A PLATFORM FOR STAKEHOLDERS IN AFRICAN FORESTRY

FOREST-WATER RELATIONS IN THE SAHEL

AFRICAN FOREST FORUM WORKING PAPER SERIES

VOLUME 1

ISSUE 7, 2011

 African Forest Forum P.O. Box 30677 00100 Nairobi GPO KENYA Tel: +254 20 7224203 Fax: +254 20 722 4001 Website: www.afforum.org

Citation: Tougiani, A. 2011. Forest–Water Relations in the Sahel. African Forest Forum, Working Paper Series, Vol. (1)7, 36 pp.

Cover photo: The African Forest Forum

Forest–Water Relations in the Sahel

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Acronyms and abbreviations

ABN	Autorité du Bassin du Niger
ABV	Autorité du Bassin de la Volta
AUE	Associations des Utilisateurs d'Eau
CBLT	Commission du Bassin du Lac Tchad
CILSS	Comité Inter-Etats de Lutte contre la Sécheresse au Sahel
DTP	Diagnostic Transfrontière Préliminaire
ET	Evapotranspiration
GIBV	Gestion Intégrée de l'eau par Bassin Versant
GPF	Gestion Participative des Forêts
IWRM	Integrated Water Resources Management
NED	Northern Electricity Department, Ghana
NEPAD	New Partnership for Africa's Development
OERS	Organisation des Etats Riverains du Sénégal
OMVG	Organisation pour la Mise en Valeur du fleuve Gambie
OMVS	Organisation pour la Mise en Valeur du fleuve Sénégal
OSS	Observatoire du Sahara et du Sahel
PAS	Programme d'Action Stratégique
PEI	Producteurs d'Energie Indépendants
SOGED	Société de Gestion et d'Exploitation du Barrage de Diama
UNEP	United Nations Environment Programme
VRA	Autorité du Fleuve Volta

Foreword

The Sahel region is endowed with a lot of water resources from rivers, permanent water ponds and rich aquifers. These water resources are interconnected with forest resources either at national or sub-regional levels and control the productive capacity and the livelihoods of the populations. In the Sahel the most important watersheds and river basins are the Niger River basin, the Lake Chad watershed, the Senegal River basin, the Gambia River Basin and the Volta River Basin. Each country of the sub-region shares international water with its related forest ecosystems. A basic weakness in all the river basin commissions or authorities is a lack of political will. The compelling evidence of the degradation of most of the rivers and their basins, and the urgency of the need for restoration, has stimulated member countries to muster some political will to cooperate. Most of the policies and institutions required to prevent environmental degradation, and promote sustainable development, are similar throughout the sub-region and a number of community projects are ongoing or planned in which stakeholders are involved at various stages.

As part of its contribution to managing the African forests sustainably, as well as generating and sharing knowledge and information for sustainable forest management, the African Forest Forum commissioned a study on the broad area of forest–water relations, covering the Sahelian region. The issues addressed in this study include: the extent of shared commitment to and desire to promote synergy and strengthen cooperation of the member states on water, water issues in the sub-region, water supply in the region as related to forest ecosystems, learning and sharing of experiences and best practices, potential for collaboration in managing and using water resources and related forest ecosystems in the sub-region. This was essentially a desk study primarily aimed at identifying the major water resources in the sub-region, how they are linked to various forest ecosystems that serve as water catchment forests, and challenges and opportunities in managing these forests to improve supply of quality water to the sub-region.

This report provides a modest initial step in this direction, by highlighting key aspects related to the link between these two resources, as well as some issues that could be addressed by various stakeholders including researchers, local communities and policy makers. The report has been made possible through collaborative efforts of the African Forest Forum and Dr. Abasse Tougiani was responsible for writing this report.

Prof. Godwin Kowero

Executive Secretary, African Forest Forum.

Executive Summary

Forests are significantly important to a large part of Africa because they support the livelihood of millions of people. The Sahel region is endowed with a lot of water resources from rivers, permanent water ponds and rich aquifers but it has been seriously disturbed in the past decades by droughts and other climatic effects. These water resources are interconnected with forest resources either at national or sub-regional levels and control the productive capacity and the livelihoods of the populations. In the Sahel the most important watersheds and river basins are the Niger River basin, the Lake Chad watershed, the Senegal River basin, the Gambia River Basin and the Volta River Basin. Each country of the sub-region shares international water with its related forest ecosystems.

A basic weakness in all the river basin commissions or authorities is a lack of political will. The compelling evidence of the degradation of most of the rivers and their basins, and the urgency of the need for restoration, has stimulated member countries to muster some political will to cooperate. Most of the policies and institutions required to prevent environmental degradation, and promote sustainable development, are similar throughout the sub-region and a number of community projects are ongoing or planned in which stakeholders are involved at various stages. The member countries need enabling legislation to guide integrated and sustainable water utilization and management as well as the associated ecosystems. The financing strategies should not only rely on one country or donor. Poor coordination is the most critical managerial problem confronting the river basins and their national components. There is lack of coordination at the national level between the various tiers of governments, the private sector and the organized civil society for the river basins in the sub-region. The serious climatic problems facing the Sahel have led governments to react differently with variable results (cropping out of season through irrigation, in investments in water use and availability, more efforts are put on legislative and institutional aspects to combat drought).

Each of the main trans-boundary rivers and Lakes of West Africa has its own basin authority to conduct necessary investments for the development and the coordination of interventions of neighbouring countries (i.e. the Niger Basin Authority (ABN), the Lake Chad Basin Commission (CBLT), the Gambia River Basin Organization (OMVG), the Senegal River Basin Organization (OMVS), the Volta River Basin Authority (ABV).

Available water resource statistics of the countries contain discrepancies (differences in reference times, differences of approach in regionalization of flow, etc.) and must therefore be used with caution.

The main challenges for Sahelian countries sharing water resources are: provision of water for consumption and for food production, protection of vital ecosystems, spatio-temporal water variability, droughts and floods risk management, sensitization of public opinion. A

precise and complete knowledge of the present uses of water by all of the economic sectors is necessary if future demand is to be determined and if resource management guidelines are to be developed. This knowledge is however still imperfect and has discrepancies due to statistics based more on estimations, or statistics based on few historical records, lack of synchronism, non availability of macro-economic statistics on the weight of the water sector, etc.). Efforts to improve the knowledge and usage of data are particularly necessary in the countries where the management of water must and should increasingly combine the management of demand of the resources.

The structure of water uses is quite uniform in the Sahel with two major sectors (irrigation demand with 86% of all water used, community drinking water supply), the industrial demand being minor. It is primarily between these two sectors that conflicts of use are likely to arise. The sources of conflicts over water sources are mainly due to uses and other conflicting interests (upstream/downstream usage, interference of ground- and surface water uses, traditional and modern exploitation, geopolitical constraints and rivalries, short and long term development objectives, etc.). With regard to climatic change and variability and their impacts on the water resources, one of the main common constraints in the Sahelian countries is the lack of knowledge and information on the resources (non availability of hydrologic and hydro-geologic data in quantity and quality, lack of equipment to collect and archive, absence and/or weakness of research and systematic observation institutions, few national expertise on vulnerability, adaptation and mitigation of climate change impacts).

The adaptability of management structures should also extend to non-signatory riparian countries (i.e. those within the same hydrological system) by incorporating provisions that address their needs, rights and potential accession. The focus of the emerging culture is water sharing, such as the Integrated Water Resources Management (IWRM) that seeks more effective and equitable management of water through increased cooperation. Bringing together institutions dealing with surface water and aquifer resources, calling for new legislative agreements worldwide, raising public participation, and exploring alternative solutions to resolving disputes should all be part of the process. Integrated Water Resources Management must take place within institutional environments conducive to its development.

It has been experienced in past years a decrease in water flows in various rivers of the Sahel as well as the drying up of some permanent water ponds. In agriculture, much of expected increase in food production is from semi-arid areas and rain fed agriculture. Increasing efficiency in cultivation systems may shift losses in evaporation to productive transpiration. There is need for fundamental process knowledge about rainfall partitioning in forest ecosystems to be able to elaborate on effects of forestry applications. For better efficiency of biomass productivity, forestry itself needs to develop in the understanding of

multispecies systems or intensively managed multi-species plantations in general which have been shown by meta-analysis to be more productive than monospecific plantations.

Key watersheds and river basins (cited above) and associated ecosystems face the following problems: degradation of vegetation cover and soils, degradation of water resources, degradation of wetlands biological diversity and the spreading of aquatic plants. These problems, even though localized, will extend and accentuate rapidly due to the high increase of dams construction, intensification of irrigated agriculture, increase of human and animal population as well as industrial development along the rivers.

Integrated water management in the basin involves different issues relevant to national authorities of each country, such as monitoring, planning, coordination of different uses, institutional and legal aspects and financing of water related projects. Lack of cooperation may lead to conflicts and disputes that may aggravate the problems and delay sustainable socio-economic development in the region.

In terms of way forward in forest-water relations in the Sahel, the followings instruments need to be considered and applied in the implementation of programs and activities in the sub-region:

- institutional means (adaptation of water laws and regulations governing intervention and arbitration of government authorities, creation of inter-sectorial coordinating organizations or authorities at the government or local level, creation of consultative or deliberative institutions grouping the various public and private participants involved in the management of a given resource unit
- technical means (saving water and reducing losses, improving irrigation efficiency, increasing output of treatment plants and promoting reuse of wastewater)
- economic and financial means (macro-economic criteria to determine allocation of resources, market mechanisms, price policies, the ‘polluter- payer’ principle)
- educational and information means (consciousness-raising , integrated water management)
- forest-water research needs in the Sahel (evaluation of the overall hydrologic response to forestation, studying forest-water relations at the watershed scale, computer modelling to effectively examine individual hydrologic process and separating the roles of various factors, fully understanding the role of land-cover change on the water cycles)

CHAPTER 1 Introduction

PROMOTING SYNERGY AND STRENGTHENING COOPERATION OF MEMBER STATES ON WATER

Forests are significantly important to a large part of Africa because they support the livelihood of millions of people (Campbell et al. 2007). Sahelian countries of West Africa (Figure 1) are known to have been seriously disturbed in the past decades by droughts and other climatic effects. This situation is mainly due to the positive relation or trade-off between plant (forest) production and water available for other uses. Projected water demand and supply for Africa is problematic for many of the countries in the Sahel, such as Niger, Senegal, and Burkina Faso (Figure 2). Most of these countries have a dependence factor greater than 40%. The negative impacts are on the productive systems, like forests and ground water reserves. Notwithstanding, the Sahel region is endowed with a lot of water resources from rivers, permanent water ponds and rich aquifers. These water resources are interconnected with forest resources either at national or sub-regional levels and control the productive capacity and the livelihoods of the populations.

Revenga et al. (1998) defined a watershed or river basin as the entire area drained by a major river system or by one of its main tributaries. Often extending across one or more international boundaries, watersheds play a critical role in the natural functioning of the Earth. In the Sahel the most important watersheds and river basins are the Niger River basin, the Lake Chad watershed and the Senegal River basin.

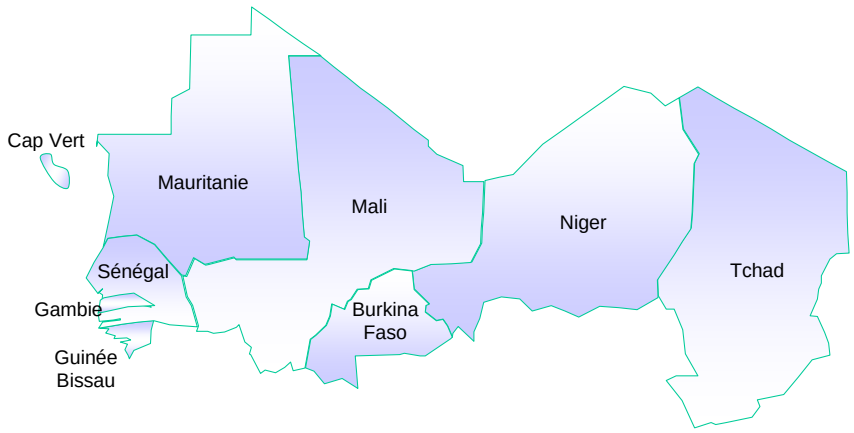

Figure 1: Sahelian countries of West Africa

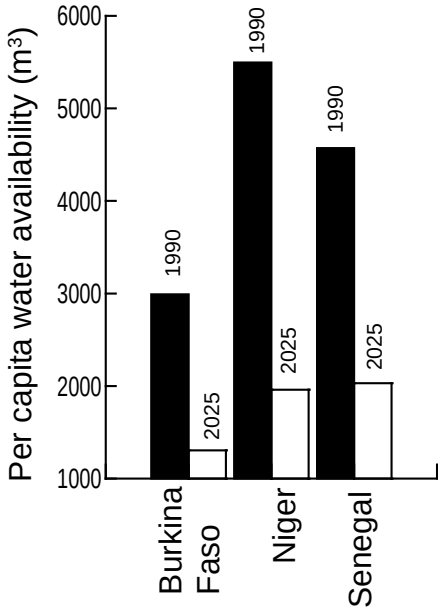

Figure 2: Water availability in 1990 and projected availability for 2025 in three Sahelian countries.
Based on UNEP (1999).

These rivers link many countries and express the interdependence of West African countries regarding the use and the management of water resources (Neisse, 2004). Another expression of this dependence is that the main water sources of the region are shared among many countries: Niger river (9 countries in which Algeria could be added even though it belongs to the non-active part of the hydrographic basin), Senegal River (4 countries), Volta River (6 countries), lake Chad (5 countries), Gambia River (4 countries), Comoe River (3 countries). Thus, with the exception of Cape Verde, each country of the sub-region shares international water with its related forest ecosystems.

EXTENT OF SHARED WATER RESOURCES

The major shared river basins in the Sahel of West Africa include the Niger basin, Lake Chad basin, Volta and Senegal basin (Figure 3).

Niger River

The Niger River is 4,200 km long (3rd in Africa and 9th in the world), drains 2,100,000 km² land area (3rd of the land area of the whole West Africa). The topographic basin is shared among Algeria, Benin, Burkina Faso, Cameroun, Côte d'Ivoire, Guinea, Mali, Niger, Nigeria and Chad. The hydrological active part of the basin covers 1,500,000 km² in nine countries, excluding Algeria. The water potential of this river is not sufficiently exploited but important projects on development and commercialization of its resources as well as for rehabilitation and construction of dams along the river are planned in the long and medium terms.

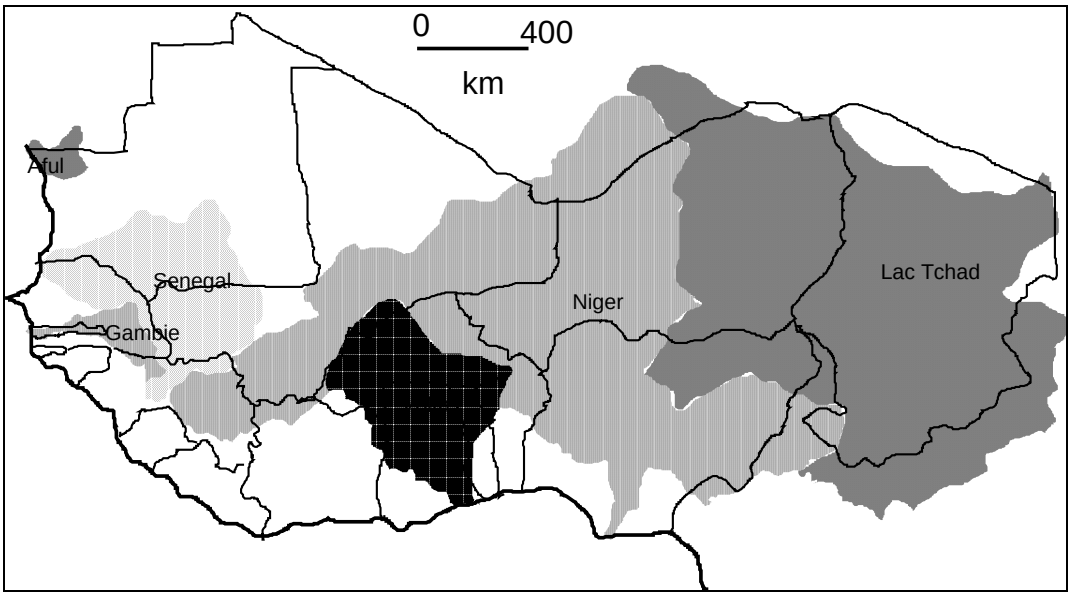

Figure 3: Major river basins in the Sahel of West Africa.

Senegal River

The Senegal River is the second longest river (1,800 km-long) of this sub-region, and its main tributaries (Baring, Bakoye and Aflame Rivers) have their source in the Fouta Djallon Mountains (Guinea). The Senegal River basin is shared by Guinea (31,000 km^2), Mali (155,000 km^2), Mauritania (75,500 km^2) and Senegal (27,500 km^2) and has three distinct parts:

1) the upper basin which is mountainous,
2) the valley and
3) the delta which is rich in biological diversity and wetland habitats.

Topographical, hydrographic and climatic conditions are very different in these three regions and seasonal temperature variations are high.

Gambia River

The Gambia River is 1,130 km long and runs from the Fouta Djallon plateau in north Guinea westward to the Atlantic Ocean at the city of Banjul. It is navigable for about half that length. From the Fouta Djallon, the river runs northwest into the Tambacounda province of Senegal, where it flows through the Park National du Niokolo Koba, then joined by the NieriKo and Koulountou before entering The Gambia at Fatoto. At this point the river generally runs westwards but gradually widens to over 10 km wide where it meets the sea.

Volta River

This is the main river system of Ghana which is formed from the confluence of the Mouhoun (formerly Black Volta), the Nakambe (White Volta) and the Nazinon (Red Volta) headstreams. The Volta flows generally southward through Ghana, discharging into the Gulf of Guinea. Its major tributaries are the Afram and the Oti (Pandjari). The river system has a length of 1,600 km and a drainage basin of 398,000 km^2 with and an average annual discharge of 1,210 m^3 per second. Both of the river's two main upper branches, the Mouhoun and the Nakambe, rise in the open plateaus of Burkina Faso and unite in north-central Ghana.

Lake Chad

Lake Chad is located in the far west of Chad, bordering north-eastern Nigeria. The Chari River provides over 90% of Lake Chad's water, with a small amount coming from the Yobe River in Nigeria/Niger. Over half of the lake's area is taken up by its many small islands, reed beds and mud banks, and a belt of swampland across the middle divides the northern and southern halves while the shorelines are largely composed of marshes. It is economically very important because it provides water to more than 20 million people living in the four countries that surround it (Chad, Cameroon, Niger, and Nigeria) on the edge of the Sahara Desert.

It was one of the largest lakes in the world when first surveyed by Europeans in 1823 but it has shrunk considerably since then. In the 1960s it had an area of more than 26,000 km^2, making it the fourth largest lake in Africa. An increased demand on the lake's water from the local population has likely accelerated its shrinkage over the past 40 years. By 2000 its extent had fallen to less than 1,500 km^2. A 2001 study published in the Journal of Geophysical Research blamed the lake's retreat largely on overgrazing in the area surrounding the lake, causing desertification and a decline in vegetation.

LEARNING AND SHARING EXPERIENCES AND BEST PRACTICES

The following is a description of the lessons learnt in the management of shared water resources in the Sahel sub-region.

Political will

A basic weakness in all the river basin commissions or authorities is a basic evidence of ''super nationality''. In fact, a key factor of success achieved by some organizations is the preparedness of some member countries to be bound by decisions made by the regional

institutions. It is not a matter of getting a protocol or convention ratified that make such agreement works, but rather the degree to which it is binding on member States. Such a step depends on political will and commitments of the members to the regional organization and its goals.

The compelling evidence of the degradation of most of the rivers and their basins, and the urgency of the need for restoration, has stimulated member countries to muster some political will to cooperate. Moreover, within their limited resources, there is evidence of improved commitment by Member States to their financial obligations.

Need for sustainable institutions and effective stakeholder participation

Most of the policies and institutions required to prevent environmental degradation, and promote sustainable development, are similar throughout the sub-region. Stakeholder participation is being gradually encouraged. A number of community projects are ongoing or planned in which stakeholders are involved at various stages. In addition, there are water users associations (WUA) which manage rural water supplies and maintain the facilities while the governments assist in repairing major breakdowns. Such users associations are being streamlined and replicated for other activities, such as fisheries, livestock farming and crop farming in most of the member countries in the sub-region.

Legislative framework and financing strategies

Integrated river basin management requires an appropriate and effective legal framework, in order to achieve the desired goals. Most of the commissions or authorities in the sub-region are yet to accomplish this prerequisite. The member countries need enabling legislation to guide integrated and sustainable water utilization and management as well as the associated ecosystems.

The financing strategies should not only rely on one country or donor. Member countries are more committed to programmes in the various basins. External support agencies and donors as well as some national funding agencies could actively be involved either in supporting the national component or at sub-regional level. The commissions or authorities should continue to reach out both directly or through the New Partnership for Africa's Development (NEPAD) or the African Union and various potential donors. This mobilization of potential donors should be within a wider framework of multilateral support to member countries and the commissions or authorities in restoring water resources and ecosystems of global importance, an undertaking currently beyond the member countries or the sub-region.

Linking local, national, regional and international entities

Poor coordination is the most critical managerial problem confronting the river basins and their national components. The sub-basins are often granted limited autonomy, which produces artificial divisions and precludes basin-wide long term planning. Consequently, the project approach to development in the basins areas involves schemes developed in isolation of each other.

Policy

The policies that are in use in various river basins are kind of “laisser faire ones” which require review in order to sustainably manage the rivers for the benefit of present and future generation.

There is lack of coordination at the national level between the various tiers of governments, the private sector and the organized civil society for the river basins in the sub-region. There is need for the authorities of the basin countries to evolve necessary mechanisms for coordination, for listening to and consulting with various stakeholders to ensure effectiveness of awareness of and involvement in policy formulation, implementation, monitoring and decision-making. There is also a need for better environmental education at all levels.

Large scale irrigation

Large scale irrigation developments underutilize completed dams in various river basins. This is attributed to lack of proper management, as well as non-completion of downstream developments for which the dams were constructed. This problem often gives rise to insufficient waterflows to floodplains downstream of existing dams. Furthermore, government interventions in large-scale developments often disregard existing water users and continue to degrade the environment.

Key lessons have emerged from experiences in various countries with respect to domestic and industrial water supplies, including:

- water systems should respond to local demands and utilize appropriate technologies,
- community involvement in water and sanitation project planning is a crucial component of successful planning,
- governments should improve the efficiency and sustainability of system operation and maintenance, and
- water should be treated as an economic, ecologic and social good paid for by its users.

Ground water recharge

In the Sahel direct infiltration from rainfall through the non-saturated zone is usually very small. This is the case in the Lake Chad drainage basin where discharge into the shallow

groundwater is due mainly to infiltration from the water courses, floodplains, and from the edge of the lake. For example from a normal Lake Chad condition at 280 m altitude, it was estimated that the water volume removed annually from the lake via seepage is 8.8 billion m3 (i.e. 18 % of the mean annual water inflow into the lake).

Experiences and best practices

The serious climatic problems facing the Sahel have led governments to react differently with variable results. The followings are the political and institutional responses:

- At grassroots level, the climatic degradation has caused chronic food insecurity in rural areas. The population living along the rivers in the Sahel (Senegal, Niger and Komadougu Yobé valleys) have, during these hydro-climatic deficit periods, attenuated their food vulnerability by cropping out of season through irrigation in order to supplement the rainy season crop production (Magistro and Lo, 2001).
- In West Africa, there is an increase in investments in water use and availability:
    - small water adduction in the villages,
    - water boreholes in pasture lands,
    - more voluntary policy for the promotion of irrigated agriculture and
    - increase of investments in the dams.

The Sahel has to date 100 to 150 big dams (against 1300 for the whole Africa).

- At national level, more efforts are put on legislative and institutional aspects of water management leading to reforms in water sector that are supported by international institutions. Private sector was involved particularly in water distribution. This allowed many countries to enact their water codes (Senegal in 1981, Niger in 1998, Burkina Faso in 2001 and Mali in 2002).
- Also, at national level, Sahelian countries developed their strategies and national action plans (to combat drought) which were completed by sub-regional action plan to combat desertification.
- The establishment of the Permanent Inter-State Committee for drought control in the Sahel (CILSS) is also an answer at regional level to climatic variability and recurrent droughts. The Inter-State Committee for drought control in the Sahel was established in 1973 with the mission of devoting efforts towards achieving food security and combating the effects of drought and desertification for a new ecological balance.
- Each of the main trans-boundary rivers and Lakes of West Africa has its own basin authority to conduct necessary investments for the development and the coordination of interventions of riverine countries (Table 1).

- The Sahara and Sahel Observatory (OSS) was created in 1992 to help understand and manage the main trans-boundary aquifer basins in the Sahara and the Sahel and promoting inter-State cooperation in the management of main water resources.

Table 1: Basin authorities for the main rivers in the Sahel

Basin authority	Headquarter	Year created	Members States
Niger Basin Authority (ABN)	Niamey	1980	Benin, Burkina, Cameroun, Côte d'Ivoire, Guinea, Mali, Niger, Nigeria, Chad
Lake Chad Basin Commission (CBLT)	N'djamena	1964	Niger, Nigeria, Chad, Cameroun, RCA
The Gambia River Basin Organization (OMVG)	Dakar	1978	Gambia, Guinea, Senegal, Guinea - Bissau
Senegal River Basin Organization (OMVS)	Dakar	1972	Guinea, Mali, Mauritania, Senegal
Volta River Basin Authority (ABV)	Ouagadougou	2007	Burkina, Togo, Ghana, Côte d'Ivoire, Mali, Benin:

POTENTIAL FOR COLLABORATION IN MANAGING AND USING WATER RESOURCES

Niger Basin Authority (ABN)

The mission of ABN is to promote the cooperation among member States and to insure an integrated development of the basin in terms of energy production, water, agriculture, livestock husbandry, fisheries, forest exploitation and silviculture, transport and communication, infrastructure and industries. The convention that created ABN (revised in 1987) assigned to this authority the following objectives:

1) Harmonize and coordinate national policies for water resource commercialization of the basin.
2) Participate in the development planning of the basin by elaborating and implementing an integrated development plan of its resources.
3) Promote and participate in the conception and exploitation of infrastructures and projects of common interests.
4) Insure the control and law enforcement of all forms of navigation on the river, its tributaries and sub-tributaries.

Lake Chad Basin Commission

The Lake Chad Basin Commission was created in 1964 by the four countries bordering Lake Chad - Cameroon, Chad, Niger, and Nigeria. They were joined in 1994 by the Central African Republic. The aims of the commission are to regulate and control the use of water and other natural resources in the basin and to initiate, promote, and coordinate natural resource development projects and research.

Gambia River Basin Organization (OMVG)

In 1978, the Gambia River Basin Organization (OMVG) was formed with a purpose to:

- achieve self-sufficiency in food for the whole Sahel sub-region,
- increase rural income and ensure a more equitable distribution of income in the Sahel, and
- promote industrial development.

It was joined by The Gambia and Senegal, and later, by Guinea in 1981 and by Guinea-Bissau in 1983, which is not even a part of the river basin. The original idea of this organization was to follow the example of the Senegal River Basin Organization and build a hydroelectric dam coupled with an anti-salinity dam to prevent the tidal salt water from entering the river basin. If the salt level was controlled and water could be released from the reservoir at a steady basis, then with proper irrigation machinery, it would be possible to have two harvesting seasons a year instead of just one. Before the Kekreti and Balingho dams were built, they needed foreign investment, so an Environmental Impact Statement was completed by the University of Michigan. It was found that the Kekreti Dam was planned to be built in the middle of a national park which was inhabited by some of the last elephants in the Gambia (Robin, 2010). In addition, the study found that the anti-salinity barrage would cause the soil to become too basic to support agriculture. The study also found that the barrage would create a supersaline environment on the downstream end of the barrage so as to negatively impact the coastal fishermen who make their living in the delta of the Gambia River Basin.

Senegal River Basin Organization

The first institutions to develop the Senegal River valley were created during the colonial period. On 25 July 1963, very soon after independence, Guinea, Mali, Mauritania and Senegal signed the Bamako Convention for the Development of the Senegal River Basin.

This convention declared the Senegal River to be an ‘International River’ and created an ‘Inter-State Committee’ to oversee its development. The Bamako Convention was supplemented by the Dakar Convention, signed on 7 February 1964, concerning the status of the Senegal River. The Interstate Committee laid the foundation for sub-regional cooperation in development of the Senegal River basin. On 26 May 1968, the Labé

Convention created the Organization of Boundary States of the Senegal River (OERS, Organisation des Etats Riverains du Sénégal) to replace the InterState Committee, broadening the field of sub-regional cooperation. Indeed, OERS objectives were not limited to the economic utilization of the basin but aimed at the economic and political integration of its four member States. After Guinea withdrew from the OERS, Mali, Mauritania and Senegal decided in 1972, to set up the OMVS, which pursues the same objectives. The OMVS has since created a flexible and functional legal framework enabling collaboration and a co-management of the basin. The principal legal provisions governing OMVS are listed below:

- The Convention concerning the status of the Senegal River (Convention relative au statut du fleuve Sénégal) of 11 March 1972. By this convention, the Senegal River and its tributaries were declared an 'International Watercourse', guaranteeing freedom of navigation and the equal treatment of users;
- The Convention that created the OMVS (Convention portant création de l'Organisation pour la Mise en Valeur du Fleuve Sénégal) ;
- The 1978 Convention concerning the Legal Status of Jointly-owned Structures (Convention relative au statut juridique des ouvrages communs), supplemented by the Convention concerning the Financing of Jointly Owned Structures (Convention relative aux financements des ouvrages communs) of 12 March 1982. These declare that:
    - all structures are the joint and indivisible property of the member States,
    - each co-owner State has an individual right to an indivisible share and a collective right to the use and administration of the joint property,
    - the investment costs and operating expenses are distributed between the co-owner states on the basis of benefits each co-owner State draws from the exploitation of structures. This distribution can be revised on a regular basis, depending on profits,
    - each co-owner State guarantees the repayment of loans extended to the OMVS for the construction of structures,
    - two entities manage the jointly-owned structures for the OMVS: one dedicated to the management and development of the Diama dam (SOGED, Société de gestion et d'exploitation du barrage de Diama) and the other to the Manantali dam (SOGEM, Société de gestion de l'énergie de Manantali), both created in 1997, and
    - the 1992 framework cooperation agreement between Guinea and the OMVS (Protocole d'accord-cadre de coopération entre la République de Guinée et l'OMVS), creating a framework for cooperation in actions of mutual interest

concerning the Senegal River and its basin, including a provision allowing Guinea to attend OMVS meetings as an observer.

Volta River Authority

The Volta River Authority (VRA) was established on 26 April 1961 under the Volta River Development Act of the Republic of Ghana, as a body corporate with the mandate to operate mainly as a power generation, transmission and distribution utility. In 2005, following the promulgation of a major amendment to the VRA Act in the context of the Ghana Government Power Sector Reforms, the VRA's mandate has now been largely restricted to generation of electricity. The transmission function has been hived off into a separate entity, designated National Grid Company to perform the transmission activities. During this process of transition, the VRA is planning to operate its distribution agency, the Northern Electricity Department (NED) as a subsidiary company to merge with the Electricity Company of Ghana into a single distribution utility after the transition period. The amendment has a key function of creating the requisite environment to attract independent power producers (IPPs) onto the Ghana energy market.

The VRA has now become the Volta Basin Authority (VBA) which has larger scope to cover more countries and activities rather than electricity generation alone. The 1st Assembly of the Heads of State of the riparian countries of the Volta Basin, which was held on 19 January 2007 under the auspices of the Government of Burkina Faso in Ouagadougou, signed a Convention for the establishment of the VBA. The mandate of the VBA is to:

1) Promote permanent consultation tools among the parties for the development of the basin.
2) Promote the implementation of integrated water resources management and the equitable distribution of the benefits resulting from their various utilizations.
3) Authorize the development of infrastructure and projects planned by the stakeholders and which could have substantial impact on the water resources of the basin.
4) Develop joint projects and works.
5) Contribute to poverty alleviation, the sustainable development of the Parties in the Volta basin, and for better socioeconomic integration in the sub-region.

CHAPTER 2 Management of Water Resources in the Sahel

CURRENT KNOWLEDGE ON DISTRIBUTION, AVAILABILITY AND SUFFICIENCY

Available water resource statistics of the countries contain discrepancies and must therefore be used with caution. The principal causes for discrepancies are:

- the differences in reference times used for calculating average values or variability;
- the differences of approach in regionalization of flow based on hydraulic data in basins poorly retaining locally formed flow, thus the different degrees of underestimation of the global flows produced (Table 2);
- The summation of surface and groundwater flows estimated separately and non-additive, even occasionally the summation of spring discharge (counted as surface water discharge) and the discharge of the aquifer from which these springs emerge; all of these double-counts lead to overestimations;
- discrepancies in the average discharge of cross-border rivers in the statistics of delivering and receiver countries, as well as different ways of taking into account border river discharge;
- the unwarranted summation of rather long term 'exploitable potential' or of aquifer discharge capacity (non-renewable resource) with flow (renewable resource);
- the inclusion, in certain cases, of 'secondary' resources (return of water after it has been used, notably of water used for irrigation) in primary natural resource figures.

Table 2: Estimated natural groundwater resources in some Sahelian countries

Country	Natural groundwater flow estimated by calculating aquifer recharge (10^9 m^3 per year)	Natural groundwater flow calculated using stream base flow (10^9 m^3 per year)
Burkina Faso	9.5	5.0
Mali	65.0	16.0
Senegal	9.3	7.6
Chad	20.6	11.5

Source: Oss (2004)

Moreover, an evaluation of the natural water resources of most of the countries within the sub-region cannot be based solely upon mean data. Such evaluation requires knowledge of the variables, especially the interannual variables, so that a layout of multiannual trends over a sufficiently long period of time can be made from hydro-climatological and hydrological data concerning several Sahelian countries, for the period running from 1926 to 1985, the results of which are presented, as follows (Table 3).

Water resources of each of the three types below may be subject to instabilities, but in a very different manner. Type (1) resources, due to the progressive degradation of the ability of streams to control irregular discharge (inevitable long-term silting) and occasionally due to the impact of human activities on the regime and quality of the water (desert formation, pollution) that water conservation measures can decrease or slow down, if not completely halted. These are also the only resources directly exposed to the consequences of desertification on the groundwater regime, particularly in the Sahelian countries and Northeast Africa where the impact of deforestation and intensive land use are the most prominent. The hydrological consequences of desertification – very different from those of droughts – have, however, rarely been reported. Type (2) resources, due to the evolution in water use in countries upstream (increase in consumption, evaporation in flow regulation dams, even input of pollutants), can be increased in certain cases if measures are taken to reduce evaporation in *'inland deltas'* (with respect to Niger and Mali). Type (3) resources are subject to the normal depletion of reserves because of reduced accessibility (lowering of levels), aggravated occasionally by a decrease in quality (increased salinity).

Table 3: Annual internal and external inputs of certain Sahelian countries

Pays	Annual internal inpu				Annual external input			
	Average (km^3/an)	Maximum (km^3/an)	Minimum (km^3/an)	Coefficient de variation	Moyenne (km^3/an)	Maximum (km^3/an)	Minimum (km^3/an)	Coefficient de variation
Sénégal	21.4	31.1	6.31	0.28	0.32	21.9	59.2	0.3
Gambie	3.97	5.69	1.24	0.28	0.43	9.62	194.0	0.28
Mali	39.6	62.2	18.64	0.32	54.8	82.5	21.8	0.27
Niger	2.33	5.4	0.28	0.43	32.1	47.2	13.7	0.24
Tchad	10.4	13.2	7.1	0.32	36.6	59.2	3.7	0.31

Source: OSS (2004).

CONFLICTS AND CHALLENGES

The main challenges facing Sahelian countries in sharing water resources are:

- provision of water for food production and to the populations;
- promotion of job creating activities;
- protection of vital ecosystems;
- spatio-temporal water variability (rainfall variation – increase in the infrastructural demands, etc.);
- droughts and floods risk management;
- sensitization of public opinion;
- stimulating political will to act;
- ensuring collaboration among sectors and beyond borders.

A precise and complete knowledge of the present uses of water by all of the economic sectors is necessary if future demand is to be determined and if resource management guidelines are to be developed. This knowledge is however still imperfect and has discrepancies due to the following.

1) The available statistics on demand and pumping are based more on estimations than on measurements. They are affected by varied uncertainties, especially in the agricultural sector. They do not always distinguish clearly between the supply requested by users and the quantities pumped from the resources or water 'production', in the countries where these do not coincide.
2) There are few historical data and there is a lack of synchronism because they are not consistent in successive estimations. They reflect as much the evolution of the level of knowledge (precision and validity of figures) as that of the real variables themselves, which makes them difficult to compare. Moreover, dates of the statistics are not always given in the sources, which frequently refer to the 'present' without specifying whether this refers to the year of publication or a previous date.
3) Water consumed by water works (evaporation in storage tanks) not generally attributable to specific usage sectors, is rarely considered. The same is true of losses by evaporation in irrigation water transport systems, included in certain estimations and not in others.
4) There is occasionally confusion between the amounts of water which are actually requested and used and the resource allocations, notably in the agricultural sector. These may explain differences in the macro-economic statistics (significant in some cases) for close dates and the apparent inconsistencies in the historical data) within a given country.

5) The distribution of the sectorial demands depending on the source of the supply is frequently omitted.
6) Data on the return flow and total consumption, including in the dams, are rare.
7) The impact of uses, notably of discharges, are incompletely described, quantified and evaluated.
8) The macro-economic statistics on the weight of the water sector (public and private expense) in the national economies are rarely available.

Efforts to improve the knowledge and usage of data are particularly necessary in the countries where the management of water must and should increasingly combine the management of demand of the resources.

MANAGEMENT OF WATER RESOURCES

The structure of water uses is quite uniform in the Sahel with two major sectors:

- Irrigation demand, which is predominant everywhere, ranges from 80% to 90% in one out of two countries; the total volume of water used at present in the region for irrigation would be about 90,000 million m3 per year (86% of all water used);
- Community drinking water supply, especially in urban areas, is everywhere below irrigation demand but is generally increasing more rapidly.

It is primarily between these two sectors that conflicts of use are likely to arise. The industrial water demands are, on the other hand, minor and little dissociated from the demands for drinking water (except those of the mining sector, significant in some countries, such as Niger where, nevertheless, it is in recession).

The supply and demand of natural resources vary a lot according to the geographical area (Table 4).

Over-pumping of groundwater from renewable resources in Mauritania and Senegal may also increase the apparent exploitation rate, as well as the fact that part of the resources may be used several times. In the Sahel countries demands on resources are still very low due to the lack of agricultural wells and urban and rural drinking water networks. The exploitation rates (ratio of total withdrawals from renewable resources/average flow of these resources) range from nearly 1% to over 100%. Naturally, this rate would be higher if reference was made to the only resources considered at present to be exploitable, in the countries where internal resources of type (1) predominate (Table 4).

Table 4: Current water supply sources in Sahelian countries

Country	Surface water	Ground water	Total
Burkina Faso	86	14	100
Cape Verde	20	80	100
Chad	47	53	100
Gambia			
Guinea-Bissau	82	18	100
Mauritania	53	47	100
Mali	92	8	100
Niger	91	9	100
Senegal	82	18	100

Sources: OSS (2004).

KEY ISSUES AND ACTIONS AND MEASURES TO ADDRESS THEM

Key issues

In the Sahel the sources of conflicts over water sources are mainly due to uses and other conflicting interests and are summarized in Table 5.

With regard to climatic change and variability and their impacts on the water resources, one of the main common constraints in the Sahelian countries is the lack of knowledge and information on the resources. This is essentially due to lack of data on underground water resources and low local scientific capacity.

Table 5: Water problems and major zonal conflicts in the OSS region

Sub-regions classified according to the predominant type of water resource	Specific problems and conflicts
Internal renewable resources	Conflicts of upstream/downstream usage.
	Conflicts due to interference of ground- and surface water uses, or of traditional and modern exploitation techniques.
	Imbalances and competition between regions: transfer problems.
	Competition between completion of conventional hydraulic development, with increasing cost and environmental impact, and recourse to unconventional resources.
Fluvial resource of external origin	Conflicts of upstream/downstream usage (quantity and quality), notably in the case of mobilizing resource development by reducing losses by evaporation, conflicts between downstream beneficiaries subject to impacts from upstream developments.
	Conflicts between traditional methods of water usage (e.g. irrigation) and need for water conservation (related to the inter-sectorial conflicts).
	Geopolitical constraints and rivalries.
Non-renewable resources	Conflicts between short and long term development objectives (which may correspond to conflicts between unfairly 'developing' uses).
	Competition between use of non-renewable resources and recourse to unconventional resources.
	Competition between regions and transfer problems.

The main constraints are summarized as follows:

- non availability of hydrologic and hydro-geologic data in quantity and quality (most of the series of data are less than thirty years), making it difficult to estimate water resources and their tendency to climate change and variability;
- lack of equipment to collect and archive (database not computerized), to analyze and communicate (GIS, NTIC) for most of the offices dealing with data production;
- lack of knowledge on water resources (detailed studies on different water resources systems are rare);
- absence and/or weakness of research and systematic observation institutions in water sciences (meteorological and hydrological institutions);

- few national expertise on climate change (lack of regional climatic model showing adequate spatial resolution to develop scenarios of climate changes at a given temporal horizon) ;
- little scientific training in vulnerability, adaptation and mitigation of climate change impacts;
- absence of efficient mechanisms for climatic and hydrologic previsions to help decision making and results based management systems.

As part of the integrated water/basin management and development in the sub-region, the following actions are to be given immediate attention:

- improvement of dam design, coordination and efficient operations of the reservoirs. The various basin commissions might consider the possibility of promoting adaptation by member States of reservoir operation policy;
- promotion of water resources augmentation through inter-basin water transfer and rainwater harvesting;
- empowerment of the communities to apply scientific techniques geared towards rational exploitation of water;
- management policies and legislation that would articulate water quality and effluent standards, protection zones, etc.
- promotion of sustainable use and management of forest ecosystems in the various basins.

Integrated Water Resources Management approaches

Although widely accepted, it is noted that Integrated Water Resources Management (IWRM) approaches should be tailored to local circumstances and needs. This will require the development of a series of tools and methodologies - in some cases adapting those used in different habitats and situations. Some governments and international development and conservation organizations use the Integrated River Basin Management (IRBM) approach. This concept is similar to IWRM and considers the river or lake basin/aquifer as the ecologically defined management unit. Integrated River Basin Management can therefore be applied at a variety of scales depending upon the size of the river basin. This can range from small catchments of a few km^2 to major national basins, as well as trans-boundary basins where allocation and pollution issues cross international borders (CEDEAO, 2005).

At the same time, partnerships between governments, communities, non-governmental organizations, industry and research groups must proceed beyond general commitments to specific actions and should have flexible and durable working arrangements. Effective institutional management structures should allow for public input, changing basin priorities and the incorporation of new information and monitoring technologies. The adaptability of

management structures should also extend to non-signatory riparian countries (i.e. those within the same hydrological system) by incorporating provisions that address their needs, rights and potential accession. In the past, some attempts to resolve partnership issues have included the establishment of freshwater and regional seas agreements at local, basin or regional levels (Lake Chad). While such initiatives have met with some success, they often still lack the policy tools necessary to promote long-term IWRM.

The focus of the emerging culture is water sharing, such as the Integrated Water Resources Management (IWRM) that seeks more effective and equitable management of water through increased cooperation. Bringing together institutions dealing with surface water and aquifer resources, calling for new legislative agreements worldwide, raising public participation, and exploring alternative solutions to resolving disputes should all be part of the process (CEDEAO, 2005).

However, cooperation rather than conflict is becoming the norm. Conflicts occur, in particular, between users sharing the same resource - a situation often exacerbated by traditional values, customs and practices, historical factors and geographical vagaries. However, in an increasing number of cases, treaties, agreements and the principles of international water law are helping to crystallize mechanisms for resolving disputes. As decision-making processes in water governance and management become more complicated, legislative and institutional developments and guidelines for capacity building have become increasingly critical for ensuring equitable and efficient water sharing. The strengthening of institutional mechanisms and legal frameworks for IWRM is of central importance both for facilitating this process, and ensuring that the burden of associated transaction costs is equitably shared. Integrated Water Resources Management must take place within institutional environments conducive to its development. This means capacity-building structures, regulatory principles and organizational mechanisms for promoting cooperation and conflict management. Treaties, conventions, agreements, as well as international conferences that mobilize politicians, administrators, NGOs and knowledge communities are also critical elements in the creation of such a nurturing environment.

Reversal of land and water degradation trends in the Niger River Basin project

The goal of the project was to ensure the sustainable development and management of the land and waters of the basin in three phases. Phase 1 includes the compilation of a preliminary Transboundary Diagnostic Analysis (TDA). Phase 2 concerns the implementation of a number of pilot projects dealing with Transboundary issues and the completion of the TDA for all nine countries sharing the basin and Phase 3 relates to the implementation of the Strategic Action Programme (SAP).

Degradation of the land through water and wind erosion, siltation of the river bed and its tributaries complement the list of issues that the project is tackling:

- Deforestation and bush fires;
- Reduction of river flows;
- Deterioration of water quality;
- Proliferation of water-induced diseases;
- Endangerment of aquatic flora and fauna;
- Invasion of new alien species.

CHAPTER 3: Forests and Water Supply in the Sahel

FOREST MANAGEMENT AND WATER BUDGETS

It was in 1997 that Falkenmark (1997) introduced a useful terminology with “green and blue water”. Green water is the return of water to the atmosphere as evapotranspiration (ET), including transpiration by vegetation, evaporation from soil, lakes, and water intercepted and evaporated from (mainly tree) canopy surfaces, i.e. to a large part water that is used to produce food and environmental services by forests and agricultural crops. Blue water is on the other hand what is left for deeper groundwater and stream runoff, i.e. water available for animal and human consumption, for example, in downstream urban areas. Critical processes are the partitioning of rainfall between green and blue water, which is (i) infiltration of water into the soil or surface runoff and (ii) uptake of soil water by plants or recharge of groundwater. It is an empirically and theoretically well established general scientific paradigm that forests use more water than lower vegetation and rain-fed agriculture. This could also be expressed as a positive relationship between biomass production and water use (Rockström, 2003). Consequently, empiric evidence is strong that cutting forest results in increased stream flows (Bosch and Hewlett, 1982). Typically also regenerating forests and afforestation are shown to partition more of the rainfall to green water, reducing availability of blue water (Farley et al., 2005; Scott et al., 2005). This situation is well experienced in the Sahelian region in terms of forest-water relations. It has been experienced in past years a decrease in water flows in various rivers as well as the drying up of some permanent water ponds. This situation was scientifically, as well as empirically has been explained. The disappearance of vegetation can result in sand dune formation and silting river banks.

In agriculture, much of expected increase in food production is from semi-arid areas and rain fed agriculture. Falkenmark and Rockström (2008) stress the importance of increasing efficiency in cultivation systems to shift losses in evaporation to productive transpiration, Makurira et al. (2007) give a good example from Tanzania. In the same manner, there is need for fundamental process knowledge about rainfall partitioning in forest ecosystems to be able to elaborate on effects of forestry applications, like the ones discussed above. Specific fields of study include:

1) study of infiltrability and actual groundwater recharge;

2) links between groundwater recharge and macrospore flow, top soil carbon and aggregation;
3) tree root development and symbiosis, deep roots and water uptake by parkland trees;
4) dry zone tree species transpiration in relation to productivity;
5) interception (evaporation from tree canopies) by various forest structures and species.

For better efficiency of biomass productivity, forestry itself needs to develop in the understanding of multispecies systems or intensively managed multi-species plantations in general which have been shown by meta-analysis to be more productive than monospecific plantations (Piotto, 2008).

KEY WATERSHEDS AND RIVER BASINS IN RELATION TO FOREST ECOSYSTEMS

Niger River basin and associated forest ecosystems

Guinea has a sudan type of vegetation structure with a decreasing rainfall south- west and north-east (Faranah has 1,500 to 1,600 mm of rainfall with sometimes 4 months with less than 50 mm of rain and at Siguiri, 1,200 to 1,300 mm with seven dry months). This region is characterized by high inundated plains of Niger River and its effluents, separated by vast plateaus. The vegetation of the region was tree savannah and an irregular understorey of bamboos *(Oxythenanthera abyssinica)*.

The Forest Guinea region is more different. The southern part with many hills receives more rain and has a dense semi-deciduous forest, sometimes evergreen, but is now being transformed to savannah with some forest galleries. In the south-eastern part of this region, there are three types of dense ombrophil forests.

In Niger the characteristic flora is related to agroclimatic zones. There is Sahelian flora characterized by climatic aridity and spiny vegetation which is discontinuous and shrubby. At meridian limit of the Sahel and in some specific biotopes, transgressive species of sudanian regime having large ecologic amplitude are present. Physionomically remarkable taxa like *Hyphaene thebaïca* in the alluvial plains of Niger River are present sometimes mixed with *Borassus aethiopum*, and rarely with *Phoenix reclinata* and *Phoenix dactylifera*. Some sparse dry dense forests are characterized by xerophytes species. In the dense shrubby forests with spiny species, there are herbaceous groups in drained soils as well as some therophytes.

In Mali the whole of the savannah vegetation is composed of gallery forests. The flora is characterized by some preferential species with adaptable frequency. In the sudano-guinean, sudanian and sahelo-sudanian climates, and on drained soils, the more frequent associations with characteristic species are:

- Riverine forests/gallery forests along rivers and other small streams whose existence is related to the presence of rivers and associated water tables. This could resemble during the rainy season to dense forests of semi-deciduous type with flora varying form one climatic zone.
- Dense dry forests with herbaceous species.
- Open forests and wood savannah:
- Tree and shrub savannah with variable floristic composition according to agroecological zone with species determined by the frequency and virulence of seasonal fires.

Senegal River and associated forests ecosystems

After the construction of two dams in the Senegal River (the Diama dam near the mouth of the river, 25 km north of the city of Saint Louis in Senegal, operational since 1988), and the Manantali dam in Mali (operational since 1986) the water level in the river was regulated. In consequence, large parts of the floodplains were permanently dried up and the brackish water in the lower part of the river became fresh. This change in ecological conditions led to an annually recurrent, explosive development of the floating aquatic weed *Pistia stratiotes* in the Djoudj National Park during the first half of the dry season (Niasse, 2004). The Park, located approximately 60 km upstream from Saint Louis in Senegal in the former floodplain, is artificially flooded when inlets from the river are opened during the rainy season. An additional result of the changed ecological conditions is prolific growth of the emergent weed *Typha australis* in the lower part of the Senegal River. This applies in particular to a shallow reservoir, just upstream of the Diama dam, which was formed as a result of the construction of embankments (surface area approximately 180 km²) and the Lac de Guiers, a lake which is about 50 km upstream of the Diama dam connected to the river (surface area approximately 240 km²). In September 1999 the very aggressive floating weed *Salvinia molesta* was for the first time observed in the Senegal River in the vicinity of the Djoudj National Park.

Lake Chad and associated forest ecosystems

The Lake Chad Game reserve is currently the only protected area around Lake Chad. This area is only a conservation area in theory and local communities have claimed the land for settlements, farms and cattle grazing as bases for fishing.

The dominated vegetation type is grassland where flooding is extensive because most of the species cannot tolerate prolonged flooding conditions. Woody communities dominated by Acacia species grow interspersed with the grasslands. These woody communities vary in density, ranging from scattered trees and bush grasslands to woodlands and thickets. Xeric woodland species found around Lake Chad include baobab, desert date palms, African myrrh, and Indian jujube (Mockrin and Thieme, 2001).

Gambia River and its associated ecosystems

With its characteristic Sudano-Savanna woodland vegetation type, ecosystems of Gambia include closed and open woodlands, plantations, tree and shrub savannas, and wetlands. The wetlands of Gambia cover almost 20% of the total land area of the country. Of this, 6.4% is mangrove forest, 7.8% is uncultivated swamps and 3.2% cultivated. Wetlands are increasingly being used for rice cultivation and for dry season grazing for livestock and they provide the main breeding and nursery areas for the main commercial fish species. Many species of wildlife are totally dependent on wetlands including the rare and threatened West African Manatee, the clawless Otter and the Sitatunga antelope. The forest ecosystem has dramatically changed in the last two to three decades from a dense and highly diverse biological environment to its present degraded state. Agriculture is the main source of food for the population and the major foreign exchange earner. Fifty-two percent of the total land area is arable, 28% to 36% of which is cultivated annually. However, due to overgrazing and poor farming practices, the loss of soil through erosion is estimated at 12.5 tonnes per ha per year. Loss and fragmentation of habitats due to deforestation, wetland drainage and infrastructural development also constitute direct threats to Gambia's biodiversity. Certain fish species such as the lobster, shark, catfish, and the white grouper are threatened as a result of unsound exploitation.

Several protected areas have been established, including 6 national parks and nature reserves, 66 forest parks and one Ramsar site. The Gambia is in the final stages of designating Tanbi Wetlands Complex and Niumi National Park as additional Ramsar sites. The national Parks and nature reserves cover a total area of 4.09% of the national territory.

Volta River and associated forest ecosystems

The Volta river basin has an ecosystem dominated by savanna woodland, with more than 50% cropland concentrated in the north of the watershed (Hayford, 2008). Cropland and open woody vegetation are found in northern Ghana and Burkina Faso; deciduous shrub-land with sparse trees in northern Ghana, eastern Burkina Faso and northern Togo; deciduous woodland in central and southern Ghana; and degraded lowland evergreen forest in south-eastern Ghana and Togo.

Forest cover in all the sub-basins of the Delta river has been very low (Table 6). The highest forest cover of about 14.2% is in the Black Volta sub-basin, and the lowest of 2.2% in the Daka sub-basin. In 2000, the main Volta sub-basin had the highest forest cover (5.2%) and the Black Volta, the lowest (2.1%). As far as the annual rate of change in forest cover is concerned, all sub-basins experienced decline in forest cover.

Table 6: Forest cover (in km²) by sub-basin in 1990 and 2000 in the Volta river basin.

Sub-basins		1990		2000		Annual change (1990 – 2000)	
	Land area (km²)	Forest cover (km²)	% land area	Forest cover (km²)	% land area	km²	% change
White Volta	39948	4891	12.2	1408	3.5	-348	-7.1
Black Volta	27580	3911	14.2	575	2.1	-334	-8.5
Main Volta	36424	4259	11.7	1897	5.2	-236	-5.6
Daka basin	6656	146	2.2	143	2.2	-0.3	-0.2
Total	110608	13207	11.9	4023	3.6	-918	-6.9

Source: Samuel (2004).

MANAGEMENT OF FORESTS IN WATER CATCHMENT AREAS

Regional priority issues

The main problems identified in the Sahel are:

1) degradation of vegetation cover and soils,
2) degradation of water resources through the reduction of availability and quality and the modification of water regimes as well as the loss of plant and fauna biological diversity, and
3) degradation of wetlands biological diversity and the spreading of aquatic plants.

These problems, even though localized, will extend and worsen rapidly due to the high increase of dams construction, intensification of irrigated agriculture, increase of human and animal population as well as industrial development along the rivers.

It is evident that the importance of these environmental problems varies among countries and types of ecosystems in a given basin (Table 7).

Table 7: Classification of main environmental problems

Global environmental problem	Sectorial environmental problem	Immediate causes	Serious causes	Possible solutions
Land degradation	Vegetation cover degradation	Increase of crop lands Vs forests and pasture lands; uncontrolled wood cutting; overgrazing; bush fires.	Increase of human population; Human life styles; Poverty of people depending mostly on natural resources; Poor implementation of laws and policies regulating land management; Lack of appropriate laws and policies regarding land management.	Awareness creation/ information towards riverine populations and dissemination of legislative texts; bylaws, national and international conventions on natural resources management; tree plantation along the rivers; Assisted natural regeneration; Diversification of economic activities and access to credits for revenues generating activities; Implementation of population regulating policies.

Specific priority issues and possible solutions

Table 8 shows priority issues and their possible solutions.

Table 8: Specific priority issues and their possible solutions

Problem	Suggested solution
Loss of biological diversity	Restoration and conservation of biological diversity
Loss of biological diversity of wetlands	Restore and conserve the biodiversity of wetlands
Loss of biological diversity of protected areas of Park W of Niger River, in Chad and North of Cameroun	Restore and conserve these protected areas
Deforestation of mountain forest ecosystems of High Guinea, Sikasso region of Mali and the Bani, Adamaoua in Cameroun and north of Benin	Restore and manage these ecosystems
Siltation of the Niger River in the Interior Delta in Mali, Kainji in Nigeria and the Chad portion of the Bénoué	Stabilize watersheds and improve water regime in the Interior Delta in Mali, Kainji in Nigeria and Chad portion of the Bénoué

In terms of forestry related issues, strategic actions to be implemented are to:

- study the tendency of forests ecosystems and pasture lands through use of remote sensing and GIS;
- elaborate and implement programs and projects for the restoration of degraded ecosystems;
- capitalize experiences of domestic energy strategies based on participatory forest management (PFM) in order to sustainably provide fuelwood and other alternative sources of energy;
- develop and implement afforestation programs and projects;
- develop and implement programs and projects for diversification and improvement of revenues in rural areas;
- define an institutional and legal framework for harmonious exploitation and management of forest ecosystems and pasture lands.

STAKEHOLDERS IN WATER SUPPLY, USE, TRADE AND MANAGEMENT

Integrated water management in the basin involves different issues relevant to national authorities of each country, such as monitoring, planning, coordination of different uses, institutional and legal aspects and financing of water related projects. However, the key element for effective water resources management is cooperation between the riparian countries at different levels, i.e. local, national and regional. Political willingness for cooperation is very important and institutions and stakeholders on both sides of the border should exchange data and information and develop common plans for water resources management. Lack of cooperation may lead to conflicts and disputes that may aggravate the problems and delay sustainable socio-economic development in the region.

Water is a subject in which everyone is a stakeholder. Real participation only takes place when stakeholders are part of the decision-making process. This can occur directly when local communities come together to make water supply, management and use choices. Participation also occurs if democratically elected or otherwise accountable agencies or spokespersons can represent stakeholder groups. Additionally, there are circumstances in which participation in decision-making can take place through market processes; if appropriate pricing systems are in place, local governments, community organizations or irrigation districts could signal their demands for bulk water services. The type of participation will depend upon the spatial scale relevant to particular water management and investment decisions and upon the nature of the political economy in which such decisions take place.

MONITORING OF WATER FLOWS

Along with desertification, which affects soils, the Niger's water resources have been affected by the drought in the Sahel region since 1970. Since then, the river's average flow rate has decreased by 30%. Moreover, changes in the river flow during low water conditions are increasingly severe. Before 1970, low water conditions occurred in May and June, while they are now observed from April to July (4 months). Consequently, minimum flow rates in low water conditions have dropped considerably. In Niamey, the average flow rate during the driest month used to be 70 m^3s^{-1}; it now barely reaches 20 m^3s^{-1}. In particularly dry years, it has become practically impossible to measure the flow rate.

This drastic flow rate decrease, whose evolution is not foreseeable, is having degrading effects on the river's ecosystem, irrigation, public health, and on the water supply for human populations, cattle and industry (CEDEAO, 2005). Some of the impacts are:

- breaking of hydrological series;

- decreasing of groundwater level;
- important decrease of main rivers discharge;
- increasing of runoff coefficient.

This situation is applicable to most major rivers in West Africa.

CHAPTER 4 Way Forward with Forest-Water Relations in the Sub-Region

In terms of way forward in forest-water relations in the Sahel, the followings instruments need to be considered and applied in the implementation of programs and activities in the sub-region.

INSTITUTIONAL MEANS

1) Adaptation of water laws and regulations governing intervention and arbitration of government authorities (by regulation of development and exploitation of resources as well as uses, by financial incentives). The status of public property (or the public domain) of water resources, written into most legislation, must be reconciled with the safeguarding of water rights and private appropriation of certain resources. The legal definition of the ranking of water uses determines the differences in price depending on the sector.
2) Creation of inter-sectorial coordinating organizations or authorities at the government (e.g. National Water Council) or local (e.g. river basin) level. The hydrographic basin (or occasionally, the aquifer system) is the most appropriate physical management unit and the field of a management authority should correspond as closely as possible to this unit. These organizations should not be solely consultative but endowed with the power of decision and coordination functions should be defined at an inter-ministerial level rather than attributed to an administration with sectorial competence. Coordination may be limited to public investments, notably in the field of pluri-annual planning of equipment (Master plans), or be extended to the acts of other semi-public or private economic participants, by means of regulatory or financial intervention (authorizations, subsidies and credit).
3) Creation of consultative or deliberative institutions grouping the various public and private participants involved in the management of a given resource unit (river basin, aquifer). Their competence might include objectives of water development plans or schemes funded by the State, local authorities or groups of users, the ‘flow allocation’ to be reserved in certain rivers, definition of quality objectives, or even day-to-day management depending on the circumstances (restrictions in times of drought).

It goes without saying that in the case of transborder river basins, or even aquifers, joint management is also quite desirable but requires political agreement at a national level.

TECHNICAL MEANS

The fragmented approaches usually provide only partial, local and occasionally temporary solutions. Therefore, for integrated water management, their application must be organized and coordinated planned in an optimal way, in space and also in time, for all uses, starting with the harmonization of actions on supply and demand, by coordinating, for example:

- efforts both to save water and reduce losses in urban networks and increase water production and distribution,
- efforts to improve irrigation efficiency and those aimed at reusing drainage water, or to increase pumping of aquifers overcharged by excess irrigation water,
- efforts to increase output of treatment plants and the development of uses for waste water.

ECONOMIC AND FINANCIAL MEANS

1) Macro-economic criteria may be used to determine allocation of resources having different exploitation costs between productive use sectors with different added values (agriculture, industries...) or more widely between productive use sectors and the 'consumer' uses (food, hygiene and socio-cultural uses).
2) Market mechanisms may contribute, up to a certain point, to this distribution, notably in the form of renting or transfer of water rights. However, it may be necessary to regulate the market to an extent which depends on the socio-economic policy of each country. From this point of view, an increase in the commercial proportion of water used, by means of distribution networks, may be appropriate, in conjunction with an attempt to balance exploitation accounts of the public water distribution services.
   Given the particular circumstances (shortage of water as a result of economic conditions during periods of drought) of the negotiated transfers of water between unequally vulnerable use sectors might be a means of modifying water distribution adapted to average situations (transfer of water from the energy or industrial sector to agriculture or community supply, for example).
3) Price policies concerning water and commercial services or, more widely, the fiscal policies determining the charges passed on to the costs (taxes, fees) may be a means of distributing costs between unequal commercial water use sectors (example: different prices for water distributed to tourist businesses, industry, populations or agriculture, in Algeria and Tunisia), without affecting the objective of overall financial balance. Prices may also be used as an incentive to save water by accentuating already generalized progress in most of the countries in the region.
4) The 'polluter- payer' principle, backed up by funding of pollution reduction efforts financed by its application, has proved effective in industrialized countries. If its application can be adapted to situations, could usefully contribute to public efforts to

combat pollution. From the same angle, a certain readjustment of costs brought about by water conservation efforts – whose costs are not necessarily proportional to the quantities of water saved per sectors – could be the result of the application of a 'waterwaster-pays' principle: charging of fees for 'excessive consumption' in relation to fixed standards to finance water conservation efforts.

EDUCATIONAL AND INFORMATION MEANS

Consciousness-raising and informing all those involved in water management, especially users, is essential for effective application of regulatory, technical or financial means. This includes everything from education in school to communication using all modern audiovisual means. The 'water culture' deeply rooted in many countries of the sub-region offers a favourable platform for the necessary evolution of such a culture.

Integrated water management, in the widest sense, means bringing together and 'orchestrating', as well as possible, all these means and harmonizing the powers of decision-making: public and private, central and local, general and sectorial. It also involves integrating water management into the economic and environmental policies.

In general, the more the demand for water approaches and, a fortiori, exceeds conventional resources, as is already the case in several countries in the Sahel, the more water management and policy objectives become necessary to correspond to the objectives of socioeconomic and development policies, notably agricultural policy and food independence objectives.

FOREST-WATER RESEARCH NEEDS IN THE SAHEL

1) Evaluate the overall hydrologic response to forestation through integrated watershed-scale experiments and monitoring that is a key component of national environmental reconstruction.
2) Studying forest-water relations at the watershed scale by considering the followings (Andreassian, 2004):

    a. watershed size,
    b. using models to mimic a control basin,
    c. forest descriptors,
    d. gradual changes,
    e. long-term impacts,
    f. distinguish forest stands from forest soils and
    g. number of watersheds.

3) Ecological Network promises to provide useful results on forestation impacts on hydrology. A paired watershed approach with a long-term plan should be adopted across the Sahel.
4) Another way of examining the impact of land-use change on hydrology is by simulation models
5) Computer modelling has been well accepted by the hydrologic community as an effective way to examine individual hydrologic process and separating the roles of various factors (soil, climate, and plant growth status) (Sun et al., 1998; Deng and Li, 2003).
6) To fully understand the role of land-cover change on the water cycles, such as precipitation, meso-scale distributed computer models are needed to account for the feedbacks between land and climate. Such types of models require even more close integration of remotely sensed spatial databases and energy and water balances. Meso-scale models are becoming increasing operational at the regional scale (Chen et al., 2005).

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