands Conservation Project (HNWCP) (recently taken over by the Jigawa Enhancement of Wetlands Livelihoods (JEWEL) project), and the Stakeholders Consultative Forum, are concerned with the sustainable utilisation of the water resources of the Komadugu-Yobe sub-system. The Federal Ministry of Water Resources has accordingly set up the Komadugu-Yobe Basin Consultative Commitee. All the other institutions are inward-looking concerned only with meeting their water requirements, with minimal or no concern for the impacts of their activities on other users. There is no organisation that regulates the water uses in the Basin. Furthermore there are overlaps in the roles and mandates of the various governmental institutions in the Basin. This scenario clearly calls for a coordinating and control mechanism (Bdilya et al. 1999). The two River Basin Development Authorities (RBDAs), which are implementing agencies of the FMWR, are called the Hadejia-Jama'are River Basin Development Authority (HJRBDA) and the Chad Basin Development Authority (CBDA). They both act independently of each other and their development-orientated mandates do not take responsibility for environmental protection. While the River Basin Development Authorities are required to control pollution in the projects, there is no specific provision for Health Impact Assessment (HIA), or for the mitigation and control of vector-borne diseases. Although Nigeria is known to have endemic schistosomiasis and other water-related diseases, the institutional arrangements for water resources development have not taken health issues into consideration (Ofoezie 2002).

Lack of coordination: Water resource management in the Komadugu-Yobe sub-system is fragmented with ill-defined and often conflicting responsibilities between government agencies and stakeholders. The Nigerian water resource sector is treated as a different sector to the environment ministry. The environment ministry is not consulted during the planning of water projects. They concentrate on managing toxic substances. When environmental problems from water resource projects did arise, the environment departments were requested to assist. However they had no expertise in water-related environmental issues. Consultants were hired to assess the concerns, but the departments still lack the expertise to analyse the results of their studies and turn recommendations into policy. The recently established Komadugu-Yobe Coordinating Committee chaired by the Minister of water resources also includes the ministries of environment and health as members.

There is a lack of coordination and cooperation between the two River Basin Development Authorities operating in the sub-system (IUCN 2003b) and between Nigerian States during planning and implementation of water projects. Uncoordinated water developments (e.g. the recently approved expansion of the Hadejia Valley Project without execution of an Environmental Impact Assessment for the Basin) throughout the Basin due to increasing water demands for water are resulting in an inequitable water allocation and environmental damage (Bdliya et al. 1999).

Lack of water resource environmental planning: The Nigerian Government with increasing revenues from oil exports during the period 1970-1980, focused on general expansion in all areas of the economy. Concerns over the food security for the rapidly expanding population resulted in agricultural policy focusing on increased production. It was decided to invest in large-scale agro-industry projects that included large dams, particularly in the Hadejia river system. They relied on modern technologies and focused on producing maximum yields in the shortest time (Neiland & Béné 2003). These hydro-agricultural schemes that now threaten the wetland ecosystems and economies were planned based on data gathered during a wet period in the 1960s. Planners did not take into consideration the climatic variability that has been demonstrated throughout the Lake Chad Basin's history. Droughts lowered the flow at Gashua by 23% while the Tiga Dam lowered it again by a similar measurement (Hollis et al. 1993). The large irrigation projects have put stress on the available water resources. For example the water requirements in the Hadejia river system are already at times exceeding the available water resources (Bdilaya et al. 1999). The possibility of reduced flows and the impact this could have on populations in the downstream Nigerian States and Niger, whose productive systems are highly dependent on the river flow, was not sufficiently taken into account. The governments of the sub-system have continued to demonstrate a lack of political commitment at the leadership level with no long-term goals and objectives to solve freshwater shortage concerns.

Lack of stakeholder participation: The upstream dam developments had minimal stakeholder involvement. Decision-making and consultations were only made at the state and federal level in Nigeria. Lobbying from state officials for large dams occurred at the Federal Government level as capital required to finance the projects exceeded state funds. Niger, which is located downstream of the dam constructions was not consulted or considered during planning. There was no involvement of the public in the planning or implementation process including the traditional communities of the Hadejia-Nguru wetlands. At the Nigerian national level, the National Council on Water Resources, which is comprised of the state water authorities under the chairmanship of the FMWR, is responsible for coordinating water use (Bdliya et al. 1999). There have been concerns that stakeholders are not represented in the technical committee who make recommendations at these forums. The water authorities (RBDAs) control the dams and are therefore a water user rather than a regulator. The federal or national authorities are dominating the decision making process at the Nigeria-Niger Joint Commission with little interaction with, and involvement of the local populations (Lemoalle 1997).

Capacity to promote compliance and enforce agreements and policies: The LCBC lacks the capacity to enforce issues under its mandate (see Root causes, Chari-Logone and Lake Chad, Lack of capacity to promote compliance and enforce agreements and policies). Earlier agreements in the Komadugu-Yobe sub-system had guaranteed that certain amounts of flow from the Hadejia river system would be released for downstream communities. For instance, the Bagauda Agreement which emerged after the construction of Tiga Dam in 1974 stipulated the long-term average annual flow at Gashua as minimum guaranteed flow at Gashua. This has not been implemented (IUCN 2003b). Following the promulgation of the Water Use Decree 101 of 1993 in Nigeria, rules and regulations for the administration and enforcement were drafted. They have never been published as a White Paper and therefore the law has not been implemented.

Poor water use efficiency: The scarcity of water in the Basin has not prompted management to utilise resources that are available in a more efficient manner. There are no guidelines or incentives for the farmers to conserve water with inefficient gravity irrigation still being employed rather than more efficient techniques such as drip or sprinkler irrigation systems. Irrigation channels are open and unlined, and therefore prone to infiltration and evaporation losses. There are no immediate incentives for the upstream farmers to conserve water, as they do not pay for the resource, which consequently allows farmers to grow water intensive crops such as rice. It also has to be questioned whether growing such crops is appropriate in a region prone to freshwater shortages.

An international dam safety specialist recruited by the World Bank as part of the GEF project has reviewed the Tiga Dam (Hadejia River Basin). The main threats were identified in decreasing order of probability: internal erosion due to arching of fill material over the cut off trench, internal erosion caused by a fracture of one of the two secondary outlet pipes, and slope failure under seismic load. The probability of failure was considered high for the 8 km zoned earthfill embankment, with the main threat coming from piping i.e. water creating channels through the dam. Tens of thousands of people are at risk at Tiga. The Challawa Gorge Dam is newer and was not considered to pose an immediate threat (World Bank 2002a). Although the Tiga Reservoir has approximately twice the inflow of the Challawa Reservoir, the maximum capacity of the main Tiga Dam outlet is just a third of the maximum of the two outlets of Challawa Gorge Dam.

The operation of dams is highly uncoordinated (Bdliya et al. 1999). The Greater Kano Water Supply (GKWS) intake is located on Kano River before the confluence between the Challawa and Kano rivers. The intake has a sump that is easily silted, so that constant dredging is necessary. A canal had to be constructed on the Kano River to bring water to the sump. Sandbagging is also used to simulate a weir structure, but they are eroded with time, particularly with varying water releases. The Challawa intake is expected to have an even more severe problem with silting. The water at this intake is very turbid as a result of severe erosion upstream in the Watari and other tributaries. The siltation decreases the inflow by diverting water to the other bank. Inadequate sediment studies were made when situating the intakes. The discharge in the Hadejia River from the Tiga and Challawa Gorge dams towards the end of the dry season is maintained at higher than optimal levels to ensure that the sumps are filled (Diyam 1996 in Bdliya et al. 1999). The Kano State Government puts pressure on the HJRBDA to release more water in order to meet the requirements of Kano City. This consequently results in the flooding of downstream farmland (JEWEL 2003). This is highly wasteful particularly during periods of low water availability (Bdliya et al. 1999).

Stream flow conveyance is hampered by the proliferation of blockages from weeds and siltation in the Hadeijia river system. The blockages in the Old Hadejia River have prevented the Hadejia River from contributing to the Yobe River. These have not been cleared and have consequently continued to impede freshwater from reaching the main river channels. The water is instead restricted to the wetlands of the Hadejia-Nguru and does not reach downstream users.

Slow progress in implementing environmental degradation mitigation measures: As with the Chari-Logone sub-system, the aforementioned root causes have long been realised by the governments, and international assistance organisations as a result of the studies by GEF and UN organisations (see Root causes, Chari-Logone and Lake Chad, Slow progress in implementing environmental degradation mitigation measures). Specifically to the Komadugu-Yobe Basin, the FMWR conceived a strategy for the "ultimate utilisation of the water resources potentials" of the Basin in 1996. This strategy has still not been finalised and the intended in-house coordinating body to facilitate the implementation of the strategy has not materialised (Bdliya et al. 1999).

Traditional management systems

In the Komadugu-Yobe sub-system, the rural population is highly differentiated and the poor, critically, do not have access to fishing and farming resources (Bene et al. 2002). This can be attributed to the predominance of traditional management systems at a local level (83% of Nigerian villages) and the absence of strong modern systems, which results in the majority of the benefits from water resources, such as the fisheries, being retained by a powerful elite minority, including local leaders, their extended families, and other prominent people and their associates (Neiland & Béné 2003).

Climate change

See Chari-Logone/Lake Chad, Root causes, Climate change.

Conclusions

The root causes of the stream flow modification are similar in both the Chari-Logone/Lake Chad sub-system and the Komadugu-Yobe sub-system. Table 11 gives a summary of the root causes identified by the Causal chain analysis. The causes include poor water policy and legal frameworks, particularly the absence of water allocation laws, a lack of coordination and cooperation between stakeholders at all levels and poor enforcement partly due to institutional weaknesses. These key problems have led to the unsustainable use of water resources, and the subsequent non-implementation of agreed recommendations from the Master Plan (LCBC 1992) and further initiatives from GEF and other partners. Policy options will need to directly address some of the prominent root causes such as the lack of integrated water management, the inequitable sharing of available water, and the poor water resources management. Other root causes such as poor stakeholder involvement need to be taken into account during the planning and implementation of policy options/projects.

Table 11 Summary of root causes.

Chari-Logone/Lake Chad sub-system	
Broad root cause	**Specific root cause**
Demographic	- Population: High population growth rates increasing water requirements. - Migration: Large influx of migrants from north arid regions of Lake Chad Basin.
Economic	- Poverty: Vulnerable to environmental changes. - Inadequate valuation of environmental goods and services: The construction of dam and flood infrastructure as part of the SEMRY irrigation project did not take into account the economic value of the Waza-Logone floodplains downstream of the Maga dam.
Knowledge	Lack of: - Public awareness; - Information sharing; - Identifying and quantifying water abstraction; - An insufficient knowledge of water resources and the functioning of aquatic ecosystems; - Pollution data; - Scientific resources.
Legal	- No water allocation laws. - No legal instruments to enforce agreements. - Weaknesses in Fort Lamy Convention. - See also conflicting policies between ministries. Legal aspects relating to land management and use.
Governance	- Conflicting policies between ministries; - Lack of water resource environmental planning; - Lack of stakeholder participation; - Lack of capacity to promote compliance and enforce agreements and policies; - Poor water resource management; - Slow progress in implementing environmental degradation mitigation measures.
Climate change	- Reduction in rainfall in region.
Komadugu-Yobe sub-system	
Broad root cause	**Specific root cause**
Demographic	- Population: 55% of the Lake Chad Basin's population live in this sub-system (based on ORNL 2003). Water requirements are 2.6 available water supplies in the Hadejia river system. - Migration: Large influx of migrants from north arid regions of Lake Chad Basin.
Economic	- Poverty: Unsustainable exploitation for short-term survival. - Inadequate valuation of environmental goods and services: Upstream water developments did not take into account the value of the downstream Hadejia-Nguru wetland resources. - Lack of incentives promoting environmentally sound practices.
Knowledge	Lack of: - Public awareness; - Information sharing; - An insufficient knowledge of water resources and the functioning of aquatic ecosystems; - Scientific resources.
Legal	- No water allocation law between Federal Nigerian States and between Nigeria and Niger. - Influence of customary rights. - Regulations and rules for enforcement of Nigerian Decree 101 Water Resources has not been published.
Governance	- No integrated management strategy; - Institutional weakness; - Lack of coordination; - Lack of water resource environmental planning; - Lack of stakeholder participation; - Lack of capacity to promote compliance and enforce agreements and policies; - Poor water efficiency management; - Slow progress in implementing environmental degradation mitigation measures.
Traditional management systems	Traditional management systems are dominant in the region. Socio-economic differentiation restricts access of water resources to the poor.
Climate change	Reduction in rainfall in region.

Policy options

This section aims to identify feasible policy options that target key components identified in the Causal chain analysis in order to minimise future impacts on the transboundary aquatic environment. Recommended policy options were identified through a pragmatic process that evaluated a wide range of potential policy options proposed by regional experts and key political actors according to a number of criteria that were appropriate for the institutional context, such as political and social acceptability, costs and benefits and capacity for implementation. The policy options presented in the report require additional detailed analysis that is beyond the scope of the GIWA and, as a consequence, they are not formal recommendations to governments but rather contributions to broader policy processes in the region.

Problem definition

The Policy options analysis aims to describe the freshwater shortage issues that need to be resolved or mitigated, and will describe alternative courses of action that may be taken by policy-makers in the region. Each course of action will have a set of projected outcomes with the trade-offs of each action discussed. The policy options are a preliminary analysis of actions and conceptual ideas for projects that are currently being considered and/or being developed. Specific policy options are evaluated for the entire conventional basin and for the Chari-Logone/Lake Chad and the Komadugu-Yobe sub-systems.

Two of the broad challenges facing water management in the Lake Chad Basin were noted as being: (i) how to control unsustainable water consumption; and (ii) how to enhance the water allocation mechanisms. However to successfully implement projects/policy actions aimed at alleviating these challenges, water governance issues, primarily the institutional and legislative failures identified during causal chain analysis, need to be addressed as a priority. Many of the root causes were identified, and recommendations made, by the Lake Chad Basin Commission (LCBC) Master Plan (LCBC 1992), followed by an update of this plan and the formulation of a Strategic Action Plan (SAP) (LCBC 1998). Implementation of these recommendations by riparian countries has been very slow (see Root causes, Governance, Slow implementation of mitigation measures). The GEF project entitled the 'Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem' is beginning to implement prioritised recommendations made by the Master Plan and SAP. The projects development objective is "to build capacity within the LCBC and its national committees so that it can better achieve its mandate of managing land and water resources in the greater conventional basin of Lake Chad" (World Bank 2002a). The GIWA Policy option analysis firstly outlines the recommendations made by the SAP, followed by project options aimed at addressing base-wide root causes, and then in turn, more specific project options that can be implemented once the fundamental root causes have been addressed.

The following projects were discussed for the entire Lake Chad Basin:

1. Implementation of the GEF project 'Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem';
2. Water allocation agreement;
3. Inter-basin water transfer.

The following projects were discussed for the Chari-Logone/Lake Chad sub-system:

4a. Reinundation of the Waza-Logone floodplains (Chari-Logone sub-system);
4b. Assessment of changing land use in the head waters of the Chari-Logone sub-system.

5. Chad-Niger Transboundary Project to Combat Sand Dunes and Reverse Water Degradation Trends in Lake Chad (Lake Chad sub-system).

The following projects were discussed for the Komadugu-Yobe sub-system:

6. Grant subsidies to irrigation farmers in northern Nigeria for implementing water conservation measures;
7. Maintenance and improvements for safety and improved efficiency of dams and stream flow.

Recommendations from the GEF project Strategic Action Plan

The Strategic Action Plan described the aims and objectives for a 20 year strategic plan (LCBC 1998). The overall aim was 'Sustainable Development of the Lake Chad Basin' and the main objective 'Lake Chad is sustainable protected by concerted, integrated management of the Basin's resources, guaranteed by all players within the Basin taking responsibility and cooperating'.

Long-term objective 1

Concerted management of international waters, based on regional cooperation and national policies harmonised and applied in each sub-basin.

- A water policy in each country, taking into account, the value of hydrosystems and aquatic ecosystems in sectoral economic policies and in environmental legislation.
- Updated regional cooperation agreements between countries with a view to ensuring sustainable management of the international waters of the Lake Chad Basin, particularly with respect to risks of cross border pollution and overexploitation of water.
- Reforms and new institutional mechanisms for cooperation and consultation in each country, for each international sub-basin and for the Lake Chad Basin, so that water can become a link and catalyst for balanced regional development, and not a source of conflict.
- People placed at the heart of decision making, in particular by enabling local associations to draw up their own community development scheme and seek sustainable means of existence, with the active participation of the local inhabitants (environmental awareness teaching), linking up this activity with policies and water management in the Basin.
- The creation of essential links between research programmes, the fight against poverty, biodiversity programmes, the fight against desertification, modifications in the climate and in international waters throughout the Lake Chad Basin.

Long-term objective 2

Integrated management of the use of finite and vulnerable water resources in the ecosystem, based on better knowledge of these resources.

- Rehabilitation and development of a permanent network to monitor water, the environment and the way they are exploited, to provide better knowledge of the way in which the hydrosystems function.
- Dynamic monitoring of water management (floods, droughts, etc.) and regular monitoring of development works and resources in the Basin, using modern integrated data management tools and simulations to assist in decision-making and anticipate possible crises.
- Preparation of two Sustainable Basin Development Plans to enable the LCBC member States to evaluate, on a continuous and scientific basis, the break-down of costs, benefits and environmental impacts of the alternative development works proposed by the various countries.

Long-term objective 3

Players in the Basin take responsibility for protecting common heritage.

- Concrete priority actions, to protect Lake Chad, and the international waters that feed it, in order to preserve the ecosystems against new risks.
- Regional promotion of productive, water saving, economically beneficial techniques and practices that are accepted by local people and local economic operators, and do not harm the environment.
- A renewed framework of incentives and laws in each country harmonised on a regional basis in particular with respect to risks of cross-border pollution.
- Development of suitable mechanisms and instruments for mobilising internal and external financial resources, aimed at progressively achieving self-sufficiency for the sustainable management of patrimonial resources in the Lake Chad Basin.

Priority actions

Once the main guidelines had been met the SAP (LCBC 1998) identified through national workshops six priority actions:

1. Initiate shared management of water resources, with mechanisms for cooperation and integration both within and between the countries, at the various levels (national, sub-basin and basin).
2. Set up viable networks for collecting basic information in order to identify and monitor water resources, ecosystems and the ways in which they are exploited more accurately.

3. Carry out basic sectoral measures to control water demand in order to combat desertification and the loss of biodiversity.
4. Ensure the prevention and control of contaminants and preserve fisheries resources.
5. Improve methods of exploiting aquatic ecosystems and protect floodplains in relation with regional development.
6. Begin pre-feasibility studies (physical, technical and economic) and environmental impact studies to intra- and inter-basin water transfers.

The 8-year action plan in fact includes four programmes, the first of which (A) represents the GEF comprehensive regional programme based on: (i) institutional coordination; (ii) scientific knowledge of water resources and ecosystems; and (iii) pilot or research actions, to be carried out on cross-sector (priority) issues and in the particular sub-system of the Lake Chad itself.

Each of the 36 projects of the Master Plan (LCBC 1992) was examined critically to take account of the new strategy and conditions outlined in the SAP. Certain pertinent modules will be taken up at the time the sub-programmes are formulated in detail.

Lake Chad Basin

Political and organisational frameworks

For details on the political and institutional framework for the entire Lake Chad Basin, see Regional definition, Institutional arrangements.

Options

Option 1: Implementation of the GEF project for the 'Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem'.

The development objective of the GEF project is "to build capacity within the Lake Chad Basin Commission (LCBC) at its national committees so that it can better achieve its mandate of managing land and water resources in the greater conventional basin of Lake Chad" (LCBC 2002).

The United Nations Development Programme (UNDP) first prepared the project, and a PDF-B was approved by the Global Environment Facility (GEF) in 1995 and executed by UN Department of Economic and Social Affairs (UNDESA). Work at that time resulted in an update of a Diagnostic Study, an update of LCBC Master Plan, as well as the elements of a Strategic Action Plan.

The project will address the following root causes identified by the GIWA Causal chain analysis: Lack of water resource environmental planning, lack of stakeholder participation, lack of coordination and integrated management, and the lack of capacity to promote compliance and enforce agreements and policies. The LCBC member States recognised that uncoordinated development is unsustainable in terms of investment, socio-economic and ecosystem welfare, and that they needed to coordinate their national plans and actions with each other at the regional level (World Bank 2002a). The GEF project appraisal states that "for the LCBC to assume a more central role within the basin, working with the countries and regional projects, its capacity will need to be strengthened" (World Bank 2002a).

The primary development objective of the GEF project, in accordance with the SAP, is to strengthen the capacity in the LCBC, by placing a Project Management Unit (PMU) to work within and alongside it, to work together in implementing the project, so that the LCBC may be able to execute fully future projects. Although the project will not undertake national-level policy or institutional reforms, it will strengthen existing regional policies and institutions to better manage the shared Lake Chad resources. This will occur by drawing support from LCBC member States in order to raise awareness of impacts at regional level of national policies, and therefore, the need to harmonise national actions at the regional level. This should in turn translate into stronger regional mechanisms and coherence, as voiced in the SAP, and raise donor interest.

Links to policy and institutional change and renewal in each component are highlighted as follows in the first component of the project: (i) LCBC members review and recommit to the institution; (ii) define and promote integration of transboundary water and environmental policies into national development plans; (iii) review and recommend means to harmonise relevant frameworks so as to get integrated regional approach to long-term management of the resources; and (iv) establish regional structures that review, harmonise and coordinate management of shared resources and uses. The second component of the project will initiate a number of pilot projects that constitute the country-identified most urgent priority actions, and it is hoped, the successful implementation of these projects by the LCBC and countries as soon as possible, will build donor confidence. Formulating these new institutional mechanisms will link regional, national and local planning initiatives. The third component of the project will finalise a Transboundary Diagnostic Analysis (TDA) with regional validation and agreement on LCBC SAP, and subsequent mobilisation of donor support (LCBC 2002).

Option 2: Water allocation agreement

A water allocation agreement has been proposed by the LCBC and a draft agreement based upon an earlier draft by the FAO is presently under negotiation.

Integrated river basin management requires a suitable and effective legal framework to achieve its required goals. There needs to be an agreement between the member States to share responsibility for the management and allocation of water resources. A water allocation process cannot simply be achieved from technical specifications, but to be successful requires economic analysis and a legal framework to be installed. The Lake Chad Basin Commission has not had the legal framework to implement and enforce the equitable sharing of the Basin's water resources. A draft water allocation agreement was prepared by the FAO after a request in 1969 at the 9th Council Meeting of the LCBC, but was never ratified. A revised version of this draft was presented in 2000 and has since been under discussion by member States. This agreement will set minimum flow rates for points along the Komadugu-Yobe and Chari-Logone sub-systems. Water users will not be able to abstract water at a level that would cause flows to drop below these levels. The flows will be maintained by controlled flood releases from the dam infrastructure. This aims to increase water availability for downstream users and ecosystems and maintain the extent of the Lake Chad during times of low precipitation. There is a need to "formulate principles of equitable water utilisation, development, conservation, management and protection, with a view to the promotion of optimal and sustainable utilisation thereof for present and future generations" (LCBC 2000a). Water allocation is distinct from the task of distribution, which is defined as delivering water in accordance with allocations.

The theory "Tragedy of the Commons" is applicable to water use in the Lake Chad Basin (Hardin 1968). Each water user sees the benefits of using more water as the productivity of an individual's economic activities increase with a greater use of the common water resource. However with common access to the water supply, if one individual after another uses too much, other water users will suffer. The "tragedy" appears when the common resource is overused, and then all will suffer (Hardin 1968). Property rights to any resource are therefore much more than a title on paper: they are essentially a relationship between people and the use of natural resources. A single user rarely has full ownership rights to control, use, and dispose of the resource purely as he or she sees fit. Rather, it is useful to think of a bundle of rights, with different users and stakeholders having the right to use water for a certain purpose, or subject to various types of conditionality. Water rights are a basis for a claim on the resource, and include formal rights embodied in official titles, permits and seasonal irrigation schedules, less formal rights based on customary patterns and rights implicit in social norms and local practices.

A possible incentive could be to put a value on the quantity of water that farmers save. Water that is saved can be purchased and then diverted to the river channels to reallocate the water to downstream users.

Option 3: Inter-basin water transfer

The LCBC Master Plan and Strategic Action Plan identified water transfer as an option amongst a list of projects.

Preliminary studies of the feasibility of this project have now begun in accordance with the SAP (LCDC 1998). Inter-basin transfer supporters argue that "there cannot be much water saving to be expected from efficient management as the largest amount of water is attributed to evaporation" and thus "conditions in the Lake Chad Basin call for measures beyond management of the available water resources in the Basin." It is argued that a major water transfer to the region is "required to restore the Lake, improve base flow and channel storage, arrest groundwater recession and falling water table, and enhance groundwater recharge, so that a state of equilibrium may ultimately be attained" (UNECA unpublished).

The 49th session of the Council of Ministers of LCBC held in Yaoundé, Cameroon, January 2002, discussed a possible feasibility study of the project to feed Lake Chad with water from the Congo Basin. The commission members directed a contribution of 1 million USD by member States for the project feasibility study. However a feasibility study has not found backing from any international donor organisation. Feasibility studies for the inter-basin transfer in terms of engineering design have not yet begun, as not all member States have submitted their contributions. There are therefore insufficient funds to finance the feasibility studies and requisite social and environmental assessments. There was a previous International Competitive Bidding (ICB) process launched unsuccessfully, for which several private sector firms submitted bids (and tendering fees), but which was later suspended for lack of funds on the part of the LCBC.

This project proposes moving 900 m^3/s of water from the Oubangui; the major tributary of the Congo River in a navigable canal. In current proposals the infrastructure comprises: construction of one dam at Palambo (65 km upstream from Bangui) to regulate the flow on the Oubangui River in CAR; construction of one main canal to transfer water by gravity from Palambo Dam reservoir to Fafa-Ouham River in CAR and to link the two basins; river channel improvement works from Ouham River through Chari to Lake Chad; construction of a navigable canal to link Chari, Logone, and Benue rivers through the Mayo Kebbi onward to Port Harcourt; improvement works on the existing river port at Garoua, taking into consideration the new river flow regimes; improvement works to increase the Lake Chad storage capacity and reduce evaporation losses; construction works of river port at Bouca in CAR; identification of irrigable areas and agro-allied industries for profitable uses of available water resources; and installation of a hydroelectric power plant at Palambo to supply Bangui and other regional demands.

Proponents suggest that by restoring Lake Chad, it will also allow the reinstatement of activities such as recession farming, fishing, and animal husbandry in which the local population used to be engaged. It is also intended that it would facilitate communication among countries by allowing year round navigation. The water transfer project is envisaged to deter environmental degradation, enhance environmental and ecosystem equilibrium and reduce migration of people and conflict among settlers and environmental refugees (UNECA unpublished). However there has been no environmental or social assessment (including stakeholder analysis) of the negative impacts this could have on both the Lake Chad Basin and the Congo Basin. This option remains firmly in a conceptual stage and there are many drawbacks in resorting to this option (see Identification of recommended policy options for drawbacks) .

Global change mitigation

Global change was identified as playing a very important role in determining freshwater shortage in the Lake Chad Basin. There are many policy options being discussed at the global forum that are aimed at reducing the extent of anthropogenic climate change. The emission of greenhouse gases such as carbon dioxide has been identified as one of the causes of global warming. Box 4 provides estimates of potential greenhouse gas reductions in the 2010 to 2020 time frame.

Box 4 Potential greenhouse gas emission reductions.

The GIWA Assessment identified global climate change as a key factor in determining rainfall patterns in the Sahel and thus the freshwater availability in the Lake Chad Basin. Below is a summary of the results from many sectoral studies, largely at the project, national and regional level with some at the global levels, providing estimates of potential greenhouse gas emission reductions in the 2010 to 2020 timeframe. Some key findings are:

- Hundreds of technologies and practices for end-use energy efficiency in buildings, transport and manufacturing industries account for more than half of this potential.
- At least up to 2020, energy supply and conversion will remain dominated by relatively cheap and abundant fossil fuels. Natural gas, where transmission is economically feasible, will play an important role in emission reduction together with conversion efficiency improvement, and greater use of combined cycle and/or co-generation plants.
- Low-carbon energy supply systems can make an important contribution through biomass from forestry and agricultural by-products, municipal and industrial waste to energy, dedicated biomass plantations, where suitable land and water are available, landfill methane, wind energy and hydropower, and through the use and lifetime extension of nuclear power plants. After 2010, emissions from fossil and/or biomass-fueled power plants could be reduced substantially through pre- or post-combustion carbon removal and storage. Environmental, safety, reliability and proliferation concerns may constrain the use of some of these technologies.
- In agriculture, methane and nitrous oxide emissions can be reduced, such as those from livestock enteric fermentation, rice paddies, nitrogen fertiliser use and animal wastes.
- Depending on application, emissions of fluorinated gases can be minimised through process changes, improved recovery, recycling and containment, or avoided through the use of alternative compounds and technologies.

(Source: IPCC 2001)

Chari-Logone/Lake Chad sub-system

Political and organisational framework

In CAR the Ministry of Transport and Civil Aviation (Department of Meteorology and Hydrology) is responsible for surface water, but the Ministry of Mines and Energy also play a role in groundwater. The Chad government formed in 1997 includes a Ministry of Environment and Water and a Master Plan was prepared in 2000 by the Ministry of Planning and Co-operation regarding water resources. Institutes therefore exist to control environment and water policy in Chad. The Chad-Cameroon Joint Commission was created to develop consultation on the water use in the Logone River between the two neighbouring states, but it is presently inactive. In Cameroon local technical administrations and other institutions operate in the region, which include the Hydrological Service. The SEMRY is a company for agricultural development in Cameroon, which formerly specialised on rice but has diversified in recent years. The present project in the Chari-Logone (SEMRY 3) is aimed at small irrigation schemes.

IUCN Waza-Logone or CACID project

The IUCN Waza-Logone Project (WLP), which is also known as the 'Cellule D'Appui a la Conservation et aux de Initiatives Développement Durable' (CACID), was started in 1987 with the support of the Government of the Netherlands. Over three phases CACID did the following: (i) gathered data and conducted studies in socio-economic, ecological and hydrological issues; (ii) provided training for villages, and study tours and seminars for project and government staff; (iii) undertook ecomanagement activities regarding resource management for livestock, sustainable forest use, formed apiculture groups, ecotourism and water and sanitation; (iv) encouraged community participation and awareness through a communication programme; (v) catalysed pilot releases for floodplain rehabilitation through a large-scale reinundation programme; (vi) audited releases made in 1994 and 1997; (vii) jointly with the communities drafted proposals for the sustainable use of floodplains' natural resources; and (viii) assisted in developing management plans for the Waza and Kalamaloue National Parks (World Bank 2002a).

Waza-Logone Pilot Project

Based upon recommendations from the Lake Chad Basin Commission's member countries and institutions involved, and guided by integrated ecosystems management principles and GEF objectives, the Waza-Logone Pilot Project aims to support the CACID project and its partners by promoting the sustainable management and use of the Basin's resources (water and biodiversity) by relevant institutions and communities; and developing and implementing an effective monitoring and evaluation system that looks at the overall ecosystem, hydrology and socio-economic issues (World Bank 2002a). The project has not been implemented and is still in a planning stage.

Table 12 The incremental benefit of reinundation over current situation.

	Additional flow (m^3/s)	Reflooded area in average year (km^2)	Incremental net benefit of flooding (million USD/ year)	Net present value of investment (million USD @ 10%)	Benefit: Cost ratio of investment
Maximum flood release option	215	867	2.32	7.76	6.57
Middle flood release option	165	687	1.78	7.19	6.13
Minimum flood release option	115	479	1.15	5.61	4.66

(Source: IUCN 2002)

Options

Option 4a: Reinundation of the Waza-Logone floodplains

(Proposed by the IUCN Waza-Logone Project)

The high productivity of the Waza-Logone region depends to a large extent on the overbank flooding of the Logone River between September and December each year. Since 1979 the annual inundation of the Waza-Logone floodplain has reduced significantly, due to a combination of climatic factors and the construction of the Maga Dam as part of the SEMRY project. The Project of Conservation and development of the Waza-Logone has initiated studies to explore the effects of reinundation by controlled flood releases (IUCN 2002) that led to two pilot flood releases in 1994 and 1997. The studies concluded that although reinundation could not re-establish the flooding patterns seen before the construction of SEMRY, the release of waters from the Logone River and Lake Maga will be able to contribute towards the rehabilitation of the region's hydrology, ecology and biodiversity and consequently restore the economic activities that depend on the Waza-Logone floodplain (IUCN 2002).

Reinundation could have many positive impacts on floodplain goods and services (IUCN 1999b, Mott MacDonald 1999, Wessling et al. 1994 in IUCN 2002). Increased flooding will contribute to the restoration of the floodplain fisheries including greater fish migration. It may also rehabilitate some of the dry season grassland and improve crop agriculture including an increase in the area available for dry season millet, cultivation around Lake Maga and the SEMRY scheme and the return of flood-fed rice around the Logomatya, El Beid and Waza National Park borders. A recovery of wildlife populations may also be possible, through the restoration of grazing and watering areas in and around Waza National Park, and an increase in fish and waterfowl populations in the wider floodplain. Increased flooding will assist in the replenishment of surface water through increased storage and availability of water, especially in dry seasons.

Valuation studies conducted by IUCN (2002) on the economic impacts of the pilot flood releases in 1994 and 1997, calculated an added value of 800 000 USD per year through restoring floodplain goods and services. They predict that by implementing the reinundation options currently under consideration there will be incremental economic benefit of between 1.1 million USD and 2.3 million USD per year over the current situation, translating into positive net present values of between 5.6 million USD and 7.8 million USD when investment and operational costs were taken into account (Table 12). On a per capita basis, this equates to 50 USD added economic value per floodplain-dependent member of the population (IUCN 2003b). Non-monetary benefits and development improvements could include poverty alleviation, food security, diversified production base, and future economic growth with possible multiplier effects.

The studies also identified that there would be management and opportunity costs and economic costs to other activities in the Waza-Logone floodplain and give rise to a number of flood related economic costs. These will include: investment and recurrent costs of designing, planning installing and maintaining the infrastructure required to reinundate the floodplain, and of monitoring its effects; costs of training staff to operate and monitor the reinundation programme; programmes to mitigate any negative health and other socio-economic impacts of the reinundation programmes; loss of millet, sorghum, and gum Arabic harvesting areas to flooding; and crop damage resulting from increased populations of wildlife and birds.

According to the Pilot release studies when comparing the economic costs and benefits, all of the proposed flood release options would have net economic benefits over the current situation of reduced flooding. The flood release measures proposed by the project would cost between 2-8 billion CFA (franc de la Communauté Financière Africaine) to implement over a period of 5 years. The incremental benefits would be 0.9-1.8 billion CFA per year or 2 million CFA/km^2.

The IUCN argue that the results of their valuation study present a convincing argument for investment in flood release measures in the Waza-Logone floodplain as a mechanism for rural poverty alleviation and sustainable livelihood development (IUCN 2003b).

Option 4b: Assessment of changing land use in the head waters of the Chari-Logone sub-system

This project initiative is based on the concern of the CAR Ministry of Environment on the present rapid changes in land use in the north-northeastern part of the Central African Republic and its likely impact on water resources downstream in the Lake Chad Basin (Scholte 2000). From an agricultural point of view, the changes in the northwest seem to be equally pressing, an argument supported by the northwest's important hydrological functions. Given the low knowledge level of both parts of the basin, these concerns have been considered as complimentary. It is therefore proposed that this project will be dealing with the entire CAR part of the Lake Chad basin. A comprehensive land use information system needs to be developed and disseminated. There is also need for data rescue especially from numerous studies previously conducted on vegetation, wildlife, livestock agriculture and fisheries in the area but scattered in different places. These studies would culminate in a detailed impact study of upstream activities on the water resources of the Chari-Logone sub-system.

Option 5: Chad-Niger Transboundary Project to Combat Sand Dunes and Reverse Water Degradation Trends in Lake Chad

The project has been proposed under the GEF project 'Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem'. It is planned that the intervention zone will cover Diifa, N'Guigmi, and Mainé-Soroa in Niger and Bol, Liwa and Rig-Rig in Chad.

The overall objective of the project is to restore the ecosystems of the Lake Chad. The specific objectives are to develop a mechanism for coordination of the management of shared resources; to create greater synergy in implementing the Conventions on desertification (UNCCD 1994), the Climate Change Convention and the Kyoto Protocol (UNFCCC 1992, UNFCCC 1997), the Convention on Biodiversity (CBD 1992) and to improve living standards.

The decline in rainfall which has caused a decline in the Lake Chad poses a serious threat to farming, pastoral, and fishing activities, at both the local and transboundry level, and is leading to the degradation of the Lake's ecosystem, upstream and downstream. This project attempts to reverse the influence that soil and vegetation cover degradation has had on the rainfall and temperature fluctuations in the region, which in turn have influenced water flow patterns. This will be based upon the rationale, that to halt the degradation of waters and ecosystem of the Lake Chad Basin, it is essential to combat the degradation of soils and vegetation cover, which is exacerbated by sand dune formation in areas either side of the Chad-Niger border.

Reversing the degradation, tributary basins will require efforts to promote sustainable water management practices and to preserve biodiversity. The chances of survival and reproduction of plant and animal species will be improved through sand dune fixation by biological means (planting). Over the long-term, the regeneration of vegetation cover will promote carbon fixation. This will assist in mitigating severe atmospheric disturbances resulting from the level of soil humidity, the roughness of terrain, and the composition of the atmosphere.

The Environment Ministry in both Chad and Niger will be responsible for monitoring sand dune fixation. The Lake Chad Basin Commission (LCBC), and the livestock extension and environmental services agencies will be closely involved in pastureland management and dissemination of information. Regional coordination will be provided by the LCBC. An important task is to ensure the logical alignment between the implementation of the regional Action Program to Combat Desertification (UNCCD 2003) and the execution of this project.

Both the Chad and Niger Governments back the project. The traditional management systems that are predominant in the region must participate in the planning and implementation process for the long-term success and permanence of the project. The project aims to benefit groups that rely on the fertile "sinks" and ponds; users of the surrounding grazing lands; women engaged in farming and algae production; residents of villages isolated by encroaching sand dunes. The pastoralists must be consulted, but communications may be difficult due to the migratory nature of their activities. Educational programmes facilitated through local community groups would be a useful tool in increasing awareness amongst these stakeholders.

Komadugu-Yobe sub-system

Political and organisational framework

(extracted from Bdilya et al. 1999, updated).

The Federal Ministry of Water Resources (FMWR) is the apex organ of the government that has the statutory responsibility for policy formulation and coordination for water resources development and management throughout the Federation of Nigeria. The FMWR functions through the

National Council on Water Resources (the highest policy body) and the National River Basin Development Coordinating Committee (NRBDCC). However, due to the dependence of other sectors of the economy on this critical resource, as well as the three tier system of government which Nigeria operates, several other statutory and non-statutory institutions are active players in the management of water resources in the sub-system. These include the following: the Federal Ministry of Environment (FME); the Hadejia-Jama'are River Basin Development Authority (HJRBDA) and the Chad Basin Development Authority (CBDA); the governments of Bauchi, Borno, Jigawa, Kano and Yobe States which have interests in the Basin; the North East Arid Zone Development Programme (NEAZDP); Local Government Authorities; the IUCN Hadejia-Nguru Wetlands Conservation Project (HNWCP) recently taken over by the Jigawa Enhancement of Wetlands Livelihoods (JEWEL) project and several water-user associations, such as the Stakeholders Consultative Forum.

Only two governmental institutions (FMWR and FME) and two non-government organisation (HNWCP-JEWEL and the Stakeholders Consultative Forum) are concerned with the sustainable utilisation of the water resources of the Komadugu-Yobe sub-system (Bdilya et al. 1999).

The Niger sector of the Komadugu-Yobe Basin is far from the capital Niamey and the government institutions involved consists of the Department of Hydraulics and Department of Agriculture. The Nigeria-Niger Joint Commission was established to resolve bilateral disputes.

The Federal Government of Nigeria has two legal instruments which, when properly applied, can control the uncoordinated development of water resources in the Basin. These are the Water Use Decree No. 101 of August 1993, and the Environmental Impact Assessment Decree No. 86 of 1992. Although both decrees are already enforced the modalities are being finalised by their custodians. It is planned that a water management plan is to be implemented according to the provisions of the two decrees.

Hadejia-Nguru Wetlands Conservation Project (HNWCP)

The project was established in 1987 by the Federal Government of Nigeria, the Nigerian Conservation Foundation, the World Conservation Union (IUCN), and the Royal Society for the Protection of Birds (British NGO) and the International Council for Bird Preservation (now renamed Birdlife International). Objectives of the project were (World Bank 2002a):

- To explore appropriate use options for water resources for the benefit of wildlife and human communities;
- To monitor wildlife resources, especially migrant water birds;
- To develop conservation education and public awareness programme;
- To train the staff in the State Wildlife Departments.

Komadugu-Yobe pilot project

Based upon recommendations from the Lake Chad Basin Commssion's member countries, and institutions involved, and guided by integrated ecosystems management principles and GEF objectives, the Komadugu-Yobe pilot project aims to support the HNWCP by promoting the sustainable management and use of the Basin's resources (water and biodiversity) by relevant institutions and communities; and developing and implementing an effective monitoring and evaluation system that looks at the overall ecosystem, hydrology and socio-economic issues (World Bank 2002a).

The Komadugu-Yobe Integrated Management Project

The project "aims to create the institutional environment that allows participatory and informed decision-making […] based on agreed principles for equitable use and sustainable management of the Komadugu-Yobe Basin" (IUCN 2003b). The project is part of the IUCN Water and Nature Initiative (WANI), which is a 5-year partnership for action to promote sustainable water use and management.

Options

Option 6: Grant subsidies to irrigation farmers in northern Nigeria for implementing water conservation measures

This option was formulated during the GIWA workshop hosted by the LCBC. However, water conservation has already been under discussion within the LCBC and by donor organisations. In exchange, farmers would dedicate water rights to water saved. This water could be allowed to flow into the river systems so that there is greater water available for downstream users.

The current water requirements from the Hadejia river system are already exceeding available resources during periods of lower precipitation. Any further expansion of the requirements of one use will deprive others of water. Potential water requirements are at least 2.6 times greater than the mean available water resources. Annual available water resources are able to sustain the present water requirements in the Jama'are and Yobe river systems. However, if construction is finished on the Kafin Zaki Dam (Jama'are Valley Irrigation Project), the potential water requirements for the Jama'are river system will be 1.8 times the available water resources in a mean year (Bdilya et al. 1999). Table 13 compares the available surface water resources with current and potential water requirements in the Hadejia, Jama'are and Yobe river systems. Water demand management therefore needs to be a priority in addressing freshwater shortage.

Increasing demands for water and the increasing costs of water supply are giving rise to a need for countries to maximise the use of their

Table 13 Relationship between water resources and both current and potential water requirements for the Hadejia, Jama'are and Yobe river systems.

River system	Available surface water resources (million m³/year)	Mean river flow reduction (million m³/year)	Present water requirements (million m³/year)		Potential water requirements (million m³/year)	
			Formal	Informal	Formal	Informal
Hadejia	536-2 567 (mean 1 739)	798[1]	894[4]	765	2 353	2 241
Jama'are	518-4 577 (mean 2 194)	919[2]	0	1 620	1 388	2 635
Yobe	381-2 551 (mean 1 201)	855[3]	58	246	111	504

Note: Part of the natural flow reduction is due to evaporation. The total surface water resources are the flows at the upstream ends of each river system. [1]Wudil to Hadejia, Hadejia to Likori and Likori to Nguru. [2]Foggo to Gashua. [3]Gashua to Yau. [4]144 million m³/year extra in 2002 when expansion of the Hadejia Valley Project has been completed.
Formal requirements: evaporation and domestic water supply from reservoirs and irrigation.
Informal requirements: all other users (e.g. flood and small-scale agriculture and contribution to Yobe River), these partly depend on natural flow reductions.
(Source: Blidya et al. 1999, updated)

existing water supplies and make use of hitherto unexploited freshwater resources. Despite the freshwater shortage concerns that the people of the Komadugu-Yobe Basin face, water is utilised extremely inefficiently. For example, Isiorho et al. (2000) estimated that in the Maiduguri region of Nigeria 10 to 25% of water is used inefficiently. However, there have been no studies that accurately quantify the level of water wasted in the sub-system. Agriculture is the largest user of water in the Komadugu-Yobe Basin; in the Hadejia river system upstream of Hadejia, irrigated agriculture accounts for approximately two-thirds of the total water requirements for agriculture, domestic, industrial and livestock use (Bdilya et al. 1999). These irrigation projects, particularly large-scale government schemes, are utilising water resources inefficiently. Irrigation channels are unlined and open resulting in infiltration and evaporative losses. By implementing water conservation measures less water will be needed to produce a unit of rice. Presently there are no guidelines or incentives for the farmers to conserve water; farmers do not have to purchase the water and by saving water they do not achieve any personal gain. Education programmes and incentives may therefore be necessary to promote water conservation. Water conservation strategies in northern Nigeria are discussed in a study by Dabi & Anderson (1999).

Water conservation is one of the most effective tools in demand management and is often the cheapest policy action to increase water availability (Box 5). More efficient use of water in the Hadejia river system would allow more water to reach the Hadejia-Nguru wetlands without decreasing the productivity of large irrigation projects e.g. Kano River Irrigation Project (KRIP). Greater flooding of the Hadejia-Nguru wetlands will rejuvenate fishing, flood and recessional farming, grazing lands and other wetland resources. In order for communities downstream of the Hadejia-Nguru wetlands to benefit from the increased water supply, channels in the Hadejia river system will need to be cleared of weeds and silts on a regular basis to allow Hadejia River to contribute to the Yobe River.

Box 5 Water conservation techniques.

Numerous techniques, modern and traditional, for improving the use, and augmenting the availability of water resources have been developed and implemented in different parts of the world that can be replicated within the Lake Chad Basin. The technological improvements to conserve water must be suitable for the farmers; operation and maintenance must require minimum technical skills and financial constraints must be considered. Commercial farmers in the sub-system have objectives usually aiming to maximise yield and income, but the subsistence farmer is likely to be more interested in improving food security by reducing crop failure, or improving the return on inputs of seed, fertiliser, and labour (Hudson 1995). Technologies must therefore be suited to the local and specific conditions based on local resources, skills and knowledge (Batchelor et al. 1998).

Technological methods that could be employed in the agricultural sector for water conservation include: improved maintenance of existing irrigation systems; altered tillage and soil management; changes in cropping patterns (e.g. reduce hectares cropped, and switch from rice to less water intensive crops e.g. sorghum). Structural methods include: lining of irrigation canals; replacing of open canals with underground pipes; and the switching from gravity irrigation to more efficient irrigation techniques such as drip or sprinkler irrigation systems.

Rain water harvesting would also be another useful technique of storing water from the rainy season for later use during periods of low rainfall. Rainfall can be collected either from rooftops or *in situ*. For freshwater augmentation using rainwater harvesting from rooftops, there are three components to the rainwater harvesting system: the collection area, the conveyance system, and the storage facility. The collection area is usually the individual rooftop of a house or other building. Large communal catchments including hillsides may also be used. The conveyance system is a series of gutters that carry the rainwater from the collection area to the cistern. The cistern or storage facility varies from steel and polyethylene tanks of various sizes to underground concrete tanks. It could be a part of the home or constructed separately, above or underground (IETC 2000). Rainfall harvesting *in situ* consists of using topographic depressions, either natural or artificial, to store rainwater where it falls for future use. Construction of furrows and raised beds is a normal practice in this technology.

Another form of water augmentation method is run-off collection using surface and underground structures. There are two types of structures commonly used: local impoundments and dams. Local impoundments are storage ponds dug into the ground, while dams are designed to increase the storage capacity of areas of a river or stream by intercepting run-off and storing it for future use. The extension of this technique is the artificial recharge of aquifers. There are several different artificial recharge techniques, ranging from infiltration basins and canals, water traps, surface run-off drainage wells, to septic tank system effluent disposal wells, and the diversion of excess flows from irrigation canals into sinkholes.

A study on the efficiency of water uses by the large irrigation projects, such as KRIP and Hadejia Valley Project, and the applicability of freshwater augmentation technologies would be required before efficiency improvements could be implemented. An education programme and improved communication networks would promote the advantages of using more efficient water use techniques, provide training in new techniques and help farmers to adapt from habitual methods. Local associations that represent the interests and needs of the user communities should be utilised as a means to disseminate information and to promote appropriate technologies. However there may be difficulties in encouraging the farmers to change and invest in more efficient methods, due to there being no purchase price for water and also due to financial constraints in a poverty stricken region. Incentives may therefore be needed (Dabi & Anderson 1999, Gardner & Stern 2002).

A possible incentive could be to put a value on the quantity of water that farmers save. Water that is saved can be purchased and then diverted to the river channels to reallocate the water to downstream users. A regulatory body would be needed and meters installed to monitor water use. A source of funding for the subsidies would need to be found, be it governmental or from donor agencies. However a concern of providing incentives to save water is that farming may become more attractive, and hence increase the number of farmers and thus water requirements. Consequently, the net outcome on water demand is uncertain. Subsidies may also not be the most cost-effective technique for encouraging farmers to convert. An alternative economic incentive for more efficient use could be to put a price on the water used by irrigation farmers; the revenues collected can then be used to help invest in more efficient technologies. In the economic situation of this region, particular attention needs to be paid to what price the farmers can afford and the impact of increased costs on domestic and export markets.

Although improved policies of the Nigerian government will not result in the adoption of water efficient technologies, they can play an important role in encouraging the uptake of improved technologies or methods as well.

Option 7: Maintenance and improvements for safety and improved efficiency of dams and stream flow in the Komadugu-Yobe Basin

Option 7 was formulated at the GIWA workshop, although the World Bank/GEF project, LCBC and others have discussed the issue of maintenance and improvements that are needed in the Basin.

Water resources management is the application of structural and non-structural measures to control natural and man-made water resources systems for beneficial human and environmental purposes (Grigg 1996). The goal is to provide water in the quantity and quality required, when it is needed, where it is needed, and with the appropriate level of reliability. In the Komadugu-Yobe dam infrastructure is not effectively regulating the flow of water to achieve these goals. Currently the dams have been ill-maintained and therefore to implement the water allocation agreement (Option 2) the dams need to be repaired so that flood releases can be undertaken effectively. The height of the Tiga Dam has already been lowered, and the reservoir level accordingly, in 1992 due to structural instability. Although the GEF project does not plan to construct dams, the safety of dams is important, as the project will rely on the performance of existing dams. The project reviewed two dams in the Komadugu-Yobe Basin (Tiga and Challawa Gorge) and the Maga Dam in the Chari-Logone. The Maga and Tiga dams were considered a threat to the safety of the populations below the dams (see Root causes, Governance, Poor water use efficiency).

The following activities were recommended by the review for the Tiga Dam (World Bank 2002a):

- Further lowering of reservoir level as a short-term non structural measure, to minimise overtopping by floods;
- Improved monitoring e.g. improved seepage monitoring;
- Installation of an Early Warning System, e.g. sirens in communities downstream;
- An Emergency Preparedness Plan (EPP). To include a dam-break analysis, flood propagation study, population awareness, and training;
- Reduction of the full storage level by additional excavation of the emergency spillway of the left bank.

The installation of a valve at the second outlet structure of Tiga Dam is recommended to enable the dam to contribute to peak wet season releases for flood farmers and to serve as back-up in case the other outlet is out of order.

Some recommendations have been made by different studies within the Basin, particularly in what concerns the Komadugu-Yobe Basin. A flow proportioning structure has been recommended for installation at Likori in the Hadejia-Nguru wetlands (Diyam Consultants 1996). The structure is expected to distribute water between the Marma Channel, the Burum Gana River and the Old Hadejia River. The proposal is considered to be the best option for conveying water from the Hadejia River to the Komadugu-Yobe River without any adverse impact on water uses along the Marma Channel and the Burum Gana River.

There has been proliferation of blockages from weeds and siltation in the Hadejia river system. The blockages in the Old Hadejia River have prevented the Hadejia River from contributing to the Yobe River. These have not been cleared and have consequently continued to impede freshwater from reaching the main river channels. The water is instead restricted to the wetlands of the Hadejia-Nguru and does not reach downstream users. There needs to be a programme to clear these channels to improve flow rates.

Identification of the recommended options

The World Summit on Sustainable Development (WSSD 2002) included a special agreement related to Africa "Sustainable development for Africa". Paragraph 66 states "promote integrated water resources development and optimise the upstream and downstream benefits…" and to "develop and implement integrated river basin and watershed management strategies and plans for all major water bodies". In accordance with this agreement and the SAP, before projects considered by the GIWA assessment can be implemented, there is a need to coordinate the member States national plans and actions with each other at the Lake Chad basin level (see Root causes, Governance, Lack of coordination and Institutional weakness). To achieve regional coordination a review of the LCBC is needed and subsequent strengthening of its capacity. Therefore the GIWA Assessment recommends as a perquisite to all the proposed projects, the development and prioritisation of recommendations made in the SAP and subsequently the implementation of the GEF project (Option 1).

The two broad challenges facing policy makers in the region were identified as: (i) to improve the allocation of water; and (ii) how to increase freshwater availability. The improvement of water allocation will require the implementation of Options 2, 4a and 7 that complement each other by facilitating the equitable distribution of available surface and groundwater supplies. A water allocation agreement enforced and coordinated by a strengthened LCBC is necessary if integrated management of the Basin is to be achieved. Such an agreement will support the SAP Long-term objective 1: "Concerted management of international waters based regional cooperation and national objectives and national policies harmonised and applied in each sub-basin" by creating "new institutional mechanisms for cooperation" (LCBC 1998) (see recommendations from GEF project Strategic Action Plan). The implementation of a water allocation agreement will address the root causes: (i) lack of coordination; (ii) legal - no water allocation law; and (iii) lack of capacity to promote compliance. The legal framework that this will provide will allow the implementation of Option 4a (the reinundation of the Waza-Logone floodplains). Dam maintenance and enhancement, and the improvement of stream flow (Option 7) will allow the effective implementation of Option 2 (water allocation agreement) and Option 4a by allowing greater control and efficiency of water conveyance.

The GIWA Assessment recommends Option 6 (water conservation) as a possible means of increasing freshwater availability and addressing the root causes of: (i) poor water management; and (ii) the lack of incentives to promote compliance. The implementation of water conservation measures would allow water supplies that are available in the Komadugu-Yobe sub-system to be used more efficiently and would be an effective tool for long-term water demand management as part of the wider allocation of water in the Basin. Such a project would support the SAP Long-term objective 3: "Players in the basin take responsibility for protecting common heritage" through "regional promotion of productive, water saving, economically beneficial techniques and practices that are accepted by local people and local economic operators, and do not harm the environment" (LCBC 1998).

Justification for not recommending Option 3, 4b and 5

Option 4b and 5 were not selected as recommended options not because the GIWA Assessment recognised them as poor actions but because the selected options were more specific in addressing the root causes identified during causal chain analysis and it was therefore considered that these options should be prioritised.

Option 3, inter-basin water transfer, was not selected as a recommended option as it would require substantial investment and although it could significantly increase freshwater availability such projects are associated with high costs per unit of water. The effect that possible future climatic scenarios could have on the current water developments, irrigation and the ecosystems of the Basin would need to be assessed. To undertake such a project, large financial investment is required and the economic viability of such a project in the Lake Chad Basin is undetermined. The systems involved in inter-basin transfer require high operation and maintenance costs. There is usually extensive networks of pipelines and canals. Highly qualified engineers and technicians are required to plan, design and implement and operate inter-basin transfer schemes. The technology employed has high capital and operational costs (IETC 2000). These costs could make this option unaffordable and inappropriate for the people of the Lake Chad Basin.

There is some evidence now that river discharges are increasing in the Lake Chad Basin, with an associated increase in the Lake Chad and the regional floodplains. Presently there are no accurate models for predicting future precipitation rates in the region and although some studies point to greater or similar levels of aridity, there is also the possibility that precipitation will increase and provide greater water resources for the region.

The livelihood strategies of the Lake Chad Basin's population have always been dependent on the intra and inter-annual fluctuations in the water availability. The economic activities of the Basin have adapted to this dynamic environment. The question should be asked, whether flooding the Lake Chad Basin would actually alleviate poverty and promote economic development or be yet another large-scale water development which on the contrary derogates the rural livelihood safety-net (Neiland & Béné 2003).

Particular attention should be paid to the medium and long-term consequences for the original biodiversity of the Lake Chad Basin with the introduction of alien species into a fragile ecosystem, and 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 (Nami 2002). There are also often public health impacts associated with water transfer canals that can serve as water-borne disease vectors (IETC 2000).

At the UNESCO International Workshop on Inter-basin Water Transfer (UNESCO 1999), it was highlighted that "the recipient catchments need to demonstrate that available water is optimally used and reasonable water conservation measures enforced. On the other hand, the rights of donor catchments need to be respected …." (UNESCO 1999). There has been no economic analysis or exploration of least-cost alternatives, including demand management and solutions that utilise the surface and groundwater resources already in the Lake Chad Basin. It is argued that more effective use and management of current water supplies should be investigated before resorting to such an option. So far, there has been no non-objection from some of the riparian countries with the Congo Basin for such a development to commence and there has been little involvement from the countries of Democratic Republic of Congo (DRC) and Congo Brazzaville.

CAR, Cameroon, Congo, and DRC have formed a new regional organisation called Commission Internationale du Bassin du Congo-Ubangi-Sangha (CICOS) at the 49th Session of the Council of Ministers of the LCBC, 14-15 January 2002. This commission has been formed both to respond to the LCBC's plans for the transfer of water out of the Congo Basin as well as to respond to a hydroelectric dam-building project in the region near Inga. International environmental organisations are also closely monitoring progress in the identification and design of the inter-basin transfer proposal.

Priority recommended option

Option 1: Implementation of the GEF project for the 'Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem'.

Table 14 evaluates the option using criteria stipulated at the GIWA Workshop.

Main reasons for selection

The project directly addresses the root cause of institutional weakness and the lack of coordination in the region by strengthening the capacity of the LCBC. It also addresses secondly, the root causes of: lack of water

Table 14 Evaluation of priority recommended option, using criteria stipulated by GIWA regional experts.

Priority recommended policy option							
Project option	**Legal & Institutional framework**	**Political feasibility (stakeholder analysis)**	**Administrative feasibility**	**Information intensity**	**Efficiency**	**Equity**	**Permanence**
Option 1: Implementation of the GEF project "Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem".	National legislative and regulatory changes to enhance transboundary institutional mechanisms.	Political will and cooperation has been expressed by member states. Pilot projects will bring water users at the local level into the decision making process. Consultations have been undertaken with stakeholders. Risk of member States not realising long-term benefits of regional approach.	LCBC currently lacks capacity to solely implement project. PMU established to implement project, in cooperation with the LCBC. Only five pilot projects were selected due to financial feasibility and project realism. Project financed by GEF and co-financing organisations, as well as member states in kind.	TDA will determine the precise linkages between environmental and social-economic systems. LCBC will report to the World Bank and ensure compliance with GEF project design and contracts. Environmental and social assessments undertaken and an Environmental Management Plan is being prepared. Designated bodies will undertake evaluation and review procedures.	Benefits: Primarily addresses the root causes of institutional weakness and lack of coordination but also: Lack of water resource environmental planning; lack of stakeholder participation; and the lack of capacity to promote compliance and enforce agreements and policies. The primary regional benefit is a stronger LCBC for the decision making process at all levels. Costs: Total project cost 18.07 million USD. Does not include associated infrastructure costs. Technical staff recruitment and training costs. Creation of inter-ministerial committees, and the PMU.	Greater coordination, cooperation and stakeholder participation will ensure a more equitable use of the water resources of the basin.	Consistent and committed effort by member states to the long-term implementation of project. The project needs to work within existing regional mechanisms to ensure the long-term capacity to harmonise national policies at regional level. However, what influence would negative changes in economic and social conditions have on the long-term commitment to a regional approach?

resource environmental planning; lack of stakeholder participation; and the lack of capacity to promote compliance and enforce agreements and policies.

The primary regional benefit of the project is a stronger LCBC for the decision making process at the regional, national and local level. This should result in: (i) strengthened regional institutional capacity for coordinated decision making; (ii) local communities more empowered in managing the Lake Chad resources; (iii) design of an effective mechanism to translate regional policies at the local level for managing the natural resources; and (iv) regional consensus and support for the next phase of work voiced in the SAP (LCBC 1998).

The LCBC will be stronger, as it will be able to build more commitment from members, more capacity to implement projects, and serve its member States efficiently.

There will be improved coordination and environmental planning, as member governments will have mechanisms in place with which to harmonise their activities, will be better prepared to attract donor support and investment following the Project, and will perceive the benefits of a longer-term perspective. The finalisation of the LCBC SAP with implementation methodologies validated on a regional level will create an integrated strategy for environmental planning at the regional, national, and local level. Pilot demonstration projects will test and validate methodologies and implementation modalities before implementing projects throughout the region and therefore reduce the risk of inappropriate project ideas being implemented (LCBC 1998).

There will be improved stakeholder involvement, as local communities will be more involved in decision making processes to manage the natural resources that they depend upon. The parallel design and implementation of the TDA, SAP and pilot projects will stimulate public participation.

The TDA will address the deficiencies in knowledge identified during the causal chain analysis in both the Chari-Logone and Lake Chad sub-system and Komadugu-Yobe sub-system.

Conditions for successful implementation

Countries will have to make national legislative and regulatory changes to enhance transboundary institutional mechanisms. Changes will include new and updated national water policies in each country that take into account transboundary water issues, encourage environmental protection and are incorporated into National Action Plans (NAPs). Recommendations will be made regarding changes in existing relevant legislation frameworks to enhance prospects for an integrated regional approach for long-term, sustainable basin management.

The long-term success of the GEF project depends on the political willingness of the LCBC member States, to continue project programmes and approaches after the life of the GEF intervention, and the extent to which activities successfully engage end users at the community level. The LCBC member States have few economic resources and have found it difficult to focus on long-term environmental imperatives. There is however a growing realisation by the countries that environmental sustainability is inextricably linked to the economic and social well-being of the region. Consequently, they have increasingly demonstrated their commitment to improving environmental management and have begun to realise the advantages of a regional approach to environmental concerns. Subsequently, political will and cooperation have been expressed for the GEF project and there has been a high level of participation in the preparatory process. However LCBC member States may not realise the long-term benefits from a regional approach to water issues. To mitigate this risk, the role of LCBC should be strengthened and parallel national-level water resource management dialogue should continue.

Stakeholders will further be encouraged to participate in the project through links to national institutions and the pilots will bring users at the local level into the decision making process. Efforts have already been made to include the public during environmental planning, by disseminating a short version of the executive summary from the environmental and social assessment report to LCBC member States for publication in national and local media outlets in 2002. Stakeholders have also been visited by consultants hired to prepare initial technical demonstration reports, and the Environmental and Social Assessment team.

Although the LCBC is the executing agency, given the current capacity of the institution, it was decided to have the LCBC focus their capabilities on the organisational review of roles and responsibilities, cross-project learning opportunities, and hosting TDA and SAP workshops. A Project Management Unit (PMU) will be established and will be responsible for contracting, fund management, procurement, disbursement, programme administration and project level monitoring. The LCBC will therefore participate in the project but will not carry the whole burden for implementing the project. It is anticipated that by the end of the GEF project in four years time, the capacity of the LCBC will be sufficient to take sole responsibility for project implementation (LCBC 1998).

Only five pilot projects were selected due to financial feasibility and project realism. GEF financing, in the amount of 10.1 million USD, is required to remove barriers to regional management of the Basin, completion of a TDA, and subsequent development and negotiation of the SAP. There is also a total co-financing of 7.3 million USD. There is a risk that the pilot projects are not sufficiently supported in terms of financing, implementation and technical support, and therefore arrangements need to be made to work directly with local communities to serve their needs as well as the interest of the Basin.

The risk of the PMU working independently of the LCBC should be addressed through incentives to balance project implementation with LCBC institutional capacity-building in the project implementation plan.

The third component of the project will undertake a TDA to address the insufficiencies in knowledge building upon and refining priorities from previous efforts, such as the Diagnostic Analysis (Kindler et al. 1990), the Master Plan (LCBC 1992), the PDF-B project, and this GIWA Assessment. The TDA will need to determine the precise linkages between environmental and socio-economic systems and their transboundary impacts.

LCBC will report to the World Bank and be responsible for ensuring that all GEF-funded activities are carried out in compliance with the project design and contracts. Evaluation should rely on both quantitative and qualitative criteria using World Bank guidelines, with independent reviewers to ensure the correct conduct is adhered to.

An Environmental Assessment has been undertaken and an Environmental Management Plan is in preparation. The Lake Chad GEF project has had to comply with GEF Environmental Operational Policy (OP), which has prompted the designation of Lake Chad shoreline as a transboundary Ramsar site, and also initiated field visit assessments on dam safety issues. Evaluation and review procedures will be undertaken by the Project Task Force (PTF), UNDP, Scientific and Technical Advisory Program (STAP) and through the Project Implementation Review (PIR) of the GEF.

The project needs to work within existing regional mechanisms in the Lake Chad Basin to ensure that in the long-term they have the capacity and constituency to coordinate and harmonise national policies at the regional level. There has been consistent and committed effort from the LCBC headquarters and member States, which suggests a long-term commitment to implementing the project. The ability of the countries, with GEF assistance, to solicit enhanced donor support will be crucial to the permanence of project efforts.

Unresolved questions

- What level of donor support will there be following the GEF project?
- Will the PMU work in isolation from the LCBC?
- Will LCBC member States continue to realise the long-term benefits from a regional approach to water issues?
- Will LCBC work in isolation from local level and water resource initiatives in Lake Chad basin member countries?
- Will key regional institutions and national governments work cooperatively?
- Will countries seek to develop alternative, bi-lateral approaches to resolving existing and future potential disputes rather than taking a broader regional approach?
- Will suitable levels of cooperation be established and maintained?
- Will all stakeholders be willing to participate?

Recommended options for enhancing water allocation mechanisms

Option 2: Water allocation agreement
Option 4a: Reinundation of Waza-Logone floodplain
Option 7: Dam maintainance and enhancement, and the improvement of stream flow

The above options compliment each other in achieving greater equitable allocation of water resources. They address the transboundary water allocation difficulties that have been experienced in the Lake Chad Basin. A prerequisite to addressing water allocation, and achieving integrated river basin management, is a suitable and effective legal framework. It is therefore critical for a water allocation agreement to be ratified amongst the LCBC member States (Option 2). Within this framework it will then be possible for the other options to be implemented.

To implement Option 4a (the reinundation of the Waza-Logone floodplains) it is necessary to set minimum flow rates for both the water entering the wetland systems and of that flowing in the main channels to the Lake Chad. The water allocation agreement will stipulate these flow rates. Option 4a can also be replicated for the Hadejia-Nguru wetlands.

The implementation of Option 7 will be necessary to ensure the effective distribution of the water resources. Dam maintenance and enhancement, and the clearance of river channels will allow improved water conveyance and control, to ensure the adherence to minimum flows stipulated by the water allocation agreement.

Table 15 Evaluation of recommended options to improve the allocation of freshwater, using criteria stipulated by GIWA regional experts.

Policy options to improve freshwater allocation							
Project option	**Legal & institutional framework**	**Political feasibility (stakeholder analysis)**	**Administrative feasibility**	**Information intensity**	**Efficiency**	**Equity**	**Permanence**
Option 2: Water allocation agreement	A water allocation agreement will provide a legal framework. There are currently no water regulation authorities in the river basins. A strengthened LCBC could serve as a regulatory body.	There may be difficulties in achieving an equitable agreement due to political pressures. Politically stronger nations may insist that their water demands are met. Water Authorities and irrigation projects may not cooperate, as they will lose out on water resource rights.	Dam maintenance and enhancement, and the clearance of channels to ensure flow rates that are stipulated by the agreement can be technically implemented.	An analysis of the water requirements of all stakeholders. A study to calculate the appropriate minimum flow rates. An accurate model to predict the ecological and social impacts. Stream flow monitoring network. An analysis of existing information and educational systems.	Benefits: Increased water availability for downstream users and ecosystems. Maintain the extent of the Lake Chad during times of low precipitation. Costs: Decreases in water for upstream users including the large irrigation projects.	Increased water supplies for downstream users. Although traditional management systems may still restrict access to water resources for the poor.	Minimum flows can be maintained in dry years. In wet years, water is stored in reservoir as fall back for drier years. If freshwater shortage continues to increase in severity upstream states may not comply with the agreement.
Option 4a: Reinundation of Waza-Logone floodplains	A legal mechanism for the equitable management of water between riparian countries is needed. A regulatory organisation is needed to manage flood releases.	Objections from remaining SEMRY irrigation farmers, although the project is operating on a smaller scale now.	Maga Dam is presently in poor condition and maintenance is required. There are presently difficulties in effectively releasing floods due to poor upkeep of the flood release outlet. Generally a low cost option. Design and installation of flow proportioning mechanism is required.	IUCN Pilot releases have demonstrated benefits and there is information available on the economic benefits provided. Flow rate-monitoring network, to ensure equitable allocation between Waza-Logone floodplains, and discharges to the Lake Chad.	Benefits: Includes the restoration of fisheries, dry season pasture, recovery of wildlife populations, replenishment of surface water in Waza-Logone floodplain. Costs: Investment and recurrent costs, training. Loss of millet and sorghum production. Crop damage from increased wildlife.	Will give greater water allocation to the communities of the Waza-Logone floodplains.	Minimum flows can be maintained in drier years. In wet years, water is stored in reservoir as fall back for dryer years.

Table 15 uses criteria to rate the performance and feasibility of Option 2 and 4a. Option 7 supplements these policies and is a requirement for the implementation of Option 2 and 4a; it has therefore not been subject to evaluation under the performance criteria.

Option 2: Water allocation agreement

Main reasons for selection

Integrated river basin management requires a suitable and effective legal framework to achieve its required goals. There needs to be an agreement between the member States to share responsibility for the management and allocation of surface and groundwater resources.

The agreement will form the basis for integrated river basin management that will allow increased coordination between water users (see Root causes, Governance, Lack of coordination).

The water allocation agreement will fill the current legislative gap in both the Komadugu-Yobe and Chari-Logone/Lake Chad sub-systems (see Root causes, Legal).

The increases in population in the conventional basin will increase the water requirements of the region, and it will be necessary for water resources to be equitably shared if the population is to be able to subsist (LCBC 2000b). A legal framework for water allocation will allow disputes to be resolved by the rule of law rather than through conflict where users are confused as to who has the right to the water resources (see Root causes, Demographic).

Water allocation will quantify and designate water resources through a negotiated process involving consultations between claimants/stakeholders, rather than unilateral decisions that have been associated with previous water management in the Basin (see Root causes, Governance, Lack of water resource environmental planning). The sequencing of legal reforms may be best engaged at the LCBC Heads of State and Council of Ministers.

Within a legal framework it will be possible for Option 4a and 7 to be implemented.

A regulatory body will improve the coordination and cooperation between member States, water users and other relevant organisations (see Root causes, Governance, Lack of coordination).

Conditions for successful implementation

Studies will be required to establish recommended minimum flow rates for surface and groundwater at strategic positions in the river basins to ensure the equitable distribution of water resources. The development of groundwater data management tools and surface-groundwater interaction modelling (studies that are being initiated by the World Bank/GEF project) will be required to accurately monitor and predict the impacts of a proposed water allocation agreement.

For an equitable and effective water allocation, stakeholders must be involved through consultations so that the water requirements of the various water users can be identified. If the stakeholders are not included during the planning and implementation of the water allocation agreement, there will be a high level of non-compliance. Consultations should involve all water users ranging from traditional fishing communities to large irrigation projects. Farmers and their representative organisations should be involved in the formulation of policy (UNCED 1992). An effective dissemination of information to disadvantaged groups can help to maintain their rights and thus bring about equality. To improve public awareness educational systems need to be strengthened through supporting local networks and developing education and information programmes (Gardner & Stern 2002).

Furthermore, the institutions through which water rights are negotiated and renegotiated have a critical influence on the possibility of generating equitable and efficient solutions to conflict, or increasing confusion, rigidity, inefficiency and inequity. Traditional management systems are predominant in the Basin and access to water is generally controlled by village leaders rather than modern systems (Neiland & Bene 2003). For an allocation law to be effective, it is essential that these management systems are included during planning and implementation. Educational programmes and improved information dissemination could improve the involvement of these stakeholders. The utilisation of existing community groups could assist in raising the awareness in traditional communities.

For the effective implementation of the water allocation agreement where integrated basin management is achieved it is essential to "encourage knowledge generation and transfer through research, extension, education and communications" (WEHAB 2002). National policies can be designed to facilitate the establishment of function linkages between these desirables (WEHAB 2002).

There must be an extensive process of consultations between member States and stakeholders where water allocation is agreed based on scientific studies on surface and groundwater and the interactions between them. Member States must be willing to make concessions in order to achieve an equitable allocation agreement, as some riparian countries will undoubtedly have to concede water to other member States.

The agreement should apply to the abstraction, diversion or other utilisation of surface waters but also groundwater as well. Applicable minimum rates for groundwater levels and stream flow should be determined. A network of monitoring points will be required to ensure that these minimum rates are maintained.

A comprehensive analysis of the water requirements of all stakeholders in the Lake Chad Basin is required before an allocation process can begin. There should also be an accurate model to predict the ecological and social impacts resulting from alterations in the hydrological cycle by the implementation of an allocation agreement. This model should build upon existing models, such as the flow model management tool already existing for the Komadugu-Yobe Basin (Hollis et al. 1993), and apply remote sensing and GIS technologies. The member States must agree to forward to the LCBC, on a regular basis, available data on the condition of the watercourse.

The agreement should be flexible in that the "minimum" and "safe maximum" rates may be altered by the LCBC should changes in climatic conditions trigger river or lake fluctuations that fall below the "safety level" (see Root causes, Climate change). In other words, it should prescribe rates for different climatic scenarios of wet, average and dry years.

A water regulatory body is required to enforce the agreement. It is important that it is independent and is not associated with a water user group/sector (see Root causes, Governance, Institutional weakness). A strengthened LCBC could be best suited for this task. Equitable access to water resources will only be achieved through a participatory and transparent management including support of effective water users associations and involvement of marginalised groups (UNEP 2003) such as traditional farming and fishing communities of the Waza-Logone floodplains. The agreement should support and enhance the legal capacity of vulnerable groups with regard to access and use of the water resources (UNCED 1992).

Dam maintenance and enhancement, and the regular clearance of river channels (Option 7) will allow the effective implementation of water allocation by allowing controlled flood releases from dam infrastructure and by improving stream flow by clearing river channels and installing appropriate flow proportioning structures.

Unresolved questions

There may be political difficulties in accomplishing a workable agreement that achieves equitable water utilisation, as the upstream countries will be under political pressure to retain adequate water to meet the demands of their people. The willingness of upstream member States to concede water rights to downstream users is undetermined. In Nigeria there are further irrigation developments planned in the upstream states and water requirements will continue to increase.

The permanence of the agreement will depend on the willingness of the member States to abide by the abstraction rates stipulated, when demand will be increasing as a result of population growth. This is why it has to be a negotiated process involving all the parties from the onset.

- How will the River Basin Development Authorities in Nigeria react to a water allocation agreement that will limit the amount of water that can be stored in the reservoirs and used for irrigation?
- How will the issues of insufficient oulet capacity of Tiga and Maga dams impact on the objective of flow redistribution in the Basin?
- If an agreement is ratified, will member states comply if freshwater availability decreases again in future years? (The draft Agreement already makes provision for reviews of set minimum flow rates and maximum abstraction rates as and when necessary).
- How will natural and human systems respond to changes in water distribution?

Option 4a: Reinundation of Waza-Logone Floodplain

Main reasons for selection

Increased flooding will restore some of the environmental goods and services that were lost/reduced after the construction of the Maga Dam (see Root causes, Economic, Inadequate valuation of environmental goods and services). Reinundation will contribute to the restoration of the floodplain fisheries, rehabilitate some of the dry season grassland and improve crop agriculture and the return of flood-fed rice production. Wildlife populations may also recover, through the restoration of grazing and watering areas in and around Waza National Park, and an increase in fish and waterfowl populations in the wider floodplain.

IUCN predicted that by implementing the reinundation options currently under consideration there will be incremental economic benefit of between 1.1 million USD and 2.3 million USD per year over the current situation (IUCN 2003b).

According to the IUCN studies the proposed reinundation options are robust in the face of possible future changes in climate, flooding, and resource use conditions (see Root causes, Climate change).

By restoring the floodplains, the Chad and Cameroon government policies of: (i) poverty reduction and increasing economic growth and food sufficiency; and (ii) wildlife conservation through the creation of national parks, can both benefit. The floodplain economic activities will be restored and national parks rehabilitated and in the long-term the enhancement of the national parks could also lead to greater tourism (IUCN 2003b).

Conditions for successful implementation

A legal mechanism for the equitable allocation of water between Chad and Cameroon, or for the entire conventional basin (see Option 2) is necessary so that a multi-lateral allocation is achieved. Flood releases from Maga Dam should also be used to feed the Logone River channel to ensure the regulation of stream flows below the Waza-Logone floodplain so that the benefits from flood releases are also experienced by downstream and Lake Chad water users.

A regulatory body would be required to monitor stream flow and regulate flood releases. It should be independent from a water user group so that flood releases are not biased to a particular sector (see Root causes, Governance, Institutional weakness).

Stakeholders such as the SEMRY project, Waza-Logone floodplain communities and Lake Maga fishing communities must be included during planning and the implementation of flood releases (see Root causes, Governance, Lack of stakeholder participation). Community awareness raising programmes and meetings are possible methods to ensure stakeholder participation. The traditional management systems must be taken into account and kept fully informed of flood releases and the impact that this will have on their activities. Communication networks with the rural communities may need to be improved in order to effectively communicate the project (see Root causes, Knowledge, Public awareness and Information sharing). This could be achieved through the IUCN Waza-Logone project, as they have experience in working with the local communities.

A network of flow rate monitoring points is required to ensure flood releases are reaching the intended areas of the floodplain and that downstream water users are also receiving adequate water supplies (see Root causes, Knowledge, Insufficient knowledge of water resources and the functioning of aquatic ecosystems). In accordance with the SAP (LCBC 1998) priority must be given to the following three uses of water resources: (i) inflow to the northern and southern pools of the Lake Basin; (ii) maintenance of the annual flood on the Chari-Logone and Hadejia-Nguru wetlands; and (iii) consideration for the supply of water to big riparian cities and large irrigation areas where there has been considerable investment and which ensure a minimum guaranteed production. There is equally a need to prioritise water uses to apply to the allocation of water resources when there is shortfall in supply.

There needs to be studies on the impacts on the Maga Reservoir for each flood release option, such as shoreline erosion. Dam maintenance and enhancement, (Option 7) will ensure that the flood releases from the Maga Dam are controlled safely and according to stipulated flow rates.

There also needs to be investigations on the impact of increased flooding on terrestrial wildlife communities in the downstream floodplains. The SEMRY project has been recognised as a failure and has diversified including a new irrigation project, SEMRY 3, which has an emphasis on smaller-scale irrigation rather than large irrigation areas associated with the previous SEMRY projects. The SEMRY 3 needs to be fully incorporated with the flood release scheme and its farmers considered during planning. Many of the original SEMRY farmers have diversified, with many fishing in the Lake Maga, the impact of reduced lake levels on these reservoir fisheries needs to be taken into account. All stakeholders must be kept informed of the new flooding regime so that they can adapt if necessary to the modified environmental conditions.

Communication networks within rural communities should be improved to effectively implement the project. This could be achieved through the IUCN Waza-Logone or CACID project, as they have experience in working with the local communities. The flood release outlet needs maintenance, so that effective and controlled flood releases can be implemented (see Option 7).

Unresolved questions

- What will the impacts be on the Maga Reservoir for each of the flood release options such as shoreline erosion and the fisheries?
- What impacts from increased flooding will there be on terrestrial wildlife communities in the downstream floodplains?
- Who will finance the flood releases, the associated management and opportunity costs, and economic costs to other activities?

Option 7: Maintenance and improvements for safety and improved efficiency of dams and stream flow in the Komadugu-Yobe Basin:

Main reasons for selection

Currently the dams have been ill-maintained and therefore to implement the water allocation agreement (Option 2) and the reinundation of the Waza-Logone floodplains (Option 4a) the dams need to be repaired so that flood releases can be undertaken effectively.
Dams are currently unsafe and are threatening thousands of people down stream, particularly the Tiga Dam. Flow proportioning structures at Likori will convey water from the Hadejia River to the Komadugu-Yobe River without any adverse impact on water uses along the Marma Channel and the Burum Gana River.

The clearing of weeds and silts from river channels will improve flow rates and thus allow improved water distribution. This will assist in the implementation of Option 2 and 4a. These measures will address the root cause of poor water efficiency management in the Komadugu-Yobe Basin identified in the Causal chain analysis.

Conditions for successful implementation

A legal water allocation agreement, based upon scientific predictive modelling of environmental responses to different water allocation scenarios, should stipulate minimum flow rates. The flow proportioning structures can then be positioned and calibrated to these rates.

Channels should be dry during several months of the year, a pattern similar to pre-dam period, to help control the invasion of Typha. Its growth is limited by a prolonged dry soil, as is occurring naturally in the Jama'are River Basin.

To ensure stakeholder involvement there should be consultations with local fishermen who use the river channels. The clearance of weeds and silts may affect their activities.

Improved monitoring of dam safety, in accordance with recommendations made by GEF review, requires the following elements: upgrading instrumentation system; training local staff; local staff for surveillance; quality control; and independent review on annual basis. Essential records that should be kept are: daily readings of reservoir water levels; weekly readings of seepage flows; monthly readings of piezometer and wells; annual level survey of crest of dam; and inspection of vulnerable areas.

The Hadejia-Jama'are River Basin Authority needs to cooperate to the fullest extent with the civil authorities in the preparation of an Early Warning system. A pre-feasibility study for the further reduction of the full storage capacity of the Tiga Dam is required.

Unresolved questions

- What maintenance and enhancement is required to ensure the effective implementation of Option 2 and 4a? Technical studies on all dam and water infrastructure should be undertaken to set a work plan for maintenance and enhancement.

- What environmental and social impacts will there be from dam maintenance and stream flow improvements?
- Who will fund the installation of additional oulet structures on the Tiga Dam so that more releases can be effected from the dam?

Recommended option for increasing freshwater availability and/or reducing water demand

Option 6: Grant subsidies to irrigation farmers in northern Nigeria for implementing water conservation measures

Main reasons for selection

Increasing demands for water and the increasing costs of providing water for the sub-systems population will result in the need for authorities to maximise the use of their existing water supplies. Despite the freshwater shortage concern, water continues to be utilised extremely inefficiently. The ever-increasing populations in the Komadugu-Yobe Basin will continue to stretch available water supplies and there is little that can be done to change climate patterns in the region; therefore the population of the Komadugu-Yobe sub-system need to utilise available water resources efficiently. By implementing water conservation measures the poor water management that is currently employing inefficient practices such as the unlined and open irrigation canals, which were identified during the causal chain analysis, will be addressed.

Subsidies will address the current absence of economic incentives for farmers to conserve water resources. An incentive will encourage farmers to learn about and take up the water conservation measures, as they will receive a personal gain. An alternative incentive could be to put a price on water resources to encourage the efficient use of water and reinvest revenues in water efficient technologies. This would be a more cost efficient policy action than subsidies (see Root causes, Economic, Lack of incentives promoting environmentally sound practices).

The Lake Chad Basin is essentially one of the poorest regions in the world. Freshwater augmentation technologies will allow individuals to become self-sufficient in freshwater rather than relying on upstream water developments releasing enough water for downstream users to meet their requirements. Rainwater harvesting will allow the storage of water from periods of abundant rain for use during dry periods, thereby reducing the vulnerability of the poor to climatic variability (Dabi & Anderson 1999) (see Root causes, Climate change).

Numerous techniques, modern and traditional, for improving the use, and augmenting the availability of water resources have been developed and implemented in different parts of the world that can be replicated within the Basin. These can be tailored to suite the particular local and regional budgetary, technical and workforce skill constraints found in the Komadugu-Yobe Basin.

More efficient use of water in the Hadejia river system would allow more water to reach the Hadejia-Nguru wetlands without decreasing the productivity of large irrigation projects e.g. Kano River Irrigation Project (KRIP). Greater flooding of the Hadejia-Nguru wetlands will rejuvenate fishing, flood and recessional farming, grazing lands and other wetland resources.

Conditions for successful implementation

A fundamental requirement for implementing water conservation measures is the involvement of stakeholders, namely the farmers and other water resources users. Incentives will be a useful tool in promoting compliance with water conservation schemes. Traditional management systems that are predominant in the region need to be taken into account, and it is therefore critical that village leaders etc. are kept fully informed and involved in the project.

Although water conservation will not provide a 'quick fix' answer to freshwater shortage due to the time it will take to change attitudes and habits (Eagly & Chaiken 1993), it will contribute to a long-term solution to the concern and will be particularly applicable during future periods of low rainfall. Changing attitudes and habits will be critical for the successful implementation of this project. Strategies on how to change attitudes and behaviour are further discussed by Gardner & Stern (2002). The current lack of public awareness, identified during the causal chain analysis, about conservation measures and the advantages of employing such methods needs to be addressed. The communities need to be empowered, "including through capacity building, to implement projects and programmes to enable small farmers to take up improved technologies" (WEHAB 2002). The promotion of information exchange, networking and technology generation and dissemination related to best practices of agriculture (WEHAB 2002) can strengthen the farmer's role in applying water conservation measures. Education programmes facilitated by local community groups such as farmer organisations could help to increase the awareness and benefits of water conservation measures, and trigger farmer to farmer exchange of water saving practices (WSSD 2002) and hence improve the level of participation and cooperation of local farmers with the project. Farmer organisations should be supported through cooperation with international and national research centres in developing location-specific water conservation measures (UNCED 1992). The Nigeria and Niger Governments, multilateral and bilateral development agencies and NGOs such as the Hadejia-Nguru Wetlands Conservation Project (HNWCP), the Jigawa Enhancement of Wetlands Livelihood (JEWEL) Project, the North East Arid Zone Development Programme (NEAZDP) and the IUCN-BRAO Initiative on "Improving Land and Water Resources Management in the Komadugu-Yobe Basin", should collaborate with farming organisations in formulating a water conservation project specific to the Komadugu-Yobe Basin.

Investigations are needed to identify what appropriate technologies will be required to meet local conditions and constraints. This can be implemented through consultations with farmers and through evaluating technologies employed in other drought prone river basins. There is limited public sector finance available for sustainable agriculture. Therefore the provision of appropriate technical and financial assistance and the promotion of private sector investment and support efforts in the Komadugu-Yobe Basin are necessary to strengthen agricultural research in water conservation and the dissemination of the results from this research (WSSD 2002).

There needs to be installation of a monitoring system to quantify water saved, to allow the effective payment of subsidies to farmers and for evaluation purposes. Maintenance and improvements to the efficiency of stream flow in the Komadugu-Yobe Basin will be required to ensure that water that is saved will be able to reach downstream communities (see Option 7).

Unresolved questions

- Should subsidies or water pricing be used as the incentive for farmers to convert to more water efficient practices? How effective would each incentive be?
- Where would the funding for the subsidies come from? Would the governments of countries of the Lake Chad Basin fund the scheme or would external donors be needed? If it is the governments, would they initiate the policy from their own large-scale schemes and extend to small-scale farmers in the Basin? If external donors intervene with respect to small-scale farmers, would they also consent to subsidising the large-scale schemes belonging to government agencies, particularly in view of the perceived poor regime of cost recovery presently practised on such schemes?
- If donor funds are used, who would implement the project and distribute funds?
- Will the governments also benefit from donor support?
- In what form should the subsidies be provided; monetary, agricultural inputs (agro-chemicals, technologies etc.), inter-sectoral income transfers from other water users to agriculture, or other?
- If pricing is used as an incentive, what impact will this have on domestic and export markets, and how much will the farmers be able to afford?
- How will subsidies be allocated and how much water needs to be saved to justify 'x' amount of subsidy?
- How much capital for subsidies will be required to ensure a high level of participation by farmers?
- Will subsidies have to remain in place for farmers to continue to employ water conservation measures, or will farmers change their habits and attitudes in the long-term?
- An analysis of Option 6 would be required to compare the cost efficiency with other freshwater availability increasing measures. Water conservation will not increase freshwater availability to totally meet potential water requirements and it needs to be identified how much water can be potentially saved by implementing water conservation measures and at what cost.
- What probable changes in agricultural cropping choices will there be to obtain lower water consuming crops? What consequences will this have on domestic and export markets? Will the more water efficient crops be marketable? If the crops are not marketable, what impact will this have on the permanence of the project?

Table 16 uses criteria to rate the performance and feasibility of Option 6.

Table 16 Evaluation of recommended option to increase freshwater availability using criteria stipulated by GIWA regional experts.

Policy option to increase freshwater availability							
Project option	**Legal & Institutional framework**	**Political feasibility (stakeholder analysis)**	**Administrative feasibility**	**Information intensity**	**Efficiency**	**Equity**	**Permanence**
Option 6: Water conservation	Minimal legislation needed as it would be voluntary participation. Regulatory body needed to monitor water use and oversee subsidy allocation. Might require a new mandate for the River Water Development Authorities so that they enforce methods.	Possible difficulties in farmers complying as water is presently free, and there may be an unwillingness to change habits. Subsidies may therefore be needed.	Capital required to purchase saved water. Technology must take into account low budgets and minimal technical skills.	Feasibility study of water conservation techniques. Monitoring system to quantify water saving. Educational programmes for increasing the knowledge and awareness of water issues.	Benefits: Decrease water demand by irrigation scheme whilst not reducing yields. Relatively low cost. Costs: Will not be sufficient enough to solve future imbalance between water availability and potential water requirements. How much capital will be required for farmers to continue to comply?	Increased water supplies for downstream users. Downstream communities will be less reliant on stream flow if they employ freshwater augmentation technologies.	Will subsidies have to remain in place for the continued efficient use of water? However, once technology is in place e.g. drip irrigation, greater efficiency will continue. What effect will changes in agricultural cropping choices have? What consequences will there be on domestic and export markets?

Conclusions and recommendations

The GIWA Assessment of the Lake Chad Basin aimed to identify priorities for remedial and mitigatory actions. The report investigates the ecological status, the causes of their degradation and the policy options available to improve their status. The Assessment focused on the five major problem areas of: Freshwater shortage, Global change, Habitat and community modification, Unsustainable exploitation of fish and other living resources, and Pollution.

The GIWA Assessment ranked Freshwater shortage as severe and it was considered the priority concern in the Lake Chad Basin. All the other concerns except for Pollution (rated as slight) were rated as having a moderate impact. Although there has been significant modification of habitats and significant fluctuations in fish production, these were primarily a function of freshwater shortage, rather than as a consequence of direct habitat modification or unsustainable exploitation of fish. Stream flow modification as a result of decreased rainfall events and upstream dam impoundments primarily in the Chari-Logone and Komadugu-Yobe river systems, have impacted on the habitats downstream. Wetlands have been the most affected as a result of changes in the timing and extent of seasonal flooding. For example the surface area of Hadejia-Nguru wetlands, located in the Komadugu-Yobe sub-system, at one time covered nearly 300 000 ha, today, these wetlands have shrank to an estimated 70 000-90 000 ha (Barbier et al. 1997). The reduction in the stream flow has also caused the Lake Chad to shrink to less than 10% of its former surface area in the 1960s (Lemoalle 1991, USGS 2001). This has significantly altered the Lake from being an open water environment to being a predominantly marshy environment. The fish species composition has correspondingly been modified. The fluctuations in fisheries production is also primarily attributed to the variations in freshwater availability in the region.

The Causal chain analysis (CCA) focused on the priority issue of stream flow modification. The Chari-Logone/Lake Chad sub-system was identified as one hotspot and the Komadugu-Yobe sub-system as another where there had been severe impacts from stream flow modification. In the Chari-Logone/Lake Chad sub-system the immediate causes of stream flow modification were the significant decreases in precipitation in the catchment and the increased diversion caused by the construction of the Maga Dam in 1979 as part of the SEMRY irrigation project.

The root causes behind the stream flow modification witnessed in the region were identified to serve as a foundation for the selection of policy options. In the Chari-Logone and Lake Chad region the demographic pressures from rapid population growth and environmental refugees escaping drought in the northern regions of the Basin and from fishermen migrating following the receding lake waters have concentrated the pressure on water resources in this region. The poverty in the region and reliance of the population on flooding and the lake resources made the population particularly vulnerable to the environmental changes. The planners of the SEMRY project did not take sufficient account of the impacts of stream flow modification from the Maga Dam, on the downstream populations and the ecosystems that support them. Planners also did not take into account the value of the environmental goods and services provided by the Waza-Logone floodplains. The inundated area of the Waza-Logone floodplain was reduced by almost 30%, incurring annual economic costs to the local economy of more than 2 million USD (IUCN 2002). Stakeholders were not involved in the initial planning and implementation of and management of the SEMRY project. The lack of available information is a hindrance to sound decision-making and to public awareness in the region and the countries have difficulties in cooperating and sharing information. According to the WSSD (2002) it is important to "enhance and accelerate human, institutional and infrastructure initiatives and promote partnerships in that regard that respond to the specific needs of developing countries in the context of sustainable development". The governments active in the Chari-Logone sub-system, namely Cameroon and Chad have two conflicting policies, one to reduce poverty and increase economic growth and food self-sufficiency, which they hope to achieve through irrigated rice cultivation, and the other to conserve wildlife through the creation of national parks. These policies need to be integrated so that they are able to benefit each other. The irrigations projects use water inefficiently; the farmers receive a low return on the amount of water used in the irrigated fields, at the expense of downstream traditional farmers (King 1993). King (1993) identified that rice extraction rates in Chad and Cameroon are very low by modern standards and it has to be questioned whether water intensive crops such as rice, should be grown anyway in a region prone to freshwater shortages.

Stream flows in the Komadugu-Yobe sub-system have also been reduced by the decrease in rainfall events and because of the many dams constructed aimed at utilising the water resources of the region. During the 1970s and early 1980s around 20 reservoir dams were built on the Hadeija River system, to supply irrigation and domestic water supply projects. They had a negative impact on the hydrology of the Yobe River, the only inflowing river into Lake Chad's northern pool. The potential water requirements in the Hadejia river system are 2.6 times higher than available water supplies (IUCN 2003b).

There has been rapid population growth that has led to greater pressure on the natural resources including water resources in the Komadugu-Yobe sub-system. The population currently represents over 55% of the Lake Chad Basin's population. The communities suffer from endemic poverty, which is often a catalyst for environmental degradation as they exploit natural resources at an unsustainable level for their short-term survival. The hydro-agricultural schemes were planned without consideration of the climatic variability of the region and there was insufficient account of the impact of reduced flows on these communities in the downstream Nigerian States and Niger. For example the Hadejia-Nguru wetlands that provide essential income and nutrition benefits for local populations have been reduced in extent since the construction of upstream dams (Barbier 1997).

The traditional communities and other stakeholders most affected by the water developments were not consulted during the planning or during the management of the dam infrastructure. Large irrigation and water developments are thought to have provided more negative economic impacts than positive. Existing knowledge is not utilised with poor information dissemination, particularly to the traditional communities, weak information sharing networks, and limited pollution monitoring and regulations. Information, education and local networks are important strategies for awareness raising (Gardner & Stern 2002, UNCED 1992, WSSD 2002).

There is no overall water management strategy for the Komadugu-Yobe sub-system (Bdliya et al. 1999) and the most acute obstacle in achieving this is the absence of a coordinating mechanism to harmonise the activities of the water users such as a water allocation law between the Federal Agencies and the Nigerian States or between Nigeria and Niger. Water management institutions are only concerned with meeting their water requirements, with minimal or no concern for the impacts of their activities on other users (Bdilya et al. 1999). Management is also fragmented with ill-defined and often conflicting responsibilities between government agencies and stakeholders. Water continues to be used inefficiently whilst poor water use management continues, and farmers are given no incentives or guidelines aimed at conserving water resources. Traditional management systems that are predominant in the region also play a role in the inequitable use of water. The rural population is highly differentiated and the poor, critically, do not have access to fishing and farming resources (Béné et al. 2002).

The Policy option analysis described alternative courses of action that may be taken by policy-makers in the region, and discussed the projected outcomes and trade-offs of each action. These actions should address the root causes identified during the CCA. Firstly, basin wide options were discussed followed by projects under discussion for the Chari-Logone and Lake Chad sub-system and Komadugu-Yobe sub-system.

The following options were discussed for the entire Lake Chad Basin:

1. Implementation of the GEF project for the "Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem".
2. Water allocation agreement.
3. Inter-basin water transfer.

The following projects were discussed for the Chari-Logone and Lake Chad sub-system:

4a. Reinundation of the Waza-Logone floodplains (Chari-Logone sub-system).
4b. Assessment of chaning land use in the head waters of the Chari-Logone sub-system.
5. Chad-Niger Transboundary Project to Combat Sand Dunes and Reverse Water Degradation Trends in Lake Chad (Lake Chad sub-system).

The following projects were discussed for the Komadugu-Yobe sub-system:

6. Grant subsidies to irrigation farmers in northern Nigeria for implementing water conservation measures.
7. Maintenance and improvements to the efficiency of dams and stream flow in the Komadugu-Yobe Basin.

Two of the broad challenges facing water management in the Lake Chad Basin were identified as increasing freshwater availability and/or reducing water demand and enhancing water allocation mechanisms. However to successfully implement projects/policy actions aimed at alleviating these challenges, the institutional and legislative failures identified during CCA that are resulting in the unsustainable and inequitable use of water resources needs to be addressed as a priority.

Many of the root causes were identified in the LCBC Master Plan (LCBC 1992), followed by an update of this plan and the formulation of a Strategic Action Plan (LCBC 1998), but unfortunately the implementation by riparian countries of recommendations made in these plans has been very slow. They serve as foundation from which the root causes identified in the CCA can be addressed. The GIWA Assessment recommends as a perquisite to all other proposed projects, the development and prioritisation of recommendations made in the Strategic Action Plan (SAP). The GEF project entitled "Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem" is beginning to implement prioritised recommendations made by the Master Plan and SAP. It has a development objective "to build capacity within the Lake Chad Basin Commission (LCBC) and its national committees so that it can better achieve its mandate of managing land and water resources in the greater conventional basin of Lake Chad" (World Bank 2002a). A strengthened LCBC will coordinate the member States national plans and actions with each other at the Lake Chad basin level and primarily address the root causes of: lack of coordination; and institutional weakness.

As a subsidiary priority to the strengthening of capacity in the LCBC, a water allocation agreement would be a key legal instrument in addressing the inequitable allocation of the water resources in the Lake Chad Basin. A water allocation agreement enforced and coordinated by a strengthened LCBC is necessary if integrated management of the Basin is to be achieved. The implementation of a water allocation agreement will address the root causes: i) lack of coordination, ii) legal - no water allocation law, and iii) lack of capacity to promote compliance. The reinundation of the Waza-Logone floodplains (Option 4a) can be incorporated within the flow rates stipulated by this legal framework, so that increased flooding can restore floodplain economic activities. Dam maintenance and enhancement, and the improvement of stream flow (Option 7) will allow the effective implementation of Option 2 (water allocation agreement) and Option 4a by allowing greater control and efficiency of water conveyance. The GIWA Assessment also recommends Option 6 (water conservation) as a possible means of increasing freshwater availability and addressing the root causes of poor water management and the lack of incentives to promote compliance. The implementation of water conservation measures would allow water supplies that are available in the Komadugu-Yobe system to be used more efficiently and would be an effective tool for long-term water demand management as part of the wider allocation of water in the Basin.

The GIWA Assessment recommends the following actions in priority order:

1. Continued development of recommendations made by the Master Plan and Strategic Action Plan.

2. Implementation of the GEF project "Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem".

3. An agreement on the equitable and reasonable allocation of water resources should be negotiated, finalised and ratified by member States (Option 2).

4. The reinundation of the Waza-Logone and Hadejia-Nguru wetlands (Option 4a), according to flow rates stipulated by Option 2.

5. Maintenance and improvements in efficiency of dams and stream flow in both the Chari-Logone and Komadugu-Yobe basins, to ensure the effective implementation of the allocation agreement (Option 7).

6. Feasibility study of water conservation techniques suitable for selected project sites (Option 6).

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Annexes

Annex I
GIWA workshop participants.

Name	Institutional affiliation	Country	Field of work
Dr. Johnson A. Oguntola (regional co-ordinator)	Lake Chad Basin Commission	Chad	Chief Water Resources Unit
Mr. Martin Gbafolo	Lake Chad Basin Commission	Chad	Director, Department of Water Resources and Environment
Mr. Alainaye Jogromel	Direction des Ressources en Eau et de la Météorologie	Chad	Hydrologist
Mr. Anza Zakara	Lake Chad Basin Commission,	Chad	Fishery Expert
Mr. Abdallah Adam Mohamed	Société du Développement du Lac (SODELAC),	Chad	Agronomist
Mr. Dodo Garba	Direction Régional de l'Environnement	Niger	Deputy Regional Director of Environment
Mr. Timothée Essang	Institut des Récherches Agronomiques pour le Développement (IRAD)	Cameroon	Agro-Economist
Mr. Maman Moussa	Direction Régional de l'Hydraulique	Niger	Directeur Régional de l'Hydraulique
Mr. Mahmat Mey	Lake Chad Basin Commission	Chad	Live stock
Mr. Ndong Ebozo'o Daniel	Délégué Provincial des Mines, de l'Eau et de l'Energie de l'Extrême Nord	Cameroon	Ingénieur du Génie Rural
Engr. Usman K. Sandabe	Chad Basin Development Authority (CBDA)	Nigeria	Assistant Chief Irrigation Engineer (SCIP)
Mr. Anada Tiega	Lake Chad Basin Commission,	Chad	GEF Project Manager
Dr. Belomal Yongar	Sécretaire Exécutif, ONU-SIDA, s/c Commission du Bassin du Lac Tchad (CBLT)	Chad	Health Project Manager
Mme. Asta Morombaye	Lake Chad Basin Commission	Chad	Translator
Mr. Marcus Njumbe Ediage	Lake Chad Basin Commission	Chad	Translator
Mr. Yakubu Ramoni	Lake Chad Basin Commission	Chad	Technician
Mr. Matthew Fortnam	Global International Waters Assessment (GIWA)	Sweden	Consultant
Ms. Edith Mussukuya	Global International Waters Assessment (GIWA)	Sweden	GIWA coordinator, sub-Saharan Africa
Dr. Juan-Carlos Belausteguigoitia	Global International Waters Assessment (GIWA)	Sweden	GIWA coordinator for the Southern Hemisphere
Mr. Stephen Donkor	United Nations Economic Commission for Africa (UNECA)	Ethiopia	Senior Regional Adviser

Annex II
Detailed scoring tables.

I: Freshwater shortage

Environmental Issues	Score	Weight %	Environmental Concerns	Weight-Averaged Score
1. Modification of streamflow	3	60	Freshwater shortage	2.5
2. Pollution of existing supplies	1	10		
3. Changes in the water table	2	30		

Criteria for Economic Impacts	Raw Score	Score	Weight %
Size of Economic or Public Sectors Affected	Very Small – Very Large 0 1 2 3	3	40
Degree of Impact (cost, output changes etc)	Minimum – Severe 0 1 2 3	3	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	25
Weight Average Score for Economic Impacts		**3.0**	
Criteria for Health Impacts	**Raw Score**	**Score**	**Weight %**
Number of People Affected	Very Small – Very Large 0 1 2 3	2	40
Degree of Severity	Minimum – Severe 0 1 2 3	2	35
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	25
Weight Average Score for Health Impacts		**2.0**	
Criteria for Other Social and Community Impacts	**Raw Score**	**Score**	**Weight %**
Number and/or Size of Community Affected	Very Small – Very Large 0 1 2 3	2	30
Degree of Severity	Minimum – Severe 0 1 2 3	2	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	30
Weight Average Score for Other Social and Community Impacts		**2.0**	

II: Pollution

Environmental Issues	Score	Weight %	Environmental Concerns	Weight-Averaged Score
4. Microbiological	0	0	Pollution	1.0
5. Eutrophication	1	15		
6. Chemical	1	15		
7. Suspended solids	1	40		
8. Solid wastes	1	30		
9. Thermal	0	0		
10. Radio nuclide	0	0		
11. Spills	0	0		

Criteria for Economic Impacts	Raw Score	Score	Weight %
Size of Economic or Public Sectors Affected	Very Small – Very Large 0 1 2 3	1	55
Degree of Impact (cost, output changes etc)	Minimum – Severe 0 1 2 3	1	45
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	0	0
Weight Average Score for Economic Impacts		**1.0**	
Criteria for Health Impacts	**Raw Score**	**Score**	**Weight %**
Number of People Affected	Very Small – Very Large 0 1 2 3	1	50
Degree of Severity	Minimum – Severe 0 1 2 3	1	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	20
Weight Average Score for Health Impacts		**1.0**	
Criteria for Other Social and Community Impacts	**Raw Score**	**Score**	**Weight %**
Number and/or Size of Community Affected	Very Small – Very Large 0 1 2 3	1	50
Degree of Severity	Minimum – Severe 0 1 2 3	1	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	1	20
Weight Average Score for Other Social and Community Impacts		**1.0**	

III: Habitat and community modification

Environmental Issues	Score	Weight %	Environmental Concerns	Weight-Averaged Score
12. Loss of ecosystems	2	60	Habitat and Community Modification	2.0
13.Modification of ecosystems or ecotones, including community structure and/or species composition	2	40		

Criteria for Economic Impacts	Raw Score	Score	Weight %
Size of Economic or Public Sectors Affected	Very Small 0 1 2 3 Very Large	2	45
Degree of Impact (cost, output changes etc)	Minimum 0 1 2 3 Severe	2	30
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	25
Weight Average Score for Economic Impacts		**2.0**	
Criteria for Health Impacts	**Raw Score**	**Score**	**Weight %**
Number of People Affected	Very Small 0 1 2 3 Very Large	2	40
Degree of Severity	Minimum 0 1 2 3 Severe	2	30
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	30
Weight Average Score for Health Impacts		**2.0**	
Criteria for Other Social and Community Impacts	**Raw Score**	**Score**	**Weight %**
Number and/or Size of Community Affected	Very Small 0 1 2 3 Very Large	2	40
Degree of Severity	Minimum 0 1 2 3 Severe	2	30
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	30
Weight Average Score for Other Social and Community Impacts		**2.0**	

IV: Unsustainable exploitation of fish

Environmental Issues	Score	Weight %	Environmental Concerns	Weight-Averaged Score
14. Overexploitation	2	25	Unsustainable exploitation of fish	2.0
15. Excessive by-catch and discards	2	25		
16. Destructive fishing practices	2	50		
17. Decreased viability of stock through pollution and disease	0	0		
18. Impact on biological and genetic diversity	0	0		

Criteria for Economic Impacts	Raw Score	Score	Weight %
Size of Economic or Public Sectors Affected	Very Small 0 1 2 3 Very Large	2	33.3
Degree of Impact (cost, output changes etc)	Minimum 0 1 2 3 Severe	2	33.3
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	33.3
Weight Average Score for Economic Impacts		**2.0**	
Criteria for Health Impacts	**Raw Score**	**Score**	**Weight %**
Number of People Affected	Very Small 0 1 2 3 Very Large	2	33.3
Degree of Severity	Minimum 0 1 2 3 Severe	2	33.3
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	2	33.3
Weight Average Score for Health Impacts		**2.0**	
Criteria for Other Social and Community Impacts	**Raw Score**	**Score**	**Weight %**
Number and/or Size of Community Affected	Very Small 0 1 2 3 Very Large	1	40
Degree of Severity	Minimum 0 1 2 3 Severe	1	35
Frequency/Duration	Occasion/Short 0 1 2 3 Continuous	1	25
Weight Average Score for Other Social and Community Impacts		**1.0**	

V: Global change

Environmental Issues	Score	Weight %	Environmental Concerns	Weight-Averaged Score
19. Changes in the hydrological cycle	2	100	Global change	2.0
20. Sea level change	0	0		
21. Increase UV-B radiation as a result of ozone depletion	0	0		
22. Changes in ocean CO_2 source/sink function	0	0		

Criteria for Economic Impacts	Raw Score	Score	Weight %
Size of Economic or Public Sectors Affected	Very Small – Very Large 0 1 2 3	3	30
Degree of Impact (cost, output changes etc)	Minimum – Severe 0 1 2 3	3	40
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	3	30
Weight Average Score for Economic Impacts		**3.0**	
Criteria for Health Impacts	**Raw Score**	**Score**	**Weight %**
Number of People Affected	Very Small – Very Large 0 1 2 3	2	40
Degree of Severity	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	30
Weight Average Score for Health Impacts		**2.0**	
Criteria for Other Social and Community Impacts	**Raw Score**	**Score**	**Weight %**
Number and/or Size of Community Affected	Very Small – Very Large 0 1 2 3	2	40
Degree of Severity	Minimum – Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	2	30
Weight Average Score for Other Social and Community Impacts		**2.0**	

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of Impacts								Overall Score
	Environmental Score		Economic Score		Human Health Score		Social & Community Score		
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	3	3	3	3	2	3	2	3	**2.8**
Pollution	1	2	1	2	1	2	1	2	**1.5**
Habitat and community modification	2	3	2	3	2	3	2	2	**2.4**
Unsustainable exploitation of fish and other living resources	2	2	2	3	2	3	1	2	**2.1**
Global change	2	3	3	1	2	3	2	3	**2.4**

The Global International Waters Assessment (GIWA) is a holistic, globally comparable assessment of all the world's transboundary waters that recognises the inextricable links between freshwater and coastal marine environment and integrates environmental and socio-economic information to determine the impacts of a broad suite of influences on the world's aquatic environment.

Broad Transboundary Approach

The GIWA not only assesses the problems caused by human activities manifested by the physical movement of transboundary waters, but also the impacts of other non-hydrological influences that determine how humans use transboundary waters.

Regional Assessment - Global Perspective

The GIWA provides a global perspective of the world's transboundary waters by assessing 66 regions that encompass all major drainage basins and adjacent large marine ecosystems. The GIWA Assessment of each region incorporates information and expertise from all countries sharing the transboundary water resources.

Global Comparability

In each region, the assessment focuses on 5 broad concerns that are comprised of 22 specific water related issues.

Integration of Information and Ecosystems

The GIWA recognises the inextricable links between freshwater and coastal marine environment and assesses them together as one integrated unit.

The GIWA recognises that the integration of socio-economic and environmental information and expertise is essential to obtain a holistic picture of the interactions between the environmental and societal aspects of transboundary waters.

Priorities, Root Causes and Options for the Future

The GIWA indicates priority concerns in each region, determines their societal root causes and develops options to mitigate the impacts of those concerns in the future.

This Report

This report represents the GIWA Assessment of the Lake Chad Basin, which is located in one of the poorest and most drought prone regions in the world. Climatic variability and poor water governance has threatened the ecological and socio-economic integrity of the region. The past and present status and future prospects are discussed, and the transboundary issues traced back to their root causes. Policy options have been recommended that aim to address these driving issues and reverse the environmental degradation trends witnessed in the region over the past 30 years.