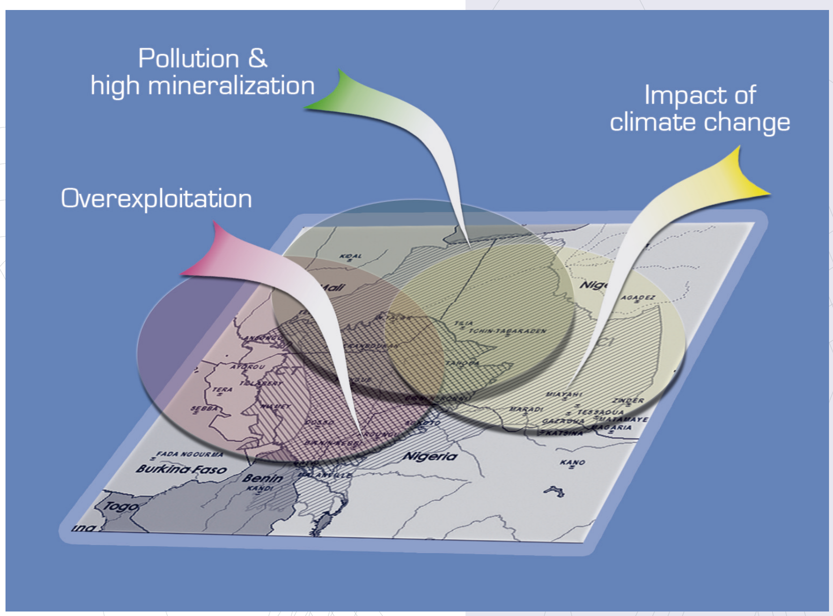
Iullemeden Aquifer System

Mali - Niger - Nigeria

Volume I

TRANSBOUNDARY DIAGNOSTIC ANALYSIS



SAHARA AND SAHEL OBSERVATORY

Iullemeden Aquifer System

Mali - Niger - Nigeria

Volume I

TRANSBOUNDARY DIAGNOSTIC ANALYSIS

Tunis, 2011

Other documents (IAS)

Volume II : Common Database

Volume III : Hydrogeological Model

Volume IV : Participatory management transboundary risks

Volume V : Monitoring & Evaluation of transboundary aquifers

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Water Programme coordinator

Abdelkader Dodo

Executive Secretary

Dr. Chedli Fezzani

Contents

LIST OF ACRONYMS/ABBREVIATIONS

ABN	Autorité du bassin du Niger
ABV	Autorité du bassin de la Volta
ACDI	Agence canadienne de développement international
ACMAD	African Centre of Meteorological Application for Development
ADT	Analyse diagnostique transfrontalière
AIEA	Agence internationale de l'énergie atomique
AMCOW	African Ministers' Council on Water
ASAR	Advanced Synthetic Aperture Radar
ASTER	Advanced Spaceborne Thermal Emission and Reflection
BAD	Banque africaine de développement
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Institut Fédéral des Géosciences et des Ressources Naturelles)
BRGM	Bureau des recherches géologiques et minières
CCNUCC	Convention-cadre des Nations unies pour les changements climatiques
CCRE	Centre de coordination des ressources en eau de la CEDEAO
CEDEAO	Communauté économique des Etats de l'Afrique de l'Ouest
CEN-SAD	Communauté des Etats sahélo-sahariens
CI	Continental intercalaire
CILSS	Comité inter-Etats de lutte contre la sécheresse au Sahel
CNCS	Comité national de coordination et de suivi des activités
CRA	Centre régional Agrhymet
CT	Continental Terminal
DDC-SUISSE	Direction du développement et de la coopération - Suisse
DSRP	Document de stratégie de réduction de la pauvreté
ENVISAT	ENVIronment SATellite
ERS	European Remote Sensing Satellite
ESA	European Space Agency (Agence Spatiale Européenne)
FAE	Facilité africaine de l'eau
FAO	Organisation des Nations unies pour l'alimentation et l'agriculture
FEM	Fonds pour l'environnement mondial
FFEM	Fonds français pour l'environnement mondial
FIDA	Fonds international pour le développement agricole
GEF	Global Environment Facility
GIRE	Gestion intégrée des ressources en eau
GICRESAIT	Gestion intégrée et concertée des ressources en eau des systèmes aquifères d'Iullemeden, de Taoudéni / Tanezrouft et du fleuve Niger
GIS	Geographical Information System

GIZ	Agence de coopération technique allemande pour le développement
IGAD	Inter Governmental Authority for Development
JRC	Joint Research Center
MCA-WEAP	Multi-Criteria Analysis tool - Water Evaluation and Planning System
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NEPAD	New Partnership for Africa Development
OMVS	Organisation de mise en valeur du fleuve Sénégal
OSS	Observatoire du Sahara et du Sahel
PANA	Plan d'action national pour l'adaptation aux changements climatiques
PAS	Programme d'action stratégique
PHI	Programme hydrologique international
PNUD	Programme des Nations unies pour le développement
PNUE	Programme des Nations unies pour l'environnement
PO	Programme opérationnel du GEF
SAI	Système aquifère d'Iullemeden
SAR	Synthetic Aperture Radar
SASS	Système aquifère du Sahara septentrional
SAT	Système aquifère de Taoudeni/Tanezrouft
SEI	Stockholm Environment Institute
SIG	Système d'information géographique
SRTM	Shuttle RADAR Topographic Mission
UMA	Union du Maghreb arabe
UNESCO	United Nations Educational, Scientific and Cultural Organization
WEAP	Water Evaluation and Planning System

I. INTRODUCTION

The present report belongs in the framework of the project entitled "Management of Hydro-geological Risks in the Iullemeden Aquifer System", financed by UNEP/GEF and implemented by the Sahara and Sahel Observatory (OSS). The other partners are in support in their domains. This is mainly, FAO, UNESCO, the International Atomic Energy Agency (IAEA), GIZ and the European Space Agency (ESA).

The Sahara and Sahel Observatory proceeded to implement the GEF/UNEP project activities that were conducted by experts from the countries supported by consultants. They were accompanied by the strengthening of national capacities (to control the management tools).

The overall objective of the project is to establish capacity under a sustainable cooperative framework for joint management of risk and uncertainty, to jointly identify, reduce and mitigate transboundary risk from changing land and water use and from climate change in the shared Iullemeden Aquifer System.

The outcomes are: 1) a joint mechanism for identification of transboundary risk issues in the IAS, 2) a joint mechanism for policy formulation and implementation to address and mitigate transboundary risk issues in the IAS; 3) a joint development and conservation strategy, une stratégie de développement et de conservation des eaux et des terres, 4) a joint tripartite legal and institutional cooperative framework for the IAS, 5) a joint programme for awareness, participation and inter-governmental communication for managing transboundary risks.

The outputs are: 1) the document of the Transboundary Diagnostic Analysis, 2) the Database and Geographic Information System, 3) the mathematical model, 4) the elements for the development of transboundary risk reduction policy, 5) the elements for a strategy of development and conservation of water and land, 6) the mechanism for monitoring the transboundary aquifers, 7) the "Iullemeden" Website.

The Iullemeden Aquifer System (SAI) is located in the arid and semi-arid West Africa. It is mainly shared between Mali, Niger and Nigeria, covers an area of 500,000 km^2. The IAS is a strategic resource for sustainable development of the concerned countries. However, it is:

- **exposed to a fragile and constraining environment:** 1) reduction in rainfall of about 20 to 30% since 1968, 2) reduction of surface runoff about 20 to 50% with low water up to the sometimes severe stop flow, 3) and establishment of sand dunes in recharge areas of aquifer and in the Niger River hydrographic network;
- **faces multiple constraints in particular:** 1) difficulties of access to resources related to the excessive depth (over 600 meters) in some places of water abstraction, 2) degradation of water quality (pollution, pumping deep water highly mineralized), 3) non-cooperative management of waters shared by several countries.
- **subject to:** 1) increasing population pressure (about 6 million inhabitants in 1970, 15 million in 2000, 30 million in 2025), 2) increased annual water abstraction of about 50 million m^3 in 1970 to 180 million m^3 in 2004.

In order to understand these risks and their associated threats, this project adopted an approach based on risk management (risk-based management approach). This approach is based on the principle of an assessment of both consequences and probability of occurrence of risk (frequency).

Risk assessment means the determination of its) potential effects (or impacts. This assessment includes questions like: is it a risk or not? This risk is relevant? What are its consequences (impacts)? What is the likelihood of this risk? Once the risk assessed what decisions to make: to mitigate this risk, control, or ignore it?

To identify, analyze and assess risks that may affect the hydrogeology Groundwater of the Iullemeden Aquifer System, the Transboundary Diagnostic Analysis/Strategic Action Program (TDA/SAP) GEF International Waters approach has been adapted and applied. It is important to remember that this is the first application of this approach on transboundary aquifers in Africa, and the second in the world after the Guarani Aquifer System in Latin America (shared by Argentina, Brazil, Paraguay and Uruguay)..

The diagnosis of transboundary risks, in a first step was qualitative. Data and additional information was necessary to understand, first, the dynamics of groundwater flow. Thus, OSS has developed management tools (Database, Geographic Information System, hydrogeological model) specific to the SAI with the full participation of technical staff of countries. The results derived from them have enabled to quantify risks and identify the most vulnerable areas.

The Transboundary Diagnostic Analysis (TDA) was conducted by National Committee for Coordination and Monitoring of project activities (CNCS) of the three countries, supported by the national consultants. The CNCS implemented in each country is multidisciplinary: it includes state institutions (Ministry of Water, Environment, Agriculture, Livestock, Foreign Affairs on the transboundary legal aspects, the water agencies), Non Governmental Organizations concerned with the issue of water. CNCS activities were conducted as thoughts through their regular meetings to identify risks that threaten the IAS water resources and also examine the investigations conducted by national consultants.

This regional report has not been confined to the synthesis of national reports produced by members of the CNCS and national consultants. It was developed by the OSS team, which carried out its investigations to further enrich the document with new data. It has also integrated the results from the management tools (Database, Geographic Information System, hydrogeological model) that has developed in Tunis with the participation of countries.

The Transboundary Diagnostic Analysis of the Iullemeden Aquifer System includes the following elements:

- identification and "prioritization" of transboundary issues;
- final detailed prioritization of transboundary issues;
- analysis of environmental impacts and socio-economic consequences;
- mapping the major risks;
- the causal chain analysis.

II. GENERAL FRAMEWORK

The basin is named “Iullemeden” which identifies the name of the Tuareg. They coexist with other ethnicities Hausa, Songhai, Fulani, Arabs, Kanuri.

II.1. Brief overview of the GEF process: From the Transboundary Diagnostic Analysis (TDA) to the Strategic Action Programme (SAP)

II.1.1. The Global Environment Facility (GEF)

The Global Environment Facility[1] (GEF) is an independent financial organization which provides grants to developing countries for the implementation of projects which are of benefit to the world environment and promote sustainable existence in local communities.

GEF projects are managed by the GEF Executing Agencies, namely:

- the United Nations Environment Programme (UNEP),
- the United Nations Development Programme (UNDP), and
- the World Bank.

Seven other international organizations, called GEF Executing Agencies, contribute in the management and execution of GEF projects. These are: the African Development Bank (AfDB), the Asian Development Bank (AsDB), the European Bank for Reconstruction and Development (EBRD), the Inter-American Development Bank (IDB), the International Fund for Agricultural Development (IFAD), the United Nations Food and Agriculture Organisation (FAO) and the United Nations Industrial Development Organisation (UNIDO).

The GEF projects relate to six (6) complex and global environmental issues[2] (or focal zones), name-

1 GEF, 2004. Training Course on the TDA/SAP Approach in the GEF. International Waters Programme. Six volumes.

2. **A. Biodiversity**
1. Arid and Semi-Arid Zone Ecosystems
2. Coastal, Marine, and Freshwater Ecosystems
3. Forest Ecosystems
4. Mountain Ecosystems
13. Conservation and Sustainable Use of Biological Diversity Important to Agriculture

B. Climate Change
5. Removal of Barriers to Energy Efficiency and Energy Conservation
6. Promoting the Adoption of Renewable Energy by Removing Barriers and Reducing Implementation Costs
7. Reducing the Long-Term Costs of Low Greenhouse Gas Emitting Energy Technologies
11. Promoting Environmentally Sustainable Transport

C. International Waters
8. Waterbody-based Operational Program
9. Integrated Land and Water Multiple Focal Area Operational Program
10. Contaminant-Based Operational Program

D. Multifocal Area
12. Integrated Ecosystem Management

E. Persistent Organic Pollutants
14. Draft Operational Program on Persistent Organic Pollutants

ly: 1) Biological Diversity, 2) Climate Change, 3) International Waters, 4) Multifocal Areas, 5) Persistent Organic Pollutants, and 6) Land Degradation.

Each one of these issues is examined through Operational Programmes (OP). International Waters, which concerns, among others, the activities of the Transboundary Diagnostic Analysis (TDA), is organized around three complementary operational programmes, namely OP8, OP9 and OP10:

- OP8 Waterbody-Based Operational Programme;
- OP9 Integrated Land and Water Multiple Focal Area Operational Programme;
- OP10 Contaminant-Based Operational Programme.

The objectives of programmes OP8, OP9 and OP10 are as follows:

- the OP8 focuses on extending assistance to the countries to change the human activities which seriously threaten, or have already damaged, a water surface or its drainage basin;
- the OP9 addresses problems of a larger scope in order to obtain environmental benefit through projects that integrate a sound management of financial and water resources. It is more focused on prevention measures than on remedial measures. The OP9 may also provide general advantages in multifocal areas;
- the OP10 is focused on specific issues of the global context and seeks projects contributing in removing barriers that impede the adoption of best practices aimed at reducing the contamination of the environment of international waters.

The OP8 and OP9 require the development of a Transboundary Diagnostic Analysis (TDA) and the formulation of a Strategic Action Programme (SAP).

The formal objective of the GEF operational strategy in the International Water Focal Area **is to contribute, above all, as a catalyst, to the implementation of a more comprehensive eco-systematic approach to manage international waters as a means to achieve global environmental advantages**.

"**To act as catalyst**" means that the GEF programmes serve mainly to promote and sustain the other national and international programmes which have top responsibility over action.

II.1.2. International Waters

In order to distinguish between the GEF concept of "International Waters " and the legal definition of the United Nations law on the Seas Convention[3], the GEF operational strategy focuses on "Transboundary " water resources and emphasises the management of pollution and water resources based on a binational and multinational stakeholders' participatory process[4].

On the other hand, most of the international waters projects, financed by GEF, relate to environmental water problems which extend beyond any single country and, therefore, have a Transboundary character. The areas concerned are: marine waters, lakes, rivers, wetlands and aquifers (figure 1).

Each problem of management of international waters can justify the achievement of the desir-

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F. Land Degradation

15. Operational Program on Sustainable Land Management.

3. Under UNCLOS III, the high seas (or international waters) apply to all parts of the sea which are not included in the exclusive economic zone, of the territorial waters or inland waters of a State or of the archipelago waters of a archipelago State.

4. The stakeholders are the parties involved or affected by an environmental problem or by its solution.

able environmental objectives based on a International Waters project. One component of a International Waters project is the TDA/SAP process[5].

Three key principles are prevalent in the whole of the process:

- consultation[6] with the persons affected by the problem (they are the stakeholders);
- adaptive management[7], follow-up, adjustment and revision as work progresses;
- gradual involvement of the waters responsible of the action.

The process comprises several points at which financing may be arranged. There are three main types of financing called PDF-A, PDF-B full project fund. PDF means "Project Development Fund".

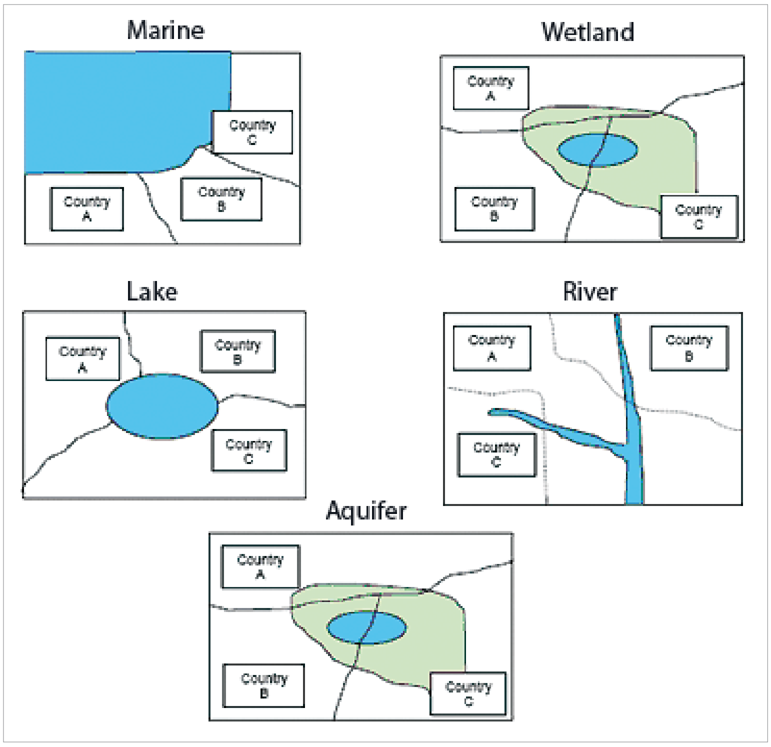


Figure 1 : Examples of Transboundary Waters

However, the **TDA/SAP** process is not a fast procedure. Rather, it **is a directive which must adapt to the cultural realities of the region**. Indeed, the development of a TDA and the formulation of a SAP would, in principle, take between 1 to 3 years. On the other hand, reversing environmental degradation in complex Transboundary marine or freshwater situations can take decades. A whole range of scientific, social, political, institutional, cross-sector and sovereignty issues may need to be addressed by the cooperating countries before they commit to undertaking the necessary reforms and investments.

The experience of developed countries shows that this may take as much as 15 to 20 years before ensuring significant commitments to joint management of the improvements. A proper time-period is necessary before the reductions in the pressure of pollution, of overexploitation activities in the field of fishing, of sedimentation, eutrophication or alteration of habitats, would result in measurable improvements of the environmental state of waterbodies. Single-handed efforts by individual countries may take between 20 and 30 years.

II.1.3. Development of the Transboundary Diagnostic Analysis (TDA)

The Transboundary Diagnostic Analysis is an objective evaluation, an analytical study of the scientific and technical facts, which serves to determine the relative importance of the sources, the causes and their impacts on Transboundary issues in matter of water. In other words, the Transboundary Diagnostic Analysis uses the best technical and scientific information, both **available**

5. UNEP. The GEF IW TDA/SAP Process: Notes on a proposed best practice approach.

6. By including a clear representation of the stakeholders at all stages, consensus building will be more likely and will increase the likelihood of ownership by the stakeholders of the result which will, therefore, have long-term viability.

7. Adaptive management is a process by which the long term environmental goals are reached in a series of pragmatic action measures. Within each measure, agreed performance indicators are controlled and an exercise of joint planning is initiated to review progress and to adjust the approaches as required, as well as to plan the next stage.

and validated, to examine the state of the environment and the underlying causes of its degradation. It must be an objective evaluation and not a negotiated document.

The analysis is conducted in a cross-sector way, while focusing on Transboundary issues, and without losing sight of national concerns and priorities. So that the analysis would be more effective and sustainable, it must include a detailed analysis of governance, which examines local, legislative and political environment.

The process of the Transboundary Diagnostic Analysis makes it possible to break down complex Transboundary situations into smaller components, which are more manageable within the framework of the actions to be conducted, such as degradation specific sub-zones or priority "hot spots".

The TDA is a scientific and technical process of study of the facts (or of diagnosis) of the state of, and threats to, international waters. Its objective is to:

- identify, quantify and prioritise the environmental problems of a Transboundary character;
- identify their immediate, major and underlying causes.

The identification of the causes comprises: the practices, sources, sites and sectors of human activity from which environmental degradation originates or represents a risk.

Wherever possible, the experts of the countries concerned would do the work but, often, international experts would also be brought on board in order to emphasise recourse to a better independent expertise available. The regional experts of the technical taskforce need to be selected by representatives of the stakeholders and consulted during the process. This is important to confer regional ownership of the process and its products.

The stages involved in the TDA development process are (figure 2) :

- preparation of the TDA;
- analysis of the impacts and consequences of each Transboundary problem;
- final prioritisation of the Transboundary problems;
- analysis of cause/ effect chains and analysis of governance;
- production and submission of the complete draft TDA;
- the TDA is adopted by the Steering Committee.

Throughout the world, Transboundary Diagnostic Analysis has very often been applied to the first four surface areas, i.e. rivers (basins), lakes, wetlands and marine water[8]. Apart from very rare exceptions (case of the Aquifer of Guarani (in Latine America), for instance), the Iullemeden Aquifer System represents the first case, at least in the African continent, to have developed a TDA/ SAP process.

Examples of application abound in the region, as attested by the "Reversal of Land and Water Degradation in the Niger River Basin" and "Reversal of Land and Water Degradation in the Chad Lake Basin". The development of the Transboundary Diagnostic Analysis of the Iullemeden Aquifer System by the countries and the consultants is sometimes influenced by the expansion of the existing documentation largely dominated by the study of natural surface resources.

The special character of the groundwater of shared aquifers is that it is not visible, unlike the water of Transboundary Rivers and lakes (figure 3). The conceptual hydro-geological model characterizes the Transboundary aquifers in terms of hierarchical local, intermediate and regional flow systems

8 http://www.iwlearn.net/ftp/iwps.pdf

Project development

- Preliminary project request
- Appointment of facilitator
- Identification of, and consultation with, stakeholder groups
- Identification of Technical Task Team (TTT)
- Preparation of a draft concept paper
- Project approved by GEF CEO

Planning the TDA/ SAP

- Appointment of Project Manager
- Form of Interministry Committees
- Form Steering Committees
- Set up of the TDA Technical Task Team
- Design work plan for the TDA/ SAP implementation phase, including budgets
- Detailed stakeholder analysis and draft public involvement plan
- Preparation of full Project brief

Development of TDA

- TDA preparation
- Identification and initial prioritisation of the transboundary problems
- Analysis of the impacts/ consequences of the Transboundary problems
- Final prioritisation of the Transboundary problems
- Causal chains Analysis and governance analysis
- Production and submission of complete draft TDA
- TDA adopted by steering committee

Formulating the SAP

- Bridging the TDA and SAP, and developing long-term EcoQOs
- Planning the remaining steps of the SAP and appointing SAP and NAP formulating teams
- Brainstorming ways to attain the EcoQOs
- Examination of and political consultation on alternative options
- Development the targets and indicators
- Agreement on the institutional framework
- Drafting the NAP and the SAP

SAP Implementation

- Adoption of SAP. Ministerial conference
- Conducting a donors' conference
- Development of the relevant interventions by GEF and/or other donors

Figure 2 : Diagramme of the whole process. The main decision boxes are highlighted in red colour

(Király, 1978; 1985; Tóth, 1962; 1963; 1966; 1978; Freeze & Witherspoon, 1966; 1967; 1968; Marsily, 1978; Ophori D., Tóth J, 1989; 1990)[9].

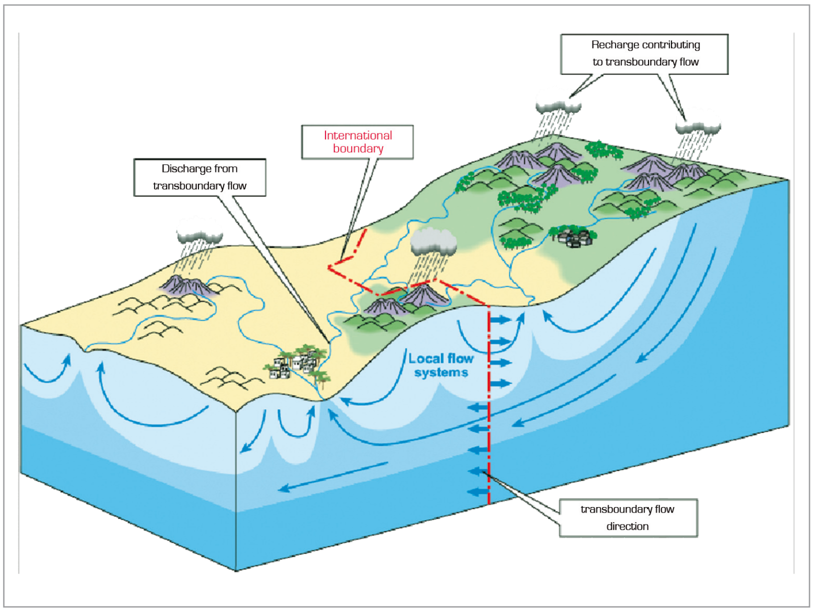


FIGURE 3 : Block diagramme between the boundary of the Transboundary water basins and the inter-State shared aquifers (State border in red colour)

Knowledge of the ground flows implies knowledge of the recharge zones, the outlets (or discharge zones) and the various flow systems. The activities conducted in certain recharge zones, on one side of the State border, may affect the quantity and quality of the groundwater on the other side of the border (Almássy and Buzás, 1999; UN/ECE, 2000).

The characterization of the groundwater flows requires information based on geology, geophysics, as well as on the whole range of hydro-geological investigations. It also requires the seasonal and long-term responses of the aquifer, the variations of and changes in direction of flow induced by human activities and, more particularly the changes in the pattern of land use in recharge areas and aquifer tapping fields.

The “visibility” of groundwater takes place through the piezometric maps (figure 4) which are developed based on reliable data on the water levels measured in the wells, the drillings (and springs) graded at absolute elevation (with respect to sea level).

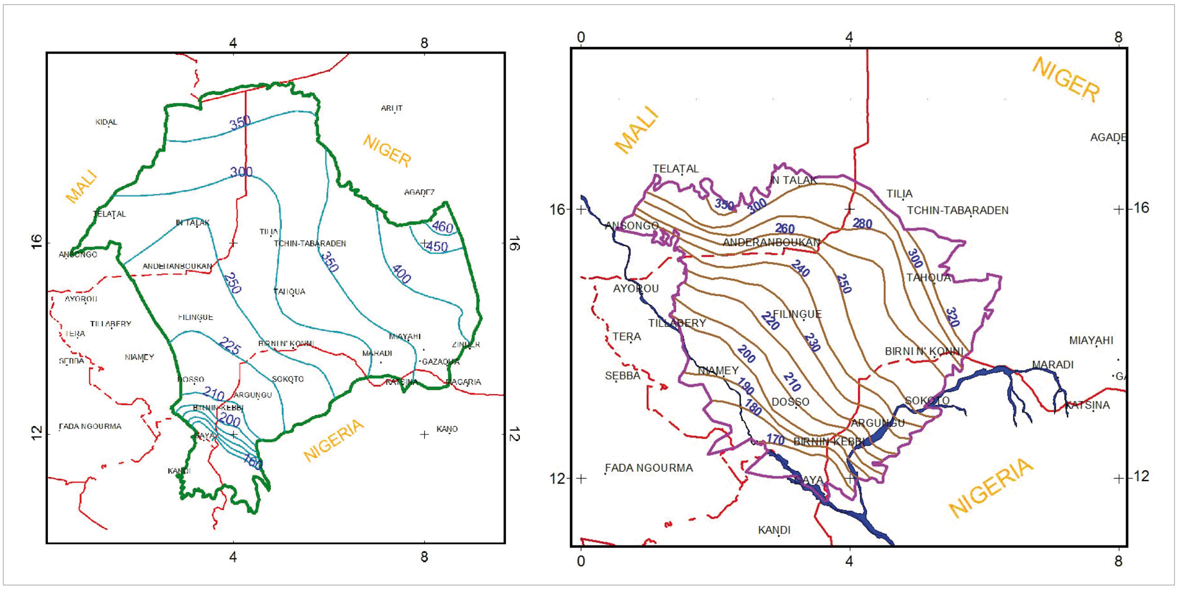


FIGURE 4 : Piezometric map of the Continental intercalaire (to the left) and of the Continental Terminal (to the right) of the Iullemeden Aquifer System (OSS, 2007).

9. Tóth J., 1963. A theoretical analysis of groundwater flow in small drainage basins. J. of Geophys. Res., vol. 16, n°11, pp4795-4811.

The first piezometric map of the Iullemeden aquifers is that of the Continental intercalaire (Greigert, 1978). It was, thereafter, complemented in the basin of Sokoto (Margat, 1982) and partly towards the East (Bonnier et al.., 1992). Precise details, considering the whole aquifer in its regional context, were subsequently elicited (Dodo, 1992).

So far, the mathematical modelling of the Iullemeden Aquifer System has made it possible to obtain the updated piezometric measurements of the Continental intercalaire (Ci) and the Continental Terminal (CT). This mathematical model is a regional model which will be used to develop local models according to the Transboundary aquifers which compose these two major hydrogeological entities.

These piezometric maps highlight a water supply of Niger River from the aquifers; this confirms sustaining of river low flow by the groundwater, as attested by the multitude of springs which line the banks. The preliminary estimates of the mathematical model developed based on active participation by the representatives of the three countries have given the following values (table 1) :

Continental terminal			
Inflows (m³/s)		Outflows (m³/s)	
Recharge	3,29	Niger River	2,50
Leakeance from Ci	0,013	Dallols	0,45
		River Rima	0,35
TOTAL	**3,30**	**TOTAL**	**3,30**
Continental intercalaire			
Inflows (m³/s)		Outflows (m³/s)	
Recharge	0,55	Niger River	1,60
Inflows from Northern boundary	0,29	Leakeance from CT	0,013
River Rima	0,77		
TOTAL	1,61	TOTAL	1,61

Table 1 : Water balance (budget) of the mathematical model of the Iullemeden Aquifer System (OSS, 2007).

Niger River receives groundwater inflows. On the other hand, Rima River supplies the Continental intercalaire (Ci) and receives the waters of the Continental Terminal (CT). This river originates in Nigeria, crosses the Republic of Niger under the name of Goulbi de Maradi, where it takes the shape of a loop of about 150 km, then flows back in Nigeria, thus converging in Niger River.

In fine, the whole analysis of the various issues must be conducted within this ground context.

III. MAIN FEATURES OF THE SYSTEM

III.1. Physical and Climatic Context of the Iullemeden Aquifer System

The Iullemeden Aquifer System (IAS) is located in the arid and semi-arid zone of West Africa. It corresponds to a portion of the water basin of Niger River, commonly known as "the Middle Niger".

The ecology of the basin is strongly determined by climatic factors, of which in particular rainfall and temperature. Rainfall in Niger basin is marked by a pronounced gradient: from less than 50 mm in the North to more than 800 mm in the South. The position of the normal annual isohyets singles out four climatic zones as follows (figure 5) :

- the Saharan zone (less than 150 mm) ;
- the nomadic Sahel zone (between 150 and 300 mm) ;
- the sedentary Sahel zone (between 300 and 600 mm) ;
- the Sahel-Sudanese zone (between 600 and 800 mm).

The nomadic Sahel zone is called the "pastoral zone". The "crop zone" is located south of the 300 mm isohyet. It covers the sedentary Sahel zone and the Sahel-Sudanese zone: This is, in fact, the zone of rainfed crops (millet, sorghum, corn, niébé, groundnut, cotton, etc.).

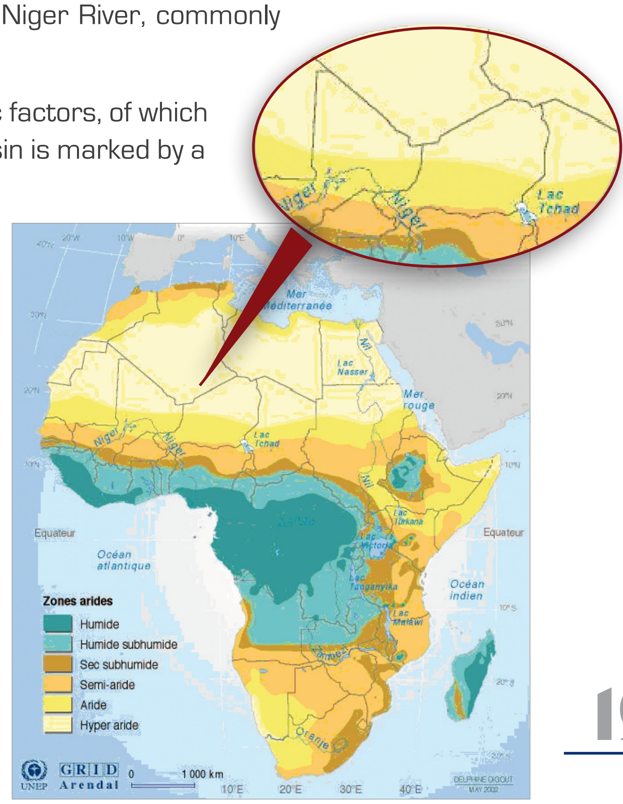


Figure 5 : The different climatic zones of Africa and of the Iullemeden Aquifer System*

* Source : World Meteorological Organisation (WMO), United Nations Environment Programme (UNEP), Climate Change 2001: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Third Evaluation Report of the Intergovernmental Panel on Climate Change (IPCC).

The analysis of the evolution of the annual rainfall total values reveals a major "shift", starting from the year 69-70 (figure 6). Thus, two (2) trends may be noted in the basin: a "Wet" period before 1970 and a "dry" period from 1970 onwards (Anonymous[10], 2003 ; Hubert and Carbonnel , 1987[11]; Hubert & al., 1989[12] ; Traoré and Abdou, 2005[13]).

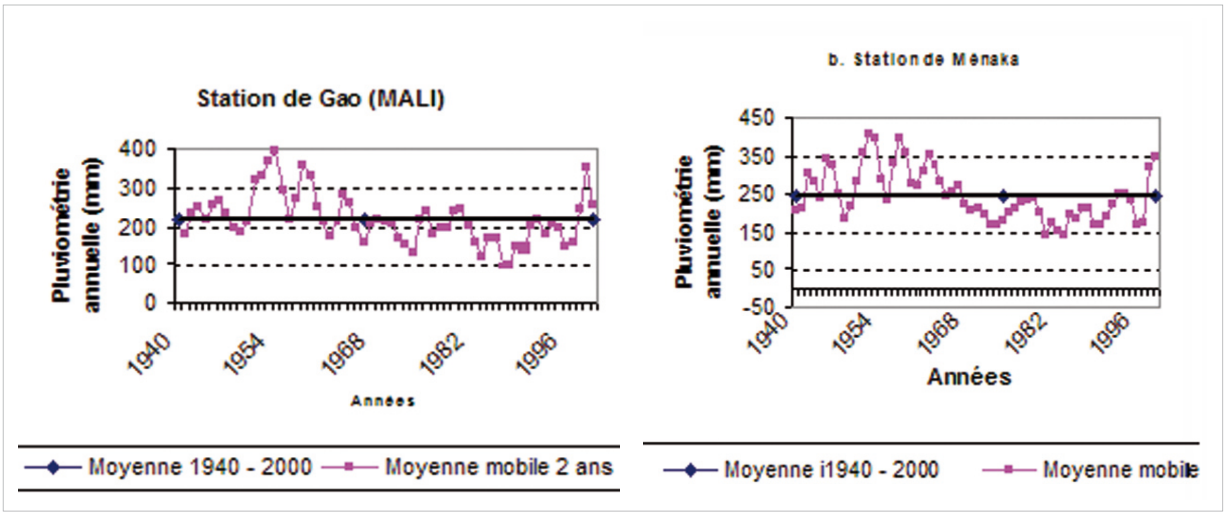
Thus, in the Sahel portion of the basin, this decrease has translated-–among other things—in a drop in the isohyets towards the South by about 100 km, which reveals signifi-

10. UICN-BRAO, GWP-WAWP, CILSS, 2003. Water, Climate Change and Desertification in West Africa: Regional Strategy of Preparedness and Adaptation.

11. Hubert P. et Carbonnel J.-P., 1987. Approche statistique de l'aridification de l'Afrique de l'Ouest. Journ. Of Hydrol.,, 95 (1987), 165-183.

12. Hubert P., Carbonnel J.-P. and Chaouche A., 1989. «Segmentation of Hydro-meteorological Series – Application to a Series of Rainfalls and Flows of West Africa". Journ. of Hydrol., 110 (1989), 349-367.

13. TRAORE Mamadou T. and ABDOU Hassane, 2005. Process of Shared Vision for the Development of the Sustainable Development Action Plan (SDAP) in the Niger Basin" – Regional Synthesis Report of the National Multisector Studies. 94 pages.



cant desert encroachment (figure 7).

Recent studies describe that in the Sahel, the last decade is characterized by a continued dry conditions in the West and a return to rainy conditions in the eastern part. The boundary between the Sahel and West Sahel Central is located at longitude 11°O, while the eastern boundary between the Eastern Sahel and the Central Sahel is located at longitude 15°E.

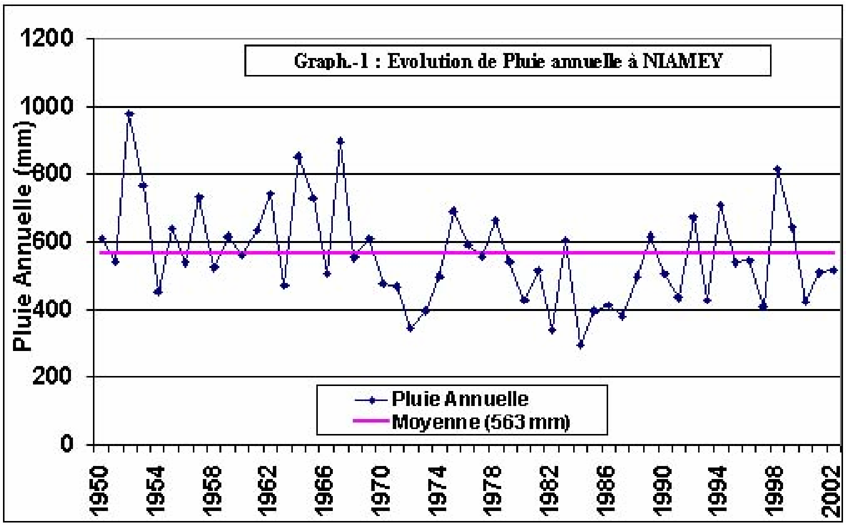
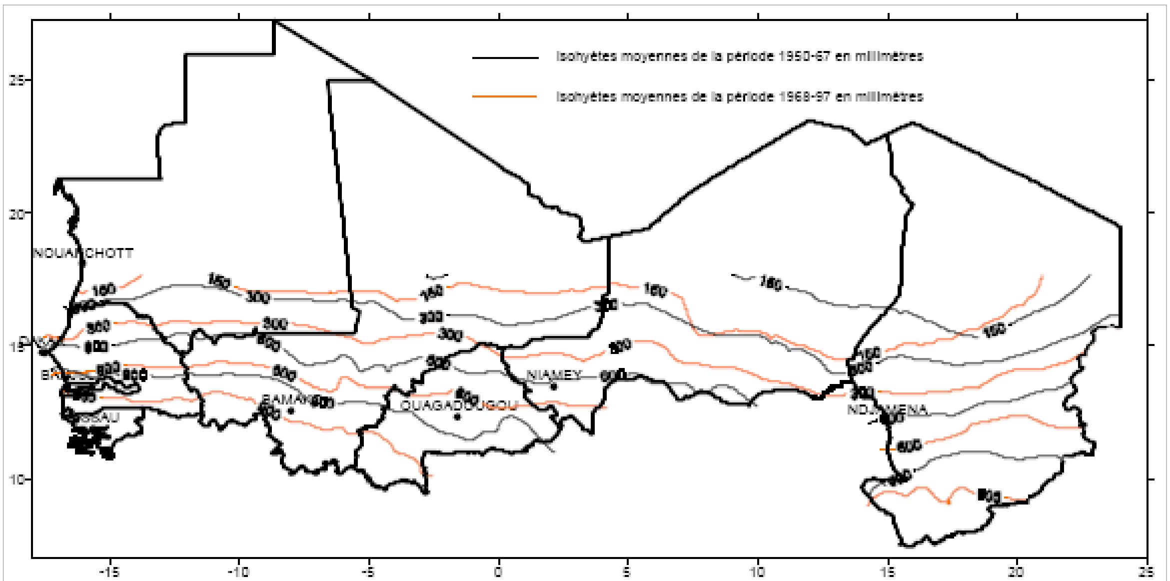


Figure 6 : Analysis of the evolution of the total annual rainfalls in Mali and in Niger.



Glissement des isohyètes entre les deux périodes avant et après 1968.

Figure 7 : Sliding of the isohyets over the two periods before and after 1968 (UICN-BRAO, GWP-WAWP, CILSS, 2003).

The indices calculated on different parts of the Sahel show a higher frequency of opposition sign indices between the Sahel and East West for the last decade (Figure 8). This difference is especially highlighted since 1993. During the 13 years (1994 – 2006), the Central Sahel has recorded very rainy three years (1994, 1999, 2003), while the western Sahel has recorded only a wet year (1999) and two years moderately moist (2003 and 2005) and the Sahel recorded seven (7) years of good rainfall. The year 1998 was very wet in the Eastern Sahel but very dry the western Sahel. Similarly, the year 2006 was rainy on the Eastern Sahel, but dry on the Western Sahel.

These figures mean that during this period, the occurrency to get the same intensity of rainfall in the Eastern and Western Sahel - as defined from the SPI (Standardized Rainfall Index) - is less than 25%. It seems therefore more appropriate to calculate three separate indices for each of these areas to better understand the concrete Sahelian rainfall.

It's relevant to mention that another interannual variability mode seems be established during the period 1994-2006 when the dry years and wet years alternate in contrast with the persistence of wet years of the period before 1970 and the dry years in the period 1970-1993.

It's relevant to note that the eastern boundary of the IAS basin is in Nigeria in the area where the rainfall conditions are improving.

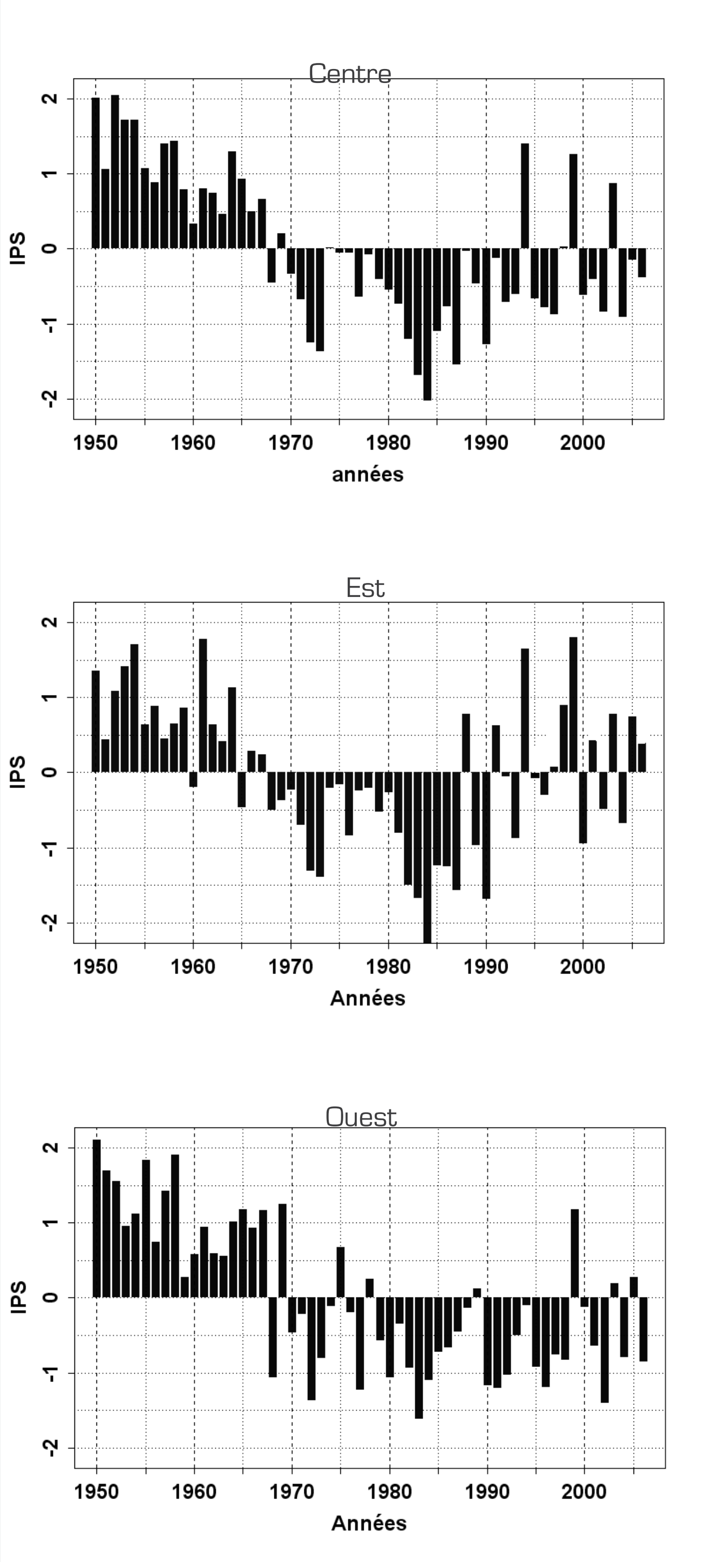


Figure 8 : rainfall indices during the period 1950-2006 for the Central, Eastern and Western areas. The boundary between the Western and Central areas is located at 11 degrees west and the boundary between the eastern and central areas is located at 15 degrees east.

Annual evaporation in the Iullemeden Aquifer System ranges, on average, between 2100 mm in the north at the base of the mounts of the shield of the Tuareg mountain range (triple point Algeria-Mali-Niger) and gradually decreases to 1800 mm to the South of the Sokoto basin in Nigeria (figure 9).

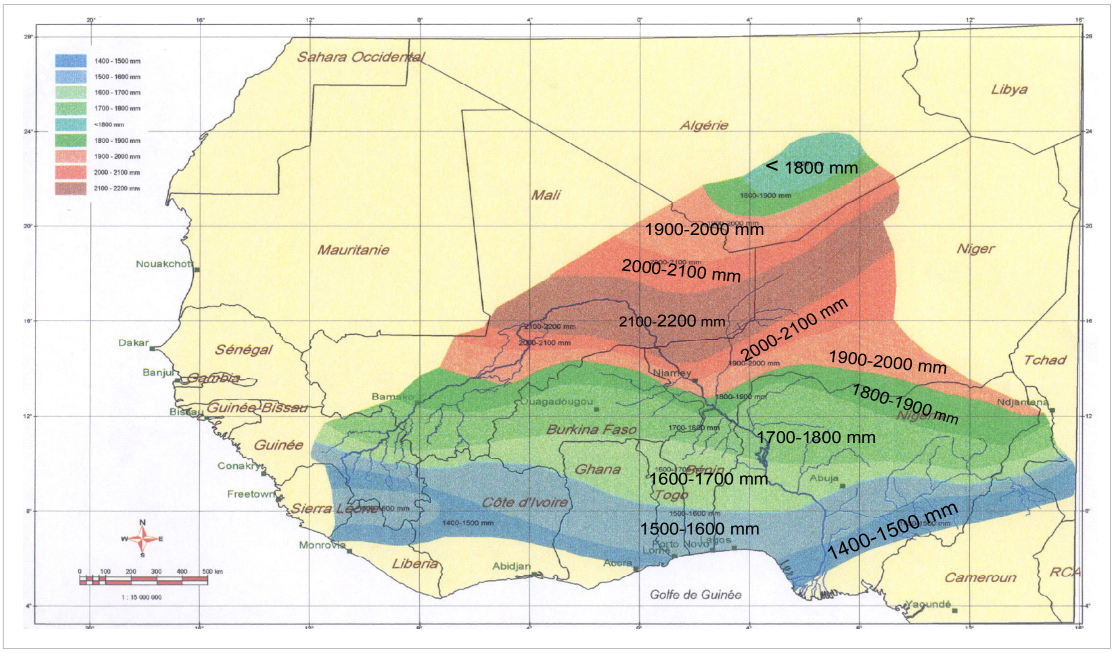


FIGURE 9 : Annual evaporation in the Niger basin (Source: ABN)

III.2. Socio-economic context

The population of the basin is primarily young, predominantly female, and with a high annual demographic growth rate of about 3%. The population is of 83.572 inhabitants in Mali, 9,5 million inhabitants in Niger (that is, 86% of the population in Niger) and about 5.746.536 inhabitants in 2001 in the basin of Sokoto in Nigeria.

The earnings of Mali, Niger and Nigeria are primarily due to a royalty-based economy (Oil, Uranium, cocoa, coffee, and cotton) and is prone to the fluctuations of the international market, or to a primary economy based on grain crop farming and traditional activities with low value added. Farming and stock-breeding generate 40 to 60% of their export earnings and occupy 80 to 90% of the active population.

According to the World Human Development Report[14], the GDP is 166 US $ (Niger), 201 US $ (Mali) and 360 US$ (Nigeria). Official Development Assistance (ODA) is of 19.5 US $ / inh. (Niger), 31.7 US $/inh. (Mali) and 1.6 US $/inh. (Nigeria), that is, 11,6 %, 15,7 % and 0,4 % of GDP, respectively (Traoré and Abdou, 2005; Diarra and Cissé, 2004[15]; Maliki and Soumana, 2004[16] ; Ude & Hanidu, 2004[17]).

The consequences of the economic imbalances and environment degradation induce rural migration which leads to settlement in sub-urban zones and adoption of an urban way of life.

Such intergovernmental organizations as UEMOA and ECOWAS attest to the will of the States to achieve a mainstreaming of development policies for purposes of a harmonious and sustainable development of the sub-region.

14. UNDP, 2002. World Human Development Report.

15. DIARRA Adama Tiémoko and CISSE Youssouf, 2004. National Multisector Study: Evaluation of Development Opportunities and Constraints in the Mali Part of the River Niger Basin. Niger Basin Authority Report. 142 pages.

16. MALIKI Barhouni and ISSA Soumana, 2004. Process of Development of a Shared Vision for Sustainable Development of the Niger Basin: National Multisector Study. Niger Basin Authority report. 213 pages and Appendices.

17. Ude M. O. and Hanidu J. A., 2004. Assessment of the opportunities and constraints to the development of the Nigeria's portion of the river Niger basin. Niger Basin Authority, 141 pages and Appendix.

III.3. Legal and legislative water resources management framework

In Mali, Niger and Nigeria, Water Legislation consists in the Act on the Water Code or the Act on Orientation of the Water Sector which lay the foundations for a new regulation of the water sector and confers legitimacy on the structures in charge of water management.

The Water Code enshrines the principle of State property over water, specifies the methods of management and protection of water resources by specifying the rights and duties of the State, local authorities, users, civil society and the private sector.

The political/legal context of the development of water resources in these countries is also marked by a strong involvement of the State in matter of acceptance and ratification of international Agreements, Conventions and Protocols related to the management of natural resources, in general, and of water, in particular. However, customary rules weaken modern law, thus often making it difficult to apply legal and legislative texts which require very wide dissemination.

III.4. Water Resources

III.4.1.Surface water

Africa is the world's continent that is most provided in surface water resources[18], with a potential estimated as 31776 billion m^3 (figure 10). Africa has 17 major rivers and over 160 major lakes, but it uses barely **4%** of its total annual quantity of renewable water resources for agriculture, industry and domestic needs (WHO, 2001).

Figure 10: Africa's surface water resources and water basins

In the zone of the Iullemeden Aquifer System, the Mali, Niger and Nigeria territories share the water basin of Niger River which is the 3rd longest river of Africa and ranks 14th internationally in terms of length (4200 km). It originates in Guinea Conakry, crosses **Mali over 1700 km** with an inner delta of 84.500 km^2, then the Republic of **Niger over 550 km**, part of Benin and Nigeria over 1314 km before flowing in the Gulf of Guinea. It covers an area of 2.170.500 km^2 of which 1.500.000 km^2 of active basin.

In Mali, at the station of Koulikoro, a reference station, the **average inter-annual flow** of Niger River is **1.350 m^3/s** (mean value for the period **1929-1970**),

18. Igor A., Shidomanov. State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational Scientific and Cultural Organisation (UNESCO, Paris), 1999: World Meteorological Organisation (WMO), International Council of Scientific Unions (ICSU), World Glacier Monitoring Service (WGMS); United States Geological Survey (USGS)

that is, **42 billion m³/year** and is about **1.039 m³/s** (mean value for the period **1971-2002**), corresponding to approximately **33 billion m³/year**, that is a decrease by 23% (figure 11).

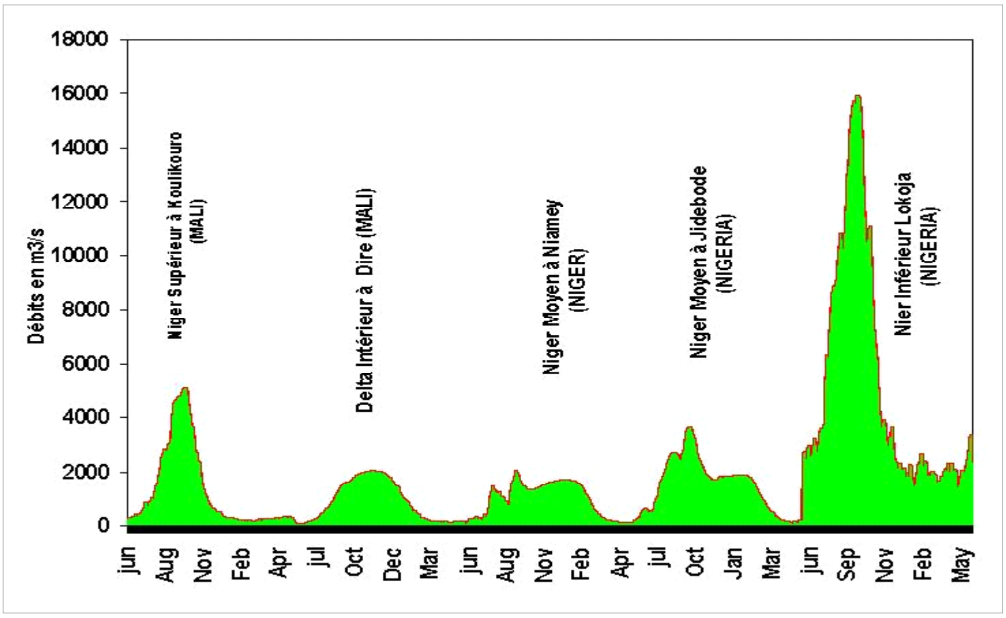


FIGURE 11 : Regime of the River in its basin areas during a water year (ABN)

In Niger territory, **the average inter-annual flow** in Niamey between **1971 and 2002** is a mere **704 m³/s**, as against **1.062 m³/s** for the period **1929-1970** that is a total reduction of about 34%.

In Nigeria, **the average inter-annual flow** of Niger River upstream of Jebba, downstream the dams of Kainji and Jebba, is of **1.454 m³/s**. After convergence with the Lokoja, it rises to **5.660 m³/s** (mean value for the period from **1915 to 2001**). The average value for the period **1929-1970** is **6.055 m³/s** against **5.066 m³/s** (**1971-2001**) that is a decrease by about 17%.

III.4.2. Groundwater

Africa ranks 2nd internationally, after Asia, in terms of its groundwater potential estimated as 5.500.000 billion cubic meters[19] (figure 12).

FIGURE 12 : Africa's groundwater potential

Mali, Niger and Nigeria are covered by the aquifer systems of the major sedimentary basins surrounded by the massifs of the shields of the pan-African loose chain (Hoggar, Aïr, Adrar des Iforas, Damagaram Mounio, Plateau de Jos) and the

19. Igor A., Shidomanov. State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational Scientific and Cultural Organisation (UNESCO, Paris), 1999: World Meteorological Organisation (WMO), International Council of Scientific Unions (ICSU), World Glacier Monitoring Service 5WGMS); United States Geological Survey (USGS).

West African craton of Man (Man ridge or ebernuan shield to the south; and the Réguibate ridge to the North) (Konaté, 1996)[20].

The Malian territory is astride the sedimentary basins of Taoudenni and of Iullemeden, the Niger and Nigerian territory is astride the Iullemeden basin and the Lake Chad basin. The sedimentary formations start with the arkosic sandstone of the Cambro-Ordovician and extend as far as the ancient and recent alluvia of the Quaternary.

On national level, the groundwater resources are estimated as **2700 billion m³ in Mali** with an **annual renewal rate** estimated as **66 billion m³**. Exploitation of groundwater is made by means of 15100 positive drillings and 9400 large diameter modern wells (DNH, 2003). **In Niger**, **renewable groundwater resources** are estimated as **2,5 billion m³** and **non renewable resources** as over **2.000 billion m³** (Anonymous, 2000). **In Nigeria**, where the insular shelf is prevalent, renewable water resources are estimated as **221 billion m³**, of which 214 for surface water and 80 billion m³ for groundwater.

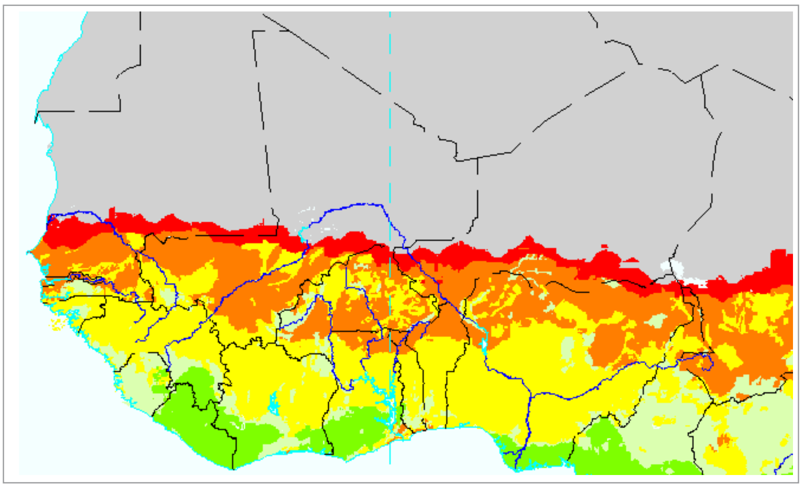


FIGURE 12 : Carte de vulnérabilité à la désertification (d'après US Department of agriculture, Washington D.C. 1998). Echelle de vulnérabilité : Vert = Faible ; Jaune = Modéré ; Orange= Elevé ; Rouge= Très élevé.

The groundwater potential of the Iullemeden Aquifer System will be evaluated based on the mathematical model (OSS, 2007[21]).

III.5. Land Degradation

According to studies conducted by FAO, out of the 3600 million hectares, 70 % of affected arid land worldwide, 10 million hectares of arable land degraded every year, 130 million hectares seriously affected, 50% are in Africa.

The continent is the most exposed because of the Sahara which represents the largest desert of the world, with an area of 10 million km2. This phenomenon of desertification affects about 480 million people throughout the world, and constitutes a threat to about one billion people. The Sahel Africa is one of the zones most vulnerable to desertification[22] (figure 13).

Deforestation for the production of firewood contributes very significantly in desertification. In developing countries, over **2 billion people** do not have access to reliable types of energy. Water is a vital source in matter of energy production, the latter being, in its turn, indispensable for economic development. While Europe uses 75 % of its potential in hydropower, Africa, where 60 % of the

20. Konaté M., 1996. Tectonic-sedimentary Evolution of the Paleozoic Basin of Kandi (Northern Benin, Southern Niger) – A Mark of the Post Orogenic Extension of the Panafrican Chain. Doct. Dissertation, Univ. Bourgogne, Lyon I, Aix-Marseille I, Toulouse III. Vol. I, II, III - in the French language

21. OSS, 2007. . Mathematical model of the Iullemeden Aquifer System. OSS, Tunis

22. US Department of agriculture, Washington D.C. 1998

population does not have access to electricity, exploits a mere 7 % of its potential[23]. This deficit is compensated by wood energy.

In the zone of the Iullemeden Aquifer System, the forestry domain[24] of Mali is estimated as 100 million ha (Diarra and Cissé, 2004), exclusive of the pastoral and desert zones. Yet, the main wood resources cover only about 32.4 million ha, i.e. less than 26% of the national area of the country. Some 118 forests, totalling about 1 million hectares, of which 20 listed forests, of a total area of 259200 ha, are amenable to sustainable development, of which 8000 ha in the Iullemeden zone[25].

For woody production, the volume of live wood is over 520 million m^3, that is, 416 million tons of live wood with productions of less than 10 m^3/ha for shrubby savannas; between 20 to 40 m^3/ha for striped bush; between 50 to 80 m^3 for woody savannas; and over 100 m^3/ha Guinean zone forest galleries.

In Mali, more than 100 000 ha of forests disappear every year. Felling for firewood and charcoal is estimated as 5 million tons per year in aggregate, which corresponds to the exploitation of 400 000 ha and is likely to reach or exceed 7 million tons in the year 2010, that is 560 000 ha. The regeneration (productivity) potential is estimated as 7 million tons per year[26]. The production of firewood and charcoal in the portion of the Iullemeden Aquifer System during the period 1984 – 1999 is estimated as 270 879 steres of wood, that is 37 095 quintals of coal.

In Niger, according to an estimate conducted during the period 1982 - 1989, the forest resources cover an area of 16 million hectares (that is, 2% of the total area of the national territory), consisting of 11.600.000 hectares of marginal forest land (a cover of less than 5%), 4.400.000 hectares of forest formations amenable to development, of which 600.000 hectares of listed forests[27]. By 1995, the forest areas (natural forests and plantations) had shrunk to a mere 2,5 million hectares[28]. In the Iullemeden basin, the inventory revealed the existence of 37 listed forests covering an area of 381.284.4 ha (that is, 79% of the total area of the country's listed forests) and 38 protected forests, totalling about 2,3 million hectares.

The Niger forests account for 87% of the population's energy needs estimated as in the range of 1,5 to 2 million tons per year, in spite of a low productivity of the Niger forests (ranging between 0,1 and 1,5 steres/ha/year)[29] due, in particular, to a high human and animal pressure, as well as to recurrent droughts. Thus, **annually, some 338'180 hectares** on average are lost to forestry areas[30].

The Federal Republic of Nigeria has significant forest reserves. In certain Northern States, the estimates amount to 840.280 hectares in Bauchi, 613.484 hectares in Kaduna and 602.631 hectares in the State of Sokoto. A forestry restoration programme has allowed the reforestation of 432.052 hectares in the State of Borno (zone of Lake Chad), 18.900 hectares in the State de Katsina and 17.150 hectares in the State de Kebbi. The production of seedlings in 1992 in the States under threat of desertification due to deforestation reported the following figures: Plateau

23. Second UN World Report on the Development of Water Resources

24. Findings of the Inventory Project of Mali Woody Resources (PIRL 1985-1991).

25. Direction Nationale de la Conservation de la Nature (DNCN), 1999

26 According to the National Directorate of Faunal, Forest and Fishery Resources (DNRFFH)

27 CNEDD, 1998 and 2004

28 National Document CSE/LCD, 2004

29 CNEDD, 1998

30. CNEDD, 2004

2.368.500, Kano 1.998.000, Borno 1.700.000 and Sokoto 1.555.875 hectares.

It is worth recalling that Nigeria has both renewable and non renewable energy resources. The non renewable resources include in particular: crude oil, natural gas, coal and lignite, nuclear fuel. The renewable resources consist of hydropower, solar energy, wind energy, firewood and biomass. Firewood accounts for over 85% of domestic energy, although Nigeria is a oil exporting country. The annual productions are about 43.3 million tons/year for wood, 144 million tons/year for animal cattle waste and crop residue, 734.2 MW for small-size hydropower, 5.25 kw/m²/day on average for solar energy and 2.0 – 4.0 (19.8 W/m² on average for wind energy[31].

In matter of, **land degradation, 0.7% of the forest potential disappears in Mali, as against 3.7% in Niger and 2.7% in Nigeria**[32].

III.6. Paradox of the African continent

Africa is the continent most provided in groundwater resources in the world (of which the Iullemeden Aquifer System); it ranks second as regards surface water (of which Niger River which represents one of the main outlets of the Iullemeden Aquifer System), next to Asia. Yet, Africa uses barely **4%** or so of this huge potential.

Accordingly, the state of access by the population to drinking water remains precarious. At present, about **65% of the rural population** and **25% of the urban population do not have access** to an adequate water distribution. The major part of the African countries, of which those of West Africa, namely Mali, Niger and Nigeria, are likely to be in a situation of water deficit by 2025. The African continent thus experiences a rather peculiar paradox, that of a water shortage in an environment which abounds in considerable water potentialities.

During a Pan-African Conference on Water held in Addis-Ababa (Ethiopia) in December 2003, the African ministers in charge of water and development planners pointed out that the lack of (financial) resources and technologies were the main obstacles to resolving the issue of water and sanitation in Africa. The meeting of Addis-Ababa had led to the development of the «African Vision 2025" which represents a reference frame for the management of water on the continent[33].

The African ministers pledged to allocate at least 5% of the national budget to water and sanitation within a five-year period. They also resolved to create a fund, the Africa Water Facility (AWF), at the African Development Bank (AfDB), with a view to mobilizing, by the year 2008, over 600 million dollars for water and sanitation related programmes.

It is in this context that the Transboundary Diagnostic Analysis (TDA) of the Iullemeden Aquifer System belongs.

31. Nigeria's Non-Conventional Energy Resources (Source : Federal Republic of Nigeria: National Assessment Report-World Summit on Sustainable Development-2002)

32. World Bank Atlas (2001)

33. Gumisai Mutume, 2004. Les vicissitudes du développement durable. Afrique Renouveau, Vol.18#2 (Juillet 2004), page 19.

IV. ELEMENTS OF THE TRANSBOUNDARY DIAGNOSTIC ANALYSIS (TDA)

IV.1. Availability of Data

The Transboundary Diagnostic Analysis (TDA) is based on the existing and available data. The hydro-geological data originate, for the most part, from the national data bases within the Ministries in charge of Water in Mali and in Niger, Nigeria being so far unequipped with a data base. These databases are supplied with data provided by the Water Directorates of the departments and regions.

These data are also available in the archives or resource centres of these Ministries; however, the data are not systematically inventoried and computerized. The data on abstractions are, for the major part, collected, managed and stored by the National Agencies and Utilities in charge of drinking water distribution to urban and sub-urban centres.

The climatological data, such as temperature, relative humidity, rainfall and evapotranspiration, belong under the authority of the National Directorates of Meteorology; these data are not accessible to the public. The data on hydrometry may be accessed from the Niger Basin Authority.

IV.2. Overview of the Mali Databases

The National Directorate of Statistics and Data Processing and the Planning and Statistics Divisions (CPS) of the government departments constitute the main sources of documentation. These are, in particular, the CPS of the Ministries in charge of Agriculture, Stock-breeding and Fishery, and the Ministries in charge of Water, Health and Education.

The data base SIGMA was designed under DOS environment and installed at the DNH in 1986 by the project UNDP/MLI/84/005 for purposes of preparing the hydro-geological synthesis of Mali and drawing up the master plan for the development of water resources. Thereafter, it was readjusted to fit under Windows environment based on the ACCESS software when updating the inventory of Modern Water Points in 2003. It thus came to bear the name SIGMA2, thus constituting the main source of information on groundwater resources. It also has information related to:

- new data relating to communal districts and the general population and housing census of 2001;
- technical and hydro-geological data on the constructed drillings (files: drillings, chemistry, pump tests, modern water points, etc). The SIGMA data base does not contain isotopic data;
- data of the inventory of updating pump operation conducted in 2003;
- climatic data on the observation stations of the National Directorate of Meteorology;
- data on rivers Niger and Senegal and their main tributaries (lists of the stations controlling the various basins and the water heights expressed in cm).

The information system (IS) for surface water, forming the subject of the hydrological data base, consists of a network of about a hundred stations controlling the two major rivers, i.e. Niger River and river Senegal, together with their various tributaries, of a data collection procedure and of a computer-based archiving and processing system resting on several software (Gestra, HYDROM, HydrAccess).

The hydrological data of this base are collected by the local observers and by the data collection equipment. Readings of water height measurements are made once or twice per day according to the stations and recorded under the form of bulletins which are passed on at the end of each month to the Water Resources Inventory Division via the Regional Directorates of Water and Energy.

This hydrological database is developed under the Access software (HydrAccess). It is not linked to SIGMA2. It comprises:

- the data on water heights from the whole network, with more or less gaps according to the stations;
- the flows related to about 50% of the stations of the network representing the standardized stations.

For the average flow of the Niger, in which the Malian part of the Iullemeden belongs, there are data related to water levels and flows, although there are gaps for the stations of Tossaye (1954–2002) and Ansongo (1950–2002); and water levels for the station of Gao for the period 1950 –2002. On the other hand, there are no data for the stations of Lelehoy and Labbezanga located downstream of the station of Ansongo.

The climatological data (temperature, relative humidity, rainfall, evapotranspiration, wind velocity and sunshine) have been provided by the National Directorate of Meteorology which has 252 rainfall measurement stations, 19 synoptic stations, 58 climatological and agro-meteorological stations that measure rainfall. Certain synoptic and agro-meteorological stations are equipped with rain recording gauges.

IV.3. Overview of the Niger Databases

In Niger, the Ministry in charge of Water has set up a data management tool called “IRH/SIGNER”. The IRH/SIGNER tool (with IRH standing for “Inventaire des Ressources Hydrauliques”/ Inventory of Water Resources, and SIGNER standing for “Système d’Information Géographique du Niger”/ Niger Geographical Information System), consists of:

- the IRH data base, the system’s centrepiece,
- the SIGNER tool allowing data processing, cartographic use and dissemination. Dedicated to operating the IRH data base, this tool can accommodate any other data which may be valorised by spatial exploitation.

This “IRH/SIGNER” tool will gradually evolve into a Water Integrated Information System (SII-EAU). In the Sustainable Development context, the SII-EAU (Water IIS) is envisaged to cover the whole information chain required for an Integrated Management of Water Resources, planning, implementation and maintenance of water structures.

The IRH data base is established at the Ministry of Hydraulics, the Environment and Combating Desertification, more precisely at the Directorate of Inventory and Management of Water Structures (DIGOH). It is run by the Division of Inventories and Rehabilitation of Water Structures (DIROH) which centralizes country-wide data and manages the water resources inventory operations on the ground.

The IRH data base owes its name to the “Inventaires des Ressources Hydrauliques (IRH)” (Water Resources Inventory service) which was created in 1972, then called “Bureau des Inventaires des

Ressources Hydrauliques (BIRH)" (Water Resources Inventory Bureau) and was attached to the Mining Service of the Ministry of Public Works, Mining and Urbanisation. In 1980, the Water Directorate became the Water Ministry and, in September 1980, the BIRH became the IRH Service.

Data capture is conducted by the Regional Water Directorates. A specially trained computer correspondent is in charge of capture, processing, storage and transmission of data. The IRH data base consists of:

- **a database management system** (DBMS): This is software capable of storage and management of a structured set of data. The IRH has used DBASE, then Visual dBase (Borland). This DBMS consists of a whole set of data files and indexes. Each data file represents a subject of interest (village, water point, chemical analysis...);
- **an interactive program allowing the input and consultation of data** (IRH-NT): This refers to the latest version of this program. It was developed under Visual dBase and uses the windows offered by Windows. It allows the capture and query of the data, as well as the generation of fields with a view to using the data by other information systems.

The IRH database is quite complete. Its structure, developed on the relational model, is rigorous. It provides for the capture and storage of data on:

- the villages and their water supply, as well as the data on population, livestock, health and educational infrastructures, etc.,
- the modern water points: drillings, cemented wells and piezometers, together with their detailed design features,
- water quality monitoring on the modern water points,
- piezometric monitoring,
- ponds, their features and their location,
- projects that conduct constructions in the field of rural water.

Thus, without being exhaustive, the IRH data base provides, by its very design, for the integration of the data necessary for a efficient management of water resources.

As for the SIGNER tool "Système d'Information Géographique du Niger"/ Niger Geographical Information System), it is in fact a Geographical Information System (GIS) initiated in 1988 by the Ministry in charge of water, with technical support by the Department of Economic and Social Affairs (DESA) of the United Nations. SIGNER is composed of a open set of data, software, hardware and methods;

The data of which SIGNER is composed come from various national sources. Among these data, one may mention the following:

- **data mapping:** These are made up of digital maps or maps digitized in course of development of the tool since 1988. The original maps come from various cartographic sources, of which the National Geographical Institute of Niger (IGNN): topographic maps, the Cartographic Service of the Ministry in charge of Mining, the Cartographic Service of the Ministry in charge of Transport, the Land Register of certain urban communities, and the Regional Centre AGRHYMET which belongs under CILSS.
- **satellite images:** SIGNER is provided with a number of satellite images obtained via its cooperation with other systems.
- **tabular or attributive data:** The IRH data base represents the centrepiece of the data exploited by SIGNER. However, according to the needs of the studies entrusted to it, SIGNER regularly uses other national data bases, as well as tabular data specific to the technical departments.

The software used by the SIGNER team may be classified into:

- **Geographical Information Systems:** These represent the geographical data (place, route, and area) under vectorial format using simple cartographic objects (point, broken line or polyline, polygon). A GIS makes it possible to relate to the cartographic objects corresponding data which are stored in tables, called attributive tables, or in a data base. The cartographic objects are clustered by type through «a layer" or topic. The superimposition of a certain number of these layers makes it possible to develop a thematic map.

  In actual practice, SIGNER operates in conjunction with IDRISI and, especially, the Atlas GIS (Strategic Mapping), though more modern GIS are currently being used: MAPINFO, ARCVIEW 3.2 and ARCGIS (ESRI).
- **Database management system (DBMS):** for the analysis and query of the data, SIGNER uses the following DBMS: Visual dBase (Borland), ACCESS (Microsoft).
- **Spatial Data Analysis software:** SURFER (Golden Software) is software which offers various algorithms of spatial interpolation of data based on spot values, via a pre-defined regular grid (meshed structure). The result of the calculations (values at the meshes nodes) may be displayed under the form of tables, maps of equal values (example: piezometry; thickness of an aquifer) or a 3D-display of spatial parameter.
- **Utilities:** these are data-processing programmes dedicated to the specific purposes of SIGNER operation, often to allow the transfer of information between the main software on offer. The utilities used by SIGNER have, for the major part, been designed thanks to UNDP/DESA assistance.

IV.4. Overview of the Nigeria Databases

The Department of Hydrology and Hydrogeology of the Federal Ministry of Water Resources in 2001 established a database and a Hydrological and hydrogeological Geographic Information System for the entire country. Thus ArcGIS 8.0 and the MS Access management system for Databases were used to create a relational database management system. In 2007, ArcGIS 9.1 Replaced the GIS software used.

Currently the database contains maps of Nigeria in various themes such as the State, the local government, 12 river basins and 8 border area of hydrological sectors and other attributes. In addition, data on the boreholes are plotted in these maps, the river gauging stations and other water infrastructure.

There are also projects on data collection that will enhance the database. These projects are in advanced stages of completion.

In addition, the department that is now moving towards a Hydrological Services Agency of Nigeria is about to embark on the management network in order to facilitate access to PCS data and information from the database. This must be done under the project called the National Hydrological Network Management Information Systems (HYDRONET).

The project "Iullemeden Aquifer System" will benefit from this database.

V. HYDRO-GEOLOGICAL FRAMEWORK OF THE IULLEMEDEN AQUIFER SYSTEM

The Iullemeden Aquifer System is bordered to the North by the Hoggar, Aïr and Adrar des Iforas mounts, which constitute the Tuareg shield, to the South by the plateau of Jos (in Nigeria) and, to the West, by Liptako-Gourma (figure 13).

The Iullemeden basin consists of sedimentary formations that range from the Cambrian-Ordovician to Tertiary and Quaternary. In this case, the Iullemeden Aquifer System is shared by Algeria, Benin, Mali, Niger and Nigeria[34]. t's represented in Algeria by the Cambrian-Ordovician formations in the Tin Séririne syncline. In Nigeria, the Iullemeden basin extends "the Sokoto Basin". In the

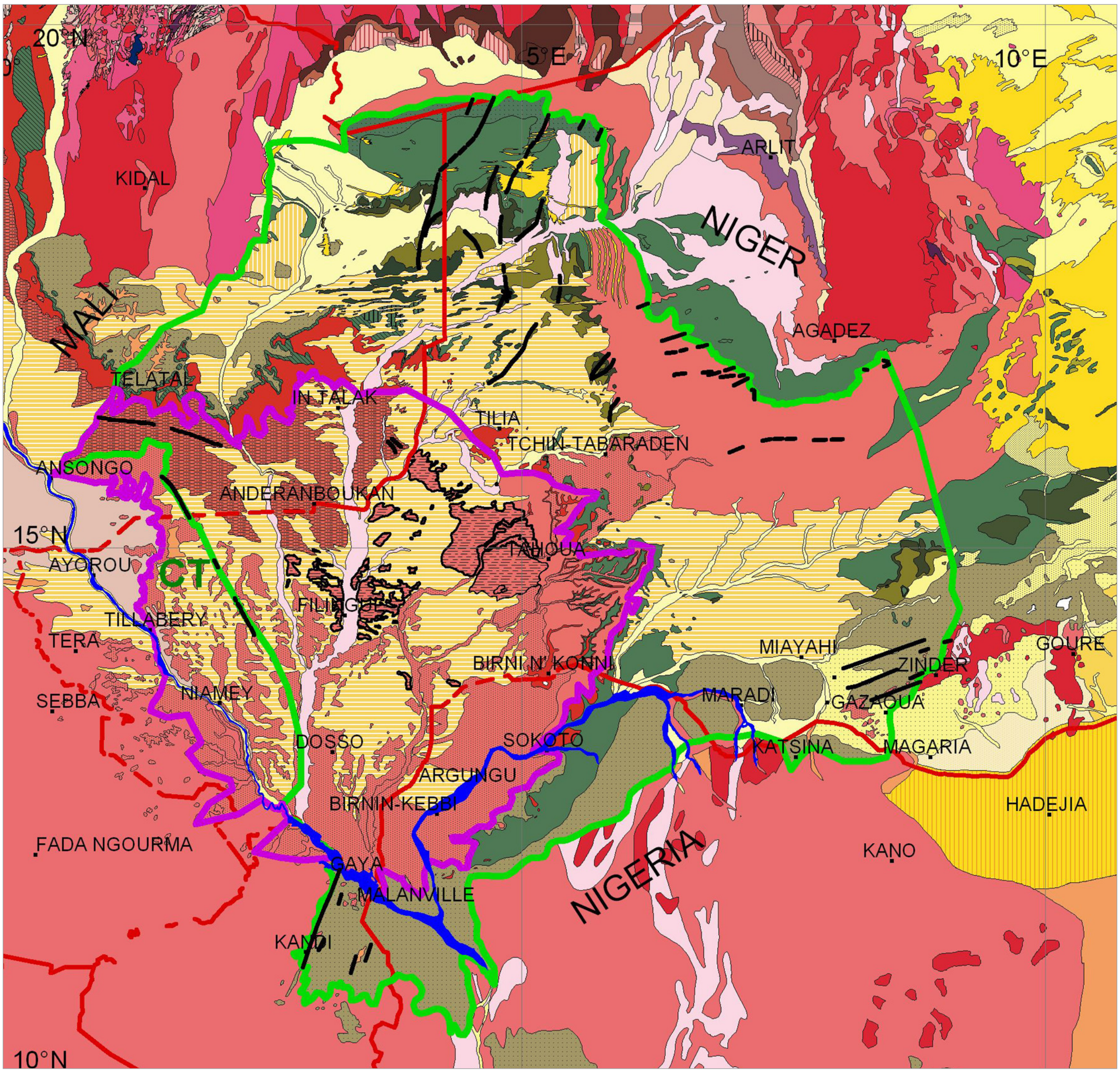


FIGURE 13 : Geological map of the Iullemeden Aquifer System

34. Dodo A., 1992. «Study of Deep Flows in the Large Sedimentary Basin of Niger: Identification of the Aquifers and Eliciting their Operation". Doctoral Dissertation (in the French language), Neuchâtel University (Switzerland), 101 pages

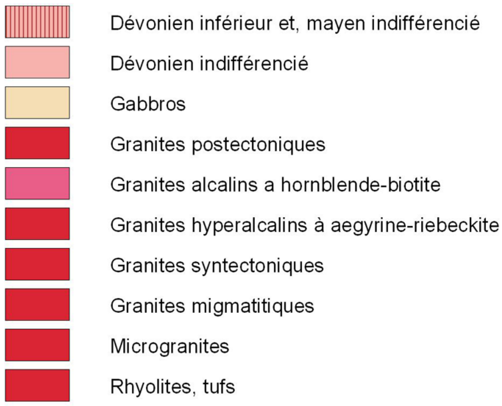
Légende pages suivantes

Geol_iullumenden.shp

Geol_iullumenden.shp

- Dunes vives
- Plage actuelle du Lac Tchad
- Dépôts actuels du Niger et des rivières non entièrement fossilisées
- Cordon dunaire littoral péritchadien
- Terrasse argileuse du bas Kadzell
- Cordon dunaire paléolittoral du Tal
- Plages perchées de Maïné-Soroa (350m) et de Sayam
- Produit de comblement des vallées du réseau hydrographique fossilisées
- Alluvions sableuses des Fayas
- Alluvions à gravier fins donnant des regs sableux
- Dépôts fluviatiles (surfaces grises du Ténéré du Tafassasset)
- Dépôts lacustres indifférenciée
- Diatomites
- Ergs aplanis par la transgression lacustre ténéréenne Plateaux sableux à cuvettes à dépôts lacustres
- Erg ancien à dunes longitudinales
- Erg ancien à dunes longitudinales ou transversales
- Erg ancien à dunes transversales
- Erg ancien à dunes non orientées
- Formations sableuses hétérogènes de piémont Grès de Mallaoua (équivalents latéraux des formations du Tchad)
- Alluvions anciennes à galets Terrasses anciennes du Ténéré du Tamesna
- Chad formation indifférenciée
- Sables plats anténéolithiques du Ténéré du Tafassasset
- Terrasses perchées a galets à oolithes ferrugineuses
- Grès argileux du Mayen-Niger
- Série argilo-sableuses à lignite
- Série sidérolithique de l'Adar Doutchi partiellement marine. Conglomérats
- Zone à Operculinoides et à Lockhartia haimei
- Upper Sandstones
- Lower Sandstones
- Sandstone
- Argiles et calcaires marins
- Série des calcaires blancs
- Zone à Nigericeras
- Zone à Neolobites vibrayeani
- Série formation Farak
- Formation d'Echkar
- Formation d'El Rhas
- Formation de Tiguedi
- Série d'izegouandane
- Série de Tagora
- Grès du Talach

Série d'izegouandane
Série de Tagora
Grès du Talach
Grès de Farazekat
Série d'Amesgueur
Schistes d'Akara
Grès de Touaret
Grès d'Idekel
Grès
Faciès Nord quartzites, schistes
Précambrien indifferencié
Basaltes (quaternaires)
Trachytes, phonolites, tufs trachytiques (tertiaires)
Dolérites post-siluriennes
Continental terminal indifférencié
Formations de Brima de Termit et de Galhama
Formations de l'Aschia Tinamou d'Agadem et de Kafra
Formation de Zoo Baba
Formation d'Alanlaro
Grès du Tegama. Formations de Dibello et d'Achegour
Continental terminal indifférencié Formations d'Agadem et de Dallé Kerri-Kerri Sandstones
Formation de Séguedine
Formation d'Arentigué
Bauxite pisolithique Continental hamadien
Grès de Nubie
Post-Tassilien
Grès de Madama
Argiles et grès, lumachelles à Gastéropodes
Argiles et grès-calcaires à Brachiopodes
Argiles, grès-calcaires, grès à plantes
Argiles et grès a Brachiopodes - Grès Spirophyton
Grès à Graptolithes
Cambrien II
Cambrien I
Cambro-Silurien
Conglomérats, arkoses, schistes
Conglomérats, grès, schistes
Dahomeyen indifférencié (migmatites, gneiss, micaschistes)
Formations d'Edoukel et d'Aauzegueur : micaschistes, chloritoschistes
Quartzites, schistes
Micaschistes, cipolins, gneiss
Suggarien indifférencié
Dévonien supérieur Viséen inférieur
Dévonien inférieur et, mayen indifférencié
Dévonien indifférencié



eastern part, the Iullemeden basin is separated to the Chad Basin by the dorsal of the Damagaram Mounio crystalline basement. This dorsal is not only geologic, but also hydrogeologic; it represents an important groundwater flow boundary limit in the same formation of the Continental intercalaire/ Continental Hamadien.

Under the current project "Managing hydrogeological Risk in the Iullemeden Aquifer System (IAS)", this system consists only of the Continental intercalaire aquifer (Cretaceous), the Continental Terminal (Tertiary), the Quaternary, and the Niger River (boundary condition with imposed Hydraulic head). In this case, the project considers Mali, Niger and Nigeria (Table 2). This table the outcome of a lithostratigraphic correlation between the three countries developed according to the lithological data from boreholes and the geological information contained in the national water resources management master plans. The Iullemeden Aquifer System covers an area of 500000 km2. It is important to remember that the wider Continental intercalaire begins with the Permian sandstone formations.

V.1. The Continental intercalaire

The Continental intercalaire aquifer is a set of the Gundumi and Illo geological formation in Nigeria. In both Mali and Niger, from bottom to up, the Continental intercalaire includes the Tegama sandstone, Farak clays and Continental hamadien. In Western part of the Iullemeden Basin, the Continental intercalaire is covered by Upper marine Cretaceous formations or those of Continental Terminal; aquifer is put in charge (Rabé 2005, Sidoro, 2005; Hanidu, 2005).

It is the largest multi-aquifer system in the Iullemeden basin. It is unconfined in its border and confined at the center and the Western part of Mali. The groundwater is converging radial to the Niger River in South-West in this area, the artesian aquifer is captive (28m above ground, 1967), and the river is draining.

The groundwater level in theunconfined part is generally quite deep, between 40 and 60 m. In Niger, in Tahoua and Dosso Department (unconfined), groundwater levels are much shallower, often less than 20 m.

It has two drainage axes: the North-South at the base of the Azaouak wadi and the North-East/ South-West and plumb the Goulbi Maradi (Niger) - Sokoto (Nigeria). The respective average values of the hydraulic gradient are 2.6 x 10^{-4} and 3.5 x 10^{-4}.

A highly transmissive sandy layer (average value = 1 x 10^{-2} m^2/s) occupies the central part of the aquifer with its counterpart in the Sokoto Basin, Nigeria (Guindumi formation). Otherwise, the values of hydrodynamic parameters are:

	Niger	Nigeria	Mali
Transmissivity (m²/s)	1×10^{-3} à 1×10^{-5}	5×10^{-5} à 9×10^{-5}	2,975 m²/h
Storage Coefficient	5% à 10% (unconfined aquifer) 0.5×10^{-3} à 5×10^{-3} (confined aquifer)	2×10^{-4} à 5×10^{-4} (confined aquifer)	5% à 8%

In Niger, the specific yield ranges from 0.1 to 26 m³/h/m. In the transmissive layer, it is an average of 13 m³/h/m with the maximum values of 7 and 26 m³/h/m m³/h/m. In confined areas, the yields are almost always higher than 50 m³/h and may exceed 100 m³/h.

The salinity varies from 0.1 m/g to 1 g/l to the River Niger. In Mali, the waters are fresh with a dry residue of not more than 722mg/l (except El Tin Bagra borehole at the north end where the global mineralization reaches 3,926 g/l. The water temperature is high in Niger where it may exceed 50°C. This parameter must not be neglected for irrigation use. The levels vary from 96% 14C PCM in the extreme north part where the aquifer is unconfined, to 1% PCM center and south part of the aquifer.

The major constraint of the economic perspective is the depth of the water point abstractions, especially in the confined aquifer: it ranges from 100 to 800m. The pumping depth is not a constraint since the groundwater level is shallow and sometimes artesian especially in the South part.

There are, however, in the Upper Cretaceous marine aquifer (secondary) in Mali and Niger.

V.2. The Continental Terminal

The Continental Terminal (CT) is a multi-layer aquifer system in Niger, but only one layer in Mali and Nigeria (Gwandu). It includes the quaternary alluvial formations.

Much of the population lives on the CT area. Due to the easy accessibility and the good water quality, this aquifer system plays a fundamental role in the sustainable management of groundwater resources of the three countries.

The Continental Terminal is contained in the tertiary continental sediments of the Iullemeden basin. These sediments occur by alternating sand and clay with many and rapid lateral and vertical changes of the facies. Thus, its lithology is complex.

In Niger, the Continental Terminal consists of three sets of aquifer formations well recognized: the Continental Terminal 1 (CT_1) or "the Siderolithic Series"; the Continental Terminal 2 (CT_2) or "the Clayey to sandy Series with lignite" and the Continental Terminal 3 (CT_3) or "Series of clayey sandstone of the Middle Niger". Currently, it agrred to consider these series as formations as follow, from bottom to top:

- the lower sandy Series (CT_1)
- the clays and greenish silts Series (CT_2)
- the ferruginous oolites formation (CT_2 or CT_3 according to the authors)
- the clayey and silty gray Formation (CT_3)
- the sandy or silty formation (CT_3).

V.2.1. The Continental Terminal 1 (CT_1)

CT1 is confined aquifer except in its peripheral part. It is slick divergent. The average value the hydraulic gradient is 4×10^{-4}. There is a sedimentological discontinuity in the western part. There is a piezometric dome elongated in a direction NW-SE, probably due to a recharge per ascensum (seepage). These patterns are oriented NE-SW and NW-SE.

The groundwater level is still shallow and artesian, except in the western Tahoua where it can exceed 35m in depth. In the Dallol Bosso and Maouri, the aquifer is artesian, where the heights of artesianism can reach 20m.

The transmissivity varies from 1×10^{-4} to 1×10^{-2} m^2/s. The specific discharge varies from 1 to 4 $m^3/h/m$.

The waters are generally fresh (0.5 g/l) except in the western part of the discontinuity (1.4 g/l). Important and High-grade of CO_2 are frequently recorded, making the water corrosive.

The exploitation of this aquifer has two drawbacks: high flow rates, and deep boreholes needed to capture the aquifer. Moreover, hydrogeological and isotopic data show that the waters are very old.

V.2.2. The Continental Terminal 2 (CT_2)

To the west of the meridian 2°30 ‘, the sands become clayey and the aquifer is then the Oolitic formation above them, composed by the ferruginous sandstone with oolites.

The aquifer is confined aquifer and radial convergent. These patterns are oriented NW-SE and NE-SW. Their respective average hydraulic gradients are 1.2×10^{-4} and 2×10^{-3}. Piezometric elongated dome is observed in the SE part of the aquifer in a direction NNE-SSW.

Piezometric levels of this semi-confined aquifer are deep: between 30 and 60m except in the Dallols where the water level is less than 10m, and the plateaus areas by which the effect of topography, it can be more than 80m. **This aquifer is never artesian**.

Transmissivity values range from 10^{-3} to 10^{-2} m^2/s, the specific discharge from 4 to 12 $m^3/h/m$.

The waters are fresh (average salinity = 0.4 g/l) except in its western part where the salinity reached 1.2 g/l. The CO_2 grades are important and require the establishment of adequate equipments (for boreholes) to prevent corrosion.

V.2.3. The Continental Terminal 3 (CT_3)

The aquifer is unconfined aquifer is radial convergent. His main Drainage axis are oriented NW-SE and NE-SW. Their respective hydraulic gradients are 2×10^{-4} to 3.2×10^{-4}. Piezometric domes and depressions characterize this aquifer.

The groundwater level ranges generally between 20m and 50m. In the lower Dallols, it is very near to the surface; many permanent ponds are linked to the groundwater table. On the plates, the level is usually beyond 60m.

Seasonal fluctuations of groundwater level have average amplitude of 65 cm. They reach 4m locally.

Transmissivity values are between 1×10^{-2} and 1×10^{-2} m^2/s, for the specific yield between 4 to 15 $m^3/h/m$. The waters are generally fresh (salinity less than 0.4 g/l). However, in the center and southwest of the aquifer, the waters are highly mineralized (1 g/l).

The exploitation of this aquifer is possible with wells. Outside Dallols areas, wells should be deep enough, until fifty meters in general. The aquifer is reached by the traditional wells, but the abstrac-

Age		Mali Group	Mali Formation	Niger Group	Niger Formation	Nigeria Group	Nigeria Formation
Quaternary		Quaternary	Alluvial, dunes **Aquifer**	Quaternary	Alluvial, dunes **Aquifer**	Quaternary	Alluvium **Aquifer**
Tertiary	**Pliocene**	Continental Terminal	Sandy and clayey sandstone **Aquifer**	Continental Terminal CT_3 **Aquifer**	Series of clayey sandstone of the Middle Niger	Continental Terminal	Gwandu **Aquifer**
	Miocene			Continental Terminal CT_2 **Aquifer**	Lignite-dominated clayey-sandy series		
	Oligocene			Continental Terminal CT_1 **Aquifer**	Siderolithic series		
	Eocene	Middle Eocene	Schists				
	Palaeocene	Terminal Palaeocene	Limestone and marly – sandy with phosphated level	Marine Palaeocene	Limestone, payra-ced schists	Sokoto	Kalambaina **Aquitard**
		Lower Palaeocene	Limestone and sand **Aquifer**				Dange
Cretaceous	**Upper Cretaceous**	Senomanian – Maestrichtian	Sandstone - Clayey **Aquifer**	Turonian – Senonian (2-3 couches)	Marine Cretaceous (While limestone)	Rima (Mæstrichtian)	Wurno **Aquitard**
							Dukamaje
							Taloka **Aquitard**
	Lower Cretaceous	Continental intercalaire	Quartzitic sandstone, micro-conglomeratic, arkoses, sand, Tégama clays **Aquifer**	Continental intercalaire **Aquifer**	Continental Hamadian	Continental interca-laire / Continental Hamadian	Gundumi & Illo **Aquifer**
					Clays of the Farak		
					Tégama sandstone		

Table 2: Litho-stratigraphic correlation between Mali, Niger and Nigeria, in the Iullemeden Aquifer System

tion is not especially easy, either by the traditional system or by hand pump. However, the aquifer is sensitive to pollution. Particular attention should be paid to the ancillary facilities of wells (curbs, anti-quagmire, and anti-slough, drinkers) to maintain water quality.

A comparative table of the formations identified in the countries has been prepared based on data and information collected by national consultants, OSS investigations and national committees for coordinating and monitoring of project activities (Table 2). This table has achieved lithostratigraphic correlations between countries and presents the composition of the two main aquifers of the basin.

VI. IDENTIFICATION AND "PRIORITISATION" OF TRANSBORDARY ISSUES

The National Committees carried out the Transboundary Diagnostic Analysis (TDA) for Coordination and Monitoring of Project Activities (CNCS), as well as by national consultations, based on the information and data existing and available. The CNCS, which is set up in each of the countries, is multidisciplinary; comprises both governmental institutions (Ministries of Water, the Environment, Agriculture, Stockbreeding, Foreign Affairs (with regard to Transboundary legal aspects), and Water Utilities), and non governmental organizations with an interest in Water issues.

The activities of the CNCS were carried out under the form of discussion sessions in their periodic meetings intended to identify the risks to the SAI water resources, as well as to examine the investigations carried out by the national consultants. Besides, national workshops dedicated to the Transboundary Diagnostic Analysis (TDA) were organized **to validate these Transboundary risks**. Thus, **14 risks** were identified **in Mali**, **8 in Niger** and **24 in Nigeria** (Table of the risks identified by the national consultants and committees).

The reports on the proceedings of these meetings have highlighted the richness of the data available in the fields of surface water, groundwater, geology and climatology. These reports are also informative about the existence of a national database, studies and projects conducted, and aquifer models developed, which are likely to be of relevance to the SAI.

The Transboundary risks which represent a threat to water resources, as analysed by the CNCS and national consultant, and in view of the investigations conducted by the OSS team, are summarised hereunder.

VI.1. Impact of Climate Variability and Change

It has been noted that, for the whole zone, there was a wet period extending from the beginning of the 20th century up to the year 1967 and that there has been a dry period running from 1968 to date. The rainfall deficit has translated into a decrease in rainfall by about 20% to 50%, inducing, on the one hand, a shift of the isohyets by about 200 km towards the south and, on the other hand, a decrease in the flows of Niger River ranging from 20% (Mali) to 36% (Niger), as well as a decrease in aquifer recharge by the hydrographic network and useful rain.

This shift has resulted in accelerated degradation of farmland, as well as the migration of the population to, and concentration in, the wetlands in the South, thus exacerbating the deforestation phenomenon.

VI.2. Deforestation

Wood cutting for energy production is a job- and income-generating activity. It produces 270 879 steres (that is, 37 095 quintals of charcoal) in Mali, and 827 442 tons of wood in Niger. Estimates for Nigeria are not available. This wood and charcoal production induces, on annual average, **a land loss of 100 000 ha in Mali, and of 338 180 ha in Niger**.

Land loss exacerbates wind and water erosion which contributes in the sanding up of the water network (Niger River, ponds). Sanding up tends to reduce aquifer recharge by useful rain, as well as affects the recharge of the water network by blocking off the recharge areas. Moreover, silting of the riverbeds does induce, by occupying the place of flow water in the Niger riverbed, frequent floods for normal flows.

VI.3. Exploitation of Water Resources

Table 3 presents the abstractions from water resources to meet water needs concerning all tapping structures.

	Niger	Nigeria	Mali
Drinking water supply (million m^3/year)	1,3 (mainly River water)	117,6 (of which 14.3 River water for Niamey)	15,4 (1990) 32,3 (2020)
Stock-breeding (million m^3/year)	84	119,77	271,36
Industries, Mines (million m^3/year)	-	9,9	-

Table 3 : Water consumption as per socio-economic sector

In spite of the irrigable land potential (390 000 ha in Mali, 226 600 ha in Niger and 42 272 ha in Nigeria) and of the land irrigated (26 030 ha in Mali, 13 500 ha in Niger and 27 230 ha in Nigeria) by River water and/or drillings or wells, there are no estimates available on the abstracted volumes. Yet, this activity is one of the largest water-consuming activities.

VI.4. Decline of Artesianism

This phenomenon has been reported on artesian drillings tapping the Continental intercalaire in Mali and Niger, and/or the Continental Terminal in Niger. These flowing drillings had remained open since their date of construction, thus sometimes creating ponds in their immediate vicinity. The flows have decreased since then, but they are not monitored to appreciate the decrease of artesianism and to seek to identify the causes (natural decrease or sign of overexploitation?).

VI.5. Water Pollution

A significant part of the pollutants disposed of in the wild (agricultural waste) ends up in Niger River, either directly or by runoff. Irrigated crops are practised especially based on water from the Niger which feeds the aquifer in period of high waters. This income-generating activity uses chemical fertilisers and pesticides. These amount, on annual average (between 2000 and 2002), to 10 000 tons of fertilisers (Urea, NPK 15-15-15, Super triple, phosphates of Tahoua, DAP) in Niger.

In Mali, 200 tons of fertilisers, on average, end up every year in the Niger River or in the aquifers around Bamako. In 1994, some 5 939 tons of urea and 4 055 tons of ammonia phosphate were applied to the **47000 ha** of irrigated land.

In Nigeria, over 15 million people and as many head of cattle live in the Sokoto basin based on exploiting the aquifers by traditional wells that are not provided with a protection zone. High nitrate contents, with respect to normal, are frequently recorded in these exploitation structures.

VI.6. Soil Salinisation

Soil degradation, by salinisation and alkalisation in Mali, affects 7 to 15% of developed land which are in process of being abandoned. In Niger, the zones irrigated in the valleys along the River, in the Dallols and in the vicinity of ponds, are affected by salinisation due to improper drainage of wastewater, as well as by the phenomenon of evaporation.

VI.7. Non Concerted Exploitation of Water Resources

In spite of the existing sub-regional structures, such as the ABN (Niger Basin Authority), ECOWAS (GIRE), CILSS (Permanent Inter-State Committee for Drought Control in the Sahel), the ALG (Liptako-Gourma Authority), **there is no organization ensuring a monitoring of the exploitation of groundwater resources**. Only ABN is provided with a surface water monitoring network with has scientific tools to estimate in real time the flows of the River at a given station, but not the abstractions made from the River. On the other hand, aquifer monitoring networks remain each country's self-imposed duty. These networks are not adapted for aquifer monitoring and evaluation, but were intended from the start to meet the water demand of the population.

Conclusion

Real risks are threatening, both in quality and in quantity, the groundwater (as well as the surface water) resources. However, these risks have been identified based on the database and the information derived from the documentation available. Their assessment (Table 4) remains more of a qualitative nature, even though major studies have been conducted in the zone.

Catégorie de risques	Mali	Niger	Nigeria	Valeur moyenne
Changements climatiques : inondations, sécheresses	H	H	H	H
Déforestation	H	H	H	H
Exploitation des ressources en eau	L	L	L	L
Déclin de l'artésianisme non maîtrisé	F	H	H	H
Pollution des eaux	H	H	H	H
Salinisation des sols	F	F	L	F
Réseau de suivi des aquifères inadéquat	H	F	H	H
Exploitation non concertée des ressources en eau	H	H	H	H

H = High F = Fair L = Low

Table 4 : Qualitative assessment of the risks to the SAI aquifers.

To appreciate the Transboundary likelihood of these risks, as well as the extent of their relevance, the need for their quantification has led to the formulation of a recommendation, the first of a set of five recommendations issuing from the meeting of the Project Steering Committee held in Abuja on February 25 and 26, 2006. The recommendation goes as follows: «**to refine the Transboundary Diagnostic Analysis (TDA)** on the level of the States of the SAI based **on a quantitative evaluation of the relevant risks**".

In this particular case, the list of the risks identified by each of the countries has been revisited. This task forms the subject of the section on detailed prioritisation of the risks

Mali	
	1. Inadequate knowledge about the aquifers and their relation with surface water 2. Discrepancies in basic understanding and perceptions of the SAI in the different countries 3. Impact of water development schemes on the shared water resources 4. Mismatch between the use of groundwater and of surface water 5. Management of water related issues on the wrong scale: issues related to the basin as a whole addressed on local and sub-basin level and vice versa 6. Abusive, non planned exploitation and non concerted management of shared aquifers 7. Non planned and non sustainable exploitation of very ancient waters 8. Exploitation and utilisation of unfit and/ or poor quality groundwater 9. Impact of land use on groundwater resources 10. Impact of polluting use of land and water in recharge zones 11. Irreversible contamination with pollutants from deep drillings in mining and oil exploitation zones 12. Impact of deforestation 13. Impact of climate change on aquifers 14. Uneven space distribution of water resources

Niger	
	1. Modification of the characteristics of underground flow 2. Modification of the piezometric area of an aquifer 3. Degradation of water quality 4. Degradation of biodiversity in Transboundary aquifer discharge zones 5. Impacts of climate change on Transboundary aquifers with a low recharge rate 6. Impediments to the socio-economic development of certain countries sharing the SAI through degradation of the natural resources (water, soil, air...) 7. Conflicts and disputes related to water 8. Disruption of the physical integrity of the groundwater resource (Aquifer)

TABLE 5 : Risks identified by the countries in national committees or national-level workshops.

Nigeria	
Nigeria	1. Groundwater contamination and pollution 2. Land Degradation, Agricultural land degradation and post harvest losses 3. Loss of strategic water resources 4. Uncontrolled Artesian flows 5. Inadequate monitoring networks 6. Absence of single authority in charge of the overall management of the IAS 7. Increasing population growth leading to increasing demand on the aquifer 8. Movement of people to and fro in the region 9. Lack of control and monitoring of the various aquifers within the basin 10. Network systems of monitoring of the various aquifers 11. Exchange of information among aquifer users 12. Sensitization of people of the area on what their role should be 13. Critically, examine the issue of climate change with respect to aquifer recharge in the Iullemeden basin 14. Look at the existing institutions on ground, their functionality and what need to be done to make them effective in the discharge of their respective mandates 15. Examine the consultation mechanisms in place among the relevant institutions within the country 16. Examine the groundwater flow pattern in the basin with respect to pollution detection and control measures 17. Creation of awareness of the development in groundwater exploitation among the concerned countries of IAS with respect to sustainability of the resources 18. Examine the type of relationship that exist between surface and groundwater in the Iullemeden basin 19. Examine the issue of population increase and the subsequent pressure on groundwater exploitation within the basin 20. Need to modernize data collection methods in the country and recommended the use of satellite technology, automatic pressure loggers in monitoring wells etc., but expressed concern on funding to undertake field baseline data collection and the security of data collection equipment 21. The need to focus on the issue of capacity building so that whatever investment made on water resources development does not lay waste due to management problems 22. The NBA, by its mandate and treaty setting it up does not cover groundwater and that it would be difficult to amend the treaty to cover the IAS but rather that a separate institution in the like of the NBA be set up to handle the basin 23. The hydrogeological section of the Nigerian portion of the Iullemeden Aquifer System should be correlated with that of the Niger Republic 24. Afforestation programmes be effected in the basin to improve recharge and soil conservation

Table 5 (continued) : Risks identified by the countries in national committees or national-level workshops.

VII. FINAL DETAILED PRIORITISATION OF TRANS-BOUNDARY ISSUES

An analysis of the list of the risks identified by the countries (14 risks identified in Mali, 8 in Niger and 24 in Nigeria) (Table 5) is necessary in order to ascertain the following aspects in particular:

- the transboundary nature of the identified risk;
- the scope of the risk with respect to national priorities and regional and international conventions, as well as the various global initiatives;
  - the impacts of the risk on economy, the environment and human health;
  - the benefits expected upon examination of the risk.

This analysis has thus revealed, among others, that certain risks are causes or consequences and/or impacts. Other Transboundary risks related, above all, to the natural surface resources: loss of biological diversity, for instance. This detailed prioritisation of the Transboundary risks has been conducted jointly with the countries and the OSS project team.

Such is the case, for instance, of the decline of artesianism or the decrease in the piezometric level of the aquifers, both of which are consequences of the combined effects of water abstractions made and the impact of climate variability and change. The phenomenon of deforestation belongs in the causes of the climate change contributing in global warming. Aquifer pollution is a major risk. The exploitation of water resources is a cause of water reduction. The non-concerted exploitation of the common resource belongs in water governance, which is related to the legal and institutional systems of each country.

Other Transboundary risks relate especially to natural surface resources. There is the case of the loss of biological diversity. In the context of the study of groundwater resources, the loss of biological diversity may be considered as the consequence of several factors:

1. degradation of the medium due to human activities (deforestation, for example),
2. impact of climate change (recurring droughts),
3. generalized decrease of the level of the aquifers, inducing an increase in the non saturated area, then the drying up of the areas of the plant roots, leading thus to aridity and then to desertification.

In view of this second analysis, the Transboundary risks which may be regarded as major concerns common to the three countries and for which the efforts of a single country could not possibly find a correcting and lasting solution, are of three types:

- **Change in water availability:** this relates to a change in groundwater potential in terms of:
- either an increase due to a recharge of the aquifers or other inflows,
- or else a reduction or scarcity of the resource. This reduction may be due to the combined effects of gradual abstractions and of a reduction of the recharge of the aquifers because of:
  - a decrease in rainfall,
  - sanding up of the water infiltration areas,
  - silting of the hydrographic network of Niger River which, in certain locations, feeds the

aquifers in period of high waters and where its low water level is sustained by the groundwater;

- **degradation of water quality:** this is equated with aquifer pollution due to the disposal of a wastewater not meeting quality standards, and of the rise of abnormally mineralised groundwater (fluorides);
- **climate variability and/ or change:** this major concern, often defined as «climate change/ variability», has the characteristic of being at the same time the cause and the consequence of certain situations.

In view of the above, the countries and the national experts, assisted by the OSS team, have undertaken an in-depth consideration of these three major concerns through national workshops. This consideration has led to the identification, for each of the three major risks, of its environmental impacts and its socio-economic consequences, as well as the identification and analysis of its causes of which water governance was analysed.

As regards the first Transboundary risk, the change of water availability is equated with t**he reduction of the water resource**. Indeed, the results of the mathematical modelling of the Iullemeden Aquifer System have highlighted the overexploitation limit exceeded in 1995 (Figure 15), a year as from which the abstractions (152 million m^3/year) exceeded the recharge (red line) estimated as 150 million m^3/year in 1970.

These are estimates based on the data provided by the countries. These data on abstractions are those resulting from the exploitation flows of the water point (drilling, well) at the date of its construction, and this, for a four (4) hour duration of exploitation per day. These estimates remain to be corroborated by an exhaustive inventory of the real abstractions made from all the exploitation structures.

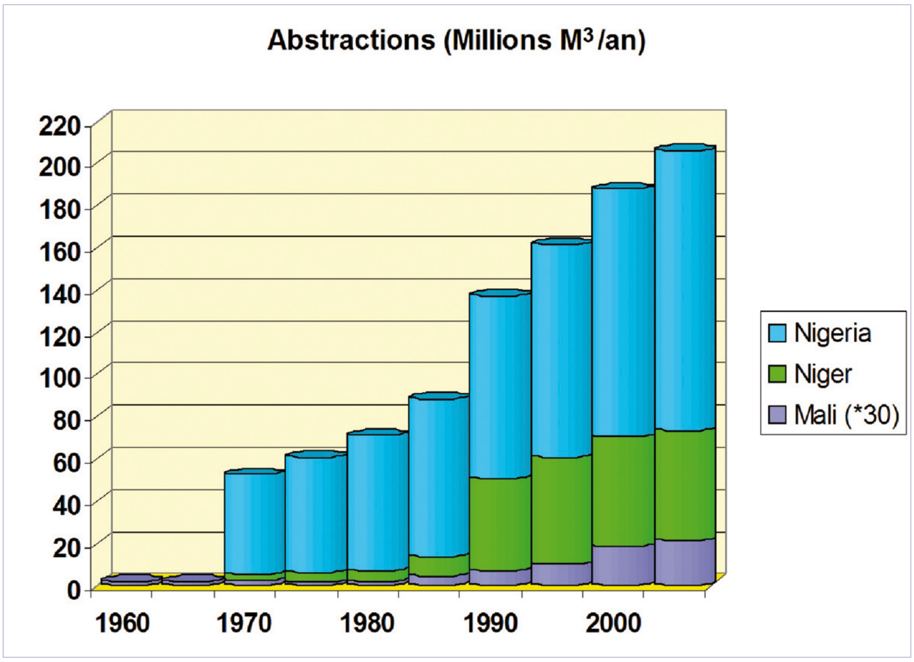


Figure 14 : The overexploitation limit was exceeded in 1995 according to the preliminary estimates. The annual abstractions, estimated as 152 million m^3, would now be in excess of the recharge which is of 150 million m^3 par year.

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VIII. ANALYSIS OF ENVIRONMENTAL IMPACTS AND SO-CIOECONOMIC CONSEQUENCES

The analyses of the environmental impacts, as well as of the social and economic consequences, of each risk have been conducted from a qualitative point of view by the National Coordination and Monitoring Committees (CNCS) and by the national experts. The need for field investigation to collect quantifiable data, as well as their monitoring over time and in space, was expressed by the countries.

This attests to the pioneer nature of the Transboundary Diagnostic Analysis (TDA) applied to the water resources of the aquifers shared by the countries. Indeed, in the majority of cases, the objective and quantifiable information collected refers to Transboundary surface water.

The objective of the Transboundary Diagnostic Analysis (TDA) is not to duplicate these studies of assessment of environmental impact and socio-economic consequences, but to select those which appear relevant and adaptable to the problems of the shared groundwater resource with a view to apprehending the threats pertaining in each risk for the ecosystem and for changes in the well-being of people.

VIII.1. Analysis of environmental impacts

The environmental impacts may be defined as the effects of a Transboundary risk on the integrity of an ecosystem. Their analysis is based on three indicators, namely the indicators of status, impact and pressure in line with those developed by the model of OECD (Organisation for Economic Cooperation and Development) which has been using, since 1989, a set of indicators based on a dynamic methodological approach of the phenomena (indicator of state, pressure, and response) , (IAURIF, 2005):

- **the status indicators (or state)** describe the environmental situation and specify the ecological, physical and socio-economic situation of a medium at a given time, as well as the changes in state over time;
- **the impact indicators** describe and quantify the impacts of each Transboundary risk.
- **the pressure indicators** account for the pressure exerted by human activities on the environment and the natural processes which cause changes on the medium. They support the causal chain developed in order to resolve priority Transboundary problems.

The quantification of the impact of the risks requires additional investigations and research work, especially of the field type. Based on the information available, the use of these indicators will be, as far as possible, of a more qualitative nature.

VIII.1.1. Analysis of the environmental impacts of the Change in availability of groundwater

▸▸▸ **Status indicators.** The change in the availability of groundwater, seen from the point of view of the reduction in the water potential, may affect the environment under several forms described hereunder.

- **Increase in the thickness of the unsaturated area of the non confined aquifers**: The reduction of groundwater induces a decrease of piezometric levels (up to 7 metres in Niger), generating an increase in the thickness of the unsaturated area of the aquifers. The latter is made up of three phases: the liquid phase (water), the solid phase (the rock), and the gas phase (air at atmospheric pressure). The increase in its thickness tends to reduce the liquid phase and to increase the temperature. This contributes in drying up the plant roots and, hence, to desertification of the zone concerned, as well as to the degradation of the soil.

In certain cases, the increase in the thickness of the unsaturated area significantly reduces the recharge of the aquifers by rain and by river runoff water.

- **Costly investments**: The search for alternatives leads to a recourse to groundwater that is reachable at great depths, sometimes being quite mineralised and presenting a high temperature. This increases the technical and technological difficulties of access to the resource, as well as the more and more exorbitant costs of their exploitation (recurrent flushing of existing drillings, construction of new drillings).
- **Decrease in land productivity**: In crop zones irrigated by groundwater, the decrease in groundwater induces a shrinkage of irrigated land and, hence, a decrease in productivity.

▶▶▶ **IMPACT INDICATORS.** The displacement of the population abandoning the drying up water points (drillings, wells) or dried resources (springs) due to a gradual decrease of groundwater exacerbates the demographic pressure on the more productive structures and multiplies the number of persons having no access to drinking water in sufficient quantity and acceptable quality (Table 6).

Country	MDG Population having access to quality sanitation equipment (%)		MDG Population having facilitated access to a quality water source (%)	
	1990	2002	1990	2002
Norway	..	..	100	100
USA	100	100	100	100
Germany	..	..	100	100
Brazil	70	75	83	89
India	12	30	68	86
Nigeria	39	38	49	60
Mali	36	45	34	48
Niger	7	12	40	46

TABLE 6 : Water, sanitary conditions (UNDP Report, 2005).

▶▶▶ **PRESSURE INDICATORS.** The change in availability of water resources can affect human activities and the environment with regard to the following aspects:

Increase in the number of people having no access to drinking water: The increase in groundwater tapping heights contributes in the abandonment of dried up water points (drying up wells, dried springs) for those of high productivity, wetlands or any other place where access to water is relatively easy. This displacement may also involve rural migration to city outskirts that are serviced by the drinking water supply network.

Increasingly exorbitant exploitation cost: The tapping of aquifers at increasingly excessive depths induces high costs for the construction of deep drillings and maintenance of the structures.

Overgrazing: This situation is frequent, especially during droughts when recharge is low and the water levels in the water points are increasingly deeper. This situation gives rise, among others, to conflicts among the various users (stock-breeders, farmers, etc.).

VIII.1.2. Analysis of the environmental impacts of the Degradation of groundwater quality

▸▸▸ STATUS INDICATORS. **Deterioration of human health:** The deterioration of the quality of consumed groundwater leads to a recourse to surface water, particularly to ponds in certain places. This type of water exposes the population to water-related diseases. These include diseases contracted by ingestion (dracunculosis, cholera, diarrhoeas) or by contact (schistosomiasis) or, still, diseases for which water is the host medium of parasite larvae (malaria, river blindness, etc.).

Soil degradation: The degradation of the quality of the groundwater used for irrigated agriculture induces a decrease in fertility and contributes in soil salinisation.

▸▸▸ IMPACT INDICATORS. Water-related diseases are estimated as over 80% of all pathology (Diarra and Cissé, 2004).

▸▸▸ PRESSURE INDICATORS. **High cost of exploitation:** The farming practised based on the use of groundwater (unfit for crop growing), leads to an increasing use of **chemical products** (fertilisers, pesticides, fungicides, herbicides, insecticides) and **natural products** (excreta, manure, etc.).

VIII.1.3. Analysis of the environmental impacts of Climate variability/ change

▸▸▸ STATUS INDICATORS. **Decrease in aquifer recharge:** The climate variability/ change, reported since 1968-1970, has induced a decrease in recharge due to a drop in rainfall and in surface runoff by about 20% to 30% (Mahé and Olivry, 1995). The decrease in recharge is estimated, in terms of significant drop in water level in wells and drillings, as between 3 meters and 7 meters in Niger (figure 15).

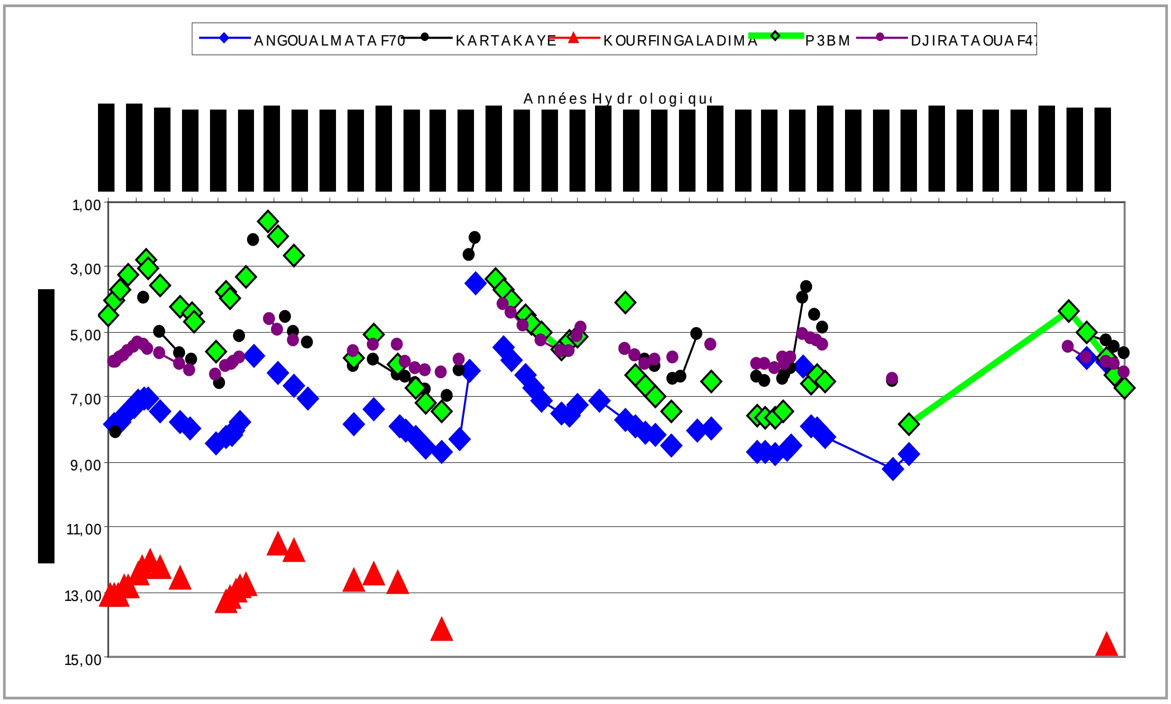

FIGURE 15: Variations in water level reported (from 1991 to 2000) in the drillings and piezometers in the valley of Goulbi de Maradi (Niger).

▸▸▸ **Impact indicators. Rate of GHG emissions:** The emission of such greenhouse gases, of which Carbon dioxide, is insignificant in the Iullemeden zone by comparison with developed countries (Norway, USA, Germany) and fairly developed countries (Brazil, India) (Table 7). On the other hand, the consumption of traditional fuel, such as wood (85%), constitutes the main energy source by deforestation.

Country	Consumption of traditional fuels (in % of the total energy consumed)	Per capita power consumption (kilowatt/hour)		GMD GDP units produced per kilo (PPA 2000)		GMD Carbon dioxide emissions		
						By inh (in tons)		Share in world total (%)
	2002	1980	2002	1980	2002	1980	2002	2000
Norway	..	22400	26640	4,6	6,1	10,6	12,2	0,2
USA	3,6	10336	13 456	2,8	4,4	20,0	20,1	24,4
Germany	..	..	6 989	3,9	6,2	..	9,8	3,4
Brazil	26,7	1145	2183	7,4	6,8	1,5	1,8	1,3
India	20,0	173	569	3,3	5,0	0,5	1,2	4,7
Nigeria	46,4	108	148	1,4	1,3	1,0	0,4	0,2
Mali	85,0	15	33	..	..	0,1	(.)	(.)
Niger	85,3	39	40	..	..	0,1	0,1	(.)

Table 7 : Energy and Environment (UNDP Report, 2005).

▸▸▸ **Pressure indicators. Loss of land areas by deforestation:** As regards land degradation, 0.7% of the forest potential is lost in Mali, as against 3.7% in Niger and 2.7% in Nigeria. In Mali, over 100,000 ha of forests disappears every year. Wood cutting for firewood and charcoal is estimated, on the whole, as 5 million tons per year. In Niger, there are **annually some 300,000 hectares** cleared from forest areas. In Nigeria, firewood accounts for over 85% of domestic energy, although Nigeria is a oil exporting country. **Annual production is about 43.3 million tons for wood**.

VIII.2. Analysis of socio-economic consequences

The socio-economic consequences may be defined as the changes in well-being of persons as resulting from the corresponding Transboundary risk or from its environmental impacts.

The assessment of socio-economic consequences may normally be classified according to the extent of detailed analysis, namely:

- **Declaration:** The range of socio-economic consequences related to a Transboundary risk is identified by mere declaration that the consequence exists;
- **Quantification:** Figures are related to the consequences to specify their scale. These figures may refer to the scope or frequency of such events;
- **Indicative evaluation:** Indicative monetary values are assigned to the costs that are related to the consequences. The monetary values present the advantage of aggregating and compar-

ing the Transboundary risks, as well as of measuring the benefit that may be derived based on their consideration;

- **Overall evaluation:** This highest evaluation level takes into consideration all the economic costs related to the consequence.

In most cases, declaration is more applied to describing the scope of the social and economic consequences of the Transboundary risk.

VIII.2.1. Analysis of the socio-economic consequences of the Change in availability of groundwater

The reduction in the groundwater of the Iullemeden Aquifer System may induce socio-economic consequences that have an adverse impact on agricultural, animal and -hence- dairy production. This situation may lead to food insecurity. Agricultural production will decrease gradually. The incomes of the stockbreeders will tend to increasingly drop. Certain farmers and stockbreeders would be likely to change their economic activities (via exodus), or end up unemployed.

This reduction in water may also slow down, if not bring to a halt, industrial and mining works. This stoppage results in a reduction in the incomes of the companies which will then be forced to significantly lay off their personnel, thus causing a drastic reduction of their contribution to the national budget. This drop in State revenue may, in turn, have a major impact on such social sectors as education and health. When the water resource becomes scarce, the various socio-economic activities may end up in a situation of competition over exploitation which may jeopardise the efforts of a sustainable management of the resource.

The reduction or scarcity of water may also have other adverse consequences on the socio-economic activities, of which in particular:

- migration of the population to other countries, with the expected socio-economic consequences resulting therefore (decrease in national production, social and economic misbalances, etc.);
- transhumance of the livestock to more remote zones during the dry period, which lasts between 9 and 10 months, thus inducing loss of the livestock and of the stockbreeders incomes;
- rise in the costs of maintenance and upkeep of the water infrastructures due to an accelerated wear resulting from the overexploitation of the water points. This increase in cost and the insufficient organization of the users of these water points result in non operating state of several equipped drillings;
- conflicts around the water points which are prompted to meet the multiple activities needs;
- disintegration of village solidarity (gradual loss of mutual social support, increase in household problems);
- increase in the time women spend on the water-fetching chore in rural areas, which affects their income-generating activities and, consequently, causes a reduction of their purchasing power.

VIII.2.2. Degradation of the quality of groundwater

Pollution of the aquifers may cause several diseases whose treatment is not accessible to the most vulnerable rural population. Certain diseases may irreversibly handicap the producers. Such a situation may lead to losses of incomes and, therefore, to difficult living conditions.

The fall of the national production may have serious impacts on the national economy. Many economic activities may be jeopardised, as is the case in particular of agricultural production, stock-breeding and even trade activities. Such a situation obliges the State to resort to foreign aid to secure the expenditure required for health, education and many other basic needs of the population.

The deterioration of water quality may be more acutely felt around multi-purpose water points (stock-breeding, farming, drinking water) through the spread of many infectious diseases (epizooties) due to human and animal concentration, such as foot-and-mouth disease, pasteurellosis, peri-pneumonia, symptomatic anthrax and the plague of small ruminants.

VIII.2.3. Climate variability/change

The impact of climate change on groundwater may induce social and economic consequences, of which in particular.

Resort to irrigated farming: In West Africa, pluvial agriculture employs on average two thirds (2/3) of the active population and contributes by about 30 % in the region's GDP (UICN, 2003)

Country	Population (in thousands) in 2000	% population loyed in the agricultural sector (1996)*	Share of Agriculture in GDP (%)
Benin	6097	54	39
Burkina	11937	84	33
Cape Verde	428	35	12
Chad	7651	72	40
Côte d'ivoire	14786	49	26
Gambia	1305	80	27
Ghana	20212	52	10
Guinea	7430	74	22
Guinea Bissau	1213	79	62
Liberia	3154	70	ND
Mali	11234	80	47
Mauritania	2670	45	25
Niger	10730	86	41
Nigeria	111506	64	32
Senegal	9481	77	17
Sierra leone	4854	61	44
Togo	4629	67	42
Total/Moyenne	**229317**	**66**	**29**

* According to Reports by UNDP (2000) and ADB (African Development Bank) (2001).

Tableau 8 : Importance of the agricultural sector in the national economies of West Africa (UICN-BRAO, GWP-WAWP, CILSS, 2003).

(Table 8).

The reduction of rainfall from 20% to 30%, reported over the whole West Africa region, as well as of surface runoff in the same proportions, tend to lead the rural population to shift gradually to irrigate farming from temporary ponds and groundwater during the dry season in arid zones («off-season crops”). This evolution may induce a decrease in the incomes of producers and a drop in the countries’ economic growth rate. Indeed, the contribution of irrigated farming from groundwater remains marginal compared with total agricultural production.

The economic value of water: The abandonment of dried up wells tapping the groundwater within the range reachable by the peasants and farmers of the rural environment, and the resort to drillings equipped with water pumping means tapping the deeper aquifers, causes the peasants and farmers to pay for access to these modern water points. This, in turn, gives rise to rural migration to sub-urban quarters.

Change of economic activities for certain economic operators: The loss of profits due to the negative impacts of climate change may also lead the peasants and farmers to take up new activities which, though income-generating, may be prejudicial to the protection and the safeguard of the environment. Such is the production of firewood for the cities and the major conurbations.

IX. CARTOGRAPHY OF MAJOR RISKS

In view of the results of the reflection conducted by the countries, as well as of the preliminary estimates issuing from the mathematical model, a risk map has highlighted the hot spots (Figure 16).

Based on the preceding thematic analyses, there emerge four (4) zones of Transboundary risk potential (cf. map further down). The nature of these primary causes is connected with factors of a geological character (nature of the aquifer reservoirs, water exchanges), of a climatic character (variation in space and time), and of a socio-economic character (agricultural and industrial activities). Thus, in most of the identified zones, the risks are due to a multiplicity of causes.

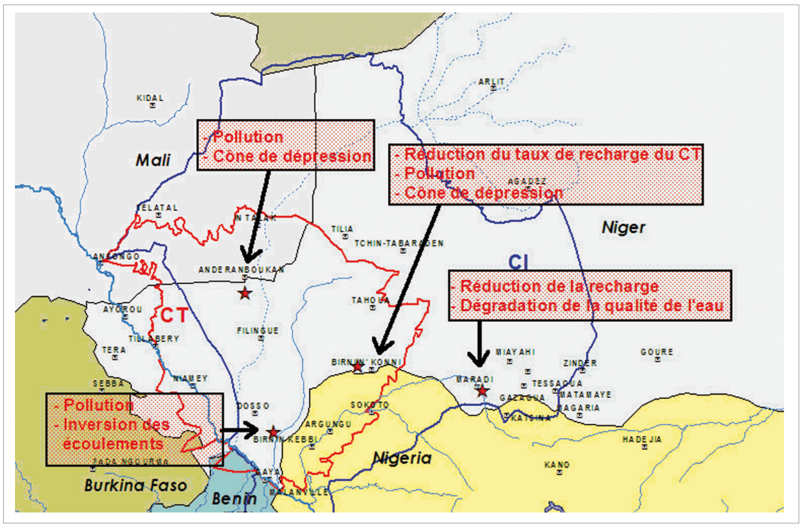

FIGURE 16 : IAS Hydro-geological risks map

The preliminary modelling estimates, pending the data to be obtained from field investigations, would attest to a trend towards an overexploitation of groundwater as from 1995. The countries would be experiencing, as of this year, a situation of water stress, contrary to the forecasts for 2025 by the United Nations Economic Commission for Africa[1].

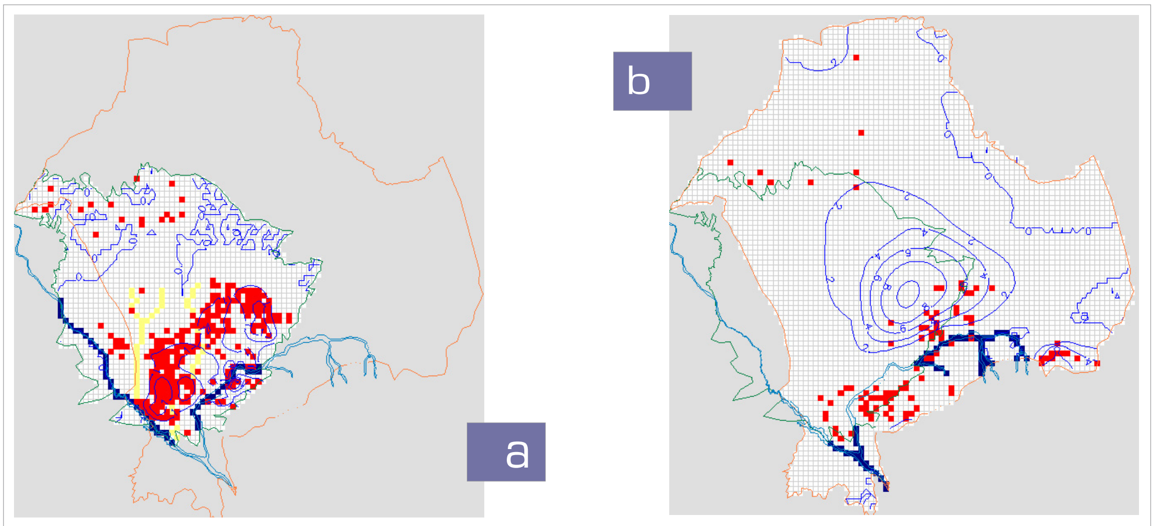

FIGURE 17 : Additional drawdowns in CT (a) and Ci (b) by 2025.

In conclusion, according to the previous thematic analysis, it identifies three types of transboundary risk areas. The nature of these primary causes is related to hydrogeological (nature of aquifers, water exchanges), climate (spatial and temporal) and socio-economic (agricultural and industrial) factors. Thus, in most areas identified, risks have multiple causes.

[1] United Nations Economic Commission for Africa (UNECA), «Future of the Global Environment « 2000, UNEP, Earthscan, London, 1999

X. CAUSAL CHAIN ANALYSIS

A causal chain is a series of statements that relate the causes of a given problem to its effects. The causal chain is composed of three types of causes:

- **immediate causes**: or primary causes, are often the problem's direct technical causes. They are, above all, tangible;
- **underlying causes**: They contribute in the immediate causes and include the uses and practices applied to the key resources, as well as the related social and economic causes;
- **root causes**: These are often related to the key aspects of macroeconomy, consumption patterns, environmental values, access to information, democratic processes, governance..

Accordingly, the three major Transboundary risks are examined based on these three types of causes.

X.1. Immediate causes

X.1.1. Change in availability of groundwater

The aquifers of the Iullemeden Aquifer System, particularly those of the Continental Terminal, are annually recharged, at about 3 mm/ year, for the Continental intercalaire (Ci) and at about 14 mm/ year, for the Continental Terminal, according to the study zones (Adelana et al., 2003; Bromley et al., 1997; Desconnets, 1994; Leduc and Desconnets, 1994; Leduc et al., 1997; Leduc and Taupin, 1997; Galle La Salle et al., 2000; Taupin, 1990; Edmunds et al., 2004). However, the ultimate conclusion of the risk analysis would converge gradually in the long run towards a reduction of the groundwater potential. This concern has translated, according to the countries, in the following way:

- abusive, non regulated exploitation and non concerted management of the shared aquifers (Mali)
- non regulated and non sustainable exploitation of very old water (Mali)
- impact of land use on the groundwater resources (Mali)
- impact of deforestation (Mali)
- impact of climate change on the aquifers (Mali)
- uneven spatial distribution of water resources (Mali)
- change of the piezometric area of an aquifer (Niger)
- impacts of climate change on Transboundary aquifers with a low recharge rate (Niger)
- critically, examine the issue of climate change with respect to aquifer recharge in the Iullemeden basin (Nigeria)
- the hydrogeological section of the Nigerian portion of the Iullemeden Aquifer System should be correlated with that of the Niger Republic (Nigeria)
- afforestation programmes be effected in the basin to improve recharge and soil conservation (Nigeria).

The situation is marked by the following features: non concerted and increasing exploitation of the water resources of a Transboundary aquifer due to an increase and multiplication of water demand (demographic growth at the rate of 3% on average per year; industrial and mining activities; development of increasingly sedentary stock-breeding, land use by mechanization of agriculture, among other aspects). All these result in a shift and reorganisation of underground flows. This situation can generate, in the long run, a whole range of practical consequences likely to have international implications. In addition to human activities, the reduction of rainfall due to climate variability/change, contributes in the reduction of aquifer recharge. Among these consequences, it is worth mentioning the following, in particular:

- **Change in the characteristics of the underground flow.** The flow (directional flow) passing through an international border is calculated by means of mathematical models. Increasing abstractions of groundwater on both sides of the border can modify the natural flow, which is likely to generate phenomena of interference by increase of depression cone. This risk is all the more probable as the countries implement programmes of execution of drillings. Thus, the location and size-measurement of drillings tapping Transboundary aquifers need to be planned and concerted in order to ensure equitable allocation of the water resource.
- **Decrease of artesianism** In the central part of the SAI, a decrease in artesianism by about 2 to 3 metres has been reported in the artesian drillings tapping the Continental Terminal in Niger in the sector of Dantiandou, Balayera and Dan Kassari. Moreover, other artesian drillings, which tap the Continental intercalaire (Ci), continuously flow in hardly renewable water since 1970, date of their execution. The majority of the SAI artesian boreholes is not regulated and is often very little developed.

X.1.2. Degradation of groundwater quality

Mali, Niger and Nigeria are unanimous as to the degradation of the groundwater quality of the Continental intercalaire (CI) and the Continental Terminal (CT), including Quaternary alluvia, as attested by the following list of risks identified by the countries:

- exploitation and use of unwholesome and/or poor quality groundwater (Mali)
- impact of polluting use of land and water in recharge areas (Mali)
- irreversible contamination by pollutants from the deep drillings in mining and oil drilling zones (Mali)
- degradation of water quality (Niger)
- groundwater contamination and pollution (Nigeria).

The degradation of water quality is due to either mineral decay of the geological formation crossed by the water, or to wastewater effluent generated by the activities of the various socio-economic activities.

Degradation of water quality by natural phenomena

The degradation of the quality of groundwater depends on the mineral para-genesis which constitutes the aquifer formation and which determines the chemical character of the existing water. Due to ionic exchanges, **water originating from the deep aquifers**, i.e. confined ones, may contain abnormally high content of certain chemical elements. This is, for instance, the case of Fluorine, being the lightest and most electronegative of the elements belonging to the set of halogens (Chlorine, Bore, Iodine, Astate).

Fluoride is abundant mainly under the form of Fluorine, of Apatites. **Fluorine**, of the chemical formula ClF2, is the most widespread because it contains up to 49% of Fluoride; it is present in the igneous (plutonic, volcanic) and sedimentary rocks. **Cryolite**, Na_3 (AlF 6) is the ore most used. **Apatite**, calcium phosphate, of the chemical formula $Ca_5 (PO_4)_3$ (OH, F, Cl), covers a series of compounds whose composition may be fairly complex: fluorapatite, $Ca_5(PO_4)_3$ F, when Fluorine is prevalent, chlorapatite, $Ca_5(PO_4)_3$ Cl, when chlorine is prevalent, hydroxylapatite, $Ca_5(PO_4)_3$ OH, when hydroxyl ion OH is prevalent. It is the main constituent of the sedimentary phosphates used, in particular, as a fertiliser. It is also found in Calcium-rich rocks (carbonatites, metamorphic limestones) and alkaline magmatic rocks (granites, syenites, pegmatites and equivalent lava, hydrothermal seams).

Fluorapatite is predominantly present in the aquifer of the Continental intercalaire (Ci) in the border zone between Niger and Nigeria where fluorine contents reach values ranging between 9 and 12 mg/l (the standard being of 1.5 mg/l for temperature values ranging between 8°C and 12°C, and 0.7 mg/l for temperature values ranging between 25°C and 30°C). This generates osseous and dental fluorosis, in particular among persons aged less than 15 years.

Besides, the tapping of highly mineralised deep water during exploitation may affect the quality of water of adjacent aquifers. This is the case of the zone of Dallol Maouri (Niger), where exchanges of water were reported between the superimposed aquifers (Guéro, 2004).

Deterioration of water quality due to human activities

The demographic growth reported in the world in general, and in the West Africa sub-region in particular, has been accompanied by an intensive urbanization, an intensification of industrial activities and the exploitation of new cultivable land[2] (Calamari, 1985). All these transformations have induced a huge increase, both in quantity and in variety, of emissions of pollutants likely to reach the aquifers.

Based on studies conducted in sixteen countries (7 of North Africa, 1 of Central Africa, 2 of East Africa, 4 of South Africa, 2 of Europe), the main sources of contamination are as follows (Yongxin and Brent, 2006)[3]: sanitation sites (latrines, septic tanks), domestic wastes, wastewater, agricultural products (fertilisers, herbicides, pesticides), industrial and mining wastes (oil, etc…), poor land management. The resulting main pollutants are microbiological (viruses, bacteria, protozoa), chemical (organic, and inorganic of which nitrates and nitrites).

In the case of the Iullemeden Aquifer System, in particular, and of the basin of the Niger river, in general, groundwater contamination is most likely to be generated by human activities (Adelana, 2006; Traoré et al., 2006), as well as by exchanges between the river water network river and the non confined aquifers (Orange and Palangié, 2006; Ousmane et al., 2006). This is the case of the inland delta of the Niger in the Malian portion. The increasing use of agricultural fertilizers affects the unconfined aquifers, particularly in the vicinity of the main course of Niger River. Statistics indicate that the average quantity of fertilizers necessary for a minimum production is of 230 kg to the hectare (kg/ha) in 2010 and of 475 kg to the hectare in 2030. In the Iullemeden Aquifer System, although this quantity of fertilizers is currently low, it is nonetheless gradually increasing (Table 9, see page 62).

X.1.3. Climate variability/change

The concept of climate variability and change is related to the significant modification or variation of the climate due to factors of natural or human origin.

The United Nations Framework Convention on Climate Change (UNFCCC), in its Article One, defines climate change as «**changes which are directly or indirectly ascribed to a human activity altering the composition of the world atmosphere and which come to be added to the natural variability**

2 Davide Calamari, 1985. State of Pollution in West and Central Africa Inland Water. FAO

3 Yongxin X and Brent U, 2006. Groundwater Pollution in Africa. Taylor & Francis ED 353 pp

Quantity applied (kg/ha)	Year								
	1970	1980	1985	1990	1995	1999	2000	2001	2002
Burkina Faso	0	2	4	7	7	13	9	0	0
Mali	3	8	10	7	13	15	9	9	9
Niger	0	1	1	1	3	1	1	1	1
Nigeria	0	6	8	14	6	6	7	8	6
ECOWAS	3	6	8	6	9	10	8	8	9
Africa	11	20	22	22	19	22	21	22	23
Asia	28,2	73,2	87	122,2	147,4	160,9	151,9	151,6	159,1
Latine America	25,2	58,8	56,9	59,1	59,3	76,9	83,3	86,4	89,3
World	52,5	86,9	93,7	99,00	93,2	100,8	96,8	98,3	100,8

Table 9 : Quantity of fertlisers used annually in the SAI region (Source: IFDC, 2005, FAO).

of the climate observed during comparable periods". The UNFCCC thus makes a distinction between «climate change" ascribable to human activity altering the composition of the atmosphere and «climate variability" ascribable to natural causes.

Climatic variability refers to the natural intra and inter-annual variation of the climate. Its space and temporal range is fairly more limited. Climate change, on the other hand, represents a statistically significant variation of the average state of the climate or its variability, persisting for a prolonged period (generally extending over decades or more).

The Earth and especially its surface absorb solar radiation. This energy is subsequently redistributed by atmospheric and oceanic circulation and is sent back to space with bigger wavelengths (infra-red). On annual average, and for the Earth as a whole, the incidental solar radiation is more or less equal to the radiation emitted by the sun to the Earth and the radiation emitted by the terrestrial sphere. Any factor which modifies the solar radiation or that which is sent back into space, or still that which modifies the redistribution of energy in the atmosphere or between the atmosphere, submerged land and oceans, can influence the climate (IPCC, 2001).

Radiant ram designates any modification of net radiant energy proper to the Earth-atmosphere system. A positive radiant ram tends to cause warming of the earth surface and the lower atmosphere, while a negative ram tends to cool them.

The increase in GHG concentrations will induce a reduction of the effectiveness with which the surface of the Earth reflects the incidental radiation back to space. Once emitted in the atmosphere, many GHGs remains there for centuries, thus contributing sustainably in a positive radiant ram (IPCC, 2001).

Volcanic activity can project in the stratosphere large quantities of sulphur gases (especially of sulphur dioxide), which are subsequently transformed into sulphated aerosols. Each eruption is liable to induce a significant, though momentary, negative ram, which contributes in cooling the surface of the Earth and the lower atmosphere for a few years (IPCC, 2001).

The changes in land assignment, whose deforestation is the main factor, seem to have produced a negative radiant ram of - 0,2 ± 0.2 Watts/m2 (IPCC, 2001). The effect is particularly marked in high latitudes. Deforestation has, indeed, caused there the replacement of snow-covered, fairly low albedo forests by uncovered, snow zones with higher albedo. Africa and, to a lesser extent, the zone of the Iullemeden Aquifer System, contributes in the production of this negative ram through the crop growing practices (fires), and the production of firewood.

Thus, climatic variability and change are due mainly to the natural or human production of GHGs. The Intergovernmental Panel on Climate Change (IPCC) confirms that the major part of the increase reported in the global mean temperature since the mid-1920s is most likely due to GHGs of a human origin[4]. These anthropogenic GHGs contribute in modern warming (1750-2005) and recent warming (1950-2005). The total average surface temperature (the average temperature of the air close to the surface of the ground and the temperature on the surface to the sea) has increased since 1861 (Figure 18). In the XXth century, this increase was of 0,6 °C ± 0,2 °C[5].

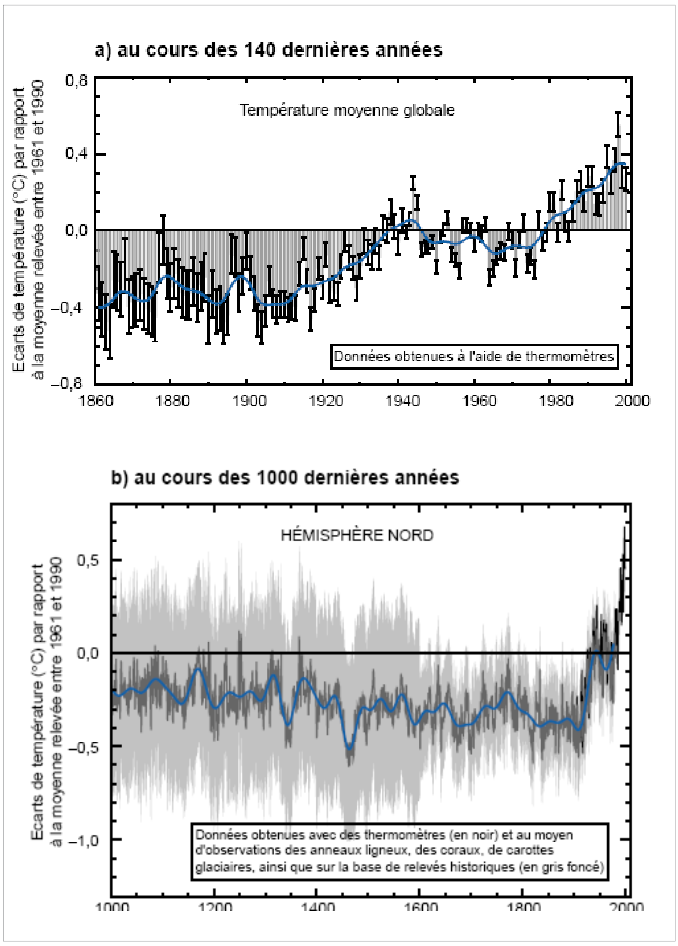

Figure 18 : Variations of temperature on Earth surface over the past 140 years and during the last millennium (IPCC, Balance 2000).

The zone of the Iullemeden Aquifer System, in particular, and of West Africa, in general, though not classified among the GHG producing countries, is quite vulnerable to climate variability and change in view of its physical and socio-economic features (UICN-BRAO et al., 2003):

- the contrast between the hyper-arid areas (Saharan desert), to the north, and the wet areas (southern Niger, northern Nigeria), a contrast mitigated by the configuration of the hydro-graphic network of Niger River, of which the inland delta in Mali;
- the lowest human development index in the world.

X.2. Underlying causes

The main causes contribute in the immediate causes; they comprise:

- **the uses and practices applied to the main resources** (land use, dumps, harmful or non sustainable practices, water uses, such as diversions and storages),
- **the related social and economic causes** (increasing development of the socio-economic sectors, investment, waste reduction procedures, parallel management of offer and demand).

These underlying causes are analysed for the respective three major Transboundary risks.

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4 Anthropogenic Carbon Dioxide Emissions (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluorine (SF_6), hydrochlorofluorocarbons (HCFCs), chlorofluorocarbons (CFCs), precursors of aerosols and chemically active gases, such as sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NOx) and non methanic volatile organic compounds (VOCs).

5. IPCC. Balance of Climate Change 2001: Summary Report.

X.2.1. Change in availability of groundwater

The modification of the water resources, particularly in terms of decrease, is mainly due to social and economic reasons.

▸▸▸ Groundwater uses and practices

The main causes of modification of the groundwater resources are due, on the one hand, to the pattern of land use and to changes in this pattern and, on the other hand, to certain practises of use of groundwater. This modification translates into a reduction in the water resources.

The overriding land use pattern is the expansion of crop areas due to demographic growth and, thus, of increasing food needs. **This is the case of Niger, for instance, where the crop area passed from 3.86 million hectares in 1985 to 7.95 million hectares in 1995**. The crops are, for the major part, pluvial; irrigated farming is generally practised in the zones equipped with Niger River hydrographic network.

This expansion of crop areas is no longer accompanied, as was the case in the past (fallow land system), by land restoration. This practice affects deeply and, sometimes, irreversibly the mineral and organic reconstruction of the land which becomes more vulnerable to wind and rain erosion. **In a system dominated by pluvial farming, the farmland deteriorates rapidly beyond 15 capta/ km²**, thus losing in land fertility.

Figure 19 : Examples of land degradation

Overgrazing, the clearing of forest land for agricultural purposes, destruction of forests to meet fire energy and service needs, as well as for fodder to feed the cattle, harmful practices of collection of herbs and plants for traditional pharmacopoeia, and bush fires are but instances of the human activities which contribute in the disappearance of the forest cover, thus exacerbating land degradation through the phenomena of wind and water erosion.

Land degradation takes various forms (figure 19) :

- formation of large expanses of glacis;
- formation and widening of temporary rivers and ravines;
- formation of dunes;
- sanding up of crop land and silting of rivers;
- flooding and leaching of the land;
- reduction of infiltration.

The formation of glacis and the disappearance of the grass cover reduce infiltration of runoff water and useful rain; this causes a lowering of the groundwater, and the drying up of water surfaces. **The silting of ponds, streams and the River is at the origin of the considerable shrinkage of the area of surface water**.

The underlying causes of **the reduction of water resources are also connected with** certain practises, such as **little control over the flow of artesian boreholes**. Indeed, almost all artesian drillings flow continuously, and this, since the date of their construction, in water originating in the Continental intercalaire (Ci) and the lower aquifer of the Continental Terminal (CT1). A drop in artesianism by about 2 to 3 meters has been reported in Niger (Dantiandou, Balayera, Dan Kassari). This also applies to the major drillings constructed in 1969 for oil exploration in the Malian portion. The piezometric level was at 4.75 m above ground, with an artesian flow of 2.6 liters/s; some **82000 m³ flow yearly in the wild, going almost unnoticed**.

▸▸▸ Social and economic causes

The change in the availability of groundwater must be seen in the sense of its decrease as induced by various social and economic causes. These are **demographic growth** and the **development of such economic sectors** as stock-breeding, farming and industrial activities.

a) Drinking water demand

According to the United Nations Development Programme (UNDP), the portion of the urban population having access to drinking water in sub-Saharan Africa had decreased rather slightly, passing from 86 % in 1990 to 83 % in 2000. Currently, **about 65 % of the rural population and 25 % of the urban population do not have access to an adequate water distribution**[6]. Similarly, **about 73% of the rural population and 43 % of the urban population do not have access to decent sanitation**. In Nairobi, for instance, 60% of the population lives in shantytowns which account for only 5% of the city territory. The same applies to the major African cities, of which 40% to 70% of the inhabitants live in shantytowns (Figure 20).

And yet Africa has abundant water resources that are not efficiently used. Having 17 major rivers and over 160 major lakes, Africa uses a mere 4 % or so of its total annual volume of renewable water resources for agriculture, industry and domestic needs[7]; in other words, a low average consumption with regard to the potential. However, by 2025, water demand will be on the increase in view of population growth (UNDP, 2005) (Table 10). This increase is likely to lead the African countries, those of the Iullemeden Aquifer System precisely, to a situation of water stress[8] (Figure 21).

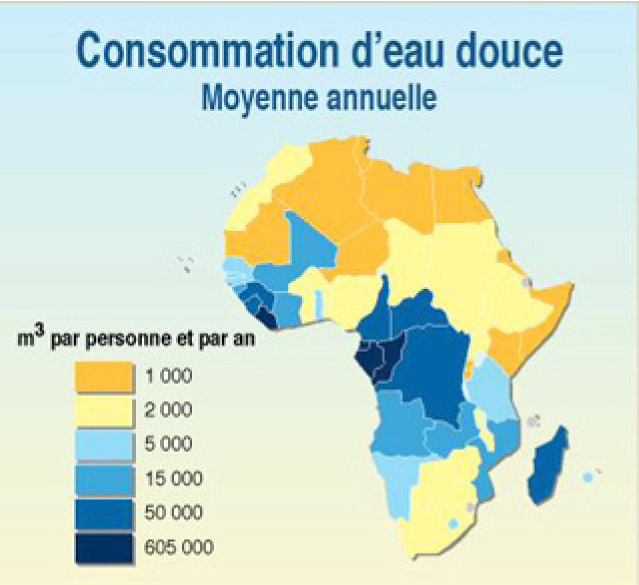
Figure 20 : Shantytown in Nairobi (Photo: ©AFP / Getty Images / Marco Longari)

Currently, **African countries depend considerably on external funding**. A recent study of the water distribution and sanitation projects sponsored by the World Bank for the financial years 1987 to 1990 reveals a larger proportion of external funding in sub-Saharan Africa

[6] Regional Hydrological Observatory of West and Central Africa (World Bank http://ohraoc.ird.bf); www.righttowater.org.uk/code/homepage.asp; www.cohre.org/water.htm; www.academie-eau.org/mot.php3?id_mot=6; www.watertreaty.org; www.worldwatercouncil.org

[7] Gumisai Mutume, 2004. Les vicissitudes du développement durable. (Vicissitudes of Sustainable Development) - Afrique Renouveau, Vol.18#2 (July 2004), page 19.

[8] UN Economic Community for Africa (UNECA), Future of the Global Environment 2000, UNEP, Earthscan, London, 1999.



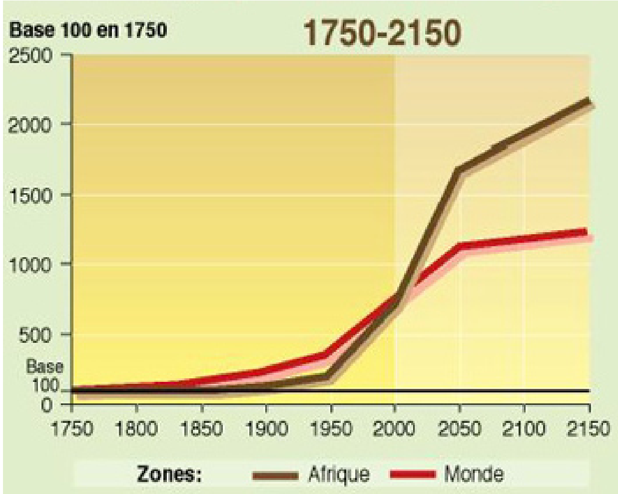


Figure 21 : Water shortage and stress in Africa for the time frame 2025 related to demographic growth.

than in any other part of the world: 81 %, as against 65 % in Asia, 58 % in Latin America, 54 % in the Middle East and North Africa. In the case of rural projects, these external funding passed from 66 %, for the financial years 1975-1979, to 84 %, for 1990-1994, while public investments were decreasing from 33 % to 13 % for this same period

Besides, throughout **the sub-Saharan region, water supply is subsidized by means of rates that are lower than the cost prices and, sometimes, even lower than the operating and maintenance costs**. Cost recovery is thus insufficient and adds to the difficulties of the administrations, which have at once to ensure the maintenance of the existing systems and invest in new infrastructures.

As regards the SAI countries, the recording of abstractions for drinking water purposes is entrusted to the national drinking water distribution companies and agencies. These bodies operate

Classification according to the HDI	Total population (million)			Annual demographic growth rate (%)		Urban population (in % of total)[1]			Population aged less than 15 years (in % of total)		Population aged 65+ years (in % of total)		Total fertility rate (par woman)	
	1975	2003	2015	1975-2003	2003-20152	1975[2]	2003	2015[2]	2003	2015[2]	2003	2015[2]	1970-19753	2000-2005[3]
158 Nigeria	58,9	125,9	160,9	2,7	2,0	23,4	46,6	55,5	44,7	41,3	2,4	3,2	6,9	5,8
174 Mali	6,2	12,7	18,1	2,6	2,9	16,2	32,3	40,9	48,3	46,7	2,2	2,4	7,6	6,9
177 Niger	5,3	13,1	19,3	3,2	3,3	10,6	22,2	29,7	49,0	47,9	1,6	2,0	8,1	7,9

1. These data resting on national definitions concerning city and conurbation, inter-country comparisons need to be made with caution

2. These data belong in the middle of the projection range.

3. These data relate to estimates for the indicated period.

Table 10 : Demographic trends (UNDP Report, 2005).

mainly in the main cities and medium-sized conurbations. The estimates of the abstractions made in rural environment by village hydraulics are very approximate.

The annual average water demand for Kidal, Gao and Tombouctou in Mali is 1.3 million m^3/year (statistics of 1999 to 2001). The annual average water demand, primarily for the fifty one urban centres totalling 1.8 million inhabitants, is 117.6 million m^3/year in Niger[9] (Maliki and Issa, 2004). Niamey, the capital, is supplied by water from Niger River. In Nigeria, annual average drinking water consumption was of 15.4 million m^3/year in 1990 for the population of the States of Kebbi, Zamfara and Sokoto[10] (JICA, 1990; Ude and Hanidu, 2004; Hanidu, 2006). The forecasts for the time frame 2020 estimate the demand for water as 32.3 million m^3/ year[11]. The major portion of the abstractions comes from the aquifers of Gundumi, Rima, Kalambina and Gwandu (Kogbe, 1972; 1976; Hanidu, 2006).

The UNDP Report (2005) has given, based on the Human Development Index, the figures related to the population having access to drinking water in the three countries (table 11).

Classification according to HDI	MDG Population having quality sanitary installations (%)		MDG Population having facilitated access to a quality water source (%)	
	1990	2002	1990	2002
158 - Nigeria	39	38	49	60
174 - Mali	36	45	34	48
177 - Niger	7	12	40	46

Table 11 : Percentage of the population having sanitary installations and easy access to drinking water (UNDP Report, 2005).

The inventory of water points (drillings and wells) in the Iullemeden Aquifer System has counted over 17,000 water points. The distribution over time reveals an increase in water demand in line with demographic growth (Figure 22).

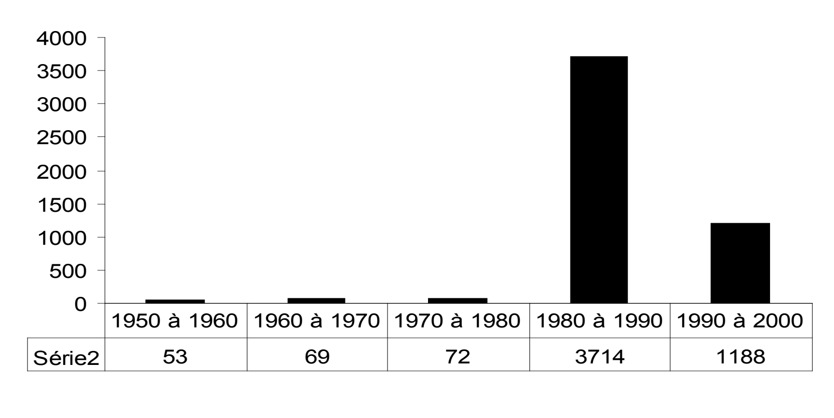


Figure 22 : Statistics on water points (boreholes and wells) in the SAI as per decade, based on the data available on the year of their construction

The period 1980 – 1990 corresponds to the launch of the International Decade for Drinking Water and Sanitation. Accessibility was defined as the distance to be covered on foot or the travel time between the household and the modern water point

[9] MALIKI Barhouni and ISSA Soumana, 2004. Development Process of a Shared Vision for the Sustainable Development of the Niger Basin: National Multisector Study. Niger Basin Authority Report - (in the French). 213 pp. and Appendices

[10] Ude M. O and Hanidu J A., 2004. Assessment of the Opportunities and Constraints to the Development of Nigeria's Portion of the river Niger Basin. Niger Basin Authority, 141 pp. and Appendix

[11] JICA (1990) - Study for Groundwater Development in Sokoto State

(borehole, modern well, tank well, water tap). One modern water point (drilling, well) corresponds to 250 inhabitants in Niger and to 400 inhabitants in Mali.

b) Water needs for agriculture

In the West Africa sub-region, the hydro-agricultural potential is very little exploited (UICN et al., 2003)[12]. **Water abstractions for agriculture**, domestic consumption, industry and hydropower, are estimated as less than **3% of the renewable water resources available**. With an area almost equal to that of the United States and China, West Africa counts only **110 major dams** (15 m high dams or of a storage volume over 3 million m^3), as **against over 6.000 for the USA and over 20.000 for China**. West Africa accounts for 1/3rd of the area of Africa but has less than 1/10th of the continent's 1300 large dams, which is revealing of **the little control over water**.

In the zone of the Iullemeden Aquifer System, the irrigable land potential of Mali is estimated as 2.2 million hectares (Diarra and Cissé, 2004; Sidoro, 2006) of which about 110 000 hectares for the zone of Gao. The grown irrigable area is about 135 000 hectares, of which 10 000 hectares in the zone of Gao. Water consumption is about 4.5 billion m^3, with 98% of these needs being covered by water from Niger River (Diarra and Cissé, 2004; Sidoro, 2006). For a total coverage of the food needs of the population of **Mali, the water needs are estimated as 10 billion m^3**, which is about **30% of the potential of the country's surface water resources** in deficit year[13].

As for the **Niger** portion of the basin, t**he major part of the irrigable land potential of Niger, estimated as 270 000 hectares**, is concentrated in the valley of Niger River, with 142 000 ha (that is, 52% of the national potential) (Maliki and Issa, 2004). **The irrigable land potential in the zone of the Iullemeden basin is estimated as 227 000 hectares, that is 84% of the potential of Niger**. The exploitation of the irrigable potential is conducted in full control over water mainly from Niger River and the ponds, and by drillings (43 drillings), (Maliki and Issa, 2004; Rabé, 2006).

In **Nigeria, the irrigable land potential is 42 272 hectares,** of which nearly 5 300 hectares are grown. Water needs for agriculture are provided by the surface water dams of Bakolori[14], Jibiya, Goronyo and Zauro (Hanidu, 2006; Ude and Hanidu, 2004). In Nigeria, irrigated agriculture represents the main water-consuming activity, with abstractions estimated as 5.5 billion m^3 (69% of the total abstractions), followed by domestic uses (1.7 billion m^3) and industry (800 million m^3) (FAO, Aquastat).

c) Water needs for livestock

The north-western part of the Iullemeden Aquifer System represents the pastoral livestock zone, particularly in Mali and Niger. It is characterized by an uneven distribution of modern water points (pastoral drillings and wells) and a high number of those which are not in operation. This results in a concentration of the population and livestock on these rare water points, thus exerting high pressure on the water resource.

According to the updated Rural Development Master Plan (SDDR), Mali counts a herd of 589 000 head of cattle, 14 444 000 head of sheep and goat, and 310 000 head of camel (Diarra and Cissé, 2004). The Saharan portion of Niger River corresponds to the nomadic stock-breeding zone par excellence. The fodder production, of less than 0.1 ton of dry matter/ha/

12 UICN-BRAO, GWP-WAMP, CILSS, 2003. Water, Climate Change and Desertification in West Africa: Regional Strategy of Preparedness and Adaptation

13. DIARRA Adama Tiémoko et CISSE Youssouf, 2004. Etude multisectorielle nationale : Evaluation des opportunités et contraintes au développement dans la portion malienne du bassin du fleuve Niger. Rapport Autorité du bassin du Niger. 142 pages.

14 Akané Hartenbach and Jürgen Schuol. October 2005. Bakolori Dam and Bakolori Irrigation Project – Sokoto, Nigeria

year, and the very low load capacity (44 hectares/Tropical Cattle Unit) are compensated by the very vast pasture expanses, whose exploitation remains dependent on the presence of water points. Assuming an average daily need for a Tropical Cattle Unit of 30 litres, the annual need would be of 56 million m^3/year in the portion of the Iullemeden basin which represents half of the national cattle population.

According to statistics for the year 2000 of the Ministry for Animal Resources, Niger counts 2'276'545 head of cattle, 2'719'482 head of sheep, 5'002'396 head of goat, 321'824 head of camel, 467'890 head of donkey, and 149'935 head of horse (Maliki and Issa, 2004; Rabé, 2006). They are distributed over approximately 230'000 km^2 from East to West of Niger in the zone of extension of the large aquifers with low renewal rate. The water needs of the pastoral zone represent about 16 million m^3/year. The annual need for the livestock is of 119.77 million m^3/year.

As for Nigeria, it counts 4 137 159 head of cattle, 4 357 962 head of sheep, 6'572'115 head of goat, 2942000 head of pig, 6 190 000 poultry, 559 500 head of donkey, and 22748 head of horse, distributed over the States of Katsina, Kebbi, Sokoto, (Ude and Hanidu, 2004; Hanidu, 2006). The annual average water demand is 271.36 million m^3/year.

To improve the living conditions of the populations and of this sizeable livestock, particularly in these northern zones dedicated to pastoral activities, which zones are quite vulnerable to recurrent droughts, more and more pastoral drillings, especially wells, are constructed. In Mali, for example, the zone counts, in 2006 , some 170 boreholes and 251 modern wells for a total area of 31000 km^2, for a population of 33445 inhabitants distributed among 170 villages and sites. The construction of these new structures in these arid areas contributes in reducing the water potential of the aquifers of the Continental Terminal (CT).

d) Water needs for industry

The water needs for industrial activities are at the same time met by water from Niger River and water from the aquifers of the Continental intercalaire (CI) and the Continental Terminal (CT).

Most of the Malian industries are supplied by the "Energie du Mali" water network, with, at times, one or two drillings in supplement. The annual water consumption of the industries ranges from **a few thousand m³** (most of the industrial plants) to **a few hundred thousand m³** (breweries and textile factories). The water demand in Niger for the food processing and mining industries, as well as for trade, is estimated as 9920400 m^3/year (Maliki and Issa, 2004; Rabé, 2006). The major part of the water resources in Niger comes from groundwater; most of the industrial and mining plants are equipped with their own drillings networks.

In Nigeria, abstractions for industry, estimated in 2000, amount to 800 million m3, i.e. 10% with respect to an annual total of 8 billion m^3.

X.2.2. Degradation of groundwater quality

▸▸▸ Groundwater uses and practices

These relate, in particular, to access to sanitary installations, urban pollution and the close vicinity of urban centres[15], as well as land use (Alhou, 2006; Calamari, 1985; Kotschoubey and Koné, 2005; Yongxin Xu and Brent Usher, 2006).

Access to installations corresponds in part to the 7th Goal of the MDGs, i.e. reducing by a half the proportion of the world population deprived of access to drinking water and sanitation. In 2003,

15 Kotschoubey and Abdoulaye Koné, 2005. Evaluation for the Monitoring of Water Quality in the Niger Basin. Niger Basin Authority (ABN) – (in French).

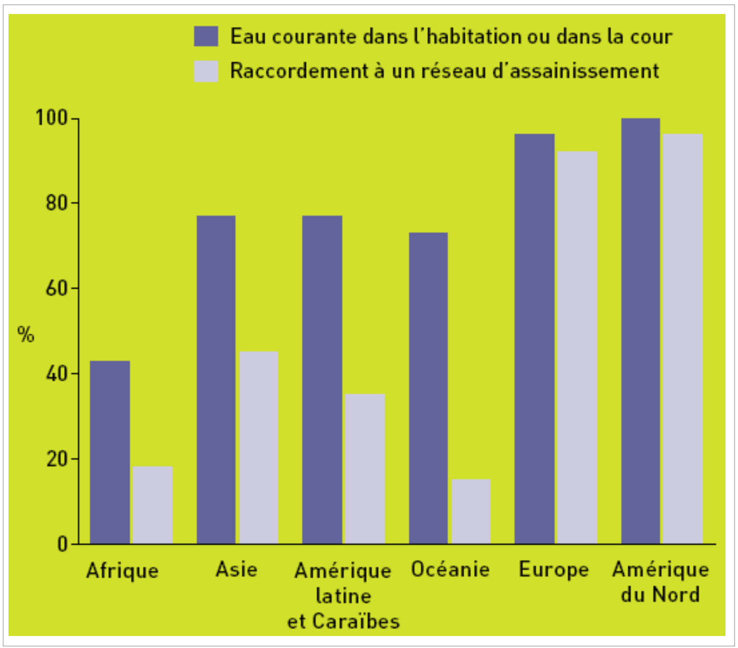


FIGURE 23 : Proportion, in urban environment, of households equipped with running water and a connection to a sewerage network (Source: WHO and UNICEF, 2000).

some 48% of the world population lived in cities (Figure 23); by 2030, this would rise to 60% (World Report 2003)[16].

Over 210 million persons in sub-Saharan Africa would be deprived of access to sanitary installations (UNDP Report, 2005). All the cities and medium-sized conurbations, located in the Iullemeden Aquifer System zone, are equipped with a storm water collection network that also receives solid and liquid domestic wastes.

Most of the major cities of Mali (Bamako, Koulikoro, Ségou, Mopti, Gao, Tombouctou) are located along Niger River and all dispose of their domestic effluent, without prior treatment, in the river. Eighty per cent (80%) of the industries are sited there (Calamari, 1985). According to the World Water Assessment Programme (WWAP), liquid domestic wastes are estimated as ranging between 25.000 and 41.600 m^3/day, which end up in the river without prior treatment.

According to the results of the Demographic and Health Surveys in Mali (EDSM – III), the combined sewer concerns less than 1.5% of the population; 32% only use septic tanks and 66.5% use latrines. Domestic wastes, evaluated based on the water consumption of the population, are estimated as between 25000 and 41600 m^3/day. The production of domestic wastes is closely related to the socio-economic activities of the population (Figure 24). The city of Bamako currently produces on average nearly 1900 m^3 domestic wastes per day that is over 70% of the total production of domestic wastes. If the current trend of waste production is maintained, the city of Bamako would end up with a daily production of 2730 m^3 by 2015.

FIGURE 24 : Urban wastewater (Badialan 1, Bamako).

In Niamey, the network is embryonic in view of its length (105 km) and its operation rate. More than 60 % of the network is clogged by solid or viscous waste of various origins, namely: 65 to 75% of organic matter, 8 to 10% of paper and rags, 3% of glass and earthenware, 2 to 3% of plastic and leather, 2 to 3% of metals (Alhou, 2006).

The major urban and sub-urban centres are not equipped with a system of storage of domestic waste (solid and liquid). Most of the urban wastewater and storm water is collected by gutters and disposed of in the river without preliminary treatment (Figure 25). In Niamey, the quantity of

[16] Programme mondial pour l'évaluation des ressource en eau (World Water Assessment Program, WWAP), 2003.

solid wastes produced every year is estimated as 273 750 ton, based on 0.75 kg per inhabitant per day (Alhou, 2006). Only 21 % of these wastes is removed and used partly to embank the small depressions in the city and the old quarries located in the immediate outskirts.

FIGURE 25 : Urban wastes in Niamey.

In the Nigerian part, the city of Lagos has an annual theoretical load of 95000 tons of Biological Oxygen Demand (BOD) and of 136000 tons per year of suspended solids (Calamari, 1985). In most Nigerian cities and conurbations, there is hardly any combined sewerage network (Figure 26). In the major cities, however, the main facilities and institutions have modern wastewater treatment installations. The main processes currently used to discharge domestic wastes are: septic tanks, latrines and hygienic buckets.

FIGURE 26 : Solid and liquid wastes in Onitsha (Nigeria).

Other practices also affect groundwater quality upstream of major conurbations. In the Malian portion of the Iullemeden Aquifer System, **a significant quantity of chemical products intended for combating locusts has been stored straight on the ground for over a decade**. The storage infrastructures and equipment for these products have deteriorated, thus inducing soil and groundwater pollution.

▸▸▸ SOCIAL AND ECONOMIC CAUSES

The main cause of deterioration of the quality of groundwater lies in the development of the socio-economic sectors, such as irrigated agriculture and industrial activities.

Hydro-agricultural developments and off-season crops, in particular vegetable crop growing, are conducted by an increasing use of chemical fertilisers and pesticides. In 2005, fertiliser consumption in West Africa amounted to about 1 500 000 tons of finished products. Nigerian consumption totalled 1 590 million tons in 1993, as against less than 600' 000 tons in 2005 (FMARD Nigeria, 2006); this decrease is mainly due to a stoppage of the fertiliser producing facilities.

Following the drought of 1970, and up to 1977, Lindane had been employed in Mali in relatively high quantities (130 tons), and then was gradually replaced by Carbamate Propoxur (Calamari, 1985). In 1982, **Fenitrothion**, an organophosphorite insecticide of moderate residual effect, was used for millet, sorghum and corn. A large-scale campaign to combat river blindness is being conducted by the World Health Organization in West Africa over about 1 300 000 square kilometres within the framework of combating the populations of larvae of dipterous **Simulium damnosum**. The pesticides most commonly used are Temephos (Abate) and, in lesser quantities, Chlorphoxim (Davide Calamari, 1985).

X.2.3. Climate variability and change

The underlying causes of climate variability and change with an impact on groundwater resources, especially of non confined aquifers, are more related to the socio-economic causes proper to the region.

West Africa, in particular Mali, Niger and Nigeria, produce very little, if not hardly any, GHG, comparative to industrialised countries (UNDP, 2005).

Land use changes, of which deforestation is the main factor, seem to have caused a negative radiative ram of - 0,2 ± 0,2 Watt/m2 (IPCC, 2001). The contribution of the countries of the Iullemeden Aquifer System zone lies in the consumption of traditional fuels, such as the production of firewood (table 12).

Classification according to HDI	Consumption of traditional fuels (in % of total energy consumed)	Consumption of electricity per inhabitant (kilowatts/hours)		MDG GDP units produced per koe (PPA 2000)		MDG Carbon dioxide emissions		
						Per inhabitant (in tons)		Portion of world total (%)
	2002	1980	2002	1980	2002	1980	2002	
1 Norway	0	22400	26640	4,6	6,1	10,6	12,2	0,2
10 USA	3,6	10336	13456	2,8	4,4	20,0	20,1	24,4
20 Germany	0	0	6989	3,9	6,2	0	9,8	3,4
158 Nigeria		46,4	108	148	1,4	1,3	1,0	0,4
174 Mali	85,0	15	33	..	..	0,1	(.)	(.)
177 Niger	85,3	39	40	..	..	0,1	0,1	(.)

Table 12 : Fuel consumption and GHG emissions

According to studies conducted by FAO, out of the 3600 million hectares, 70% of the world's arid areas affected, 10 million hectares of arable land are degraded every year, 130 million hectares seriously affected, and 50% are in Africa.

Deforestation for the production of firewood contributes in a very significant way in desertification. In developing countries, over 2 billion people do not have access to reliable forms of energy. Water is a vital resource as regards energy production, the latter being in its turn essential for economic development. While Europe uses 75% of its hydraulic energy potential, Africa—where 60% of the population does not have access to electricity—exploits only 7% of its potential[17]. This deficit is compensated by wood energy.

In the zone of the Iullemeden Aquifer System, the forestry domain[18] of Mali is estimated as 100

17 Second World Report of the United Nations on the Development of Water Resources

18. Results of the Inventory Project of the Woody Resources of Mali (PIRL 1985-1991).

million ha (Diarra and Cissé, 2004), exclusive of the pastoral and desert zones. However, the main part of the ligneous (woody) resources extends on a mere 32.4 million ha, that is less than 26% of the area of the national territory. Some 118 classified forests, totalling about 1 million hectares, of which 20 listed forests cover an area of 259200 ha, are subjected to durable installation, of which 8 000 ha in the Iullemeden zone[19].

As for woody productions, the live volume is over 520 million m^3, that is 416 million tons of live wood, with productions of less than 10 m^3/ha for shrubby savannas; of 20 to 40 m^3/ha for striped bush; of 50 to 80 m^3 for wooded savannas; and of over 100 m^3/ha in Guinean zone and forest galleries.

In Mali, over 100'000 ha of forests disappear every year. Wood cutting for firewood and charcoal are estimated overall as 5 million tons per year, which corresponds to the exploitation of 400'000 ha and is likely to reach or exceed 7 million tons by the year 2010, that is 560'000 ha. The regeneration (productivity) potential is estimated as 7 million tons per year[20]. The production of firewood and charcoal in the portion of the Iullemeden Aquifer System during the period 1984-1999 is estimated as 270879 steres of wood that is 37095 quintals of coal.

In Niger, according to an estimate made during the period 1982 and 1989, forest resources cover an area of 16 million hectares (that is 2% of the area of the national territory), consisting of 11'600'000 hectares of marginal forest land (covering less than 5%), 4'400'000 hectares of reclaimable forest formations, of which 600000 hectares of listed forests[21]. **In 1995,** the forest areas (natural forests and plantations) had shrunk to as little **as 2,5 million hectaress**[22]. In the Iullemeden basin, there have been inventoried 37 listed forests covering an area of 381.284,4 ha (that is, 79% of the total area of the country's listed forests) and 38 protected forests totalling about 2.3 million hectares. Niger forests provide 87% of the energy needs of the populations estimated as in the range of 1.5 to 2 million tons per year in spite of a low productivity of the Niger forests (ranging between 0,1 and 1,5 stere/ha/year)[23] due, in particular, to a high human and animal pressure and to recurrent droughts. Thus, on average, an annual 338 180 hectares are lost to the forest areas[24].

The Federal Republic of Nigeria claims significant forest reserves. In certain northern States, the estimates amount to 840280 hectares in Bauchi, 613484 hectares in Kaduna and 602631 hectares in Sokoto State. A forest restoration programme has allowed the restoration of 432052 hectares in the State of Borno (Chad Lake zone), 18900 hectares in the State of Katsina, 17150 hectares in the State of Kebbi. The production of seedlings in 1992 in the States under threat of desertification due to deforestation, reported the following figures: Plateau: 2'368'500; Kano: 1'998'000; Borno: 1'700'000; Sokoto: 1'555'875.

It is worth recalling that Nigeria has both renewable and non renewable energy resources. The non renewable resources include in particular: crude oil, natural gas, coal and lignite, as well as nuclear fuel. The renewable resources consist in hydropower, solar energy, wind energy, firewood and biomass. **Firewood accounts for over 85% of domestic energy although Nigeria is a oil exporting country**. Annual production is about 43.3 million tons/year for wood, 144 million tons/ year for animal waste and crop residue, 734.2 MW for small-sized hydropower energy, 5.25 kw/m^2/day,

19. National Department of Nature Conservation (DNCN), 1999

20 According to the National Department of Forestry, Faunal and Fishery Resources (DNRFFH)

21. CNEDD, 1998 & 2004

22. National document CSE/LCD, 2004

23. CNEDD, 1998

24. CNEDD, 1998

on average, for solar energy, and 2.0-4.0 (19.8 W/m², on average, for wind energy[25].

As regards land degradation, **0.7% of the forest potential is lost in Mali, as against 3.7% in Niger and 2.7% in Nigeria**[26].

X.3. Root causes

The root causes are often related to the fundamental aspects of the macroeconomics, demography, consumption patterns, environmental values, access to information and democratic processes[27] (GEF, 2004).

The underlying causes may be distributed into the following categories (GEF, 2004): 1) governance; 2) demographic pressure and change; 3) poverty, wealth and inequality; 4) development models and national macroeconomic policies; 5) social changes and development assumptions; and 6) education and formulation of values.

These categories of causes are in line with the indicators or indices developed and applied by certain international institutions, in particular the United Nations Development Programme (UNDP), to characterize each country according to its degree of development[28].

As a matter of fact, the underlying causes of the paradox of the African continent and, in particular, West Africa—of which Mali, Niger and Nigeria—, a paradox characterized by a water "shortage" within an abundance of water resources, cannot be explained based exclusively on modification of the groundwater resources on the quantitative and qualitative levels, nor based on the adverse impacts of climate variability and change. Other significant factors, related to these categories, indicators or indices, do contribute to a significant extent, towards a better appreciation of the Transboundary risks. For example, **the incapacity to apply laws on the control of pollution is not only one cause of pollution** (GEF, 2004).

It is for these reasons that, because of the specificity of governance, the root causes of the three major Transboundary risks can be examined according to two approaches:

- the human development indicators which provide a comprehensive evaluation allowing an appreciation of the progress achieved by each country in various fields of human development; these indicators cover the main part of the categories of root causes involved;
- the governance analysis of each Transboundary risks.

X.3.1. Analysis of the development indicators

West Africa is characterised by its extreme poverty. Out of the **30 countries** where **the lowest human development index is reported, 14 are in West Africa**, that is all the countries of the region, except for Liberia (non listed), Ghana and Cape Verde. On the list of the 49 countries considered as LDCs (Least Developed Countries) in the world, 14 belong in West Africa, which is all countries except for Ghana, Nigeria and Côte d'Ivoire. Average GDP for West Africa (340 USD) is less than a half of that for Africa as a whole (700 USD). This means, therefore, that West Africa is the poorest region of the poorest continent in the world (IUCN & al., 2003).

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25. Nigeria's Non-Conventional Energy Resources (Source : Federal Republic of Nigeria: National Assessment Report-World Summit on Sustainable Development-2002)

26. World Bank Atlas (2001)

27. GEF, 2004. Training course on the TDA/SAP approach in the GEF. International Waters Programme. Six volumes.

28. UNDP, 2005. World Report on Human Development 2005. ED. Economica, 49 rue Héricart, 75015 Paris (France). 385 pages

The indicators considered cover the developed countries (Norway, USA, and Germany), the fairly advanced countries (Brazil, India), the less developed countries (Mali, Niger, Nigeria). This approach is justified by the need to compare the various levels of development between the countries, but—above all—to seek to better appreciate and grasp the underlying causes of the paradox of the African continent (tables 13 to 26).

The Human Development Index (HDI) is a composite index.**It measures three dimensions of human well-being: income, education and health**. Its objective is not to provide an exhaustive representation of human development, but to measure the level of development beyond mere income. The HDI is thus a sort of barometer of the evolution of human well-being and a tool of comparison between various regions.

During the last decade, the HDI has increased in all developing countries, although at variable pace, except—of course—for sub-Saharan Africa. However, in spite of overall progress, many countries have taken unprecedented backward steps. Thus, in 2003, eighteen (18) countries, with a total population of 460 million inhabitants, were ranked lower on the HDI in 2003 than in 1990 (Table 1.1). (Only six countries had experienced similar regression in the 1980s.) Two zones are particularly affected. Twelve of the countries in regression are located in sub-Saharan Africa. Over a third of the population of sub-Saharan Africa, that is 240 million people, live in countries whose HDI has fallen. The six other countries in regression belong to the former USSR.

The development regression is reflected in the relative ranking of the countries. In sub-Saharan Africa, economic stagnation, the slowness of the progress achieved in matter of education and the proliferation of HIV/AIDS have proved to be a fatal combination involving an abrupt relegation on the HDI classification. South Africa reports one of the sharpest falls by losing 35 points, while Zimbabwe loses 23 points and Botswana 21.

Human development must progress on several fronts: a decline in human well-being, related to life expectancy, for instance, cannot be compensated by progress in other areas, such as income or education. Moreover, progress made in a given area is more difficult to maintain in the absence of a comprehensive improvement. Thus, a poor level of health may have a negative impact on economic growth and education, and a slow growth reduces the resources available for social investments.

The World Report on Human Development highlights the extent of the challenge which the world must take up at the outset of the decade which separates us from 2015. It focuses on what the governments of the rich countries can do to preserve their share of the world partnership endeavour. This does not mean that the governments of developing countries have no responsibility. On the contrary, they even have a primary responsibility. **No level of international co-operation will ever be able to compensate for the inaction of governments** that do not grant priority to human development, respect of human rights, combating inequalities or elimination of corruption. But, without renewed commitment, without a co-operation sustained by practical action, the Millennium Development Goals (MDGs) will be missed, and history will record the Millennium Declaration as yet another hollow promise.

As regards the deadline of 2015, there is a growing risk that the next ten years, just like the ten last ones, should be recorded in history not as a decade of accelerated human development, but as a period of missed chances, timid efforts and failure of international co-operation. This year is a turning point. The international community may pursue human development along the same way or change course and implement the policies necessary to give concrete expression to the commitments made in the Millennium Declaration.

The consequences of the current orientation should not be underestimated. Using the trend data on national level, we have developed an estimate of variations in terms of human cost between the MDGs and the results envisaged in 2015 if the current trends continue. Among the gaps, we may mention the following:

- the MDG on reducing infant mortality will not be reached, the gap being equivalent to more than 4.4 million avoidable deaths in 2015. Over the next ten years, the aggregate gap between the objective and the current trend would mean that more than **41 million children will die before their fifth anniversary** of the easiest evil that may be cured: poverty; a conclusion that is difficult to reconcile with the Millennium Declaration in which the States pledge to protect the world children;
- the gap between the MDGs to reduce poverty by a half and the forecasts may be translated as follows: **an additional 380 million people** in developing countries will live on less than one dollar per day by 2015;
- the MDGs on primary education for all will not be reached if the current trend continues: **47 million children** in developing countries **will not be schooled in 2015**.

However, statistics as the preceding ones must be interpreted with caution. The forecasts resting on the past trends offer an outline of the possible results, but do not define in any case an inescapable reality.

In the case of the MDGs, there is no doubt that good news is possible. It is still possible to adjust course, but time is short. As the United Nations Secretary General has said, «the MDGs can be reached by 2015, provided that we forsake usual practices and accelerate and intensify at once and in a spectacular way the implementation of the measures".

To know whether the MDGs are accessible belongs in political priority, but the investments necessary are modest compared with the wealth of the rich countries. **The 7 billion dollars necessary each year during the next decade to ensure for 2.6 billion individuals access to drinking water represent less than what Europeans spend on perfume and less than what Americans spend on ice cream, and this, for an investment** which would save some 4000 lives per year.

▸▸▸ Progress and failure in matter of human development

The most elementary components of human development are a long and healthy life, education and resources allowing a decent standard of living. Human potential also includes social and political participation in societal life.

Within a little **more than ten years, average life expectancy in developing countries has increased by two years**. In this field, the human development indicators converge: the poor countries catch up with the rich countries. The increase in life expectancy is due partly to a fall in infant mortality rate. There are, currently, 2 million infant deaths less than in 1990, and the proportion of children reaching five years of age has increased by 15%.

Improvements in matter of access to drinking water and sanitation have contributed in the above achievement by reducing the risks of infectious diseases. During the last decade, 1.2 billion people obtained access to drinking water. Thanks to the Global Alliance for Vaccine and Inoculation (GAVI), **the rapid increase in the number of vaccinations** on a worldwide scale since 2001 has also generated a fall in mortality and **saved half a million lives according to estimates**.

The progress made in the educational field is quite as remarkable. Nevertheless, 800 million people in the world do not have the basics of reading and writing. Of this total, the largest number corresponds to women for as many as two thirds. And yet, literacy levels in developing countries have passed from 70 % to 76 % during the past ten years, and the gender gap has narrowed.

Current illiteracy reflects the past gaps in matter of access to education, but the latter gaps are gradually being bridged. By comparison with 1990, thirty (30) million children less is deprived of schooling in primary education and the average schooling duration has extended by six months. Gender differences with regard to schooling, an indicator that is commonly recognized as being little representative of equality between the sexes, have decreased, although more than a half of the non schooled children are girls.

Extreme monetary poverty is on the decrease. Well-founded **doubts** have been **expressed concerning the use of the "one-dollar per day" poverty line** to represent the trends in the various countries. Consequently, the greatest caution is required as regards the interpretation of this indicator.

Whatever the difficulties related to the measurement of this phenomenon, poverty is an evolutionary process which can only partially be represented by fixed indicators. The situation evolves, however, in the right direction. **The rate of extreme poverty** has passed from **28% in 1990 to 21% today, this fall being equivalent** in absolute figures to approximately **130 million people**. Economic growth is obviously one of the requirements for a rapid fall in monetary poverty and a sustained human development. In this field, too, the main figures are encouraging.

In the 1990s, the average per capita income of developing countries reported a 1.5% increase that is almost three times more than in the 1980s. **Since 2000, the average per capita income of developing countries has increased by 3.4%** that is twice the growth of the average income in high income countries.

After two decades of decline of the average income, sub-Saharan Africa has posted a 1.2% increase per year since 2000. It is perhaps too early to declare this projection as being a decisive turning point, but there are indications which show that the growth could strike root in a growing number of the countries of the region.

Progress towards democracy is also ambivalent. Yet, democracy is a key aspect of human development. It has an intrinsic value and can, thus, be regarded as a fully fledged indicator of human development and is also a means of extending the human development goals.

The measurement of democratic progress is, by its very nature, rather complex. Among the requirements, one may mention multi-party elections, currently the mode of governance most used in the world.

More than two thirds of Africans as of now live in countries provided with a democratic multi-party electoral system and the African governments themselves have taken the lead in the movement opposing the antidemocratic coup in Togo. Nevertheless, multi-party elections are not enough to qualify a State as being democratic. Multi-party elections are far from being widespread in the Middle East.

Many countries organizing multi-party elections, in particular in some countries in the former Soviet Union, are democratic only in name, countries whose leaders are considered by the population as being corrupt and tyrannical, abusing their authority and refusing to address their country's social problems.

Multi-party elections may be a smokescreen concealing an authoritarian executive power, curtailment of the freedom of the press and violations of human rights, which have nothing democratic about them. In certain countries, popular demonstrations have been a powerful antidote against such practices.

▸▸▸ Limitations of human development

No indicator of destitution is more telling, or more disconcerting, than that of infant mortality. **Over 10 million children of less than five years die every year**. The weight of sub-Saharan Africa in the statistics on infant mortality is on the increase. **The region represents 20 % of infant births and**

44 % of infant deaths. Almost all infant deaths could be avoided. **Every two minutes, four people, of whom three are children, die of malaria**. Most of these deaths could be avoided by simple and inexpensive interventions. Diseases against which there is a vaccine (measles, diphtheria and tetanus) claim the death of 2 to 3 million children.

For each child who dies, millions of others will fall sick or miss out on school, thus being trapped in the vicious circle which makes of children in bad health adults plunged in poverty. **Like the 500 000 women per year who die of causes related to a pregnancy**, over 98 % of the children which die every year live in poor countries. In other words, they die because they have been born there.

Monetary poverty is closely related to the problem of famine. In a world of abundance, millions of people suffer from famine every day. More than 850 million people, of whom a third of preschool children, continue to be trapped in the vicious circle of malnutrition and its effects. Indeed, malnutrition weakens the immune system, increasing proneness to disease which, in its turn, further aggravates malnutrition. About a half of the deaths in pre-school age are directly ascribable to interactions between malnutrition and infectious diseases. Children presenting a relative excess insufficiency have four times more risks to die of infectious disease than the well-fed children.

Similarly, **vulnerability to infectious diseases is exacerbated by an inadequate access to drinking water and sanitation**. More than a billion people do not have access to wholesome water and 2.6 billion do not have enhanced sanitary access. Water- or human excrement-carried diseases are the second cause of death among the world children, after infections of respiratory tracts. The total number of victims per day is estimated as 3.900 children. There still remain considerable disparities in access to education. In a world economy increasingly focused on knowledge, about 115 million children are denied access to basic primary education. Most non schooled children live in sub-Saharan Africa and in South Asia. On average, a child born in Mozambique today receives four years of education, whereas a child born in France gets as many as 15 years of education at a markedly higher level of schooling.

Moreover, while the gap in matter of schooling in primary education is being bridged, the gap between rich and poor countries, measured in terms of average duration of schooling, is widening. Irrespective of the differences in quality of schooling, less than a quarter of Zambian children leave primary school knowing to read and write.

Alongside with this, access to higher education remains a privilege from which mainly high income countries can benefit. Today's inequalities in matter of education are tomorrow's global social and economic inequalities.

Gender inequalities result in an access to education that remains limited for girls. In spite of a narrowed gender gap, girls receive on average one year of schooling less than boys in Africa and in Arab countries and two years less in South Asia. In 14 African countries, girls represent less than 45% of the student-body of primary schools. In all developing countries, 75% of girls complete their primary schooling, but this percentage is as high as 85% for boys. The gender gap is even more pronounced in secondary and higher education.

These deep-seated disparities constitute not only a violation of the universal right to education, but also a threat to prospects of human development. Indeed, the education of girls is a key catalyst of social progress, such as measured by the most various indicators.

▸▸▸ Monetary poverty: Slackened progress in a world of inequalities

On the whole, the last two decades have reported the fastest reductions of poverty in human history. However, any evaluation of the evolution of monetary poverty must take into account the significant inter-regional disparities.

The reduction of world poverty is mainly due to the extraordinary success of the South Asian zone, in particular that of China.

Conversely, sub-Saharan Africa reported an increase in population living on less than one dollar per day: nearly 100 million people more in 2001 than in 1990.

In South Asia, the incidence of poverty has decreased, but not the number of the poor. Latin America and the Middle East have not made any progress, whereas Central and Eastern Europe, and CIS (Commonwealth of Independent States), have reported a sharp increase in poverty.

The number of people living on less than two dollars per day in Central and Eastern Europe, as well as the CIS, has passed from 23 million, or 5% of the population, in 1990 to 93 million, or 20% of the population, in 2001.

Of most concern for the future is the overall slackening of the progress made. The major successes in matter of poverty in the past two decades took place in the 1980s through to the early 1990s. As from the mid-1990s, poverty—as measured based on the threshold of a dollar per day—has decreased five times more slowly than between 1980 and 1996. And yet, the average growth of developing countries had risen in the 1990s, and had increased more than twofold compared to the per capita growth rate of the previous decade.

Average incomes in sub-Saharan Africa are today lower than they were back in 1990. In the past few years, there have been noted signs of redress in several countries, in particular Burkina Faso, Ethiopia, Ghana, Mozambique and Tanzania. This redress must, however, be placed in context. At the annual per capita growth rate of 1.2 % reported since 2000, it would take until 2012 for sub-Saharan Africa to restore the average incomes to their level of 1980.

▸▸▸ Management of natural resources

Besides the fact of exacerbating inequalities, the abundance of natural resources may widen the capacity gaps which make certain States more liable to conflict. **The States more liable to conflict are often hopelessly poor, though extremely rich in resources**.

The proneness to a violent conflict seems to be a characteristic of what has been called the «**resources curse**”. Once again, the connection between resources and violent conflict are neither automatic nor inevitable.

Botswana has transformed its diamond-based wealth into high growth and rapid human development, while avoiding conflict based on income-sharing. However, this example represents an exception to the rule for the majority of developing countries. **Poor governance, combined with resources that offer a prospect of extraordinary gain for those in control of production and exportation, is a major cause of violent conflict**.

In the conflict zone, the pathology of the «resources curse” acts via various channels, hampering the development of the political institutions and the market economies capable of converting natural wealth into human development. Part of this pathology lies in the misappropriation of national wealth. The financial flows which could have been used to sustain human development have frequently been diverted to financing civil wars, and the governments, rebels and warlords have sought to take control over oil, metals, ores and wood.

Angola is a glaring example. The wealth of the second largest oil reserve and the fourth largest diamonds reserve in Africa has been used to sustain a civil war that had killed or mutilated 1 million people between 1975 and 2002 and internally displaced an additional 4 million persons. Today, Angola ranks 160th out of the 177 countries of the HDI, with a life expectancy of about 40 years.

The potential incomes from natural resources may weaken the State on several levels. Two perverse effects come to exacerbate bad governance. In the first place, **the availability of significant flows of incomes may weaken the will of the governments to develop systems of stable incomes** via national taxation structures. A State which becomes less dependent on the revenues from taxes becomes less responsible vis-à-vis its population.

Secondly, in the presence of natural resources, the corruption of the State and of the individuals and groups who control them offers huge profits. Deficient governance structures offer ample room for «extra budget" activity, and these considerable income flows give the individuals that hold power a motive to ensure that these opportunities remain unchanged.

X.3.2. Governance Analysis

The analysis of Governance represents the background for developing the process of Transboundary Diagnostic Analysis (TDA) for the Strategic Action Programme (GEF, 2004) The analysis of governance should describe the dynamic relations within the social institutions which take into account aspects such as the legislative and legal frameworks, decision-making processes and budget allocations. (GEF, 2004)

The absence of good governance is not in itself the cause of pressure on the environment. It is rather a lack of willingness to address pre-existent causes. For instance, the incapacity to apply laws to the control of pollution is not only one cause of pollution (GEF, 2004). Without a minimum understanding of institutional relations, responsibilities on all levels, and the existing legal and policy frameworks (namely: what has been done, successes and failures), a number of key issues may be overlooked and inappropriate recommendations may be formulated.

"Governance" has received several definitions, of which the following.

According to the Global Water Partnership, the water crisis is often a crisis of governance[29]. The concept of "governance" encompasses the laws, regulations and institutions, but it relates to governmental policies and actions, local activities and the networks of influence, including the market forces on international level, the private sector and civil society (Global Water Partnership, 2003).

According to UNDP (2001), governance is the exercise of economic, political and administrative authority to manage a country's affairs on all levels. It comprises mechanisms, processes and institutions, by which the citizens and groups express their interests, exercise their legal rights, do their duties and settle their disputes.

Governance is a method of management, not a system of government[30] (Camdessus & al., 2004). Governance is a triangle that brings together the authorities, private interests (industrial, agricultural, commercial), associative civil society of consumers and users.

Three main exchanges gradually build up between the governance actors:

- The public authorities send in legislative and legal messages to society, which is supposed to comply with them. In the field of water, these are the European Commission directives, the national laws and decrees, the municipal ordinances that set the rules of use, authorisations, prohibitions and sanctions. Governance balances this regulatory apparatus with the user's "good practices ". It is because the law is good that the users comply with it; it is because the current users have been considered by the legislator that the law is in line with custom and that it is respected. **The authority of the state is accepted because it is negotiated**.

29. Global Water Partnership (GWP) Framework for Action, 2000 World Forum.

30. Michel Camdessus, Bertrand Badré, Ivan Chéret and Pierre-Frederic Ténière-Buchot, 2004. Water. Robert Laffont Editions.

- The second balance is established between the private, industrial and commercial interests, and the authorities. The latter accept the laws of the market: **transparency of information, competition, prices and quantities in balance between offer and demand**. The rules of liberal economy are moderated by a regulation (and not a regularization) which the public authorities apply to private companies;
- The third balance, between civil society and private interests (between the enterprises and their customers), relates to **the quality of the services provided (this quality includes their price) and the nature of the demand expressed by society**. The quantitative, but especially qualitative, aspects of the goods and services offered constitute the heart of the problem. For water, which is not a traditional economic goods, the quality of the service is not limited to observation of the technical standards and to continuity of the flow available, but extends to such values as the protection of nature, such complex psychological and social representations as landscapes and quality of life), and such ethical principles as transparency of management, solidarity with the poorer categories, humanitarian action). **This dependence of the economic on the moral is the stake of this balance**.

Each angle of the governance triangle seeks to control the proper functioning of the opposite balance (Camdessus & al., 2004) :

- Civil society ensures that it is sufficiently represented in the compromises passed between the trade interests and the public authorities. This control is exerted by political sanctions (elections) which may befall the elected representatives, or still by economic effects (boycott, press campaign) which can harm companies;
- The public authorities' angle supervises the offer and demand balance which is supposed to be established between the companies and the customers, the administrative executive authority and its users. If demand is too low (as is typically the case of under-developed countries concerning the water service, one of the last financial political priorities), then the authorities may stimulate demand based on dedicated incentives: communication, information, training, economic and financial tools, social measures;
- The regulator role of private interests with respect to the balance between regulations and good practices («codified" in Agenda 21 at the World Environment Summit in Rio de Janeiro in 1992) should not be forgotten. The legislator always tends to ask too much of the citizen. The latter readily adopts avoidance, notwithstanding Agenda 21 and the peace of mind that is supposed to be provided by the politically and socially correct.

The UN second world report on the Development of Water resources mentions a crisis of governance[31]. It underscores the importance of the methods of governance in the management of the world water resources and in combating poverty. According to this report, the current situation is mainly the result of **"management bad practices, corruption, absence of adequate institutions, bureaucratic lethargy and insufficient investment in the fields of human resources and physical infrastructures"**.

Although there are no precise figures, it is estimated that corruption costs the water sector every year several million dollars and that it is strongly prejudicial to water supply, in particular with regard to the poorest categories. Accordingly, the report quotes the findings of a survey conducted in India according to which 41 % of the respondents had paid more than one bribe during the preceding six months in order to temper with their water consumption reading; 30 % of them had paid to speed up the execution of repair work and 12 % of them had paid to speed up the execution of connection and sanitation system installation work.

31. This report, which is published every three years, was presented in Mexico City, in preparation for the 4th Global Water Forum (Mexico City, 16 to 22 March). This edition is entitled «Water, a Shared Responsibility».

It is also noted that the credits allocated to water do not increase. According to the report, the total Official Development Aid (ODA) dedicated to the water sector during the past few years amounts to 3 billion dollars per year, on average, to which there must be added 1.5 billion dollars granted to the sector under the form of non concessional loans, mainly by the World Bank. However, only a small percentage (12 %) of these funds actually reaches those who need it most. Lastly, only 10 % approximately of the credits are allocated to the development of policies, planning and design of programmes in matter of water management.

Moreover, investments by the private sector in the field of water supply are on the decrease. During the 1990s, it is estimated that the private sector had invested 25 billion dollars in water supply and sanitation services in developing countries, mainly in Latin America and Asia. However, many large multinationals present in the water sector have started to reduce their activities, if not abandon them, because of the significant political and financial risks to which they were exposed.

“ Good governance is essential for the management of our fresh water resources which are more and more limited. It is, moreover, indispensable in poverty reduction ” said Koïchiro Matsura, UNESCO General Director. “ There is no standard recipe in this complex and variable field. However, we know that good governance must rest on adequate institutions, on national, regional and local level, on stable and efficient legal frameworks, and on sufficient human and financial resources ”.

To exercise good governance also requires observing «such fundamental freedoms as freedom of expression and freedom of association,” the report indicates. It goes on to emphasize: “if the citizens do not have access to basic information relating to the quality of water and the reserves available, there is no likelihood whatsoever that they could oppose water developments that are harmful to the environment or to hold the government bodies responsible“.

There is not master plan designed for the analysis of governance (GEF, 2004). **Several organizations are working on the development of governance indicators**. However, their analysis will always translate the cultural, political and social structure of the countries where they are conducted. But, it is generally agreed that the analysis of governance serves as control of the options of Transboundary Diagnostic Analysis (TDA) and of the future interventions of the Strategic Action plan. (GEF, 2004)

The analysis of governance comprises three key elements:

- analysis of the parties involved,
- institutional analysis,
- political/ legal analysis.

The parties involved, in the case of this SAI project, are first of all the governmental institutions of Mali, Niger and Nigeria in charge of management of the water resources of the Transboundary aquifers. The beneficiaries are the populations, in particular those of the rural environment, which will be the first to be affected, being the most vulnerable to the harmful effects of Transboundary risks.

In the TDA/SAP process, concerted action amongst all stakeholders is a principle that must prevail. (GEF, 2004) The representatives of these State institutions take part in full in the TDA development process. They will be duly consulted throughout the process of the Strategic Action Plan (SAP).

It would, subsequently, be up to these governmental institutions to undertake awareness-raising among the populations concerned about the risks which threaten the groundwater, as well as to involve them in the search for sustainable solutions to address such risks.

In the TDA/SAP process, the institutional analysis and the political/ legal analysis are addressed in two stages: a static analysis and a dynamic analysis.

The institutional analysis refers to the relevant sectors. Its objective is to establish an institutional map which describes as many key connections and relations as possible amongst various actors. The institutional analysis is described by:

- **a static analysis**: a description of the political, institutional and social structures and systems on national and regional level. An institutional analysis starts with an overview of the political structure (the formal aspect of government). It should review 1) the relationship between the political forces involved, 2) the planned administration or State reforms, and 3) the political relations between the participating countries.
- **a dynamic analysis**: a diagnosis of the failures of institutional governance-specific dynamics which are identified in the analysis of the series of the causes considered as underlying ones.

The purpose of **the political/ legal analysis** is to lay the foundations for the recommendation of political and legal reforms. This consists in a comprehensive overview of the relevant instruments, while laying particular emphasis on their effective implementation, their compliance and their bringing into force. The current constraints and obstacles should be also identified. This analysis is twofold.

- **a static analysis**: it includes the current national development plans/strategies, the national environmental plans/strategies, such as- for example- biodiversity strategies, major investments. It is essential to describe how a political/legal instrument has defined the problem to which it seeks to bring a solution.
- **a dynamic analysis**: a diagnosis of the failures of the dynamic policies and of specific governance which are identified in the analysis of the series of the causes as being underlying ones.

In the case of the present project, the analysis of the stakeholders, the institutional, political and legal analyses were carried out with the contribution of FAO. The latter brings its support to the three countries under project TCP/RAF/3001, entitled «Setting up a Tripartite Consultation Mechanism for the Management of the Iullemeden Aquifer System".

Within the framework of this project (TCP/RAF/3001), two national consultations were conducted simultaneously in each of the three countries:

- the first consultation relates to the analysis and evaluation of the national water regulations and any relevant bilateral or multilateral agreements in relation to the management and development of the water resources of the Iullemeden Aquifer System,
- the second consultation relates to the analysis and evaluation of the situation in matter of management and development of the water resources of the Iullemeden Aquifer System with a view to setting up a tripartite mechanism.

The second part supports the first one by narrowing down its focus insofar as most laws and regulations, policy and strategy documents, developed in the countries, do not highlight properly the aspects related to the water resources of Transboundary aquifers.

The reports on all these consultations are mentioned below:

- Me Tinougou Sanogo (Mali), 2005. Analysis and evaluation of the national water regulations and relevant bilateral or trilateral agreements in relation to the management and development of the water resources of the Iullemeden Aquifer System. 59 pages.
- Kaïgama Kiari Noudjia (Niger), 2005. Descriptive and analytical stock taking of the water system in Niger and agreements for the management and development of water resources

in relation to the Iullemeden Aquifer System (IAS). 44 pages.

- J. Goldface - Irokalibe (Nigeria), 2005. Tripartite consultation mechanism for the Iullemeden Aquifer System (IAS). 35 pages.

The analysis of the governance of each risk will focus, based on the documents produced by the countries, on the reasons for the recurrence of negative observations and/or adverse impacts of these risks and the failures of the policy dynamics and governance.

Governance analysis of the Change in groundwater availability

The major causes of a reduction of the resource are especially related to an insufficiency of legal texts in force in matter of shared groundwater resources.

Poor knowledge of the dynamics of the underground flows by the countries concerned is related to the inexistence of legal texts of international scope codifying the law applying to Transboundary aquifers, even though Mali, Niger and Nigeria have adopted the principles of an Integrated Management of the Water Resources (GIRE).

In practice, consultation is absent between Mali, Niger and Nigeria (and, generally, for all the countries of the (GIRE) zone) as regards the development of programmes for the construction of modern water points in each country to tap and exploit their common resources. The little awareness among the countries sharing the same aquifer basin ("basin awareness") is due, first of all, to the fact that groundwater is not visible, unlike surface water, such as Niger River and its tributaries.

In spite of the evolution of international relations, the States are and remain the major actors characterized by principles such as national sovereignty, sovereign equality, and permanent sovereignty over the natural land and ground resources, which affects the effectiveness of agreed measures.

The reluctance of the States to make concessions on these principles often explains the poor implementation, if not the absence of implementation, of the Agreements and Conventions which they subscribe to. This is virtually the case of the Bilateral Agreements on the joint management of the shared waters between Niger and Mali, or Niger and Nigeria, where the joint management regulations agreed experience implementation difficulties. Moreover, the Bodies specifically created to implement such agreements are entirely dependent on the States and have only an advisory capacity allowing them to make mere recommendations, non binding to the States.

In this regard, the positive results, obtained within the framework of the present project with the active participation of the representatives of the countries, strongly encourages the countries to gather increasing awareness about the strategic character of a concerted exploitation of their shared resources for a sustainable development of the zone. Among such results, **one may mention the Common Data Base, the Geographical Information System, the Common Mathematical Model**.

The insufficiency of the legal texts in force on shared groundwater resources is due to the fact that the Bilateral or Multilateral Conventions in force between Mali, Niger and Nigeria do not take into consideration the management of Transboundary aquifers. The process of setting up a tripartite mechanism between these three countries, developed within the framework of the present project, will lead to drafting relevant legal texts, as well as to a revision of certain texts now in force.

The lack of clarity of the texts also requires their revision within the framework of a legislative reform, and this in order to adapt them to the needs in question. With the advent of decentralization in Niger, for instance, it leading to a full communalization of the national territory (now counting two hundred and sixty five (265) communes), the Law on the water system in Niger must be revisited so that it would take into account the role played by these new entities in water management. In Mali, the legal water system was governed until 31 January 2002 by Law n° 90-17/AN-RM, dated 7 February 1990; this law was not implemented, due to the absence of the legal implementation texts.

Analysis of governance of the Degradation of groundwater quality

In matter of availability of acceptable quality water, the countries have laws together with their implementation texts. However, in spite of such implementation texts, the law is not observed. An eloquent and glaring example is that relating to surface water. Wastewater is disposed of in the river without any appropriate treatment at the location of adjacent cities and from industrial, domestic and agricultural premises, though this river contributes significantly in drinking water supply of the capital cities[32] (Alhou, 2007).

The non observance of the legal texts and the decrees may be due to several underlying reasons:

- multiplication of the governmental institutions operating all in the same sanitation sector, hygiene and quality of the products consumed, in particular water, without efficient consultation;
- absence of an inspection mechanism for the quality of wastewater disposed of in the wild, in particular absence of a comprehensive inventory of the sources of pollution and investigations, particularly in quite reluctant industrial and mining plants;
- lack of rigour in taking sanctions against the polluters, which may be due either to abuse manifested in corruption, nepotism or favouritism, or else to the weakness of the control bodies which are lacking in adequate capacity.

As regards Transboundary water, particularly groundwater, the absence of legal and legislative instruments in line with the requirements of a Transboundary management focused on the degradation of the quality of the groundwater shared by the three countries, requires the definition and dissemination of a legal and legislative management framework. Within the framework of setting up the tripartite consultation mechanism between Mali, Niger and Nigeria, the prerogatives of the future management structure of the water of the Iullemeden Aquifer System should have force of law as regards environmental management of this strategic resource.

The following measures may be recommended to reduce the degradation of water quality:

- prohibiting any act of pollution by discharge, in the water, of matter of whatever nature likely to be harmful to public health, and to aquatic fauna and flora;
- submitting all discharges to control by the relevant authority in order to ensure absence of pollutants;
- the relevant authorities to set water quality standards;
- regulation or prohibition of certain activities in view of water quality standards;
- obligation for any person exercising a pollution generating activity to envisage any measure suitable to remove or prevent any risks to the water resource and the hygiene of the medium;
- obligation for any polluter to bear the cost of their polluting activities.

Governance analysis of Climate variability and change

In spite of the recurrence of droughts and floods in West Africa, in general, and in Mali, Niger and Nigeria, in particular, and though these countries have ratified environment related treaties, especially those concerning climate risks (Table 13), the extent of awareness of the countries seems

[32] Alhou B., 2007: «Impacts des rejets de la ville de Niamey sur la qualité des eaux du fleuve Niger « (Impact of Wastewater Disposal from the City of Niamey on the Water Quality of River Niger). Doctoral Dissertation, Facultés Universitaires Notre-Dame de la Paix de Namur (Belgium) and Université Abdou Moumouni de Niamey (Niger)

to be rather insufficient with regard to the threat attendant upon climate variability and change (UICN, 2003).

Classification according to HDI	MDG Carbon dioxide emissions			Ratification of environment-related conventions			
	Per inhabitant (in tons)		Portion of world total (%)	Carthagenna Protocol on Bio-technological Risks	UN Framework Convention on Climate Change	Kyoto Protocol to the UN Framework Convention on Climate Change	UN Framework Convention on Biodiversity
	1980	2002	2000				
1 Norway	10,6	12,2	0,2	●	●	●	●
10 USA	20,0	20,1	24,4		●	●	●
20 Germany	..	9,8	3,4	●	●	●	●
63 Brazil	1,5	1,8	1,3	●	●	●	●
127 India	0,5	1,2	4,7	●	●	●	●
158 Nigeria	1,0	0,4	0,2	●	●	●	●
174 Mali	0,1	(.)	(.)	●	●	●	●
177 Niger	0,1	0,1	(.)	●	●	●	●

Table 13 : Energy and Environment (World Report - UNDP, 2005). The Carthaginian Protocol on Biotechnological Risks was signed in 2000, the United Nations Framework Convention on Climate Change was signed in New York in 1992, the Kyoto Protocol to the United Nations Framework Convention on Climate Change was signed in 1997, and the United Nations Framework Convention on Biodiversity was signed in Rio de Janeiro in 1992.

The root causes of this Transboundary risk are of various types:

- insufficient implementation of the national legislations in force in matter of the environment and management of natural resources, in particular actual implementation of national water policies;
- insufficient implementation of international environment-related conventions;
- insufficiency (or absence) of a regional consultation framework on climate change due to insufficiency, within each country, of cooperation and exchanges between experts, on the one hand, and the structures, on the other hand;
- inadequate financial commitments by the States in seeking out sustainable solutions,
- inadequate use of the results of many research initiatives in the region on the climate and the water resources so as to enlighten decision-making and to step up the readiness of the countries to seek out sustainable solutions.

Within the framework of the Water and Climate Dialogue, the West African countries presented their national communication to United Nations Framework Convention on Climate Change (UNICN, 2003). These Communications proposed, among others, further measures dedicated to adaptation to climate variability and change in the water resources sector. The main measures are as follows:

- inter-basin transfers,
- combined use of surface water and groundwater,
- manmade recharge of aquifers,

- construction of structures allowing the harvesting of runoff water and rain water in order to avoid losses and reduce phenomena of erosion and flooding, while increasing aquifer recharge;
- use of covered pipes in water supply networks;
- induced rain,
- dissemination of more water saving technologies and behaviours;
- recycling of wastewater (domestic and industrial);
- sea water desalinisation;
- afforestation actions for carbon trapping.

Some of the measures proposed are often technically, financially and/or politically impossible to implement on the level of the countries taken individually. Many of these adaptation measures can only be relevant when taken on a regional scale.

XI. MITIGATION OF TRANSBOUNDARY RISKS

The strategy of reduction of the Transboundary risks is based on the assumption that, on the one hand, the latter are quantifiable and, on the other hand, that indicators exist to help alert the parties, thus leading them to take the appropriate measures and conduct the actions necessary to pass to lower emergency rates.

An indicator better translates, indeed, in a synthetic manner, a situation or an action, as well as the evolution of such situation or action. An indicator is finalized information serving to characterize an evolutionary situation, an action, the consequences and the results of an action, to evaluate and compare them to their status at other dates, whether past or projected, or to the status at the same date of other similar subjects.

The indicator thus facilitates the interpretation of a situation or reveals a trend or a phenomenon which are not apparent, as is the case for groundwater. In the case of the present project, the preliminary estimates provided by the mathematical model are the only quantifiable ones; they relate to the top major Transboundary concern, i.e. the gradual reduction of the renewable groundwater potential and gradual recourse to non renewable resources.

As of now, in the field of water resources, water saving indicators have already been developed (1996) by the Observatory of the Sahara and Sahel (OSS) and the Mediterranean Observatory for the Environment and Development (OMED) of the Center of Regional Activities of the Blue Plan (PAM-UNEP). This appreciable work contributes in the reflection issuing from Agenda 21, which, in its Chapter 40, calls upon the countries and the international organizations, both governmental and nongovernmental, to develop activities with a view to identifying useful indicators to monitor the progress made in matter of sustainable development.

The levels of investment necessary for the mobilization of water resources in sufficient quantity, particularly in the arid and semi-arid regions of the world, are quite high. The tools for evaluation and monitoring of the situation of these resources and of the uses, appear as key foundations for the development projects. The main indicators formulated are as follows:

- **indicators of state of knowledge of the water resources**: 1) data relevance indicator, 2) water competition indicator, 3) per capita resource indicator;
- **indicators of internal (natural) exploitability constraints related to the water resources**: 1) natural regularity indicator, 2) regularization indicator;
- **indicators of external exploitability constraints related to the water resource**: 1) independence indicator, 2) free action indicator;
- **indicators of water demand**: 1) water use indicator: per capita water demand;
- **indicators of sector-based demand**: 1) indicators of water demand as per sector, 2) drinking water production indicator;
- **indicators of agricultural demand factors**: 1) irrigability indicator, 2) irrigation indicator;
- **indicators of urban demand satisfaction**: 1) drinking water servicing indicator, 2) connection rate, 3) sanitation rate, 4) wastewater treatment rate;
- **indicators of quantitative pressure**: 1) indicator of exploitation of renewable water resources, 2) indicator of non sustainable production, 3) indicator of final consumption;

- **indicators of qualitative pressure**: 1) indicator of potential depletion of fresh water availability.

In the case under consideration, it is premature to apply the suitable formulas to the resources of the Iullemeden Aquifer System, insofar as the results obtained represent the preliminary estimates resulting from the data available in the existing documents. In other words, a field investigation should make it possible to corroborate these results and to engage consideration of the appropriate strategy(ies) likely to mitigate the Transboundary risks.

Due to their Transboundary character, these risks will be controlled within the framework of the prerogatives of the tripartite consultation mechanism which Mali, Niger and Nigeria have jointly accepted the need for its setting up.

XII. CONCLUSION

The Transboundary Diagnostic Analysis (TDA), as supported by such complementary studies as the mathematical modelling of the Iullemeden Aquifer System and the development of the process of setting up the tripartite consultation mechanism, has led to highlighting **three major Transboundary risks: 1) reduction in groundwater resources, 2) degradation of groundwater quality, 3) impacts of climate change and variability**.

It should be recognised that these are only general preliminary results derived from the data and information available. Their merit consists in highlighting, on the one hand, the major risks, which threaten these resources and, on the other hand, the hydraulic relations which exist between surface water and ground water.

It is understood that strategic actions must be taken to enlighten the technical experts of the countries who, in their turn, will relay the information to the respective political decision-makers. Indeed, field investigations must be carried out in each of the countries on specific issues towards a resolution of, or at least control over, the major Transboundary risks, of which:

- enhancing knowledge about the aquifers based on the collection of field data: (piezometry, abstractions, transmissivities, water chemistry) to corroborate the preliminary results obtained and take them on board;
- developing relevant indicators for monitoring and control of Transboundary risks (for instance, indicators of process of water stress and stress reduction, pressure indicators) over relevant time-periods;
- improving the evaluation (quantification) of the environmental and socio-economic impacts of the risks;
- revision of institutions, laws, policies, economic instruments, with a view to a resolution of these Transboundary risks, while keeping in mind that, to date, there is neither a relevant text governing, nor a relevant institution in control of, the management of the water resources of Transboundary aquifers.

The formulation and the implementation of a Strategic Action Plan represent the suitable framework likely to give concrete expression to these major activities.

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Scenario 2015

PROSPECTS RELATED TO THE MDGS – PROJECTIONS, NOT PREDICTIONS

Our projections for 2015 are not predictions. An analysis of the trends for 1990-2003 allows us to formulate conjectures about the state of the world in 2015, if the current trends with regard to the main MDGs were to continue. These projections do not rest on regional averages, but on national data which offer a more precise overview of the current trend. However, the trends do not lead to an inevitable scenario. They can be improved or worsened by choices of public policy, as well as by external factors on which the governments have little influence. **To examine the past in order to anticipate the future may make it possible, nevertheless, to call public attention to a possible scenario.**

Some caveats are in order concerning our analysis of the trends. For many countries and for several goals, no reliable data is available. Thus, chronological data on education are missing for 46 countries, for instance. There are also problems related to the tendency to examine the points one by one according to the relevant goal. The progress made in one field depends largely on the progress achieved in other fields, with multiplier effects on the various goals, such as related to impact of health on education. Finally, certain factors are likely to hamper progress; in particular, those which may be regarded as systemic threats are difficult to anticipate.

Among the summary observations which emerge from our analysis of the trends, we may mention the following:

- 50 countries, counting a total of about 900 million inhabitants, report a time-lag with respect to at least one MDG. Twenty four of them are located in sub-Saharan Africa;
- 65 other countries, counting a population of 1.2 billion inhabitants, will not be able to reach at least one MDG before 2040, which represents a whole generation;
- according to current trends, the States would manage to reduce infant mortality by two thirds only in 2045, i.e. with a time-lag of 31 years. To achieve the MDGs, an average annual reduction of 2.7% of the incidence of infant mortality is necessary. This rate corresponds to twice the rate reported between 1990 and 2002.

▸▸▸ Child and mother health: Millions of children condemned to die

- over 45 % of infant deaths (4.9 million in total) take place in 52 countries where the reduction of infant mortality expresses a decline or a slack progress. Children born in these countries today, and which live until adulthood, will see little improvement with regard to chances of survival of their own children;
- according to current trends, **sub-Saharan Africa would achieve the MDGs only in 2115**, that is with one century of delay. The two poles of infant mortality in this region are the Democratic Republic of Congo, where conditions are deteriorating, and Nigeria. The infant mortality rate of Nigeria has fallen from 235 per 1000 living births to 198 per 1000 since 1990. At this rate, it would take this country 40 years to reach the relevant MDG.

Two thirds of infant deaths occur in 13 country, of which only two (Bangladesh and Indonesia) are on the way of achieving the MDG. Four other countries (China, India, **Niger** and Pakistan) would achieve this goal between 2015 and 2040. The others (in particular Afghanistan, Angola, and the Democratic Republic of Congo, Ethiopia, **Nigeria**, Tanzania and Uganda) have more than one generation of delay or are regressing.

▸▸▸ Water and sanitation: Over a billion people are deprived of the

Progress in matter of access to water and sanitation will have a significant impact on child mortality. The goal which consists in reducing by a half the number of persons deprived of access to better quality water will not be achieved, thus affecting 210 million persons. Besides, over two billion persons will still be deprived of access to better sanitary conditions in 2015. **Sub-Saharan Africa is the region most adversely affected by this delay.**

▸▸▸ Reducing by a half the rates of extreme poverty and malnutrition depends on growth and distribution

About 800 million people would live on less than one dollar per day and 1.7 billion people on less than two dollars per day in 2015. The incidence of poverty measured by the "one dollar per day" threshold would decrease from the current 21% to 14% in 2015. The distribution of poverty according to the regions would also change. **The share of sub-Saharan Africa in the poverty measured by the threshold of one dollar per day would experience a rapid increase from the current 24% to 41% in 2015**.

The growing weight of sub-Saharan Africa in world poverty up to 2015 is the reflection of a weak growth since 1990, to which is added a particularly unequal distribution of income. To achieve the MDG in 2015, the region must reach an annual per capita growth rate of about 5% during the next decade, which is hardly possible.

▸▸▸ Education: Failure of schooling for al

Education is an end in itself in matter of human development and a key to progress in other fields. The pledge to ensure schooling for all children and to bridge the gender disparities in matter of education stands as symbol for the immense hope to break the vicious circle of inter-generation transmission of poverty. If the current trends continue:

- the goal of establishing universal primary education by 2015 will not be achieved before at least another decade. **Forty seven (47) million children would not be provided with education by 2015, of which 19 million in sub-Saharan Africa**.
- 46 countries are lagging behind in this field or will not achieve this MDG before 2040. Of the 110 million non schooled children, 23 million live in developing countries.

▸▸▸ Gender equality and woman participation: A MDG already missed

By 2015, the gap related to the gender equality goal would amount to 6 million non schooled girls, most of whom in sub-Saharan Africa. In the 41 countries where 20 millions girls are currently not schooled, the gender gap either increases or is narrowed so slowly that gender equality could not be achieved before 2040.

In fine,

International assistance is a most effective means of poverty reduction. As of now, it is under-utilized, badly targeted and must be revisited. **A reform of the international aid system is a key requirement to get back on course with regard to the Millennium Development Goals**.

Assistance is sometimes perceived in the rich countries as a one way act of charity. This view misses the right issue. In a world of interdependent risks and chances, threats and opportunities, aid constitutes an investment and a moral obligation, an investment in shared prosperity, collective security and a common future. The absence of investment on a sufficient scale today will incur costs tomorrow.

Development aid is at the heart of the new partnership for development instituted by the Millennium Declaration. As in any partnership, each of the parties has responsibilities and duties. The developing countries must create an environment in which aid can lead to optimal results. On their part, the rich countries must keep their commitments.

There are three requirements for effective assistance:

- firstly, **it must be provided in sufficient quantity to sustain a takeoff of human development**. It provides the governments with the means to invest in health, education and economic infrastructure in order to break the cycles of deprivation and sustain recovery; these means must be commensurate with the financing necessary;
- secondly, **assistance must be provided on a predictable, less costly and profitable basis**;
- thirdly, in order to be effective, **assistance must be a matter of «ownership»**. Developing countries, thus, assume primary responsibility in creating the conditions under which assistance can lead to optimal results. While progress has been reported in terms of quantitative increase and qualitative improvement of assistance, none of these conditions has, however, been met as yet.

When the Millennium Declaration was signed, the development aid basket was three quarters empty and there was a hole at the bottom of it.

HDI rank	Human development index (HDI) value 2003	Expectancy at birth (years) 2003	Adult literacy rate (% ages 15 and above) 2003	Combined gross enrolment ratio for primary, secondary and tertiary schools (%) 2002/03	GDP per capita (PPP US$) 2003	Life Expectancy index	Education index	GDP index	GDP per capita (PPP US$) rank minus HDI rank
1 Norway	0,963	79,4	..	101	37670	0,91	0,99	0,99	2
10 USA	0,944	77,4	..	93	37562	0,87	0,97	0,99	-6
20 Germany	0,930	78,7	..	89	27756	0,90	0,96	0,94	-6
63 Brazil	0,792	70,5	88,4	91	7790	0,76	0,89	0,73	1
127 India	0,602	63,3	61,0	60	2892	0,64	0,61	0,56	-9
158 Nigeria	0,453	43,4	66,8	64	1050	0,31	0,66	0,39	2
174 Mali	0,333	47,9	19,0	32	994	0,38	0,23	0,38	-10
177 Niger	0,281	44,4	14,4	21	835	0,32	0,17	0,35	-8

Table 14 : Human development index (HDI) (UNDP, 2005)

HDI rank	1975	1980	1985	1990	1995	2000	2003
1 Norway	0,868	0,888	0,898	0,912	0,936	0,956	0,963
10 USA	0,867	0,887	0,901	0,916	0,929	0,938	0,944
20 Germany	..	0,861	0,869	0,888	0,913	0,927	0,930
63 Brazil	0,645	0,682	0,698	0,719	0,747	0,783	0,792
127 India	0,412	0,438	0,476	0,513	0,546	0,577	0,602
158 Nigeria	0,318	0,376	0,386	0,406	0,418	..	0,453
174 Mali	0,253	0,273	0,297	0,305	0,311	0,328	0,317
177 Niger	0,236	0,252	0,242	0,249	0,256	0,271	0,281

Table 15 : Human development index trends (UNDP, 2005)

HDI rank	Human poverty index (HPI-1)		Probability at birth of not surviving to age 40 (% of cohort) 2000-2005	Adult illiteracy Rate (% ages 15 and above) 2003	Population without sustainable access to an improved water source (%) 2002	MDG Children under weight for age (% under age 5) 1995-2003	MDG Population below income poverty line (%)			HPI-1 rank minus income poverty rank
	Rank	Value (%)					$ 1 a day 1990-2003	$ 2 a dayr 1990-2003	National poverty line 1990-2002	
63 Brazil	20	10,3	10,3	11,6	11	6	8,2	22,4	17,4	-5
127 India	58	31,3	16,6	39,0	14	47	34,7	79,9	28,6	-12
158 Nigeria	75	38,8	46,0	33,2	40	29	70,2	90,8	34,1	-19
174 Mali	101	60,3	37,3	81,0	52	33	72,3	90,6	63,8	-2
177 Niger	103	64,4	41,4	85,6	54	40	61,4	85,3	63,0	4

TABLE 16 : Human and income poverty: developing countries (UNDP, 2005)

HDI rank	Total population (in millions)			Annual demographic growth rate (%)		Urban population (in % of total)			Population aged less than 15 years (in % of total)		Population aged 65+ years (in % of total)		Total fertility rate (births per woman)	
	1975	2003	2015	1975-2003	2003-2015	1975	2003	2015	2003	2015	2003	2015	1970-1975	2000-2005
1 Norway	4,0	4,6	4,8	0,5	0,5	68,2	78,6	86,4	19,9	17,5	13,3	17,5	2,2	1,8
10 USA	220,2	292,6	325,7	1,0	0,9	73,7	80,1	83,6	21,1	19,7	10,7	14,1	2,0	2,0
20 Germany	78,7	82,6	82,5	0,2	(.)	81,2	88,1	90,0	14,8	12,9	15,0	20,7	1,6	1,3
63 Brazil	108,1	181,4	209,4	1,8	1,2	61,2	83,0	88,4	28,4	25,4	4,9	7,8	4,7	2,3
127 India	620,7	1,070,8	1,260,4	1,9	1,4	21,3	28,3	32,2	32,9	28,0	4,1	6,2	5,4	3,1
158 Nigeria	58,9	125,9	160,9	2,7	2,0	23,4	46,6	55,5	44,7	41,3	2,4	3,2	6,9	5,8
174 Mali	6,2	12,7	18,1	2,6	2,9	16,2	32,3	40,9	48,3	46,7	2,2	2,4	7,6	6,9
177 Niger	5,3	13,1	19,3	3,2	3,3	10,6	22,2	29,7	49,0	47,9	1,6	2,0	8,1	7,9

TABLE 17 : Demographic trends (UNDP, 2005)

HDI rank	Health expenditure			MDG One-year-olds fully immunized against		Children with diarrhea receiving oral rehydration and continued feeding (% under age 5) 1994–2003	Contraceptive Prevalence rate (%) 1995–2003	MDG Births attended by skilled health personnel (%) 1995–2003	Physicians (per 100,000 people) 1990–2004
	Public (% of GDP) 2002	Private (% of GDP) 2002	Per capita (PPP US$) 2002	tuberculosis (%) 2003	measles (%) 2003				
1 Norway	8,0	1,6	3409	..	84	..	74	100	356
10 USA	6,6	8,0	5274	..	93	..	76	99	549
20 Germany	8,6	2,3	2817	..	92	..	75	100	362
63 Brazil	3,6	4,3	611	99	99	28	77	88	206
127 India	1,3	4,8	96	81	67	22	48	43	51
158 Nigeria	1,2	3,5	43	48	35	28	13	35	27
174 Mali	2,3	2,2	33	63	68	45	8	41	4
177 Niger	2,0	2,0	27	64	64	43	14	16	3

Table 18 : Commitment to health: resources, access and services (UNDP, 2005)

HDI rank	MDG Population with sustainable access to improved sanitation (%)		MDG Population with sustainable access to an improved water source (%)		MDG Population undernourished (% of total)		MDG Children under weight for age (% under age 5)	Children under height for age (% under age 5)	Infants with low birth-weight (%)
	1990	2002	1990	2002	1990/1992	2000/2002	1995–2003	1995–2003	1998–2003
1 Norway	..	..	100	100	..	..	..	..	5
10 USA	100	100	100	100	..	..	1	2	8
20 Germany	..	..	100	100	..	..	..	..	7
63 Brazil	70	75	83	89	12	9	6	11	10
127 India	12	30	68	86	25	21	47	46	30
158 Nigeria	39	38	49	60	13	9	29	38	14
174 Mali	36	45	34	48	29	29	33	38	23
177 Niger	7	12	40	46	41	34	40	40	17

Table 19 : Water, sanitation and nutritional status (UNDP, 2005)

HDI rank	HIV prevalence (% ages 15–49)	MDG Condom use at last high-risk sex (% ages 15–24)		MDG Malaria cases (per 100,000 people)	MDG Children under age 5		MDG Tuberculosis case			Prevalence of smoking (% of adults)	
	2003	Women (%) 1998–2003	Men 1998–2003	2000	With insecticide treated bednets (%) 1999–2003	With fever treated with anti-malarial drugs (%) 1999–2003	Per 100,000 People 2003	Detected under DOTS (%) 2003	Cured Under DOTS (%) 2003	Women 2000–2002	Men 2000–2002
1 Norway	0,1 [0,0–0,2]	..	..	..	..	..	5	46	80	32	31
10 USA	0,6 [0,3–1,1]	..	..	..	..	..	3	89	70	21	26
20 Germany	0,1 [0,1–0,2]	..	..	..	..	..	7	55	69	31	39
63 Brazil	0,7 [0,3–1,1]	..	..	344	..	..	91	18	75	27	35
127 India	[0,4–1,3]	51	59	7	..	..	287	47	87	..	..
158 Nigeria	5,4 [3,6–8,0]	24	46	30	1	34	518	18	79	..	..
174 Mali	1,9 [0,6–5,9]	14	30	4008	8	38	582	18	50		
177 Niger	1,2 [0,7–2,3]	7	30	1 693	6	48	272	54	..	..	

Table 20 : Leading global health crises and risks (UNDP, 2005)

HDI rank	Public expenditure on education									
	As % of GDP		As % of total government expenditure		Pre-primary and primary		Secondary		Tertiary	
	1990	2000–2002	1990	2000–2002	1990	2000–2002	1990	2000–2002	1990	2000–2002
1 Norway	7,0	7,6	14,6	16,2	39,5	36,5	24,7	33,0	15,2	27,5
10 USA	5,1	5,7	12,3	17,1	..	39,5	..	35,3	..	25,2
20 Germany	..	4,6	..	9,5	..	22	..	49,0	..	24,5
63 Brazil	..	4,2	..	12,0	..	38,3	..	40,1	..	21,6
127 India	3,7	4,1	12,2	12,7	38,9	38,4	27,0	40,1	14,9	20,3
158 Nigeria	0,9	..	..	..	..	..	..	..	..	..
174 Mali	..	..	..	..	..	..	..	..	..	..
177 Niger	3,2	2,3	18,6	..	..	51,5	..	24,4	..	..

Table 21 : Commitment to education: public spending (UNDP, 2005)

HDI rank	Adult literacy rate (% ages 15 and above)		MDG Youth literacy rate (% ages 15–24)		MDG Net primary enrolment ratio (%)		Net secondary enrolment ratio (%)		MDG Children reaching grade 5 (% of grade 1 students)		Tertiary students in science, math and engineering (% of all tertiary students)
	1990	2003	1990	2003	1990-1991	2002-2003	1990-1991	2002-2003	1990-1991	2001-2002	1998-2003
1 Norway	..	..	..	..	100	100	88	96	100	100	18
10 USA	..	..	..	..	97	92	85	88	..	..	..
20 Germany	..	..	..	..	84	83	..	88	..	..	29
63 Brazil	82,0	88,4	91,8	96,6	86	97	15	75	..	..	..
127 India	49,3	61,0	64,3	76,4	..	87	..	..	..	84	20
158 Nigeria	48,7	66,8	73,6	88,6	60	67	..	29	..	..	..
174 Mali	18,8	19,0	27,6	24,2	20	45	5	..	73	75	..
177 Niger	11,4	14,4	17,0	19,8	24	38	6	6	62	69	..

TABLE 22 : Literacy and enrolment (UNDP, 2005)

HDI rank	GDP		GDP per capita		GDP per capita				Average annual change in consumer price index (%)	
	US$ billions	PPP US$ billions	US$	PPP US$	Annual growth rate (%)		Highest value during 1975–2003 (PPP US$)	Year of highest value		
	2003	2003	2003	2003	1975–2003	1990–2003			1990–2003	2002–2003
1 Norway	220,9	171,9	48412	37670	2,8	2,9	37911	2001	2,3	2,5
10 USA	10948,5	10923,4	37648	37562	2,0	2,1	37562	2003	2,6	2,3
20 Germany	2403,2	2291,0	29115	27756	2,0	1,3	27769	2001	1,8	1,0
63 Brazil	492,3	1375,7	2788	7790	0,8	1,2	7918	2002	114,0	14,7
127 India	600,6	3 078,2	564	2 892	3,3	4,0	2 892	2003	7,9	3,8
158 Nigeria	58,4	143,3	428	1050	-0,5	(.)	1086	1977	26,0	14,0
174 Mali	4,3	11,6	371	994	(.)	2,4	995	2002	4,3	-1,3
177 Niger	2,7	9,8	232	835	-1,8	-0,6	1383	1979	5,0	-1,6

TABLE 23 : Economic performance (UNDP, 2005)

HDI rank	Imports of goods and services (% of GDP)		Exports of goods and services (% of GDP)		Primary exports (% of merchandise exports)		Manufactured exports (% of merchandise exports)		High-technology exports (% of manufactured exports)		Terms of trade (1980=100)
	1990	2003	1990	2003	1990	2003	1990	2003	1990	2003	2002
1 Norway	34	28	4	41	67	74	33	21	12	19	71
10 USA	11	14	10	10	22	16	74	80	33	31	119
20 Germany	25	32	25	36	10	9	89	84	11	16	117
63 Brazil	7	13	8	17	47	47	52	52	7	12	145
127 India	9	16	7	14	28	22	71	77	2	5	131
158 Nigeria	29	41	43	50	..	..	..	..	..	..	28
174 Mali	34	31	17	26	..	59	2	40	..	8	95
177 Niger	22	25	15	16	..	91	..	8	..	3	..

Table 24 : The structure of trade (UNDP, 2005)

HDI rank	Official development assistance (ODA) received (net disbursements)				Net foreign direct investment inflows (% of GDP)		Other private flows (% of GDP)		MDG Total debt service			
	Total (US$ millions)	Per capita (US$)	As % of GDP						As % of GDP		As % of exports of goods, services and net income from abroad	
	2003	2003	1990	2003	1990	2003	1990	2003	1990	2003	1990	2003
1 Norway												
10 USA												
20 Germany												
63 Brazil	296,0	1,7	(.)	0,1	0,2	2,1	-0,1	0,7	1,8	11,5	18,5	38,6
127 India	942,2	0,9	0,4	0,2	0,1	0,7	0,5	1,1	2,6	3,4	29,3	18,1
158 Nigeria	317,6	2,3	0,9	0,5	2,1	2,1	-0,4	-0,4	11,7	2,8	22,3	..
174 Mali	527,6	45,3	19,9	12,2	0,2	3,0	(.)	0,0	2,8	1,8	14,7	5,8
177 Niger	453,3	38,5	16,0	16,6	1,6	1,1	0,4	-0,3	4,0	1,2	6,6	6,4

Table 25 : Flows of aid, private capital and debt (UNDP, 2005)

HDI rank	Public expenditure on education (% of GDP)		Public expenditure on health (% of GDP)		Military expenditure (% of GDP)		Total debt service (% of GDP))	
	1990	2000–2002	1990	2002	1990	2003	1990	2003
1 Norway	7,0	7,6	8,0	8,0	2,9	2,0		
10 USA	5,1	5,7	6,6	6,6	5,3	3,8		
20 Germany	..	4,6	8,6	8,6	2,8	1,4		
63 Brazil	..	4,2	3,6	3,6	2,5	1,6	1,8	11,5
127 India	3,7	4,1	1,3	1,3	2,7	2,1	2,6	3,4
158 Nigeria	0,9	..	1,2	1,2	0,9	1,2	11,7	2,8
174 Mali	..	..	2,3	2,3	2,1	1,9	2,8	1,8
177 Niger	3,2	2,3	2,0	2,0	..	..	4,0	1,2

Table 26 : Priorities in public spending (UNDP, 2005)

HDI rank	Traditional fuel consumption (% of total energy requirements)	Electricity consumption per capita (kilowatt-hours)		MDG GDP per unit of energy use (2000 PPP US$ per kg of oil equivalent)		MDG Carbon dioxide emissions Per capita (metric tons)		MDG Carbon dioxide emissions Share of world total (%)	Ratification of environmental treaties: Cartagena Protocol on Biosafety	Framework Convention on Climate Change	Kyoto Protocol to the Framework Convention on Climate Change	Convention On Biological Diversity
	2002	1980	2002	1980	2002	1980	2002	2000				
1 Norway	..	22400	26640	4,6	6,1	10,6	12,2	0,2	●	●	●	●
10 USA	3,6	10336	13 456	2,8	4,4	20,0	20,1	24,4		●	●	●
20 Germany	..	..	6 989	3,9	6,2	..	9,8	3,4	●	●	●	●
63 Brazil	26,7	1145	2183	7,4	6,8	1,5	1,8	1,3	●	●	●	●
127 India	20,0	173	569	3,3	5,0	0,5	1,2	4,7	●	●	●	●
158 Nigeria	46,4	108	148	1,4	1,3	1,0	0,4	0,2	●	●	●	●
174 Mali	85,0	15	33	..	..	0,1	(.)	(.)	●	●	●	●
177 Niger	85,3	39	40	..	..	0,1	0,1	(.)	●	●	●	●

Table 27 : Energy and the environment (UNDP, 2005)

Iullemeden Aquifer System

Volume I – Transboundary Diagnostic Analysis

The Transboundary Diagnostic Analysis approach, advocated by the GEF for International Waters, was applied to the water resources of the Iullemeden Aquifer System. It is a first on the African continent.

It is an objective assessment of scientific and technical facts based mainly on using the best information available and checked. It is made of trans-sectional manner, focusing on transboundary issues without ignoring national concerns and priorities. The TDA is used to determine the relative importance of the sources, causes and impacts on transboundary issues in water. Its objectives are:

- to identify, to quantify and to set priorities for environmental problems that are transboundary in nature;
- to identify their immediate, underlying and root causes.

The main steps of the TDA are: 1) the analysis of impacts and consequences of each transboundary issue, 2) the final prioritization of transboundary issues, 3) the causal chain analysis and governance analysis, 4) the production and the adoption of the full document of the ADT by the Steering Committee.

Through TDA, three major transboundary risks have been identified: (a) the decrease of the water resource, (b) the degradation of water quality, and (c) the impacts of climate variability / change. This activity obviously required the development of a database of more than 17 200 water points, a Geographic Information System and a mathematical model. This mathematical model, among others, highlighted the overexploitation since 1995 and an interconnection between the Niger River and groundwater.

In the interest of good governance of this common strategic resource, countries have adopted a Memorandum of Understanding to establish a legal and consultative framework for joint management and for rational and equitable exploitation

- Volume II: Common database
- Volume III: Hydrogeological Model
- Volume IV: Participatory management of transboundary risks
- Volume V: Monitoring & Evaluation of transboundary aquifers

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