SENEGAL RIVER DEVELOPMENT ORGANIZATION (OMVS)

GEF Project/Senegal River Basin

Component 3

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Transboundary Diagnostic Environmental Analysis of the Senegal River Basin

Regional Synthesis

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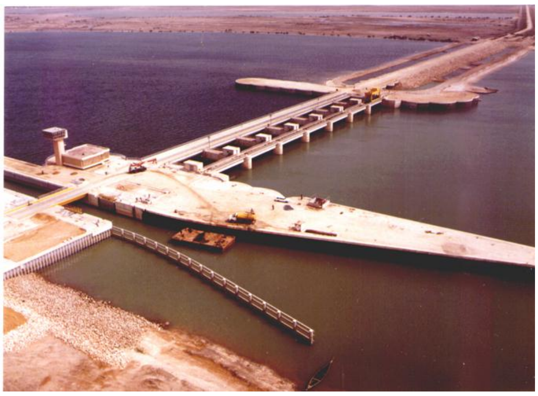
Report: Published Version



Date : June 2007

ABREVIATIONS AND ACRONYMS

ADB	African Development Bank
AGCD	General Administration for Cooperation and Development (Administration Générale de la Coopération et au Développement)
UNCCD	United Nations Convention to Combat Desertification
CIDA	Canadian International Development Agency
CRODT	Oceanography Research Center, Dakar-Thiaroye **(**Centre de Recherche Océanographique Dakar-Thiaroye)
CSS	Senegalese Sugar Company (Compagnie Sucrière Sénégalaise)
DNCN	National Directorate of Nature Conservation - Mali **(**Direction Nationale de la Conversation de la Nature Mali)
DNH	National Directorate of Hydraulics (Direction Nationale de l'Hydraulique)
DNPIA	National Directorate of Animal Production and Industries **(**Direction Nationale des Productions et Industries Animales)
DRPIA	Regional Directorate of Animal Production and Industries **(**Direction Régionale des Productions et Industries Animales)
EDM	Mali Engergy Company (Energie du Mali)
FAO	Food and Agriculture Organization of the United Nations
FCFA	French Community of Africa Franc
FOSA	Forestry Statistics and Outlook Study for Africa
GEF	Global Environnement Facility
GERF	Rural Space and Forest Management in Guinea (Gestion de l'Espace Rural et des Forêts en Guinée)
GIWA	Global International Waters Assessment
IGN	National Geographic Institute of France (Institut géographique National de France)
IRM	Islamic Republic of Mauritania
IUCN	International Union for Conservation of Nature
LCC	Local Coordination Committee
LERG	Laboratory for Teaching and Research in Geomatics (Laboratoire d'Enseignement et de Recherche en Géomatique)
MAB	Man and Biosphere
NBA	Niger River Basin Authority
NCC	National Coordination Committee
NDF	Nordic Development Fund
NGO	Non-Governmental Organization
OMVG	Gambia River Development Organization (Organisation pour la Mise en Valeur du Fleuve Gambia)
OMVS	Senegal River Development Organization **(**Organisation pour la Mise en Valeur du Fleuve Sénégal)
ORSTOM	Office of Scientific Research for Development through Cooperation **(**Office de Recherche Scientifique des Territoires d'Outre Mer)
PASIE	Environmental Impact Mitigation and Monitoring Program **(**Programme d'Atténuation et de Suivi des Impacts sur l'Environnement)

PDIAIM	Project for Integrated Development of Irrigated Agriculture in Mauritania **(**Programme de Développement Intégré de l'Agriculture Irriguée en Mauritanie)
PDIAM	Rural Integrated Development Project for Downstream of Manantali Dam **(**Projet de Développement rural Intégré à l'Aval du barrage de Manantali)
PND	Diawling National Parc (Parc National de Diawling)
PRODESO	Western Sahel Livestock Development Project **(**Projet de Développement de l'Elevage au Sahel Occidental)
PSE	Sectoral Water Project (Projet Sectoriel Eau)
SAED	Société d'Aménagement et d'Exploitation des terres du Delta (National Company for Land Management and Use in the Senegal River Delta)
SAP	Strategic Action Program
SBDT	Société de Bauxite de Dabola-Tougué **(**Dabola-Tougué Bauxite Company)
SEMOS	Société d'Exploitation des Mines d'Or de Sadiola (Sadiola Gold Mining Operations Company)
SMK	Société Minière aurifère de Kalinko (Kalinko Gold Mining Company)
SNSI	Senegalese National Standard Institute
SODESP	Livestock Development in the Sylvo-Pastoral Area Company (Société de Développement de l'Elevage dans zone sylvo-pastorale)
SOE	Service de l'Observatoire de l'Environnement (OMVS) (Environmental Observatory)
SOGED	Société de Gestion et d'Exploitation de Diama (Diama Management and Operations Company)
SOGEM	Société de Gestion de l'Electricité de Manantali (Manantali Energy Management Company)
SONADER	Société nationale pour le développement rural (National Rural Development Company)
SRB	Senegal River Basin
TDA	Transboundary Diagnostic Environmental Analysis
TDAT	Transboundary Diagnostic Analysis Team
TEA	Transboundary Environmental Analysis
TLU	Tropical Livestock Unit
UCAD	Cheikh Anta Diop University of Dakar
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
USD	United States Dollar

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EXECUTIVE SUMMARY

Since the early 1970s, climate in the Sahelian and Sudanian areas (where the majority of the Senegal River Basin is located) is marked by chronic rainfall and water deficits, which have put this area into a major ecological crisis. This crisis has been intensified by demographic growth, also unprecedented, and by the expansion of cultivated land and livestock farming. All of the river basins located at the same latitude as the Senegal River (the Gambia River, Niger River and Lake Chad Basins) have faced serious ecological challenges over the last three decades. Deforestation, overgrazing, siltation, loss of plant and animal biodiversity, etc. have had varying impacts throughout the region but are all part of a common landscape affecting all its basins, including the Senegal River.

In addition, because of its hydro-agricultural developments (and particularly the large dams), the Senegal River is one of the most modified Sahelian river basins due to human intervention. Investments in controlling water here have created other ecological challenges.

Today, one of the greatest development challenges for the Senegal River Basin's resources and conservation of its biodiversity concerns the massive presence of aquatic invasive species (particularly *Typha*). All evidence indicates that invasive plant proliferation has been promoted by large infrastructure projects, the two large reservoirs upstream (Manantali) and downstream (Diama) and the surrounding irrigated areas that together have changed the river's hydraulic regime and water quality. In addition to their immediate and visible economic and social impacts, the invasive species affect the ecological stability of the Senegal River Basin as well as productive activities (agriculture, fishing and livestock farming) and the health of communities with the high prevalence of waterborne diseases.

The Senegal River Basin's other most urgent transboundary environmental problems concern desertification and bush fires, degradation of wetlands and changes in estuarine hydrodynamics (rapidity and unpredictability of ongoing changes at the river's mouth following the opening of the channel across the Langue de Barbarie in 2003). Deforestation, overgrazing, erosion and siltation (including riverbank erosion), degradation of fish fauna, as well as changes in surface water availability are serious problems that require an urgent response. The basin must also confront other environmental problems; however, these are either determined by other factors (waterborne diseases) or occurring locally. They do not necessarily need a transboundary solution for water quality—an issue that could become extensive if protective measures are not taken in time—such as soil salinization (particularly in the delta.)

Urgent solutions must be found for some of these environmental problems because of their extent, evolution and impact.

INTRODUCTION

The Senegal River is the second largest river in West Africa. It is 1800 km long and its basin covers a surface area of 300,000 km^2. While the average annual rainfall for the basin is 550 mm/year, the Guinean part records close to 1500 mm/year compared to 200–250 mm/year in the northernmost part of the basin. This contrast in rainfall, characteristic of the basin, is somewhat alleviated by the fact that each year the river transfers billions of cubic meters of water from the upper basin's regions with plentiful rainfall toward the dry Sahelian regions of the valley and delta. This particular system explains the basin's considerable biophysical richness and the broad diversity of production systems for some 3.5 million people who live in the basin.

Because of the arid conditions affecting most of the basin, water supply (surface and groundwater) and its spatial and temporal distribution plays a major role in the river ecosystem's evolution and the basin's development. Two major factors have exerted pressure on the basin's water resources in recent years: (a) climate variability and change; and (b) the dams. These pressures on water resources, added to those linked to runaway demography and various productive activities, has had repercussions on the basin's natural environment and its ecological diversity.

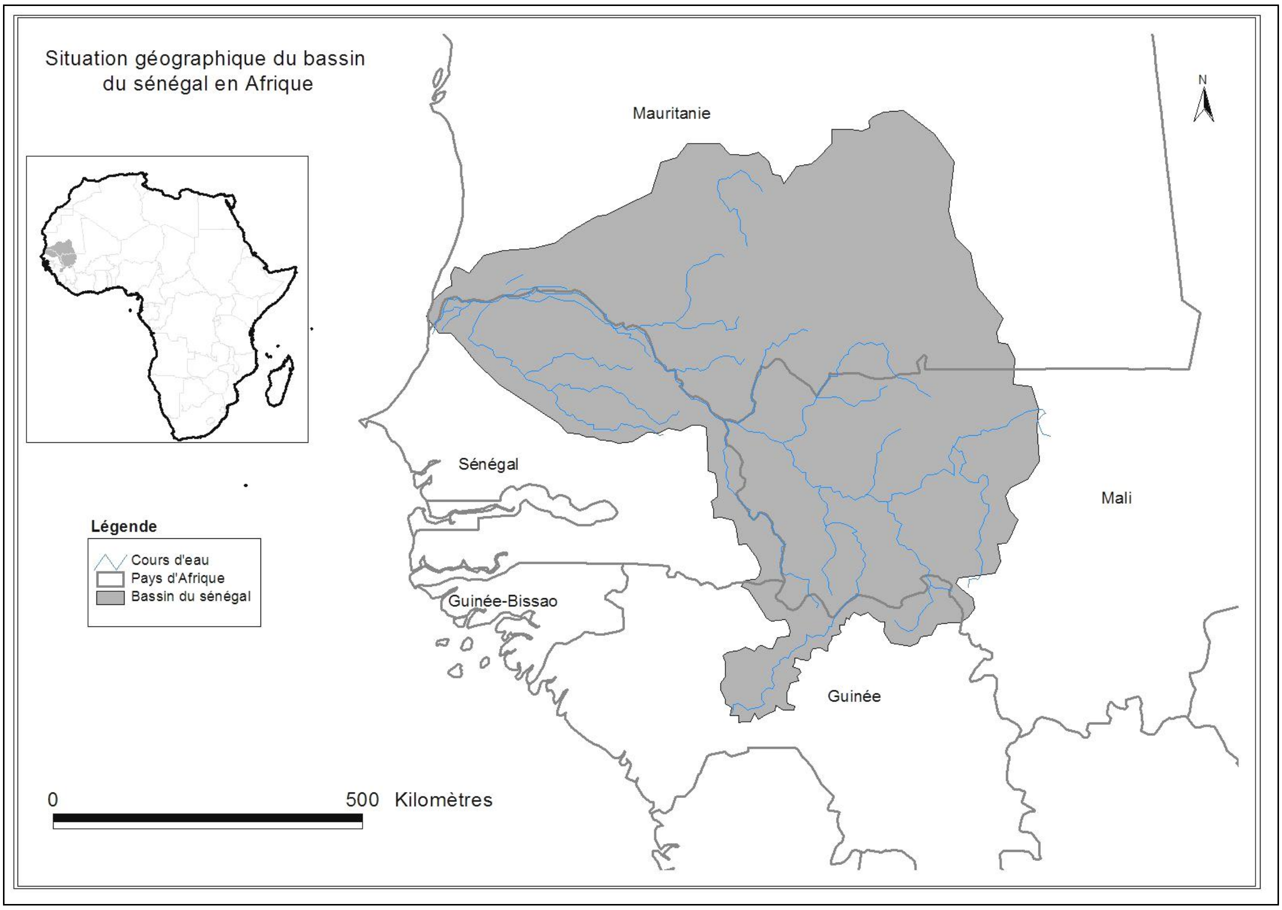

Fig. 1. Situation of the Senegal River Basin

Since the early 1970s, climate in the Sahelian and Sudanian areas (where the majority of the Senegal River Basin is located) is marked by chronic rainfall and water deficits, which have put this area into a major ecological crisis. This crisis has been intensified by demographic growth, also unprecedented, and by the expansion of cultivated land and livestock farming. All of the river basins located at the same latitude as the Senegal River (the Gambia River, Niger River and Lake Chad Basins) have faced serious ecological challenges over the last three decades. Deforestation, overgrazing, siltation, loss of plant and animal biodiversity, etc. have had varying impacts throughout the region but are all part of a common landscape affecting all its basins, including the Senegal River.

In addition, because of its hydro-agricultural developments (and particularly the large dams), the Senegal River is one of the most modified Sahelian river basins due to human intervention. These investments in water control have created other ecological challenges: proliferation of invasive aquatic species and an extraordinary increase in the prevalence of waterborne diseases.

Nevertheless, the river basin environment continues to have critical ecological importance as demonstrated by its numerous ecological sites having national, regional and, particularly, international interest. Some of these sites receive special protection while others still have none. Hence, the basin numbers two World Heritage Sites (Djoudj and the Island of Saint Louis). This status enlists the Djoudj National Park among the world's 830 natural and cultural heritage sites recognized as having universal value. The basin also has two Biosphere Reserves—the Boucle du Baoulé Transboundary Reserve of the Senegal River delta—included among the world's 480 reserves identified in the Man and Biosphere (MAB) Programme to create a network to share innovative approaches that reconcile environmental conservation and development. The Senegal River Basin is host to five sites included on the list of Wetlands of International Importance (Ramsar sites),[1] all concentrated in the river delta: Djoudj, Ndiael and Gueubeul on the left bank (or three of Senegal's four Ramsar sites); and Diawling and Chat Tboul on the right bank (or two or Mauritania's Ramsar sites).

In addition, other protected areas (national parks, wildlife reserves) include: the Bafing Wildlife Reserve created to compensate for wildlife habitat loss from filling the Manantali reservoir and that is currently a refuge area in the northernmost reaches for a few hundred chimpanzees; the Lake Magui on the Kolimbiné, an area with high concentrations of livestock, predominantly made up of herds from the Kayes region and transhumant herds from Mauritania; and the classified forest of Bakoun in the upper basin in Guinea, whose biodiversity many think could satisfy the Ramsar site eligibility criteria.

The natural lakes (including the Lac de Guiers and the Lac R'Kiz) play leading economic and ecological roles, whereas those played by the human-made lakes (Manantali and Diama reservoirs) should receive greater attention since the presence of significant fish fauna in their waters is certainly an indicator of much greater biodiversity.
There are numerous threats weighing on these ecosystems that affect conditions for using resources in the river basin.

[1] The criteria used for Ramsar list eligibility are that: (a) the site must be a representative, rare or unique wetlands area; (b) it must have particular importance for conserving biodiversity (e.g. supporting animals or plants threatened by extinction; receiving a large population of waterbirds; serving as a critical spawning ground for fish reproduction and growth).

1. PRIORITY ENVIRONMENTAL PROBLEMS

The classic approach to the TDA[2] includes the following steps: (1) a preparation phase during which the TDA Team (TDAT) collects and begins to organize data; (2) a phase to identify and classify environmental problems in order of priority, usually based on brainstorming carried out by the TDAT; (3) an analysis phase of the impacts and consequences of transboundary problems; (4) a phase to determine final classification by order of priority; (5) a phase to analyze the causal chain (concentrating solely on the priority problems identified in Phase 4 above; and (6) a phase to analyze governance, i.e., the political environment (institutions, laws, policies and investment projects affecting the identified priority problems).

Within the framework of the TDA process for the Senegal River Basin, Phases 1–3 were covered during the preliminary Transboundary Diagnostic Analysis (TEA) conducted during the PDF-B Phase of the GEF-SRB Project (2001–2002). Next, during the project implementation phase (beginning in 2003), national consultants were appointed to conduct national TDAs to develop the TEA in greater detail and validate its proposed impacts matrix and priority actions. These national TDAs were also validated during national workshops organized in each of the four basin countries. The national TDAs have placed greater emphasis on Phase 2 of the classic TDA approach described above, but have also tackled them from the specific angle of the different basin countries.

The regional synthesis phase (the subject of this document) aims to synthesize the TEA and the national TDAs while conducting Phase 4 in greater depth before covering Phases 5 and 6. The regional synthesis also suggests key intervention points to solve priority environmental problems, setting the groundwork for the subsequent phase to prepare the Strategic Action Program (SAP).

1.1. Land degradation

In arid, semi-arid and dry sub-humid areas (as is the case for most of the Senegal River Basin), land degradation is defined by the United Nations Convention on Desertification as being a decrease in or disappearance of biological or economic productivity and the complexity of cultivated land (both rain-fed and irrigated crops), livestock routes, forests or woody landscapes.[3] In other terms, land degradation denotes a decreased capacity of land to produce biomass.

Land degradation is caused by the following factors: deforestation, overgrazing and erosion. The effects of these processes contribute to desertification. Mining also causes deforestation and soil mobilization that promotes erosion.

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[2] GEF/IWLEARN. 2002. The GEF IW TDA/SAP Process: A Proposed Best Practice Approach. Source: http://www.iwlearn.net/publications/TDA

[3] This definition is very close to the one given in the UNCCD to define desertification (land degradation caused by various factors, including climate change and human activities). This does not simplify defining the parameters of the priority environmental problems of "land degradation" and "desertification," addressed separately in the validated TEA and the national TDAs.

1.1.1. Deforestation

Deforestation—reduction in wooded cover—is widespread in the Senegal River Basin.

The 2005 Environmental Observatory Report estimates that on a national level, forest surface area decreased by 800,000 ha in Senegal between 1981 and 1990, and that Mali and Mauritania loses 100,000 ha and 10,000 ha per year, respectively (SOE, 2005).

In Guinea, the national rate of deforestation was 2.08% for 1981–2000. Although the highest levels of degradation occur in Forest Guinea and Maritime Guinea, the Fouta Djallon Massif has also undergone intense deforestation.

Deforestation is widespread throughout the Malian part of the basin, but is much more prevalent in the areas of Kéniéba due to gold washing in the surrounding areas of the Manantali reservoir and the encroachment of cotton farming downstream of Kita (4000 ha/year). The environs of urban centers (Kayes, Kita, Kolokani, Kati, etc.) are also severely deforested, processes explained in part by the need to respond to high demand for firewood in these cities and expanding farm and pastureland. Lastly, construction of the high-tension line from the Manantali dam (1500 km) has also caused significant deforestation along its path. (TDA-Mali)

In Mauritania, the majority of its wooded areas are located in the Senegal River Basin where there are large groves of *Acacia nilotica* (gonakiers). These groves, which covered 23,444 ha in 1969, have clearly diminished and only amounted to 20,104 ha in 1976, recording a 14.24% decrease (TDA-IRM). Moreover, from 1997 to 1999, the loss in wood cover was 31.69% in the *wilayas* located in the Senegal River Basin: Guidimakha, Gorgol, Brakna and Trarza. In the Trarza *wilaya*, wood cover has decreased by 70%.[4] In this *wilaya*, the deforested land is divided between cultivated fields and vacant land, devoid of any vegetation. Remnants of the forests in this *wilaya* (2650 ha) are mainly located in the classified forests, and their wood cover is constantly receding. The Gani forest, which was 2200 ha in 1999, only accounts for approximately 720 ha of wood cover. According to the Mauritanian Report from the Prospective Study on the Forest Sector in Africa (FOSA),[5] the classified forests located along the river are among Mauritania's densest forests, yet they currently resemble "actual cemeteries" for trees.

In the Brakna *wilaya*, 47.74% of woodlands were lost between 1977 and 1999 and have also been transformed into crop fields or production areas for wood charcoal. The remaining woodlands are estimated at 4370 ha. For the two *wilayas* of Gorgol and Guidimakha, deforestation rates must also be quite high, especially since these two *wilayas* have been centers of wood charcoal production for the revitalization of large urban centers since the 1980s (for Gorgol) and the 1990s (for Guidimakha) (TDA-IRM).

In Senegal, wood vegetation has undergone significant regression, a process demonstrated by the evolution of the basin's classified forests. Similar to Mauritania, most of the classified forests in the Senegalese part of the basin are located in the flood plain in the valley. These forests particularly concern gonakier groves (*Acacia nilotica*). An estimated 32.5% of these gonakier forests were destroyed between 1972 and 1992 (TDA-Senegal). Moreover, the

[4] Ould Taleb, Nema. 1999. Ressources forestières en Mauritanie. FAO –European Commission – African Development Bank (ADB). August. Source: http://www.fao.org/DOCREP/004/X6812F/X6812F00.htm#TOC

[5] Ould Taleb, Nema. 2001. Etude Prospective du Secteur Forestier en Afrique – Mauritanie. July.

classified forests were not spared. The Diamel classified forest (Matam region)—despite the fact that, in theory, it was protected—supplied 58% of the firewood, 33% of the wood charcoal and 9% of the lumber consumed by the 170,000 inhabitants of the commune of Matam and its surroundings (TDA-Senegal). For this reason, this forest, like other classified forests in the basin, is in rapid regression (TDA-Senegal).

Causal analysis

Natural causes can be distinguished from human causes. Natural causes involve hydro-pluviometric conditions, which have been quite unfavorable in the basin (and in the rest of the Sahelian and Sudanian region). In the middle valley, average annual rainfall fell 30–40% between the period of 1950–1970 and 1971–1990. In the Guinea upper basin, rainfall for 1971–1990 only amounts to 21% of its total for 1950–1970.[6] To illustrate the rainfall's specificity in the context of the last three decades in the Senegal River Basin, 8 of the 10 driest years from 1904–1984 occurred in the 1970–80s. These successive years of pronounced rainfall deficits led to high tree mortality and negatively affected the capacity for regeneration of vegetation cover. Over the course of this same period, water deficits (drop in river flow) produced decreased and less frequent flooding (in terms of how much surface area was flooded and flood duration). This caused serious degradation of gonakier forests that depend on flooding.

Human causes of deforestation are: land clearing for agricultural purposes; use of lumber, firewood and wood charcoal; overgrazing; expansion of residential areas into urban and rural settings; mining; bush fires; greater open access to wooded areas, etc. Although use of wood in response to the energy and lumber needs is a primary common cause throughout the basin, the extent of most of the other causes varies depending on the country and locations in the basin.

In the upper basin, the high occurrence of bush fires is a primary factor in deforestation. In Mali, land clearing for agricultural purposes (notably, cotton farming) has resulted in massive deforestation. Overgrazing with increased numbers of local and transhumant livestock is one of the primary factors of deforestation and land degradation in places such as the *cercles* of Dièma and Yélimané.

In the Bafing-Falémé region, mining is intensive and is an important factor in deforestation. Artisanal gold mining causes serious damage to the environment with the placers (gold mining areas) quickly becoming vast fields of gaping pits. Industrial mining sites are multiplying in the area, especially over the last 20 years. In addition to the Tabakoto mine near Kéniéba in Mali, other sites are mined in the *cercle* of Kayes. In the Guinean part of the basin, several industrial mines hold concessions on areas ranging from 70–250 km^2. For example, there are two concessions toward the sources of the Falémé; one on the right bank of the Bafing toward Gagniakily and another involving dredging along a 23-km stretch of the Bafing (Bonnet, 1999). Mining creates borrow pits over vast land areas.

In Senegal, among the main contributing factors of deforestation are: high animal load and the resulting overgrazing (with the use of woody foraging to supplement livestock diets), the expansion of irrigated crops, etc. (ADT-Senegal).

[6] FAO. Analyse Diagnostique Transfrontalière du Massif du Fouta Djallon. Programme Intégrée d'Aménagement du Massif du Fouta Djallon.

In Mauritania and Mali, some pastoral practices such as topping and lopping off trees are on the increase due to the scarcity of forage resources. These practices compromise regeneration of woody vegetation.

The root causes of deforestation are population growth and low crop yields: agriculture (rain-fed, in particular) consumes so much space because it is extensive. The low standard of living among the basin population partially explains the recourse to using and selling wood in order to meet urgent survival needs. Improving access to some basin locations has also facilitated the arrival of wood users while increasing how much land is slated for speculation for exportation. In Mali, the creation of new roads and improvements for existing ones has opened access to the basin's wooded areas, making them more accessible to users of forest resources, particularly around and upstream of Manantali.

Consequences

One consequence of deforestation is habitat loss for some wildlife species, including rare species. Many of the basin's large mammals have disappeared (i.e., Derby Elands) or are threatened by disappearance. Lions and elephants no longer exist in the basin except in small numbers. Thus, deforestation decreases both fauna and flora biological diversity. Deforestation exposes soil, making it vulnerable to erosion. In some cases, the increased runoff due to rainfall can lead to deposits of transported solid matter along the river. Therefore deforestation participates in siltation of waterways and riverbank degradation.

Environmental Impact Matrix

Problem	Symptoms/Effects	Immediate Causes	Root Causes	Range
Deforestation	• Reduction of wooded areas; • Destruction of wildlife habitats & gradual degradation of protected areas; • Siltation of waterways and riverbank degradation.	• Clearing of the savannah and increased bush fires; • Unplanned use of wood (firewood, wood charcoal, lumber); • Overgrazing.	• Degradation of hydro-climatic conditions; • Demographic growth; • Poverty and wood use for survival needs; • Ineffective implementation of laws and policies related to forest management; • Increased access.	Entire basin Critical areas: Fouta Djallon Manantali region; Gold mining areas (upper basin in Guinea) Senegal River Valley (left and right banks)

Possible Priority Actions by Country Matrix

Country	Priority Actions	Type of Action
Guinea	• Promotion and increase of reforestation in mountain areas; • Combating overgrazing in sloping areas; • Development and promotion of alternative energy sources; • Raising public awareness about environmental degradation and its impacts; • Strengthening capacities of communities in forest resources management; • Proposing alternatives to slash-and-burn shifting	• Management plans for the environment and natural resources; • Transboundary approach to use of natural resources and bush fires; • Feasibility studies on small power station sites; • Awareness raising and education campaign.

Country	Priority Actions	Type of Action
	cultivation; • Intensification of law and regulation enforcement to stop encroachment in forests and protected areas; • Promotion of sustainable small-scale micro hydro power.	
Mali	• Promotion of reforestation in fragile and marginal areas; • Promotion of alternative energy sources; • Promotion of alternative grazing; • Controlling overgrazing in sloped areas; • Sustainable development in the Manantali relocation area; • Awareness raising and communication for behavior change.	• Environmental and water-resources management plans; • Application of legislation on natural resources use; • Baseline and priority development problems study in the relocation area; • Sustainable development projects for Manantali and the relocation area.
Senegal	• Restoration of gonakier forests; • Encouraging establishment of protected areas and forest reserves; • Management of natural forests.	• Transboundary actions to restore and manage gonakier forests; • Application of legislation and awareness raising.
Mauritania	• Promotion of reforestation in gonakier areas; • Promotion of alternative energy sources.	• Diffusion of simple techniques to restore gonakier groves; • Protection; • Diffusion of adapted techniques for use of forest resources; • Initiation of a targeted program in environmental education; • Extension of alternative energy.

1.1.2. Erosion and siltation

Erosion refers to degradation of the land's surface followed by lifting and transport of organic matter and minerals from the soil by wind or water. It occurs in several forms: (a) water erosion by rills occurs in the forms of rills and runnels affecting the upper soil horizon; (b) water erosion by gullies (gullying) affecting fragile terrain and occurring in the form of gullies able to reach deep soil horizons; (c) fluvial erosion occurring from sapping of riverbanks; (d) water sheet erosion resulting in the removal of the upper layer of soil on vast expanses of land; and (e) wind erosion especially affecting denuded and dry surfaces.

Siltation occurs in areas where soil matter deposits and accumulates due to erosion, particularly caused by wind.

The Senegal River Basin undergoes intense erosive activity, but the extent of the problem varies from one area to another in the basin.

In the upper basin and particularly in the Guinean part of the basin (Fouta Djallon Massif), manifestations of runoff and water erosion seem to have remained relatively low, despite the dense hydrographic network, intense rainfall and the mountainous landform. These were the results of the GERF (Rural Space and Forest Management in Guinea) Project assessment conducted in the Prefecture of Mamou, on the Bafing, the main tributary to the Senegal River (DNFF, 1996).[7] Other expert opinions highlight the increasingly alarming degradation of the

[7] DNFF. 1996. Une Expérience de Gestion de l'Espace Rural et des Forêts en Guinée. Mission de Coopération et d'Action Culturelle (France) and National Directorate of Fauna and Flora (Guinea).

Fouta Djallon Massif headwaters.[8] In all cases, erosion is a major phenomenon in the upper basin where the Senegal River takes in tons of solid matter each year.[9]

In the Malian part of the basin, the most severe cases of land degradation are found in the *cercles* of Bafoulabé and Kéniéba, particularly in the relocation sites for displaced Manantali residents. One possible explanation is that the massive and sudden arrival of the displaced populations could have increased the pressure on land tenure resources and simultaneously disturbed traditional forms of managing space.

In the river valley and delta, land erosion is prevalent as seen in the maps indicating the severity of land degradation in Senegal and Mauritania. In the Mauritanian part of the basin, the level of land degradation is between "serious" and "very serious," the highest levels for degradation based on the classification used for this FAO study. In Senegal, the levels fall around "serious" all along the valley and delta, namely from Bakel to Saint Louis.

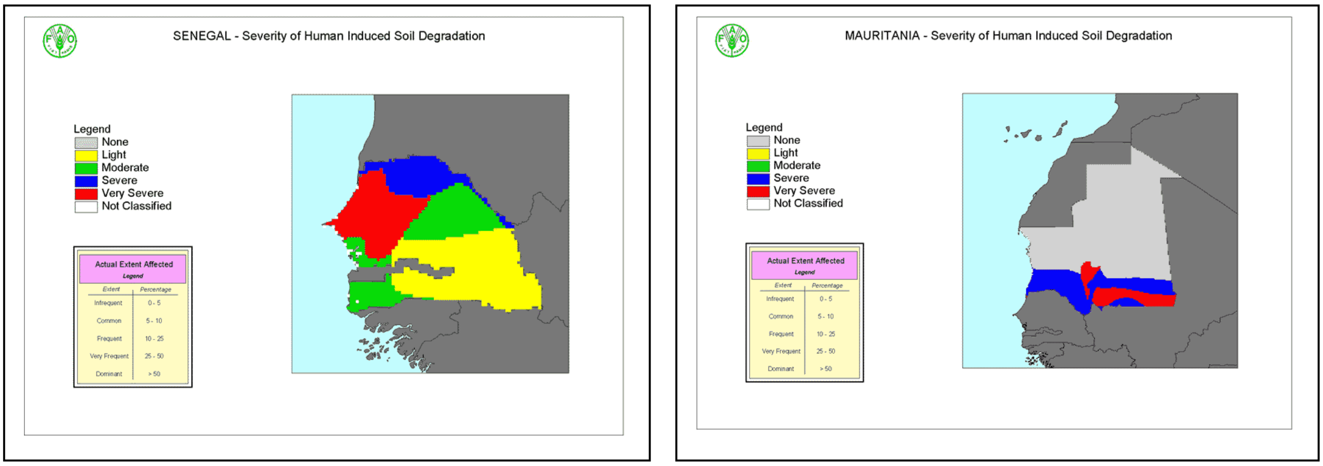

Figure 2.a & **Figure 2.b**. Level of land degradation in Senegal and Mauritania. (Source: FAO)

Causes

The direct causes of erosion include both natural and human causes. Natural causes of erosion are drought and intense wind activity. These natural factors have greater weight in the northern part of the basin: the middle and lower valley and delta.

Human factors causing erosion include slash-and-burn farming and annual bush fires that have greatly contributed to soil destruction. Extension of cultivated surfaces and leaving fields fallow for less time destabilizes land and makes it vulnerable to wind and water erosion. Overgrazing and subsequent intense soil compaction by herds increases vulnerability to water and wind erosion.

[8] DNFF.1996. Une expérience de Gestion de l'Espace Rural et des Forêts en Guinée. Mission de Coopération et d'Action Culturelles (France) et Direction Nationale de Faune et de Flore.
[9] FAO, 2004. Analyse Diagnostique Transfrontalière du Massif du Fouta Djallon. Programme d'Aménagement Intégré du Massif du Fouta Djallon.

Siltation

One consequence of erosion is siltation (or sand invasion) defined as complete invasion of objects or surfaces by grains of sand, resulting in an accumulation of sand and/or the formation of dunes. Wind erosion is the main cause of sand invasion with the wind playing the triple role of erosive agent, transporter and depositor in dune formation. It is true that in the context of the Senegal River Basin most of the grains of sand deposited by the wind to form dunes come from elsewhere, the Sahara in particular.

The most acute manifestation of sand invasion in the Senegal River Basin concerns the right bank in the lower valley (the Trarza *wilaya* in Mauritania), a region with many sand dunes. The 20–30 km of active dune fronts threaten the Senegal River valley in the Mouqata de Rosso, R'Kiz and Boghé.

Some of the waterways on the left bank of the delta are also subject to sand invasion caused by wind erosion: for example, the intermittent streams and depressions of Diovol, Djeuss, Nietti Yone and Ndiael (AGRER et al., Vol. 1, 2003:22).

Responses

To control sand invasion and thus wind erosion, significant efforts in dune fixation have been made over recent decades. The "Barrières Vertes du Trarza (Green Barriers of Trarza)" Project fit within the framework of these efforts and was operational until 1998 (AGRER et al., Vol. 2, 2003:173).

Environmental Impact Matrix

Problems	Symptoms/Effects	Immediate Causes	Root Causes	Range
Land erosion and sand invasion	• Sand dunes; • Loss in land fertility causing an expansion of cultivated land; • Loss of habitats and biodiversity; • Siltation of waterways in flood areas; • Formation of islets and sandbanks.	• Unsuitable farming practices and high pressures on fragile areas; • Lack of land and water conservation practices; • Bush fires; • Overgrazing and intensive soil compaction; • Drought and wind activity.	• Growing population with urgent economic needs; • Increase in crop farming along the river.	-Upper basin: Plateau areas and along the river/*cercles* of Kati, Kita, Kolokani, Koulikoro, Banamba, Kéniéba and Kayes; -Right bank: Lower valley (Trarza); -Right bank: Middle valley; -Left bank: lower valley and delta.

Possible Priority Actions by Country Matrix

Country	Priority Actions	Type of Action
Guinea	• Promotion of drainage basins based on a holistic approach and rational consultations between stakeholders; • Identification and evaluation of susceptible and eroded areas in the basin.	• Land management program; • Capacity building for communities, perennial structures and operators; • Education, information and communication programs.
Mali	• Develop management plans for banks of waterways; • Accelerate transfer of natural-resources management to territorial collectivities with the necessary related measures;	• Study on the causes of riverbank erosion; • Implementation of law on riverbank occupation.

Country	Priority Actions	Type of Action
	• Control overgrazing on sloped areas; • Control siltation.	
Senegal	• Establish rational policies and practices on farmland use; • Promotion of land conservation and restoration programs; • Promotion of anti-erosion measures.	• Improve techniques in land use practices; • Management information; • Strengthen capacities.

Riverbank degradation

Riverbank degradation manifests itself by receding or gullying of riverbanks and riverbed displacement. This phenomenon has been discussed in detail in the impact study by Gannett Fleming et al. (1980) in the context of construction of the Diama and Manantali dams. This study pointed out several reaches based on the size of their bedloads[10] and their effects on riverbank erosion. The bedload in the upper basin of the Senegal River (upstream of Guinea) is low, resulting in the riverbed's stability. Upstream of Kayes and in the lower valley of the Falémé, the bedload increases (100,000 tons per year in Kayes) and causes greater erosion, although particularly affecting the channel and not the riverbanks: the Falémé is described as having little exposure to riverbank erosion. Even with the Manantali dam, the Gannett Fleming study did not predict that channel instability could have a significant effect on river alignment. Instead, between Bakel and Wending (toward Boghé), Gannett Fleming et al. noted higher riverbed instability and the greatest riverbank erosion, which was due to the bedload (Gannett et al., Partial Report on the River and Estuary Regime/Rapport partiel sur les régimes du fleuve et de l'estuaire, 1980:35–36). Even here, the Gannett Fleming study predicted that regularization of the river's flow (with the Manantali dam) would result in decreased erosion of banks. Downstream of Wending, the bedload is less and even non-existent.

Regarding the current situation, the lower valley does not appear to be suffering from a serious problem of riverbank sapping. In the delta, *Typha* cover plays a stabilizing role for riverbanks. Upstream of Podor, small rockslides have been observed that are caused by rainwater runoff (the valleys of Koundi and Diou in Mauritania).

Further upstream, the issue of riverbank erosion is more serious on some reaches of the river. Field mission reports by the Malian OMVS National Unit in 2005 illustrated the extent of the problem. The most affected locations identified in this report were located on the reach between Bafoulabé (Baking-Bakoye confluence) and the confluence between Karakoro and Senegal Rivers, slightly downstream from Ambidedi. In the village of Saboussiré (Logo commune in the same *cercle*) and Ambidedi and Diakanapé (Kéméné Tambo commune), occupants abandoned their houses destroyed by riverbank erosion. The village of Sobocou (Soni commune) saw its territory encroached upon by more than 100 m due to the advancing riverbank. Even in the locality of Kayes, threats on the EDM power plant was reported. In Ambidedi, no other solution was found other than to relocate if nothing was done to stop the progression of erosion.[11]

[10] Bedload is defined as the ratio of total concentration of sedimentary particles that move by churning (sliding) along the channel bed.

[11] Sources: CNC-OMVS-Mali. 2005. Rapport de mission relatif à la collecte de données pour la protection des berges dans le Haut Bassin – 31 March to 5 April. CRM/CN-OMVS-AB. No.5. Bamako; van den Herik; Abraham Sogoba; Rien Veldhoen et al., 2005. Rapport de Mission à Kayes. Mali OMVS Unit – Royal Haskoning. April

Direct causes

A report from the Malian unit of the OMVS[12] identifies the following factors as causes of riverbank erosion in the Malian part of the basin:

- The fact that soil texture in the upper valley of the Senegal River is not very compact, making it vulnerable to erosion;
- The fact that successive droughts in the 1970–80s have gradually transformed the forest into a savannah;
- The high population concentration along the river for the last 25 years;
- Massive deforestation in areas surrounding the river related to human activities: clearing, wood cutting (notably fuel wood) to cover household needs of local communities and supply the city of Kayes;
- Poorly designed sanitation developments and systems;
- Overgrazing along the Senegal River. Relative to this, the number of herds in the basin has significantly increased and tends to concentrate along the river and its tributaries during the dry season;
- Banco (clay) extraction; uncontrolled ramp construction to access the river for human activities;
- Non compliance with the servitude of the river; a ban on building or planting at a minimum distance of 25m from the riverbank; and
- The natural hydro-mechanic process of the river (meanders).

The bedload (concentration of particles that flow along the river) is a significant factor in changes to riverbank morphology. From this perspective, speculation arose as to whether the bedload would increase with the dams and contribute to the acceleration of riverbank sapping. In the study conducted by the AGRER, et al. (Vol. 2, 2003:174), the authors think that riverbank recession maintained the same rate compared to the situation before the dam. The Manantali dam does not appear to have enabled riverbank and waterway stabilization (AGRER, et al., Vol. 2, 2003:174). No reports have even put forth the hypothesis that releasing the Manantali dam's floodgates have accelerated the process of erosion downstream of the dam.[13] Understanding the positive or negative roles played by the Manantali dam and particularly the floodgates in riverbank erosion remains a vital question that should be clarified.

Nevertheless, it is clear that runoff from rainwater into the river can cause significant gullying that, combined with the bedload can accelerate the riverbank degradation process. This process is facilitated when land has been denuded, as it the case for the majority of the basin and somewhat in the Sahelian part.

Extreme hydro-climatic events such as flooding and exceptional rainfall can act as triggers or accelerators in the riverbank erosion process. The SOE report (2005) notes that during the high flooding in 2003, several residences located close to the Senegal River were threatened

[12] OMVS National Unit – Mali. Undated. Rapport Technique sur la Dégradation et l'érosion des berges dans la partie malienne du bassin.

[13] Hypothesis made during the workshop to validate the preliminary report of this TDA. Local communities affected by this phenomenon also often suggest this hypothesis. (See Diop, Fousseyni. 2005. Erosion des berges du fleuve Sénégal dans le Cercle de Kayes. Dissertation for Degree in Engineering. Institut Polytechnique Rural de Formation et de Recherche Appliquée. IPR/IFRA. Katibougou, Mali.)

with collapse or did collapse due to riverbank erosion. In addition, the extent of this process was particularly concerning in Mali (SOE, 2005).

Root causes

The river's capacity to dislodge and transport solid matter depends on two factors: (a) output level and discharge velocity; and (b) the pre-existing sediment load in the river water. If the output and discharge velocity are low and the river is already heavily loaded with solid matter (approaching saturation), the capacity to lift new matter and therefore destroy riverbanks is low. The Manantali dam affects these various factors: regularization of flow; and continuous flood release (notably for electricity production needs and in periods of flood management). Manantali also decants some water from the Bafing, and its sediment load downstream is reduced compared to the level before the dams. However, more in-depth investigations are needed to determine if these various factors play a role in riverbank erosion that prevails in the Bafing reach downstream of Manantali between Bafoulabé and the confluence of the river with the Karakoro.

Livestock concentration along the river for most of the year is also sometimes due to insufficient water points in areas where fodder exists.

Consequences

Degradation of riverbanks can endanger villages and cultivated areas along the river. The extent of the damage caused by erosion has been described above. Besides loss of housing and physical investments in villages along the river, sapping of riverbanks can impede the goal to make the river navigable from Kayes to Saint Louis, which is one of the pillars of the OMVS program. Material removed by water from riverbanks is partly deposited in the riverbed, which can then build up into sills and banks that thwart river navigability.

Possible responses

In its report cited above, Mali's OMVS Unit cites the following options to confront riverbank erosion:

- Awareness raising for concerned communities on the need to comply to regulatory standards for land use and management;
- Reforestation (native species, live hedges);
- Fixation of riverbanks and ravines (gabion walls);
- Construction of small dikes/stone lines on contour lines; and
- Construction of hill reservoirs in the small water basins.

In addition to these measures, an in-depth study should be conducted to better determine the causes of the current intensity of riverbank erosion. It is urgent to determine whether releasing the Manantali floodgates contributes to riverbank erosion. Appropriate measures could then be taken based on the results of these investigations.

Environmental Impact Matrix

Problem	Symptoms/Effects	Immediate Causes	Root Causes	Range
Riverbank degradation	• Receding and/or gullying of riverbanks; • Raising the riverbed; • Destruction of residences along the river; • Destruction of economic investments; • Risks on river navigability.	• Bedload increase from river; • Runoff from rainwater; • High concentration of herds along riverbanks; • Devastating flooding and rainfall.	• Increased volume and velocity of river flows; • Pre-existing low sediment load in river; • Insufficient water points and thus, high concentrations of livestock on riverbanks.	Downstream Manantali, on the Bafing (Mali); Area between Bafoulabé and Ambidedi (Mali).

1.1.3. Land salinization and loss of farmland

In the Senegal River Basin, land salinization is caused by capillary action of the superficial salt layers. Within the basin, the delta has been most affected by land degradation caused by salinization. Here, land salinization results from high accumulations in the quantity of soluble salts in the soil profile (AGRER, 1998).[14] This accumulation results in a rise in the level of the groundwater aquifer, which is already not very deep and salty. The salinity of this layer is caused by the series of sea transgressions and regressions occurring in the lower delta and lower valley over thousands of years and particularly the last transgression about 2000 years ago. More recently, a rise in the level of this salt layer has been observed on the order of 0.4–0.8 meters between 1991 and 1998.

Causes

The salt layer transports large quantities of salt to the soil's surface through capillarity. This phenomenon of capillary action mainly takes place in the hot dry season, in conditions where evapotranspiration is particularly high. Since most of the irrigated areas of the lower valley and delta were managed without a suitable drainage system, irrigation water deposits considerable amounts of salt at each cycle (AGRER, 1998). This increases the effects of capillarity on land salinization. Yet studies also show that intensive irrigation farming with an adequate drainage system causes a drop in soil salinity. In effect, Ceuppens shows that salinity increases in the following order: double cropping with drainage, single cropping with drainage, single cropping without drainage and abandoned fields. Moreover, these studies highlight that salinity decreases when the number of years that fields are cultivated by rice increases, so that uncultivated land is always saltier than land that has been cultivated. Ceuppens infers that the capillary action phenomenon (and not irrigation, as such) plays the most determinant role in the process of salinization of cultivated land in the delta.[15]

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[14] AGRER. 1998. Etude d'Evaluation Environnementale du Programme de Développement Intégré de l'Agriculture Irriguée en Mauritanie (PDIAIM). Vol. 2: Main text. Final Report. World Bank/SONADER. August.
[15] Ceuppens, Johan. 2000. Water and Salinity Management for Irrigated Rice in the Senegal River Delta. October.

Consequences

The salt that rises up to plant roots eats away at the plant tissue and prevents photosynthesis, therefore contributing to decreased crop yields. When salinity increases, salt plates end up covering the soil. This leads to the abandonment of large expanses of land managed for irrigation (and particularly land with no drainage system) in the lower valley and river delta each year.

Possible solutions:

- Ensure that a proper drainage system is planned for areas with managed irrigation; and
- Accelerate construction of an effluent from the delta: a main drainage canal for water from the lower valley and delta (left bank); and plans for a similar investment on the right bank.

Results from the study on land salinization and loss of farmland have identified both immediate and root causes, symptoms and impacts as well as the range of this Senegal River basin-wide major environmental problem. All of these identified parameters have been summarized in the *Environmental Impact Matrix* below.
Identifying these various parameters made it possible to distinguish priority actions, summarized in the *Possible Priority Actions by Country Matrix* below.

Environmental Impact Matrix

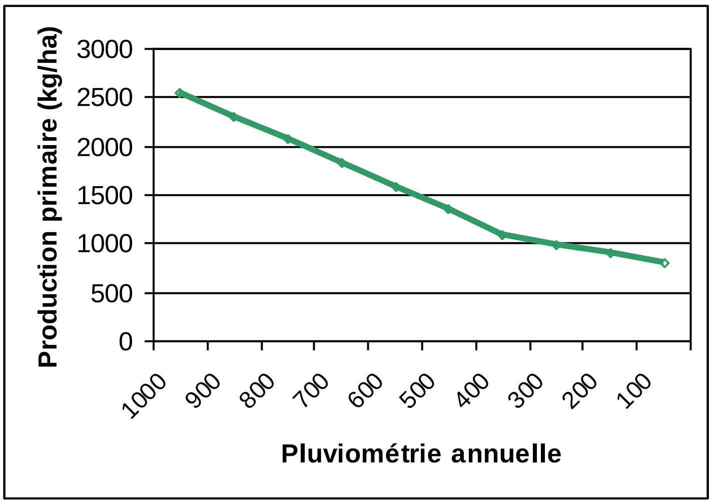
Problems	Symptoms/Effects	Immediate Causes	Root Causes	Range
Land Salinization and loss of farmland	• Salt plates covering land; • Decreased soil fertility, hence decreased yields; • Abandonment of managed land; • Increase in land unsuitable for farming.	• Capillary action of superficial salt layers.	• Rise in the salted groundwater • Lack of an appropriate drainage system for irrigated areas.	River Delta (particularly the left bank).

Possible Priority Actions by Country Matrix

Country	Priority Actions	Type of Action
Mauritania	• Appropriate policy and regulations on water use for irrigation; • Adequate planning for drainage.	• Establish standards; • Improve techniques in irrigation practices; • Strengthen capacities.

1.1.4. Overgrazing

Overgrazing occurs when the actual animal load for a given space exceeds its load capacity. Therefore, the load capacity is the maximum quantity of livestock that a pasture is assumed to be able to support without deteriorating. When the capacity load is exceeded, there is overuse and thus, degradation of routes. Load capacity is based on the necessary feed intake of dry matter for a standard animal to maintain itself. For example, daily rations of forage dry matter for a standard bovine per year is estimated at approximately 2.5% of its weight, or 2.28 t of forage dry matter per year for one Tropical Livestock Unit (TLU) weighing 250 kg.[16] The load capacity is determined by measuring the forage biomass supplied by the pasture and applying a biomass utilization coefficient (between 35 and 90 per 100), which is a function of the type of vegetation, the mode of livestock farming and the species. Since biomass production fluctuates annually depending on rainfall conditions, the load capacity of a space can vary from one year to another. (See the graph below, estimating biomass production based on annual rainfall in the context of arid and semi-arid settings.)



<u>Fig. 3.</u> Estimation of primary grass production based on annual rainfall (Breman Formula).
(Translation for Graph: Pluviométrie annuelle: Annual Rainfall; Production primaire: Primary Production (kg/ha)

In the Koulikoro region, average forage production was estimated at 2.03 t per hectare in 2005 using the Breman formula. It was estimated that only 30% of this forage production was usable by the livestock (the remainder being unavailable due to bush fires, wind or other reasons or simply because it was unappetizing to the livestock).[17] Based on this, the load capacity for this region in 2005 was estimated at 3.7 ha per TLU. The 2005 annual DRPIA report on Koulikoro estimates that the region has a resident livestock population of 1,165,000 TLUs. This herd's density is 1 TLU per 7.70 ha on a regional scale (the land area of the Koulikoro region is 90,120 km^2). However, if the actual land area of pastures is taken into account, and by deducting the agricultural fields, classified forests and areas occupied by

[16] Carrière, Marc and Bernard Toutain. 1995. Utilisation des terres de parcours par l'élevage et interactions avec l'environnement. Outils et indicateurs. CIRAD-EMVT. February.
Source: www.virtualcentre.org/zh/dec/toolbox/Refer/PARC-fre.pdf
[17] DNPIA-Mali. 2005. Rapport annuel 2005 de la Direction Régionale des Productions et Industries Animales (DRPIA)-Koulikoro. National Directorate of Animal Production and Industries (DNPIA). Bamako. December

habitats, the actual livestock load falls below 5 ha per TLU, which is very close to the estimated load capacity for the region. Nevertheless, it is well known that these livestock herds are unequally distributed in the area and tend to stick close to water points: boreholes, ponds, lakes and the Senegal River and its tributaries.

In areas of high livestock concentrations in the Koulikoro Region, overgrazing rapidly sets in especially given the massive influx of transhumant livestock each year (see Figure 4).[18] A similar situation exists in the Kayes Region. The Directorate of Livestock Services' annual report for 2005 for this region estimated the fodder needs for local livestock at 2,030,000 tons of dry matter compared to a total production of 7,000,000 tons of fodder for which over half is unavailable for the same reasons cited in the case of the Koulikoro region.[19] During the dry season, livestock in this region as well as transhumant herds are concentrated around Lake Magui and along the Senegal River.

Results from the PRODESO Project (Western Sahel Livestock Development Project) are very close to the livestock service's estimations. This project estimated the load capacity on pastoral routes in the study site (northern region of Kayes) at 8.5 TLU/ha. Specifically, the sedentary cattle herd accounts for a load of 4.5 TLU/ha on its own.[20] If small ruminants, camelidae and the additional herds that cross the area on a seasonal basis are taken into account, it is evident that the load capacity is often greatly exceeded.

This all confirms findings from the Mali TDA that estimate that the areas of Koulikoro, Kita, Kéniéba, Manantali and the environs of Lake Magui are the most exposed regions to overgrazing in the Malian part of the basin. The report also observes that livestock density, and therefore the risk or overgrazing, is moving from the *cercle* of Dièma toward the Boucle du Baoulé (TDA-Mali).

In the Mauritanian part of the basin, there are three main areas of high livestock concentration: (a) the El Aft Reserve in the Gorgol sub-basin; (b) Guidimakha (Oued Yeyi); and (c) Trarza (Aoulig depression between Keur Macène and Rosso). The Gorgol region (El Aft) can host up to 40–60% of the livestock in the dry season.[21] In Mauritania, the critical level of overgrazing is reached between December and June. According to FAO statistics (1993) cited by Corniaux (1999), the Mauritanian livestock is concentrated on the right bank of the Senegal River, with 33%, 44% and 23% of the national livestock population of cattle, small ruminants (sheep and goats) and camels, respectively (FAO, 1993).

As for the left bank (Senegal), statistics from the Directorate of Livestock show that cattle, small ruminants and camels account for 25%, 21% and 41%, respectively, of the national livestock population.

In the upper basin, the Guinean part is the area with a strong pastoral tradition because the majority of its population is Fula. The nine prefectures in the Guinean part of the basin host

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[18] Good rainfall levels were recorded throughout the Koulikoro region in 2005. Recorded rainfall was above the average for 1971–2000 by 10–30% in the region's different *cercles*, except in Koulikoro where a 10% deficit was recorded.

[19] DNPIA-Mali. 2006. Rapport annuel 2005 de la Direction Régionale des Productions et Industries Animales (DRPIA)-Kayes. National Directorate of Animal Production and Industries (DNPIA). Bamako. February

[20] DIWI Consult International/Sahel Consult. 2000. Bilan et Impact des réalisations du PRODESO (Phases I et II). Programme d'investissement complémentaire. Final version. PRODESO. Nov. 2005. Western Sahel Livestock Development Project (PRODESO II). Completion Report. December.

[21] Personal communication, Dr. Moctar Fall, Director, Directorate of Livestock, Mauritania.

one-third of Guinea's cattle herds and just over one-fourth of the small ruminants (these prefectures cover 28% of Guinea's land area and support 20% of the national population).

Immediate causes of overgrazing

Degradation of vegetation cover (decrease in primary production of biomass and degradation of the quality of forage) causes a drop in livestock load capacity.

During the dry season, livestock are concentrated in areas where water availability is independent of whether or not forage is available in sufficient quantities. Proper layout of water points in livestock areas would help reduce pressure and therefore, reduce overgrazing along the river and its tributaries.

Progress in veterinarian medicine and the extension of livestock vaccination for the most common epizooties has led to an extraordinary increase in the number of livestock throughout the Sahel, including in the four basin countries.

The expansion of agricultural land reduces the size of pastoral areas, and the irrigated areas that border the river reduce livestock access to the river. Access corridors to reach the river and riverbanks that are accessible to livestock undergo extreme trampling, and thus, exposure to wind erosion and gullying.

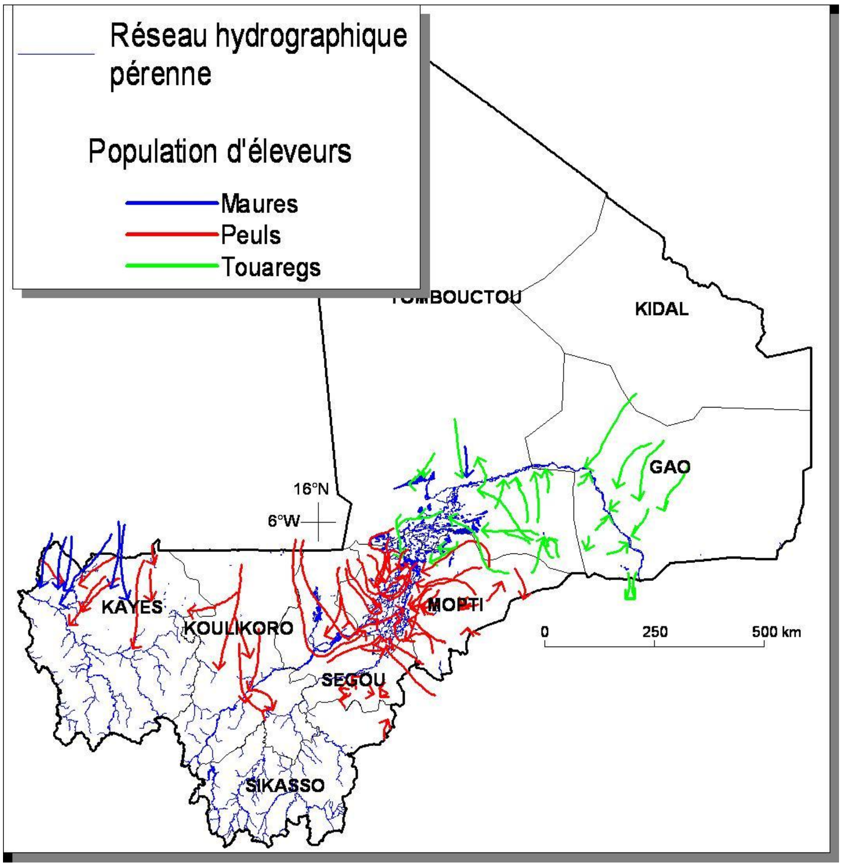

Fig. 4. Migration flows of cattle herds in Mali (MDR-Mali, 2002)[22]

[22] Ministry of Rural Development (Mali). Recensement National du Cheptel Transhumant et Nomade. Final Report. Vol.1. MRD/Planning and Statistics Unit. European Union. May.

Consequences/impacts

- Land subjected to intense compaction from herds becomes easily moveable by winds (wind erosion) and is more vulnerable to water erosion.
- Pruning trees to supplement animal diets.
- Conflicts between farmers and livestock herders.
- Changes in the floral composition of grass cover, often in a negative direction.

Possible solutions

Following the example of PRODESO in Mali or experience gained in Senegal from the SODESP (Livestock Development in the Sylvo-Pastoral Area Company/Société de Développement de l'Elevage dans zone sylvo-pastorale), plans could be made to increase the number of water points for livestock about a few dozens of kilometers from the river banks. This would allow for reducing the time that livestock are along the river and consequently help in reducing conflicts between farmers and herders resulting from the increase in irrigated areas.

Another option is to revisit the issue of livestock intensification that could take advantage of the agricultural by-products from irrigated crops (tomatoes, rice) and flood recession crops. Rice straw; rice and sorghum bran; haulm from sweet potato, cowpea and groundnut; sugar cane molasses and tomato malt could be provided for quality livestock feed.

Environmental Impact Matrix

Problem	Symptoms/Effects	Immediate Causes	Root Causes	Range
Overgrazing	• Overuse of pastures that lose their capacity to regenerate; • Appearance and expansion of *bowé* across large expanses in mountainous areas; • High degradation of plant cover; • Reduction in pasture areas and increased conflicts related to common natural resources; • Decrease in available fodder; • Damage of crop farming products in concentration areas (lakes, rivers); • Changes in floral composition of plant cover.	• Increase in number of livestock; • Degradation of vegetation cover and its animal load capacity; • Expansion of land for crop farming (reduction in pastures); • Expansion of irrigated land along the river (reduced river access for livestock); • Prolonged stays for herds around the rare existing water points, ponds and lakes and especially along the river; • Influx of transhumant livestock.	• Improved veterinarian coverage for livestock (increased herds); • Extensive livestock farming system; • Low density of pastoral water points.	Entire basin Critical areas: • Fouta Djallon; • Mali: The north and east part of the basin particularly the *cercles* of Kayes, Diéma, Yélimané, Kolokani; Banamba, Kita, Bafoulabé; • Area of Magui pond and *cercle* of Bafoulabé in Mali; • Senegal River valley in the environs of the sylvo-pastoral area and the Trarza region.

Possible Priority Actions by Country Matrix

Country	Priority Actions	Type of Action
Mali	• Development of policies and modalities for rational transhumance management; • Application of a regional master plan for pastoral management; • Development and implementation of management plans; • Institution and demarcation of transhumance corridor.	• Transboundary management plan for livestock; • Political pursuit of water points to reduce pressure on lakes and river.
Senegal	• Development of adapted regulation for livestock management; • Strengthening community management of floodplain pastures; • Integration of livestock management and the irrigation program.	• Integration of livestock management and the irrigation program; • Strengthen the pastoral water program to reduce animal pressure on the river; • Define a strict land occupancy policy; guaranteeing livestock access to the river and Lac de Guiers; • Intensification of livestock farming.
Mauritania	• Application of legislation on transhumance; • Promotion of a transboundary convention related to transhumance; • Setting up methods for monitoring and pastoral resources management.	• Integration of livestock management and the irrigation program (intensification of livestock farming); • Organization of transhumance; • Management plan for space occupancy; • Inventory of route areas; • Assessment of capacity load of pastures; • Design the best methods for route management; • Institution of seasonal closures in highly degraded areas; • Accelerate the pastoral water point policy to reduce pressure on the river.

1.1.5. Bush fires

The highest frequency and intensity of bush fires has been reported in the upper basin, particularly in the Fouta Djallon Massif (see map below). In Guinea, according to the FOSA report, between 1,500,000 ha and close to 5,000,000 ha of surface area is burned annually (figures for the 1987–1994 period) especially in 11 Prefectures, including Siguiri, Dinguiraye and Dabola, which partially lie in the Guinean part of the Senegal River Basin. For Mali, the only available data (SPOT images) show that the affected area within the country amounts to about 9,200,000 ha for 1987–1990. These bush fires affect all of the regions of this country, but the extent in the Malian part of the Senegal River Basin has not been specified.[23]

The estimated percentage of the volume of wood that is destroyed by bush fires between January and May in one Sahelian savannah region is between 4.5% and 14% (Decleire, 1999).[24]

[23] Ministry of Environment and Sanitation (Mali). 2006. *Rapport national sur l'état de l'environnement 2005.* Bamako. March.

[24] Decleire, Yanek. 1999. Développement de la gestion des feux de brousse au Sénégal. GTZ:PSACD. November. Source: www.fire.uni-freiburg.de/GlobalNetworks/Africa/Senegal-feux-1999.pdf

Causes

Some agro-pastoral practices used in the upper basin rely on seasonal bush fires. In terms of agriculture, shifting rice cultivation requires annual clearing of large surface areas of new woodland. One reason why fire is used for clearing is that this can limit weed infestation of the fields after lying fallow, and ashes from the burning act as soil fertilizers. Herders also often resort to fires (generally from November to March) to promote the growth of the nutritious grass preferred by livestock. Hunters also sometimes hunt their prey using bush fires. In some cases, fires have preventive uses: setting a controlled fire can reduce highly flammable biomass to mitigate destructive fires (Mbow, 2004).[25]

Once it has started, the bush fire becomes uncontrolable and can ravage much more land than intended by the farmer, livestock herder or hunter who started it.

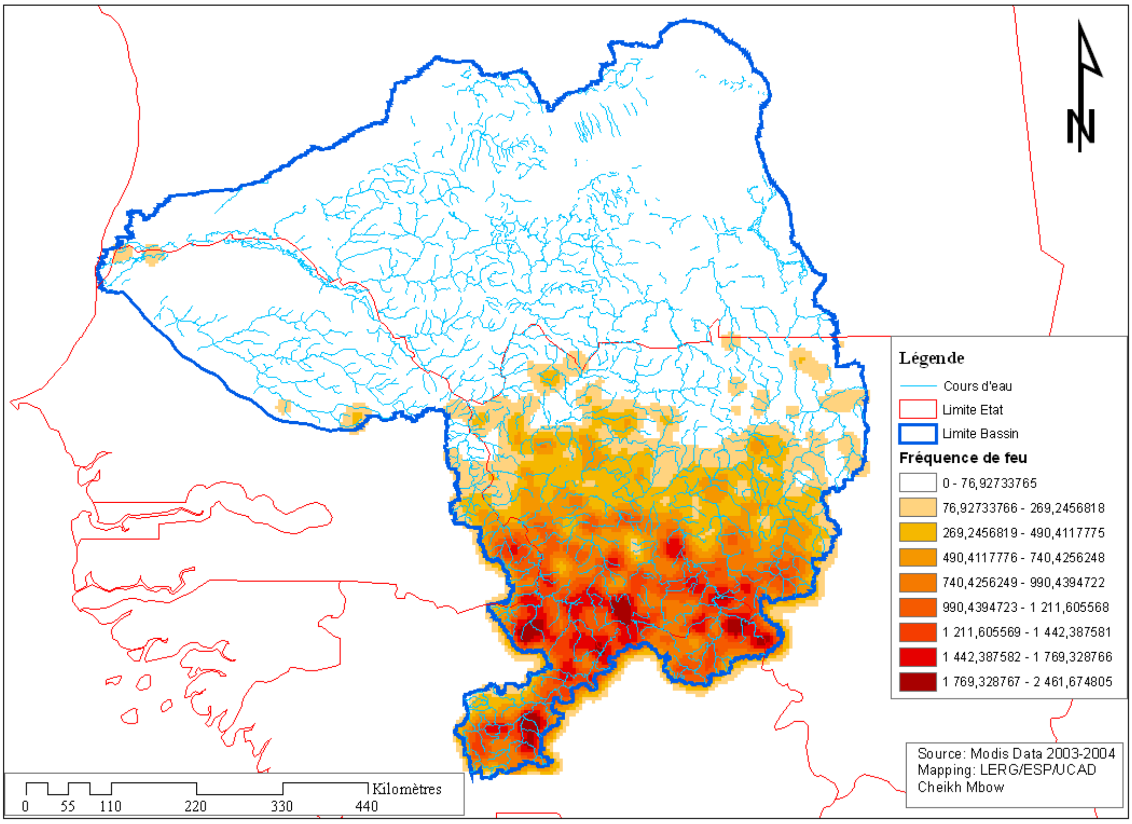

Fig.5. Frequency of bush fires in the Senegal River Basin from November 2003 to May 2004 (by Dr. C. Mbow, LERG. 2006).

Consequences

Bush fires are one of the main factors of land and ecosystem degradation in the West African savannah, particularly in the Senegal River Basin. They disturb the natural cycle of plant mortality and regeneration, and they cause or accelerate water (runoff) and wind erosion and long-term losses from soil erosion (Mbow, op. cit. 2004).

[25] Mbow, Cheikh. 2004. Rapport sur les feux de brousse au Sénégal pour la saison sèche de Novembre 2003 à mars 2004. LERG (Laboratoire d'Enseignement et de Recherche en Géomatique) and Institut des Sciences de l'Environnement (UCAD). June. Source: www.fire.uni-freiburg.de/GlobalNetworks/Africa/Senegal-Rapport-Feux-2003-2004.pdf

Possible responses

Recognizing the fact that bush fires are sometimes a "necessary evil" has helped in changing the paradigm in effect over recent years. This change has entailed moving away from strategies that exclusively focus on combating bush fires toward strategies that emphasize the concept of bush-fire management (Mbow, 2004, op. cit.).

Therefore, possibly the best response to bush fires is not punitive or aimed at a sudden reduction or end to bush fires in the short term. One alternative approach is to better rationalize and discipline the practice of bush fires so that justified fires can be set and the targeted space can be circumscribed. This type of strategy for bush fire management can only succeed if it is truly participatory and makes local communities accountable. This strategy would combine prevention (awareness raising, appropriate and deterrent legislation where needed and alternative agro-pastoral techniques), control (in the sense of circumscribing areas affected by tie-ridging) and literally combating fires that are unjustified or for which better alternatives exist (DNCN-Mali, 2006).[26]

Environmental Impact Matrix

Problem	Symptoms/Effects	Immediate Causes	Root Causes	Range
Bush fires	• Land degradation; • Loss of biodiversity (fauna and flora); • Water and wind erosion.	• Farming technique based on burning; • Early fires for livestock needs; • Hunting/poaching technique.	• Demographic pressure; • Poverty; • Lack of appropriate legislation.	• Upper basin: -Fouta Djallon Massif - Mali

1.1.6. Desertification

The United Nations Convention to Combat Desertification defines desertification as land degradation in arid, semi-arid and dry sub-humid areas resulting from climate variations and human activities.

Climate factors contributing to desertification are high variability of annual rainfall, long breaks in rainfall during the rainy season, frequent droughts, etc. The most common human factors of desertification are land overuse, overgrazing, poorly adapted agricultural practices, deforestation and bush fires. The combined effects of these factors denude the land and expose it to water and wind erosion.

[26] DNCN-Mali. Problématique des feux de brousse. Impacts et Stratégie de Lutte. Ministry of Environment and Sanitation (Mali)/National Directorate of Nature Conservation.
Source: www.malifao2006.org/pdf/feux_brousse.pdf

Thus, deforestation is the result and consequence of deforestation, land erosion and overgrazing. Desertification is the final stage of land degradation, resulting from deforestation, land erosion and overgrazing (TEA).

In the Mauritanian part of the Senegal River Basin, desertification mainly affects the marginal areas surrounding the ecosystems of Trarza’s drylands (TDA-IRM). In the basin’s Malian part, desertification is most intense in the *cercles* of Kayes, Yélimané, Diéma, Kolokani and Banamba where it results in rainfall deficits and destruction of flora. (TDA-Mali)

Impacts

Desertification’s main impacts, which are also its manifestations, are the low soil productivity, declining vegetation formation, loss of habitat for certain species and therefore, the loss of biodiversity. In addition to these effects on the environment, desertification results in social costs due to lowered food production leading to food insecurity, malnutrition, famine, civil unrest and conflicts regarding access to resources. (TDA-Mali)

In the valley, one of the greatest impacts of desertification has been the reduction in surface area of arable land, pastures and forests as well as reduced water resources. Desertification’s adverse effects on agricultural productivity and crop yields have resulted in:

- Jeopardized food security and the standard of living for communities;
- Massive migrations of populations to large urban centers;
- Difficulties in supplying water for human and livestock needs;
- Considerable economic losses. (TDA-IRM)

Possible solutions

Within the implementation framework of the United Nations Convention to Combat Desertification, three of the Senegal River Basin countries (Mali, Mauritania and Senegal) have developed their National Adaptation Programs to Combat Desertification: since 2000 for Mali and Senegal and since 2002 for Mauritania. A Sub-Regional Program to Combat Desertification in West Africa and Chad has been available since 1999. However, the implementation status of these various plan is rather disappointing.

Given the strong political will to promote cooperation within the Senegal River Basin, it is possibly foreseeable to conduct an audit of the existing national plans to draw elements from them to formulate a plan to combat desertification in the Senegal River Basin. Given its current dynanism, the OMVS could act as an effective framework to implement such an action plan.

Environmental Impact Matrix

Problem	Symptoms/Effects	Immediate Causes	Root Causes	Range
Desertification	• Decreased land productivity; • Reduction in arable land, pastures and water resources; • Loss of biodiversity; • Jeopardizing food security and standard of living for communities; • Rural exodus.	• Deforestation; • Bush fires; • Erosion/siltation; • Rainfall deficits and depletion of water resources; • Increasingly long droughts.	• Increasing climate variability; • Overuse of natural resources; • Unsuitable land-tenure plan.	Localized: Mainly in the northern part of the basin. Critical areas: Northeast part of Yélimané region; eastern part of Trarza, Environs of the Ferlo. Sahelian *cercles*: Yélimané and Dièma.

Possible Priority Actions by Country Matrix

Country	Priority Actions	Type of Action
Mali	• Promotion of rational policies to combat desertification and conserve land within the framework of the UNCCD • Rational use of natural resources.	• Bush fire management plan from a transboundary perspective; • Communication for behavior change.
Senegal	• Promotion of a rational policy to combat desertification and conserve land within the framework of the UNCCD; • Implementation of a National Action Plan developed within the framework of the UNCCD; • Promotion of sound land management.	• Land-use planning. • Dune fixation; • Re-flooding of the flood plains; • Awareness raising.
Mauritania	• Application of priority actions in cooperation with National Program of Action to Combat Desertification; • Analysis and monitoring of the wind dynamics in all its components.	• Rational land management based on a plan; • Awareness raising and education; • Conducting a survey of dune fixation efforts; • Development of a program to combat siltation and erosion; • Identification of types of siltation; • Mapping of landforms to monitor; • Implementation of protocols; • Monitoring of wind dynamics; • Development and diffusion of best practices guide; • Demarcation and rational management of irrigated areas; • Development of a communication strategy.

1.2. Water supply and quality

Achieving objectives aimed at managing waterways (dams and other investments) is sometimes compromised when the river regime behaves unexpectedly. This section investigates whether current trends in supply and quality of surface and groundwater are likely to constitute constraints for the environment, health and basin development.

However, conducting this type of analysis is made difficult by the lack of information in the available studies.

1.2.1. Water supply in aquifers

Several types of aquifers have been identified in the Guinean part of the basin that share the characteristic of low flow levels (often less than 1 liter/second) located at shallow depths (1–10 meters). Water supply in these aquifers often depends on local annual rainfall. These aquifers seldom supply water, unlike the rivers and streams that make up the population's primary source of supply. These aquifers are only used during the dry season (Kane, 2005).[27] Since these aquifers are generally covered by a relatively impermeable lithologic layer (recharge occurs through leakage into fissures in the rock), they are exposed to pollution from household wastewater or toxic products used in mining (gold, in particular).

In the Malian part of the basin, the average depth of the aquifers falls between 10 and 15 meters. Recharge mainly occurs through inward leakage of rainwater, though recharge from surface water remains considerable. The links between surface and groundwater in this part of the basin can have implications on the risks of deepwater contamination from human activity on the surface.

In the Senegalese and Mauritanian parts, a simplified analysis reveals three types of layers: (a) the superficial layers that include the dune layers (low flow) and alluvial layer (between 2–15 meters deep); (b) the Continental Terminal layer that includes the aquifers of Trarza and the Ferlo (north-central Senegal); and (c) the Maestrichtian layer (100–350 meters deep), present throughout the Senegalese-Mauritanian sedimentary basin.

Many of the villages in the middle valley are supplied by water from the alluvial layer from wells 2–15 meters deep.

Despite evidence that the superficial layers are fed directly by surface water, a long-standing question remains as to whether or not the deepest Maestrichtian layer was fossilized. Although it has been established that this layer benefitted from recharge, understanding the sites and mechanisms of this recharge remains uncertain. Studies conducted in the context of the Sectoral Water Program in Senegal aided better understanding of this aquifer's hydrodynamics. It is now generally accepted that in Senegal, this aquifer is recharged by surface water, particularly in the southwest (area of contact between the former basement and the sedimentary basin) and from the Senegal River valley (see diagram below).

Therefore, from the upper basin to the delta, surface water, particularly from the Senegal River, recharges the groundwater body—from the layer just below the surface to the deepest ones of the Maestrichtian aquifer.

Therefore, the basin's low level of hydraulicity and modification of the river regime affect conditions for recharging these layers. For example, in the valley (downstream of Bakel), water supply in the superficial layers depends highly on the extent and duration of flooding in the alluvial plain. Hence, the sinking of the phreatic and Continental Terminal layers observed in some places in the basin is explained by a recharge deficit causing a reduction in how much land is flooded and how long flood plains remain submersed.

[27] Kane, Cheikh Hamidou & Elhadj Amadou Diallo, 2005. Etude portant sur l'évaluation de l'état de l'environnement des ressources naturelles et des ressources en eau dans la partie Guinéenne du Bassin du Fleuve Sénégal. Projet de Gestion des Ressources en eau et de l'environnement du bassin du fleuve Sénégal (GEF-OMVS-SRB). OMVS, December.

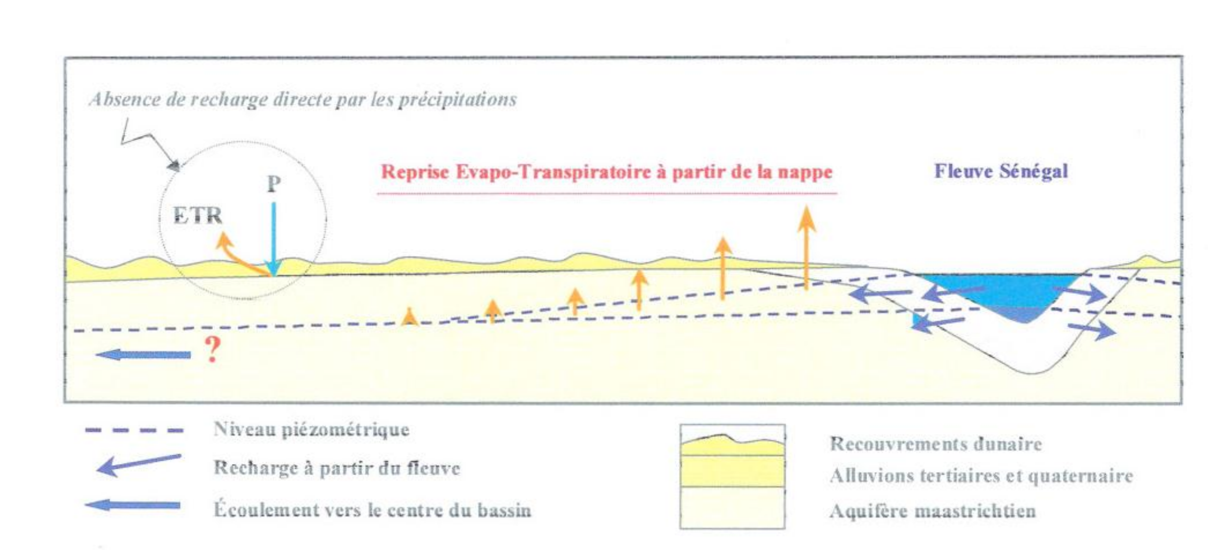

Fig.6. Process for Maestrichtian layer recharge from water from the Senegal River (COWI, 2001).[28]

The full impact of the inter-annual variation in alluvial plain flooding on groundwater is still not fully defined and is the subject of additional studies in the context of Senegal's Long-term Water Program (PLT). In the lower valley and delta, maintaining the rises of the Diama reservoir between 1.5 and 2 meters combined with irrigation and the constant flow in the distributaries has caused a rise in the piezometric level, on the order of 1 meter (Kane, 1997). This has been confirmed by the SOE report that notes the rise of underground layers in the downstream part of the valley due to the Diama reservoir water system (SOE, 2005).

That said, overall no cases of dryout of groundwater layers have been observed in the basin, affecting, for example, the availability of water resources in wells and boreholes.

1.2.2. Surface water supply

The effects of climate variability and change has seriously affected the average flow rate of the Senegal River over the last three decades. As mentioned above, current annual flow (since 1973) only accounts for 25% of what was recorded between 1903 and 1950 and only half of the average flow between 1950 and 1972. Another way to demonstrate that the Senegal River has entered into a phase of chronic water deficits is that 8 of the 10 years with the highest deficits from 1903–1992 were recorded during the 1970–80s.

Another factor that affected the quality of surface water involves the role of the Diama and Manantali dams. These dams have profoundly changed the river's water regime. The Manantali dam, built on the Bafing, controls between 40% and 60% of the Senegal River's flow at Bakel. The role of the Manantali dam is to maintain flood levels and increase minimal flow. One important question examines how Manantali dam management affected flood conditions in the alluvial plain and thus the practice of flood-recession farming. Based on a

[28] COWI & Plyconsult. 2001. Estimation de la recharge actuelle du Maastrichtien au Sénégal. COWI & Polyconsult. Ministry of Mining, Engineering and Hydraulics/SGPRE. August

period of empirical observations and studies over about 10 years, Rasmussen et al., (1999)[29] identify the two following factors to explain degraded conditions for flood-recession farming beginning in the 1970s: (a) drought and extreme worsening of climate, particularly in the 1970s and 1980s; and (b) the Manantali dam. Rasmussen et al. observe that for 5 of the 10 observation years, Manantali management had a negative impact on flood-recession farming in the middle and lower valleys. Over the course of 1988, 1989, 1991, 1994 and 1996, the Manantali dam either caused flood peak reduction or reduced the total volume of water that should have been available to flood the alluvial plain in a normal regime.

The Diama dam is a redevelopment project for the water system in the lower valley and river delta. Based on replenishment measurements, its volume varies between 250 and 535 million m^3. This quantity of freshwater stored throughout the year enables irrigation of 100,000 ha of double cropping (filling up to 2.5 m IGN) and improves conditions for filling up and maintaining water supply in the depressions of Lac de Guiers and the Aftout-es-Saheli, which supply a portion of the water for the cities of Dakar and Nouakchott.

Irrigated agriculture, the sector that receives the most surface water withdrawn from the river, still remains relatively undeveloped: less than 70,000 ha of irrigated land is cultivated compared to a theoretical availability of 375,000 ha. This means that the level of surface water withdrawal is still limited in the basin. Although hydroelectric energy production is not regarded as consuming water, it requires a specific hydrograph, sometimes in competition with the needs of other sectors: flood-recession farming, for example, or ecological needs (i.e., fish fauna).[30]

1.2.3. Water quality

Water quality has been altered in the following ways: (a) chemical pollution (effects of toxic chemical products such as pesticides and persistent organic pollutants from human activities such as disposal of pesticides used for agriculture); (b) microbiological pollution (microbial pollution from household and industrial waste disposal into basin waters); (c) eutrophication (artificial rise in primary production due to increased nutrient availability or inputs, resulting in reduced dissolved oxygen levels in the water); (d) suspended solids (particles suspended in water that can increase due to water activities, erosion, etc.); and (e) solid waste (solid matter introduced to the water, particularly from various human activities).

[29] Rasmussen, Kjeld; Nina Larsen, Fatou Planchon, Jens Andersen, Inge Sandholt & Sofus Christiansen, Agricultural Systems and Transitional Water Management in the Senegal River Basin. Danish Journal of Geography 99. 1999, pp: 1959–68.
[30] The issue of flooding and flood recession as well as the needs of fish fauna have been discussed elsewhere in this document.

1.2.3.1. Water pollution/impacts of mining

Water pollution

In terms of pollution caused by pesticides and fertilizers, the available data are vague concerning the level of use of these products and their specific impacts on water quality.[31] On the other hand, this kind of pollution has a greater effect in the valley areas where there is a high concentration of irrigated and agro-industrial areas: the delta and the lower valley. On the left bank, serious problems created by the residue of pesticides dumped into the environment from the drainage water of irrigated crops have been noted (TDA-SN). On the right bank, it has also been noted that the development of irrigated rice cultivation has led to the use of large quantities of phytosanitary products (pesticides, herbicides, fungicides and other chemical products) that contaminate the river and the phreatic layer due to runoff (ADT-IRM).

There is no precise information regarding household waste disposal in the river. However, given the basin's demographic growth, especially in cities, this issue deserves greater attention. In terms of industrial waste, the most notable example is the drainage water that that the CSS disposes into the Lac de Guiers: approximately 90,000 m^3 of drainage water per day. This issue is a subject of great concern in Senegal. Yet, the CSS, which recognizes that the water it dumps into the lake has not been pre-treated, nevertheless believes that this waste complies with international standards for drainage water (Niasse & Kruskopf, 2006).

Mining

Relative to water quality in and near mining sites, there are more questions than answers. Areas particularly affected by mining are located in the upper basin. In the Guinean part of the basin, there are industrial bauxite mining sites (Dabola-Tougué Bauxite Company/Société de bauxite de Dabola-Tougué, SBDT) and gold mining (Kalinko Gold Mining Company/Société Minière aurifère de Kalinko, SMK and Gagnakali Mining Company/Société Minière de Gagnakali). In Mali, the largest industrial gold-mining sites are in Yatéla and Sadiola (a mine run by the SEMOS Company with Anglo-Gold as the principle shareholder).

Along with industrial mining, there is also a widespread and long-standing practice of artisanal mining (gold washing) dating back to the pre-colonial period. In Guinea, the main traditional gold mining locations are: Diatiféré, Naboun, Franwalia, Gagnakaly and Kintinian (TDA-Mali). In Mali, the main sites for gold washing are eastern Faléa and southwest Faraba. Gold washing takes place along the banks of the Falémé in the Senegalese part of the basin.

Industrial gold mining can affect water quality because it is based on chemical processes such as cyanuration and/or the use of other chemical products. To limit surface and groundwater pollution, the industrial units frequently use secured watertight tanks as waste receptacles. Nevertheless, accidents remain a possibility, and managing these tanks once they are full continues to be a problem. Moreover, the consequences for the environment from cyanide products can be particularly dangerous if the waste receptacles leak.

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[31] Although the baseline study for the environment (OMVS-SOE, 2003) estimates the quantity of fertilizer per hectare based on speculation, neither this study nor the one on the PGIR Pest and Pesticide Management Plan (STUDI International, et al., 2006) provides specific information on the quantities of fertilizers and pesticides that are actually used in the river basin nor their impacts on water quality.

In Mali, it is believed that problems related to management of these waste ponds are among the greatest environmental impacts caused by industrial gold mining (GES Conseils, 2004).[32] Products containing cyanide create disease risks through intoxication and respiratory disease among human and animal populations that are exposed to them.

However, the reality and extent of gold mining's possible impacts on water quality have not been sufficiently documented. The Water Quality Laboratory of the National Directorate of Hydraulics (Mali) reports on regular monitoring of the gold mines that carry out legal mining in Mali (case of Sadiola and Yatéla)[33] and until now no irregularities have been reported; the concerned companies take appropriate measures on their own to avoid polluting local water.[34]

Little information is available about the use of mercury in gold washing and its possible impacts. During the mission to Mali and Guinea, it was not possible to further investigate this issue, which was not addressed either in the preliminary TEA or in the national TDAs.

Causes

Water quality degradation takes on diverse forms, occurring through various processes. Similarly, direct causes of water quality degradation vary greatly. Natural causes include those linked to changes in climate and water conditions in general (decreased water availability and change in river hydro-dynamics). However, in many cases, changes in water quality stem from human activities (agriculture, mining, household-waste disposal, etc.).

The underlying factor to human activities that pollute water quality is a lack of education in health, hygiene and the use of phytosanitary products. This also results from inadequate organization within the community or even among communes to implement a viable prevention strategy by developing systems for waste collection and stagnant water removal or by promoting setting up a sanitation system for waste water and encouraging extension of latrines (public and individual) (TDA-SN). Another factor often involves lack of implementing measures that sufficiently create incentives or impose restrictions.

Possible solutions

The following solutions to water pollution are noted among the envisaged options:

- Implement and/or reinforce the monitoring system of the river's chemical and microbiological water quality. Ideally each of the concerned countries and even actors involved on the ground (agro-industries, mining companies) need to equip themselves to improve water-quality control and comply with permissible limits for water pollution. However, a neutral organism such as the OMVS must still play a pivotal role in monitoring water quality; this will ensure that appropriate preventive or corrective measures are taken

[32] GES Conseils. 2004. Evaluation Environnementale et Sociale Stratégique. Rapport Final Projet d'Appui aux Sources de Croissance. Ministry for the Promotion of Small and Medium Enterprises (Mali). October. Source: http://66.102.9.104/search?q=cache:hcRQLZNtZ4MJ:www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2005/08/19/000112742_20050819111114/Original/E10630ENVRapport0Final0Octobre02004.doc+mercure+cyanure+mines+Fleuve+S%C3%A9n%C3%A9gal&hl=en&ct=clnk&cd=11

[33] Located in the region of Kayes, the Sadiola gold mine has been in operation since 1996. It produced 14.9 tons of gold in 2002. The Yatela mine, 15 km from Sadiola, has been mined since 2001. The Sadiola mine receives water from the Senegal River through a 60-km tube. In 2002, the mine's (and surrounding villages') water consumption was estimated just under 6 million m^3.

[34] Abdoulaye Koné, Director, Water Quality Laboratory, DNH: personal communication (July 2006).

if cases of water degradation start to occur on a trans-national scale. The idea that the SOGED will fully equip itself like SOGEM with a laboratory to analyze water resources points in the right direction. In addition to these planned or implemented efforts for the Diama and Manantali reservoirs, the OMVS must allocate the necessary means (possibly in collaboration with the relevant national services) to control the river's water quality in the rest of the basin and address the possibilities for water contamination from agricultural, industrial and mining activities.

- In the context of involving civil society and research structures (Component 5 of the GEF Project), campaigns to raise awareness among and educate the public are needed in addition to training for communities and local collectivities in managing water pollution problems.

- Lastly, it is important to implement suitable measures to dissuade and, if necessary, penalize polluting. On a national level and through the ratified conventions, the countries possess the judicial power needed to confront water pollution. Efforts must be centered on effective implementation of these policies.

1.2.3.2. Eutrophication

The most complete data currently available on eutrophication are on the Lac de Guiers, which was the subject of a detailed study on the biological quality of its water, conducted in the framework of the Sectoral Water Program (PSE). This study, based on parameters such as phosperous and nitrogen concentrations and the level of cyanobacteria presence, concluded that the Lac de Guiers presents a clear trend toward eutrophication, particularly in the central part where high concentrations of potentially toxic cyanobacteria could eventually cause problems in supplying safe drinking water. Conditions in the Lac de Guiers—low water velocity (given that it is virtually a closed lake), high *Typha* density and disposal of drainage water from irrigated agriculture (particularly from sugarcane)—are similar to those of the Diama dam (for which no detailed data on water quality is available).[35] The chemical quality of water in the Manantali reservoir does not appear to pose any particular problems at the moment. Based on water quality monitoring results for the Manantali reservoir, the SOGEM notes that quality has not undergone any significant modifications when compared to the situation of the Bafing River before filling the Manantali dam.[36]

1.2.3.3. Suspended dry matter and siltation

<u>Suspended dry matter</u>

Based on previous studies, Gannett Fleming et al., 1980 (Partial Report on the River and Estuary Regime) measured the total annual suspended sediment load concentrations flowing under the Faidherbe Bridge in Saint Louis at 900,000 tons per year (reference year 1971 when the average flow at Bakel was 1400 m^3/s between July and November). During the same

[35] This shows the adequacy of the information provided to the study team on plans to build a water-quality analysis laboratory within the SOGED.
[36] SOGEM memo, dated 21 July 2006.

reference year, the suspended sediment load concentration at Bakal was estimated at 2,100,000 tons. The Gannett Fleming study inferred that the difference—1,200,000 tons—must have been deposited in the flood plain of the middle valley.

It is well known that the sediment deposits in the flood plain play a primary role in the fertilization of flood land (by turning it into loam) and as a nutrient for fauna (fish fauna in particular).

During this synthesis of the TDA, no information regarding recent changes in sediment suspension load could be obtained. Consequently, it is not known how much the Manantali dam could affect the river water's concentration of sediment suspension to one extreme or the other. However, anecdotal reports maintain that farmers in the middle valley think that flooding is less productive now (in terms of crop yields in the flood lands) than it was a few years ago. It is difficult to say whether this belief corresponds to reality and whether a possible decrease in productivity for the *waalo* (flood lands) can be attributed to a decrease in sediment suspension load (silt) in the river water.

<u>The issue of siltation</u>

Siltation of waterways occurs primarily in the river's lower valley and delta. It first raised concern in 1997–1998 and was then facilitated by *Typha* colonization that would trap the sediment. Currently, the reach between the Diama lock-gate and the river mouth is silted up (AGRER et al., Vol. 1, 2003:19). Further upstream, in the middle valley (as, for example, in West Brakna on the right bank), many waterways connecting the river to flood troughs are also invaded, thus affecting flood conditions for some flood basins (AGRER et al., Vol. 2, 2003:171). Siltation resulting in accumulated sediment in the waterways promotes invasive aquatic plants that block normal flow (*Typha* and *Salvinia* in particular) and then prevent water supply to irrigated areas, natural depressions (Lac de Guiers and Lac R'Kiz) and flood troughs (AGRER, Vol. 1, 2003). In the middle valley, observed cases of siltation are explained in part by the low flood levels in recent years (AGRER et al., Vol. 2, 2003:171).

Concerning siltation in the Manantali reservoir, Gannett Fleming (Partial Report on the River and Estuary Regime) observed low levels of sediment transport in the Bafing and consequently ruled out any danger of aggradation in the future Manantali reservoir, estimating its lifespan at 450 years (estimated period to fill the reservoir's volume of still water with sedimentary deposits observed at the time). The heads of SOGEM have confirmed that the actual siltation rate in the Manantali reservoir is insignificant.

<u>Consequences/impacts</u>

Siltation in the delta's waterways negatively affects irrigation farming. For example in Mauritania, at least three-fifths of irrigated areas are fed in part by streams subject to fluctuations in the Diama dam water system. Many of these streams are silted up, which is further exacerbated by *Typha* colonization. Efforts to combat siltation of waterways, often carried out in conjunction with combating invasive plant species, proved extremely expensive. The program initiated by Mauritania in recent years to combat *Typha* through weed cutting cost 1 million ouguiya (or 4000 USD) per ha cleared and 2000–3000 ouguiya (8–10 USD) per m^3 of clearing. Therefore, efforts to clear Typha by cutting in Mauritania consumed more than 900 million ouguiya (3.6 million USD) between 1999 and 2002 and more than 5 billion ouguiya (20 million USD) between 2002 and 2005.

Causes

The waterways receive water from three types of inflow: (a) inflow from decantation of the river's sediment load; (b) lateral contributions from runoff, resulting in gullying of riverbanks due to intense rainfall, steep slopes and degraded vegetation cover; and (c) inflows from wind deflation (AGRER et al., Vol. 2, 2003:172). These processes are exacerbated and amplified in cases where abundant aquatic vegetation exists and traps the inflows. This last scenario (c) especially affects the delta and middle valley, while the first (a) affects the middle valley more and the second (b) the upper valley and upper basin (see below: Riverbank erosion).

Environmental Impact Matrix

Problem	Symptoms/Effects	Immediate Causes	Root Causes	Range
Siltation	• Reduced effectiveness of flood conditions in flood plain, ponds and irrigation canals; • Reduction in surface area of wetlands and drop in their functions and beneficial uses; • High sediment load and bedload in waterways, hence formation of sand banks and giant whirlpools, and riverbank erosion.	• Ongoing degradation of fragile areas and upstream mountainous areas; • Climate change (rainfall and water deficits); • Land degradation and erosion; • Riverbank degradation; • Degradation of drainage basins due to demographic pressures, demand for wood and expanding agriculture; • High levels of solid transport; erosion; • Proliferation of invasive aquatic species.	• Higher demographic pressure in the basin and excessive deforestation; • Unsuitable management of livestock land; • Lack of basin-wide soil conservation and protection practices; • Degradation of vegetation cover.	Entire basin Critical areas: • Tributaries from the Bafing in Fouta Djallon; • Lower valley and delta.

1.2.3.4. Changes in the estuarine hydrodynamics

The Senegal River estuary has undergone serious changes in its hydrological dynamic. The first major disturbance was the construction of the Diama dam, about 30 km from the mouth of the river. Before the dam, the river estuary alternated between freshwater and seawater depending on the season. In the rainy season, with the arrival of the flood, the freshwater invaded the estuary before flowing into the ocean. In the dry season, when the river flow subsided, the sea invaded the estuary and overtook the river for 10 or more and even up to 100 km. Tidal fluctuations can be felt as far as Boghé, about 400 km upstream (Gannett Fleming, Partial Report on the River and Estuary Regime, 1980). With the Diama, the saltwater wedge no longer flows upriver and the water is permanently salty upstream of the dam, while the Diama reservoir, over 100 km long, is full of freshwater year round.

The second major hydrological disturbance to the estuary resulted from the October 2003 opening of a overflow channel (also called the "*canal de délestage*") on the Langue de

Barbarie, 7 km downstream of Saint Louis (Thiam, 2005[37]; Diatta, 2004[38]). The Langue de Barbarie is a strip of land about 30 km long with an average width of 100 m. It separates the Senegal River and the ocean and defined the real mouth of the river, 30 km downstream of Saint Louis. Consequently, the saltwater wedge from this mouth was slowed down and the transmission time for tidal movements to the river water system was somewhat delayed. The channel, opened in October 2003, changed this situation. Even though initially it was just 4 m wide, (and 1.5 m deep), it has not stopped widening toward the south and has now become the new mouth of the river (Thiam, 2005; Diatta, 2004). The time for tidal propagation in the lower river delta is quite rapid. The consequences of this phenomenon on water quality and housing and construction safety in the lower delta are still not fully understood, but deserve considerable attention. One of the remaining unanswered questions is why the channel, unlike what has happened before, did not close back up, but on the contrary, continued to widen. Gannett Fleming et al., 1980 (Partial Report on the River and Estuary Regime) point out that in the past, the ocean frequently opened up a channel across the Langue de Barbarie. This report listed 16 breaches between 1850 and the early 1970s. However, these channels quickly closed up after they had been opened.

<u>Environmental Impact Matrix</u>

Problems	Symptoms/Effects	Immediate Causes	Root Causes	Range
Water supply and quality	• Drop in surface water hydraulicity; • Sinking of superficial aquifers; • Degradation of water quality; • Negative effects on fauna and flora; • Disposal of nutrients and pesticides, hence increased eutrophication; • Drop in quality of environment and invasion by aquatic plants.	• Drop in frequency and duration of flooding of alluvial plain; • Changes in the river regime by the dams; • Proliferation of invasive species; • Pollution from household wastewater; • Pollution from mining (gold) residues; • Untreated drainage water disposal from agriculture (agro-industry and irrigation).	• Lack of water quality standards and harmonized laws and regulations on water; • Non-application of regulations on water pollution; • Rainfall deficit due to climate change; • Flood-peak reduction by the dams; • Continuity between surface and groundwater, making the latter vulnerable to pollution; • Demographic growth; • Urban growth along the river; • Insufficient education and awareness raising for communities; • Lack of rigorous and coordinated monitoring/control of river water quality.	Entire basin Critical areas: • Senegalese-Mauritanian sedimentary basin (valley sector) • Auriferous areas (example: industrial and artisan) • Senegal River delta (drainage water) • Lac de Guiers • Estuarine area due to recent change in hydrodynamics (Langue de Barbarie channel)

[37] Thiam, El Hadji Ibrahima. 2005. La problématique des eaux douces dans l'estuaire du Fleuve Sénégal : l'exemple de la zone du Gandiolais. DEA Dissertation. UNESCO/UCAD Chair on Integrated Management and Sustainable Development of Coastal Regions and Small Islands. UCAD & UNESCO.

[38] Ibrahima Diatta. 2004. L'ouverture d'une brèche à travers la Langue de Barbarie (Saint-Louis du Sénégal) – Les autorités publiques et les conséquences de la rupture. Masters thesis in Geography. UFR. Letters and Human Sciences/University Gaston Berger of Saint Louis.

Possible Priority Actions by Country Matrix

Country	Priority Actions	Type of Action
Guinea	• Improvement of knowledge base on water availability (inventory: water demand; database and groundwater control); • Update general plans for water management; • Development of a master plan.	• Restoration/installation of key hydrometric stations; • Diagnostic study of basin; • Implementation of various laws in force in the sector and capacity building; • Promotion and extension of alternative technologies in drinking water supply systems.
Mali	• Improved monitoring of water quality and improved compliance with water policy regulations.	• Rigorous monitoring of water quality; • Effective implementation and strengthening as needed of water pollution regulations.
Senegal	• Improve information on flood release downstream of Manantali; • Manage dry-weather levels and flow; • Ensure better control of water quality.	• Forecasting model for flood release; • Finalize the water quality standards (SNSI); • Strengthen water quality control (Lac de Guiers); • Management plan for flood release; • Accelerate construction of an effluent from the delta.
Mauritania	• Promotion of policy for water planning and management; • Development of a suitable model for water allocation to enable groundwater recharge; • Strategy to improve methods in water management; • Application of legislation related to the use of pesticides; • Control contamination and wastewater disposal and control the use of fertilizers and pesticides.	• Technical studies; • Awareness raising and education; • Establishment of standards; • Best practices code for water use; • Monitoring of soil water content profile; • Implementation of environmental policy and regulations; • Awareness raising for farmers; • Research laboratories for monitoring water quality.

1.3. Invasive species

Harmful invasive species refer to species (animal, plant or micro-organisms) that invade a new space causing negative impacts on biodiversity, agriculture and other productive activities, health, etc. They can also involve native species that proliferate in new proportions due to disequilibrium in the ecosystem.

Over the last decade, invasive plant species have grown at an extraordinary rate in the river basin, particularly in the lower valley and delta. These species were mainly reeds (*Typha* and *Phragmites*), kariba weed (*Salvinia molesta*) and water cabbage (*Pistia stratiotes*). The total surface area invaded by plants was estimated at just over 100,000 ha in 2001 (SOE, 2005). In less than 10 years, harmful aquatic plants have invaded most of the active waterways.

Therefore, the proliferation of harmful aquatic plants is one of the most serious environmental problems in the Senegal River Basin, not just in terms of the phenomenon’s extent but also its ecological and socio-economic impacts and the difficulty of its eradication.

1.3.1. Typha australis

Typha is a native species in the Senegal River Basin. It is well known in local languages (*barakh* in Wolof), and its presence has been documented in the valley from at least the 1950s. Because of the creation of new hydrological conditions favorable to its development, *Typha* has undergone a sudden spread over recent years.

For the 100,000 ha of land covered by invasive aquatic vegetation in the Senegal River valley, it is estimated that *Typha* and *Phragmites* dominate 62,700 ha with the remaining land (37%) occupied by various invasive species. Today (2006), it is estimated that *Typha* occupies more than 100,000 ha[39] by itself and continues to spread at a rate of 10% per year (SOE, 2005).

Currently, the basin area most affected by *Typha* includes all the banks of the Senegal River and the delta as far as Dagana, covering close to 200 km. It is estimated that 95% of the waterways of the large developments in the delta are colonized by wide strips of *Typha*. The impressive expanse of *Typha* covering most of the Diama reservoir water system has been compared to a “giant carpet” rolling out across the reservoir of this dam (Chambers, 2003). *Typha* also proliferates in the marshy part of the Djoudj National Park and the northern part of the Parc du Diawling; most areas of stagnant water including the Lac de Guiers and the former Taouey linking the lake to the river up at Richard Toll where riverbanks have been completely invaded by *Typha*; and Ngalenka (west of the department of Podor). *Typha* is moving further and further up river and has now reached Tekane and Kaédi, where it grows in the canals of the Foum Gleïta rice growing areas. The report presented by the Malian delegation of the start-up workshops for the Restoration of River Basin Hydraulic System Study (Etude pour la Restauration du Réseau Hydraulique du Bassin du Fleuve) in Nouakchott in October 2002 even pointed out the presence of *Typha* immediately downstream of the Manantali dam site.[40] The SOGEM confirms that today, not only does *Typha* continue to be present downstream of Manantali but appears to occupy increasingly more terrain, with the estimated colonized space occupying a strip of 3 ha on the banks of the Bafing River.[41]

Causes

Typha was present in the valley, though relatively undeveloped, before the Diama dam was put into operation (1986). In the early 1980s, relatively significant stands of this species only existed in the Lac de Guiers. This lake underwent water control developments including the bridge-dam at Richard Toll built in 1947, the Keur Momar Sarr levee built in 1956 and, later, the digging of the Taouey canal and installation of sugar cane plots. This created hydro-ecological conditions favorable to *Typha* development and explains *Typha*’s presence and its proliferation in the lake in the early 1980s.[42] These same conditions would be created later in the lower valley and delta by the Diama dam. Current instructions for management of the Diama reservoir that involve maintaining the water system at a consistently high level for as long as possible creates ideal conditions for *Typha* development (AGRER et al., Vol. 1, 2003:20).

Since this appeared after *Typha* development in the Lac de Guiers and followed its sudden rapid spread since the opening of the dams, the root cause of *Typha* proliferation is the regularization of the Senegal River regime.

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[39] Personal communication from SOGED.
[40] Communication annexed in the Start-up Workshop Official Records. AGRER et al., 2003. Etude pour la Restauration du Réseau Hydraulique du Bassin du Fleuve Sénégal. Nouakchott, 2–28 October 2002. OMVS/SOGED.
[41] Personal communication from the SOGEM Head of the Manantali Division (22 July 2006).
[42] Institut des Sciences de l’Environnement. 1983. Le Lac de Guiers. Problématique d'environnement et de Développement. AGCD. Brussels.

Consequences

One of the immediate consequences of *Typha* proliferation is the clogging-up of waterways, which, right now, could compromise the potential of 100,000 ha of irrigated land in the delta and lower basin. Besides invasion of waterways (analyzed in detail above), *Typha* also negatively affects fishing activities and also provides sites for mosquitoes that transmit malaria and mollusks that are the intermediary hosts of bilharzia (waterborne diseases are analyzed below). *Typha* proliferation also harms biodiversity because *Typha* tends to grow in dense homogenous, and therefore monospecific, stands.

Possible solutions for *Typha*

Two series of options to control *Typha* have been distinguished. First are those focused on the symptom and consist of eradicating *Typha* stands. Right now, these methods seem to be favored in the Senegal River Basin. Thus, great efforts have been made in Senegal and Mauritania to conduct mechanical control, especially weed cutting. This form of control has the major inconvenience of often being extremely expensive:

- Experiments conducted on the river's left bank in Senegal (Lac de Guiers in particular) show that it takes 6 to 10 hours of work by a weed cutter to clear one hectare invaded by *Typha* (average biomass of *Typha*: 100 tons per hectare). (AGRER et al., Vol. 2, 2003: 126).
- Irrigation canal drainage is not only costly (close to 9,000,000 FCFA or 18,000 USD billed to the SAED per cleared kilometer), but rapid re-invasion of cleared areas often occurs (AGRER et al., Vol. 2, 2003:127).
- This mechanical control can be combined with promotion and economic valorization of the collected vegetation: used as fuel (bio-methanization or charcoal production[43]), or as material for construction, making paper, etc.

To make mechanical control efforts viable over the long term, the possible economic uses of *Typha* biomass were reflected upon: as a building material (fencing), in artisan industries, as a windbreak or as fuel.

In addition to mechanical control methods, there are those that try to recreate hydrological conditions that resemble the natural regime. Hence, for the Lac de Guiers, the AGRER study recommends that the lake's water system be varied to create a tidal range between 1.5 and 2 meters. From this study's perspective, this would enable controlling the development of the invasive vegetation occupying the lake's shores (AGRER et al., Vol. 1, 2003:28).

Lastly, there are approaches that recommend combining mechanical control with interventions to the river regime. The PDIAIM environmental impact study (Mauritania) suggests a temporary dryout or at the very least substantially lowering (greater than 1 meter) the water system for several weeks to improve *Typha* control (AGRER, 1998, op. cit.). Mechanical control would take place during low water. It was also highlighted that this approach makes it possible to kill two birds with one stone: lowering the water system is also beneficial in controlling pests and, in particular, mollusks and other intermediary hosts of diseases. The AGRER study proposes the same thinking by estimating that a 2–3-month dryout is necessary so that dried-out biomass on land can be eliminated by burning. Even

[43] Estimates indicate that approximately 3.3 tons of dry matter of *Typha* are needed to produce one ton of charcoal (AGRER et al., Vol. 2, 2003:167).

there, authors of the AGRER study fear that once water is returned to the treated areas, the development of *Typha* could accelerate (AGRER et al., Vol. 2, op. cit., 2003:127).

All of this demonstrates the enormous challenge posed by *Typha* for the development of the river basin and the protection of its environment.

1.3.2. Salvinia molesta

Reports claim that the introduction of *Salvinia molesta* in the Senegal River Valley occurred accidentally, first in the village of Khor (near Saint Louis) where it was cultivated experimentally along the river by a village inhabitant at the request of a botanist who foresaw its promotion in the valley as livestock feed (AGRER et al., Vol. 2, 2003:120). Because of high water, the species proliferated very quickly. Thus, *Salvinia molesta*, observed for the first time in the Senegal River delta in 1999, rapidly colonized the 50-km stretch located between the Diama dam and Rosso (AGRER et al., Vol. 2, 2003:120).

One of the economic consequences of *Salvinia* proliferation involves fishing; it is estimated that fishermen in areas invaded by these species have lost up to three-fourths of their regular fishing income (Hellsten, et al., 2003).[44]

Combating *Salvinia molesta* in the Djoudj National Park required mobilizing a unit from the military engineers, the local population, a supporting NGO and the park rangers, or close to 200 people for more than 6000 hours of work with significant logistical demands (over 5000 liters of fuel). This effort enabled extraction of more than 25,000 m^3 of *Salvinia molesta* (AGRER et al., Vol. 2, 2003:147–148). This experience demonstrates the exorbitant economic and social cost society must bear to confront invasive species.

However, the most convincing results were obtained through biological control in 2001 with the introduction of the insect *Cyrtobagous salviniae* (a natural enemy of *Salvinia*). This method has enabled a rapid regression of *Salvinia molesta* in the delta where it is present but apparently in equilibrium with its natural enemy.

1.3.3. Pistia stratiotes

At the end of the 1980s, *Pistia stratiotes* was only present in the river valley in the form of a few individual plants drifting wherever the wind blows them along the river (Thiam, cited in AGRER et al., 2003). In 1989, it was noted in the Djoudj National Park. Beginning in 1992, it would proliferate in the lower valley and delta after priming the Diama dam and become one of the top major ecological problems (AGRER, op. cit., 2003).

The environmental nuisance caused by this species' proliferation is that it forms dense mats that block river navigation (affecting transportation and fish) and obstructs water circulation in drainage and irrigation canals, choking any life forms in the water.

[44] Hellsten, Seppo; Anne Tarvainen; H. Ahonen; M. Visuri; M. Kettunen; V. Lathela; O. Varis. 2003. Policy Research to Identify Conditions for Optimal Functioning of the Senegal River Ecosystem in Mali, Mauritania and Senegal. Finnish Environment Institute (SYKE). March.

Once again, introduction of the insect *Neohydronomus affinis* (natural enemy of *Pistia*) can control progression of this water cabbage.

1.3.4. The issue of water hyacinth

The baseline study on the Senegal River Basin environment (SOE, 2005) reports the presence of water hyacinth in the Manantali dam. However, after verification from SOGEM, it appears to be nothing, and thus far, no water hyacinth has been present in the Manantali dam.[45] Yet the fact that the Niger River Basin has been seriously affected by water hyacinth justifies the need for intensified vigilance in the Senegal River to protect the basin from this formidable invasive species.

Conclusion

The issue of invasive aquatic species (*Pistia*, *Salvia* and especially *Typha*) poses one of the greatest challenges for the development of water resources in the Senegal River Basin and conservation of its biodiversity. Invasive plant proliferation has clearly been fostered by the presence of nutrients (sufficient quantities of nitrogen and phosphorous), calm waters, low currents and prevention of the up-flow of saltwater (AGRER et. al., Vol. 1, 2003:5).[46] These factors are due to large infrastructure projects: the two large reservoirs upstream (Manantali) and downstream (Diama) and their connecting structures (levees, irrigation systems) that together have changed the river's hydraulic regime and water quality (AGRER, Vol. 2, 2003).[47]

Overall, besides their immediate and visible socio-economic impacts, invasive species affect the ecological stability of colonized river systems, the Senegal River Basin in this case.

Until now, the most convincing results for combating invasive aquatic species in the Senegal River have been biological means: *Neohydronomus affinis* to control *Pistia stratiotes* and *Cyrtobagous salvinae* to control *Salvinia molesta*. For *Typha*, many means have primarily centered on the symptom (elimination of *Typha* stands). Despite the mobilization of colossal funds for mechanical control on both the river's banks (in Mauritania and Senegal), *Typha* continues to pose an enormous challenge. Although they are mentioned more and more, possible solutions based on recreating hydrological conditions close to the river regime before the dam have not been tried yet. Hence, it is believed that the idea of allowing seasonal tidal fluctuations in the water system and/or a 2–3-month dryout of the areas affected by Typha could control the development of this species much more effectively. For example, AGRER et al. estimates that maximum variations in the water system (of Diama) could block the development of aquatic plants and improve water quality (AGRER et al., Vol.1, 2003:19).

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[45] Personal communication and written memo from the Head of the Manantali Division of SOGEM (21 July 2006).

[46] Groupement AGRER-SERADE-SETICO. 2003. Etude pour la Restauration du Réseau Hydraulique du Bassin du Fleuve Sénégal. Report. Phase I. Vol. 1. Main text, 1st Part. OMVS/SOGED. March

[47] Groupement AGRER-SERADE-SETICO. 2003. Etude pour la Restauration du Réseau Hydraulique du Bassin du Fleuve Sénégal. Report. Phase I. Vol. 2. Main text, 2nd Part. OMVS/SOGED. March

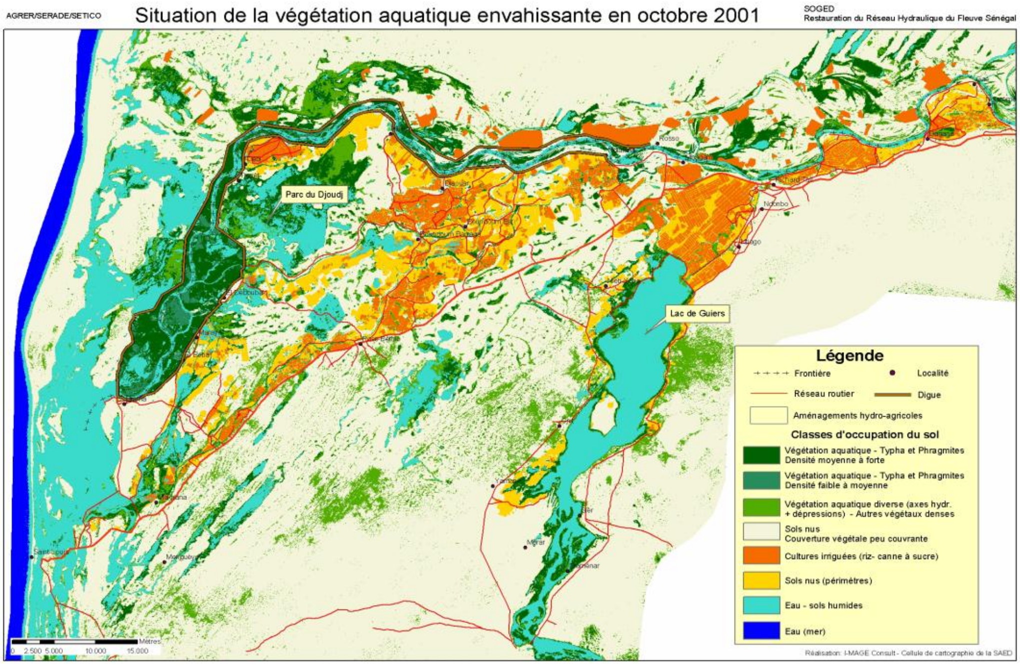

Fig.7. Situation of aquatic vegetation in the Senegal River delta and lower valley in October 2001 (Source: Water maps, OMVS).

Environmental Impact Matrix

Problem	Symptoms/Effects	Immediate Causes	Root Causes	Range
Proliferation of invasive species	• Rapid increase in colonized areas by invasive aquatic species, particularly, *Typha*; • Clogging of waterways; • Obstacles to fishing activities; • Creation of sites favorable to malaria or bilharzia vectors; • Decreased biodiversity (monospecific stands).	• Modification of the river's hydraulic regime (lack of/low tidal fluctuation); • Water softening (blockage of saltwater up-flow; • Development of irrigated crops and nutrient disposal in the river's water (nitrogen, phosphorous).	• Dams/regulation of fluvial flow; • Irrigation agriculture (nutrients in drainage water).	The entire river valley downstream of Manantali; Critical areas: • Delta area; • Lower valley (Lac de Guiers); • Middle valley (between Dagana and Kaedi); • Downstream of Manantali, on the Bafing.

Possible Priority Actions by Country Matrix

Country	Priority Actions	Type of Action
Senegal	• Development of suitable measures to combat aquatic plants; • Intensification of investigating the possible use of removed aquatic plants and their economic development; • Management of floodplains.	• Technical studies • Management plan; • Capacity building.
Mauritania	• Development of suitable measures to combat aquatic plant invasion; • Intensification of investigating the possible use of removed aquatic plants and their economic development.	• Water management plans; • Capacity building; • Pilot actions and preventive measures; • Diffusion of results from successful experiences.

1.4. Waterborne diseases

Waterborne diseases refer to diseases that develop following changes in the water regime and/or quality. The most prevalent waterborne diseases in the Senegal River valley are malaria, bilharzia and diarrheal diseases. River blindness (onchocerciasis), which was endemic in the upper valley (regions of Tambacounda in Senegal, Kayes and Koulikoro in Mali and the Guinean part of the basin) is now considered to be "controlled," the prevalence level having become stable or in regression.

Bilharzia

Bilharzia or schistosomiasis exists in two forms in the Senegal River Basin: the urinary form and the intestinal form. Urinary bilharzia causes urinary lesions that can lead to destruction of the kidneys. Intestinal bilharzia manifests in the form of diarrhea and bloody feces and can cause serious lesions on the organs, possibly leading to death (Diop and Jobin, 1994).

Urinary bilharzia was present in the four basin countries before the dams. It was not very widespread in the delta but had high prevalence rates in the middle valley (Podor, Matam) and the upper basin (Bakel, Kayes, Bafoulabe, etc.).[48]

Intestinal bilharzia was unknown in the Senegalese and Mauritanian parts of the Senegal River valley before the dams. Its presence in the upper basin was limited to just a few households. In Senegal, the first cases of intestinal bilharzia appeared in 1988 in Richard Toll, or two years after the construction of the Diama dam (SOE, 2005). Today, intestinal bilharzia has become a major public health problem throughout the delta, particularly where records note prevalence rates on the order of 90%, and even 100%, for children and extremely high infestation rates in the Lac de Guiers area. Currently, the disease has been found in Keur Momar Sarr in the Louga region (TDA-SN).

The outbreak of intestinal bilharzia three years after the dams were activated clearly indicates a causal link between the high prevalence of this disease and modification of the river regime. Specific factors that have contributed to the development of bilharzia in epidemic proportions include: reduced salinity; maintaining the water system at a stable level; and the development of aquatic plants on the banks. These different factors have come together at the Lac de Guiers, creating a favorable setting for mollusks transmitting bilharzia (TDA-SN).

Malaria

Before the opening of the dams, the malaria transmission season was short (the rainy season) with irregular spatial distribution. Endemicity was low in the delta, which recorded low rainfall, medium in the middle valley and fairly high in the rainy upper valley. The disease especially occurred during the period between the end of the rainy season and the beginning of the dry season (September to November) when anopheline mosquitoes reached their peak density of bites. However, this epidemiological profile has changed somewhat because now a second outbreak of malaria occurs in the valley between December and May, or at the time of off-season crop farming (TDA-SN).

[48] Diop and Jobin, 1994

With the opening of the dams, the highest prevalence of malaria was linked not only to the fact that the anopheline mosquito that transmits this disease (*Anopheles gambiae*) had become a better vector, but also another anopheline sub-species (*Anopheles funestis*), one of the greatest transmitters, has been highly present in the area since 1999–2000, a presence that would turn out to be linked to the dams (TDS-SN).

Fields of irrigated crops, invasive aquatic species and stagnant water throughout the year create the ideal conditions for the development of anopheline mosquitoes.

Diarrheal diseases

Diarrheal diseases are the greatest cause for medical consultation almost everywhere in the river basin, and particularly in the valley (on the right and left banks); malaria and bilharzia are the second and third causes.[49]

Diarrheal disease prevalence is linked to the quality of water for domestic use that is mainly supplied by the river and ponds. In addition to this is the notorious lack of a drinking water supply system, sanitation infrastructure, and behaviors that negatively affect hygienic conditions (TDA-SN).

Guinea worm disease

Guinea worm disease (dracunculosis) is transmitted to humans through drinking water infected with miniscule crustaceans called cyclops. Guinea worm disease is rarely fatal but is highly dibilitating. The areas with the highest prevalence are those without an adequate drinking water supply system (Diop and Jobin, 1994).

Animal diseases

In 1987 after a particularly heavy rainy season, a Rift Valley fever epidemic was declared in the area surrounding Rosso near the Diama dam (TDA-SN). In Mauritania, Rift Valley fever and hydatidosis[50] are among the livestock diseases that have emerged over recent years. The fever continues to be present in the basin. In 2002, 12 sites of Rift Valley fever were reported in Mauritania, including 2 in the lower and middle valley of the Senegal River. At the same time, epizootic disease sites were observed in the departments of Podor and Dagana (left bank of the Senegal River valley) (SOE, 2003). A waterborne liver disease affecting livestock was reported around the Lac de Guiers where it was very destructive.

Impacts

Waterborne diseases are actually the impacts of changes in the river's hydrological regime and its biophysical environment: proliferation of aquatic plants; degradation of water quality, etc.

High prevalence of waterborne diseases results in the following consequences: (a) diminishing the work capacity of the rural population, which negatively affects goals to

[49] In particular, see the PDIAIM environmental assessment study in Mauritania (AGRER, 1998).
[50] Hydatidosis or hydatid cyst manifests itself as a pocket full of liquid attached to organs such as the liver, lung or heart. The membrane that covers this pocket is a parasitic larva that creates the disease (tapeworm).

develop basin resources and thus, development in general; (b) low academic performance among children; and (c) high health costs for populations with already limited resources.

Possible solutions

Possible classic solutions to these types of health problems are:

- Health education for communities;
- Diagnosis and treatment, particularly with strengthened health infrastructure and epidemiological monitoring;
- Preventive measures such as promoting the use of impregnated mosquito nets;
- Improved availability of drinking water for communities and access to sanitation systems; and
- Larva treatment in infected areas.
- In addition, a more difficult solution to implement consists of creating hydrological and biophysical conditions that are less favorable to the development of waterborne disease vectors.

Environmental Impact Matrix

Problems	Symptoms/Effects	Immediate Causes	Root Causes	Range
Waterborne diseases	• High prevalence of waterborne diseases (diarrhea, bilharzia, cholera, malaria and dracunculiasis (Guinea worm disease)); • High rate of morbidity in communities; • Low work productivity; • Low academic performance for children; • Increased malnutrition among small children and the elderly; • Infant mortality.	• Invasive aquatic plants; • Reduction in water salinity; • Insufficient drinking water supply system and sources; • Insufficient access to sanitation; • Failed maintenance for infrastructure; lack of storm drains and refuse treatment centers; • Water stagnation causing an increase in breeding sites of waterborne disease viruses.	• Regularization of outflows (dam); • Blockage of the saltwater wedge; • Urban population growth, lack of sanitation; • Poverty and poor health in vast areas of the basin; • Lack of awareness-raising programs.	Entire basin Critical areas: Delta Lower valley of the Senegal River (Lac de Guiers) Upper basin The entire upper basin in Mali: *cercles* of Kayes, Bafoulabé, Kéniéba, Diéma, Koulikoro, Kolokani, Yélimané.

Possible Priority Actions by Country Matrix

Country	Priority Actions	Type of Action
Senegal	• Promotion of a program to combat propagation of waterborne diseases; • Awareness raising on the causes of waterborne diseases.	• Education/awareness raising on water and hygiene; • Diffusion of drugs.
Mauritania	• Promotion of a water planning and management policy; • Development of a suitable water allocation model to enable groundwater recharge; • Strategy to improve methods in water management.	• Drug diffusion program; • Awareness raising and education on health and hygiene; • Improved techniques; • Various preventive measures.

1.5. Conservation of biodiversity

The issues affecting conservation of biodiversity have been examined in terms of fish fauna (given the extensive fishing activity that depends on it) and the wetlands (areas with high concentrations of biodiversity). Since a separate chapter has been devoted to biodiversity hotspots in the basin (which includes wetlands), only a brief analysis of these wetlands is presented below.

1.5.1. Fish fauna

The Senegal River's fish fauna includes freshwater species as well as brackish-water species. The latter (mullet, sardines, pink shrimp, etc.) made seasonal migrations between the salty-to-brackish water of the river estuary and freshwater further upstream. The river's freshwater species (tilapia, Nile perch and catfish) are considered holobiotic, i.e., they complete their entire reproductive cycle in the river and its flood plain and tributaries (Albaret, 1994).[51] In 1998–1999, 63 fish species belonging to 18 families were inventoried in the river (Roche International, 2000).[52] The same study notes that the majority of the freshwater species inventoried in 1984, thus before the construction of the Diama and Manantali dams, were still present in the river in 2000.

However, the study also notes a decrease in the quantity of fish and consequently the river's fish productivity. Downstream of Diama, this decreased productivity resulted in fewer fish catches on the order of 50–70% (AGRER et al., Vol. 1, 2003:76). Conversely, upstream of Diama in the lower valley (Lac de Guiers and the reach between Dagana and Podor), fish fauna has appeared to increase since activating the dams, resulting in an increase in catches by fishermen (AGRER et al., Vol. 1, 2003:76–77). This viewpoint does not seem to be shared with many communities in the middle valley who complain of fish scarcity.[53]

<u>Factors affecting fish fauna</u>

Among the main causes of the assumed drop in fishing productivity in the valley are decreased flooding regulated by the dam and the lowered water quality due invasive aquatic plants (AGRER et al., Vol. 1, 2003:75). To fully understand this argument regarding decreased flooding, it is important to remember the critical role of the river's flood plain for fish fauna. Spawners use the flooded basins for reproduction (egg laying, fertilization and hatching). Therefore, fish production is maximized when flooding reaches also its maximum (between mid-August and mid-September). These same basins provide the juvenile fish with food and good protection from predators, allowing them to mature with a relatively low mortality rate. Hence, the longer the flood, the greater the chance of survival is for juvenile fish (Roche International, op. cit.).

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[51] Albaret, J.J. 1994. Peuplements de poissons, ressources halieutiques, pisciculture dans le delta du fleuve Sénégal ; Impact des modifications de l'environnement. ORSTOM/CRODT. Dakar.
[52] Roche International. 2000. Etude des ressources ichtyologiques du fleuve Sénégal. Final report. OMVS-ACDI.
[53] See minutes from consultations held within the PPP component of the GEF-SRB Project, including "Premières réunions d'échanges avec les Comités de Coordination des projets OMVS au Mali et au Sénégal." IUCN. October, 2005

In addition, the Diama dam obstructs saltwater fish from making their usual seasonal migrations about dozens of km upstream. Yet, few elements are available to assess the actual implication of this on the size of the fish fauna population (in terms of biodiversity and from a quantitative perspective). However, before the dams, the estuarine area was a critical habitat for some fish species such as mullet. In addition to providing the brackish water essential to some species, this habitat had the advantage of holding a large quantity of nutrients transported by the river and also being relatively shallow, thus preventing access for many offshore predators.[54] The change in water quality following the opening of the Diama dam and possibly the drop in the quantity of nutrients transported by the river could have effected the estuarine habitat in ways that remain to be seen.

Impacts

Constructing the dams has also had positive impacts on fisheries, as witnessed by the fact that the Manantali reservoir is currently one of Mali's primary fishing sites. Some 38 fish species have been identified belonging to 16 families.[55] Laë et al. (2004)[56] note that the Manantali reservoir enables 2.5 times greater fish catch per unit effort than in the Sélingué reservoir in the Niger basin. According to the same study, fishing production in Manantali is 27 kg of fish per ha, making it one of Mali's top three fishing production areas, followed by the Niger Interior Delta and the reservoir at the Sélingué dam. In 1996, total production for Manantali, estimated at 1300 tons per year, earned revenues of close to 400 million FCFA for fishermen. The FAO estimated potential fish production in the Manantali reservoir at 3000 tons per year (Breuil, 1996).[57]

Reizer (1974) estimated that in the early 1970s for the entire river basin there were close to 10,000 fishermen working full time and as many working part time, accounting for a total of 6.1% of the active population in the basin at the time. The Roche International survey (2000, op. cit.) has estimated that fishing is the primary activity for 6315 fishermen and that 1936 fishermen practice fishing as a supplementary source of income. These fishermen are divided as follows: 79% in Senegal, 16% in Mauritania and 5% in Mali. Fishing volume was estimated between 26,000–47,000 tons, earning revenues from 8–14 billion FCFA. The same survey estimates that this fishing activity contributes to feeding a population between 350,000 and 600,000 persons living along the river. Therefore, a drop in fish fauna can have significant social and economic implications on basin populations.

Possible solutions

In order to create ideal conditions for fish fauna in the Senegal River Basin, the Roche International study (2000, op. cit.) recommends the following measures for water management in the river basin:

a) During years of low hydraulicity, the study recommends that flow be maintained at a level to flood the bays, riverbanks, the low parts of the flood basins, the mouths of streams and tributaries. These are the habitats used by fish for reproduction and growth. In terms of

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[54] Personal communication, Mathieu Bernardon, Technical Advisor, Projet de Gestion Concertée des Stocks Pélagiques Partagés en Mauritanie et au Sénégal.

[55] SOGEM memo, 21 July 2006.

[56] Laë, Raymond; Jean-Marc Ecoutin & Justin Kantoussan. 2004. The use of biological indicators for monitoring fisheries exploitation: Application to man-made reservoirs in Mali. *Aquatic Living Resources*. No.17 pp. 95–105.

[57] Brueil, Christophe. 1996. Revue du secteur des pêches et de l'aquaculture : Mali. FAO. Rome. September. Source: http://www.fao.org/docrep/W4860F/w4860F00.htm

volume, Roche International estimates that meeting this need would require a minimum flow of 550 m^3/s at Bakel for almost all of August.
b) During years of good hydraulicity, Roche recommends “reclamation” of natural flooding to ensure prolonged flooding of basins in the middle valley (Matam region). Meeting this need requires a flow rate of 3000 m^3/s at Bakel for 20 days in August.
c) For the upper valley (between Bakel and Waoundé about 50 km upstream of Matam) Roche International recommends managing the control thresholds for water entering the basins so that flood conditions for these basins are optimized to promote fishing. According to Roche International, these same controlled basins could even be stocked with juvenile fish (Roche International, op. cit., 2000).

The first two recommendations require a high volume of water, and their implementation would hinder other objectives for dam management.

Environmental Impact Matrix

Problems	Symptoms/Effects	Immediate Causes	Root Causes	Range
Degradation of fauna, flora and fisheries	• Increased number of threatened species; • Decreased fishing production; • Reduced species diversity; • Decrease in the number of large mammals, hence a negative impact on tourism; • Reduced forest cover.	• Fewer unique habitats and ecosystems due to deforestation, bush fires and mining; • Increased poaching in protected areas; • Lack of replacement income sources particularly in relocation areas: poaching • Decrease in spawning areas for fish fauna (degraded conditions in alluvial flood plain).	• Climate change (decreased hydraulicity); • Weak application of policies and laws to protect species; • Misunderstandings about biodiversity issues and advantages of conservation; • High dependence on primary natural resources and farming income; • Rising demographic pressure on natural resources; • Decreased flooding regulated by the dams and lowered water quality due to aquatic plant invasion.	Entire basin Critical areas: Protected areas in the delta Protected areas in Bafing/Falémé; Baoulé/Keniebako Wildlife Reserve; Fouta Djallon Massif. Flood plain (fishing)
Degradation of wetlands	• Reduction and degradation of wetlands (siltation, flood damage, decreased flows, infestation of aquatic plants, farmland expansion); • Fewer advantages offered by wetlands (less aquifer recharge, habitat destruction and loss of biodiversity, less land area of flood plains; less pasture land (bourgou).	• Gradual encroachment of wetlands by farmland; • Deforestation, erosion and siltation; • Overuse of natural resources (fishing, hunting, overgrazing, agricultural practices).	• Climate changes (lowered hydraulicity, hence wetlands shrinkage); • Lack of knowledge about wetlands' functions and values; • Poverty and demographic pressure; • Lack of knowledge of laws protecting classified wetlands (i.e. Ramsar sites) among communities: • Lack of economic alternatives; • Many wetlands (biodiversity hotspots) with no protection (not set up as protected areas); • Low means to manage wetlands, including those set up as protected areas.	Entire basin Threatened wetlands: • Mare de Magui and Lere; • Kayes (shoals) • Cuvette du Ndiael; • Lacs de Guiers and de R'Kiz; • Senegal River valley flood plain; • Wetlands in the Guinean part of the basin.

Possible Priority Actions by Country Matrix

Country	Priority Actions	Type of Action
Guinea	• Inventory of species and habitats; • Mapping of habitats; • Improved knowledge about threatened ecosystems and species; • Integration of biodiversity management issues into land-use plans; • Capacity building in awareness raising and environmental education for communities; • Intensification of agricultural production to stop encroachment in protected areas; • Application of rules and laws related to protected areas.	• Capacity building in biodiversity management; • Management plans for protected areas; • Sedentation for farmers in the shoals and plains; • Inventory of the Senegal River Basin's wetlands; • Support for implementation of a management plan for the Bafing-Falémé transboundary area; • Strengthening the Ministry of Environment in biodiversity monitoring.
Mali	• Establishment of policies for land-use and conservation of wetlands; • Application of a master plan for wetlands; • Continuation and reinforcement of obligations resulting from ratification of the Ramsar Convention; • Controlling pesticide use.	• Accelerate the procedure to classify Lake Magui as a Ramsar site; • Updating and implement management plans for the Bafing Wildlife Reserve and the Boucle du Baoulé Biosphere Reserve; • Support for the implementation of the Bafing-Falémé transboundary area management plan (AGIR).
Senegal	• Application of appropriate regulations on fauna and flora protection; • Development of a management plan; • Reduction in fishing pressures; • Development of an environmental management policy; • Monitoring the status of the environment; • Water release to wetlands.	• Applied legislation (permits); • Protected areas policy; • Protection and rehabilitation of spawning and fry-rearing areas; • Education and awareness raising; • Application of legislation on wetlands use;
Mauritania	• Biodiversity management and capacity building; • Management plans for protected areas and their implementation; • Application of existing policies; • Demarcation of protected areas on the ground; • Development of viable models for water/flow release; • Fisheries management; • Participatory development and application of regulations on fauna and flora protection at a decentralized level.	• Capacity building and awareness raising; • Management plans for protected areas; • Increased capacity in applying regulations; • Land surveying to demarcate parks; • Creation of additional protected areas; • Improved protection of classified forests; • Training communities along the river.

1.5.2. Wetlands

The Ramsar Convention (1971) defines wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres."

In the Senegal River Basin, they include the estuary, natural lakes and human-made reservoirs, the flood plain and the alluvial valley. Among the most characteristic of the basin's wetlands are the depressions where the Djoudj and Diawling (delta) National Parks are located; the Lac de Guiers and Lac R'Kiz (lower valley); and Magui pond (upper basin).

Many of these wetlands have suffered droughts affecting the Sahel and the Senegal River Basin since the early 1970s, resulting in less flooded surface area on average and shorter flood duration. Since 1986–88, the dams have increased stress on these wetlands, including some that dried out after embankments were built with these dams (e.g., the Diawling wetlands, the

Mauritanian lower delta before being refilled with water and its restoration in 1997). The barrages have also modified water quality, for example, softening the water in wetlands such as those located downstream of Diama (the Djoudj National Park, for example) and by increasing salinity in other wetlands located downstream (SOE, 2005).

However, each wetlands area faces specific problems, which have been analyzed in the second part of this document.

2. CLASSIFICATION OF PRIORITY ENVIRONMENTAL PROBLEMS

Method for classifying priority problems

The environmental problems listed and analyzed in the previous chapter do not have the same weights and do not demand the same level of urgency in finding solutions.

However, a methodological challenge arises for several reasons:

- The national TDA and TEA validation phases identified and addressed problems that were considered as high priority, but the approach used to establish the priority problems was not documented. In any case, the priority problems had been identified since the beginning of the synthesis phase of the regional TDA, and therefore their classification by order of priority did not arise.
- Given the high number of priority problems (16 environmental problems) under consideration from the start, even if it were opted to conduct a classification, the methodology for doing so poses a problem. The GIWA method that is often used as a model in TDAs for international waters is poorly adapted. The GIWA method uses a matrix to assign scores and weights for 22 types of environmental impacts. However, it turns out that these types of environmental problems differ from those of the TEA and TDAs analyzed in the previous section of this report (see table below).

Table 1: Comparison of generic environmental problems using the GIWA method and selected environmental problems in this Senegal River Basin TDA.

Types of Environmental Problems (GIWA)	Environmental Problems (TEA-TDA SRB)
A . Problems linked to water supply	**A. Water supply and quality**
1. Changes in flow	1. Surface water supply
2. Surface and groundwater pollution	2. Supply in aquifers
3. Changes in aquifer levels	3. Water quality: pollution/siltation
	4. Water quality: pollution/mining
	5. Change in estuarine hydrodynamics
B. Pollution	**B. Land degradation**
4. Microbial pollution	6. Deforestation
5. Eutrophization	7. Erosion/siltation (in general)
6. Chemical pollution	8. Erosion—Riverbank Degradation
7. Suspended solids	9. Land salinization
8. Solid waste	10. Overgrazing
9. Changes in water temperature	11. Bush fires
10. Radioactive contamination of water	12. Desertification
11. Contaminated waste disposal	
C. Impact of changing habitats	**C. Biodiversity**
12. Loss of ecosystems	13. Fish fauna
13. Loss of biodiversity	14. Wetlands
D. Unsustainable use of fish fauna	**D. Other**
14. Overuse of fish fauna	15. Invasive species
15. Unwanted catches	16. Waterborne diseases
16. Destructive fishing techniques	
17. Decreased viability of stocks	
18. Impact on biological and genetic diversity	
E. Environmental impact of global warming	
19. Change in hydrological cycle	
20. Change in sea level	
21. Increase in UV radiation	
22. Changes in the ocean’s dissolved oxygen levels	

Therefore, it was necessary to adopt an adapted approach using the GIWA criteria as a starting point. Hence the specific criteria for classification were discussed during the validation workshop for the ADT outline held in June 2006 at the beginning of the development phase of the regional synthesis. This workshop brought together about 20 participants who recommended keeping a limited number of simple classification criteria. From the seven criteria that they discussed, four were finally chosen to provide a basis for classification by order of priority.

Table 2. Classification criteria for priority problems.

Studied Criteria	Selected Criteria
i. Transboundary nature/dimension of the problem. ii. Extent and severity of the problem's impact on the Senegal River Basin ecosystem. iii. Extent and severity of the problem's impact on socio-economic activities and human and animal health. iv. Level of priority assigned to the problem in the national environmental policy documents for the basin countries (e.g.: National Environmental Action Plans, National Plans to Combat Desertification, National Adaptation Programs of Action for Climate Change, National Strategies for Wetlands Conservation and Protection of Biodiversity, etc.). v. Degree of interaction between the problem and other environmental and socio-economic factors. vi. Diversity and importance of advantages and positive impacts resulting from the solution to the problem in question. vii. Difficulty in finding local and/or national solutions to the problems, and thus the relevance of a transboundary approach in solving the problem in question.	1. Extent and severity of the problem's impact on the Senegal River Basin's ecosystem. 2. Extent and severity of the problem's impact on socio-economic activities and human and animal health. 3. Degree of interaction between the problem and other environmental and socio-economic factors. 4. Difficulty in finding local and/or national solutions to the problem, and thus the relevance of a transboundary approach in solving the problem in question.

The 16 identified environmental problems have been assessed for each of the four criteria. For each criteria, the assigned scores range from 1 to 3:

1 = Undocumented, zero or low impact (uncertain or undocumented relevance: criteria 4).
2 = Moderate impact (medium relevance: criteria 4).
3 = Serious impact (very high relevance: criteria 4).

For simplicity, the scores have not been weighted; adding the derived scores for the various criteria results in a total value for priority ranging from 4 to 12. The results from this exercise produced the following table.

Table 3. Classification of environmental problems by order of priority.

Environmental problem	Criteria 1 Impact on ecosystem	Criteria 2 Socio-eco impact	Criteria 3 Effects on other env. problems	Criteria 4 Need for transboundary solution	Total score
1. Surface water supply problems	2	2	3	2	9
2. Groundwater supply problems	1	1	1	1	4
3. Water quality: pollution/silting up	2	2	2	2	8
4. Water quality: pollution/mining operations	1	2	2	2	7
5. Change in estuarine hydrodynamics	3	2	3	2	10
6. Deforestation*	3	2	3	1	9
7. Erosion/sand invasion*	2	2	3	2	9
8. Degradation of riverbanks*	2	3	1	3	9
9. Soil salinization *	1	2	1	1	5
10. Overgrazing*	2	3	2	2	9
11. Bush fires*	3	2	3	2	10
12. Desertification*	3	3	3	2	11
13. Degradation of fish fauna	2	3	1	3	9
14. Wetlands degradation	3	3	2	2	10
15. Invasive species	3	3	3	3	12
16. Waterborne diseases	1	3	1	3	8

* These problem types have been grouped together into a single priority environmental problem called “land degradation” in the TEA and national TDAs.

The first criteria involves the extent and severity of the impact of the problem on the ecosystem of the Senegal River Basin. This criteria analyzes the effect of a given problem on the level of degradation of fluvial ecosystem health and the cost (human and financial effort required to control the problem and its consequences and the technical complexity of possible solutions). The environmental problems that recorded the highest score for this criteria are:

— Modifications in estuarine hydrodynamics, even if it is still too soon to fully grasp the exact extent of disturbances resulting from the combined effects of the opening of the channel on the Langue de Barbarie and the existence of the Diama dam.
— Deforestation, bush fires and desertification are environmental problems that directly affect plant and animal biodiversity as well as land stability.
— Wetlands degradation, given that these wetlands are sites with high concentrations of biodiversity and are also a type of natural infrastructure that plays a role in flood regulation (decreasing flooding and generating minimal flow) and as filters that can improve water quality.
— Proliferation of invasive species such as *Typha* seriously affect the fluvial ecosystem (biodiversity, water flow, water quality).

The second criteria involves the severity and impact of the analyzed problem on socio-economic activities and human and animal health. This criteria measures the studied environmental problem's effect on the uses of river basin resources and therefore on the rural and urban productive systems. It also measures the extent of the problem's impacts on the health status of the basin's human and livestock populations. The environmental problems that recorded the highest score for this criteria are:

— Riverbank degradation: As noted, riverbank degradation causes the destruction of residences and social and economic infrastructure. From the perspective of the OMVS Program's development of the navigation component, riverbank degradation can also pose an obstacle to river navigability.
— Overgrazing: Overgrazing has serious socio-economic consequences: decreased pastoral productivity; trampled farmland by livestock; and increasing conflicts between farmers and livestock herders.
— Desertification: The drop in rainfall and stress of climate variability have made rain-fed farming—still the pillar of rural economies in the basin, particularly in the upper basin—even more precarious. This then causes chronic decreases in food production and compromises food security. Over the long term, this explains the depopulation of countryside in the river valley and the massive rural exodus occurring in this part of the basin since the early 1970s.
— Degradation of fish fauna: Some parts of the basin (middle river valley) have recorded a large drop in fish catches (50–70%) over recent years. Since fishing activity involves close to 6% of the basin's active population, improved assessment of the economic impact of fish fauna degradation is needed (which remains assumed).
— Wetlands degradation: Both natural (the flood plain) or human-made (dam reservoirs) wetlands support productive activities (flood-recession farming, fishing, livestock farming and gathering) that are negatively affected by any significant degradation to these ecosystems. For example, the drop in frequency and extent of annual flooding has made flood-recession crops and fishing on the floodplain more precarious, which makes the rural production systems of the middle valley less diversified, and therefore, more vulnerable.
— Proliferation of invasive species: The proliferation of invasive aquatic plants has a significant effect on agricultural activities (colonization of irrigated areas, blocked irrigation canals) and fishing (by obstructing fishermen's mobility and functioning as inaccessible refuges for fish). Up until now, responses to invasive species such as *Typha* have only been excessively costly for relatively insignificant results.
— Waterborne diseases: The socio-economic impact of waterborne diseases can be analyzed at three levels: (a) waterborne diseases such as malaria are hazards that make life difficult along the river, its tributaries and around the irrigated areas; (b) the high prevalence of malaria, bilharzia and other diseases such as onchocerciasis affect the available workforce and the work capacity for the basin's active population resulting in an enormous loss of work days; and (c) the cost of treating waterborne diseases puts a strain on household budgets in communities and incurs high costs for the States and their development partners.

The third criteria involves the level of interaction with other environmental and socio-economic problems. This criteria relates to a given environmental problem's capacity to act as a reinforcement to other environmental and socio-economic problems, thus creating a domino effect for environmental problems that interact with each other. The environmental problems having recorded the highest score for this criteria are:

— Problems related to surface water supply: The drop in the river's hydraulicity (40–60%) since the early 1970s and modification of the river regime (with the construction of the dams) affects environmental factors such as groundwater recharge, water quality degradation, proliferation of invasive plants, wetlands degradation, riverbank erosion, land salinization, ichthyological status, etc.

— Change in estuarine hydrodynamics: This phenomenon, which followed the combined effects of the existence of the Diama dam and the opening of the channel on the Langue de Barbarie, initially altered the delta fluvial regime and modified water quality in the floodplains and estuary. It has had an increasingly more noticeable impact on groundwater quality over time.

— Deforestation: Deforestation causes a decrease in floral biodiversity and deteriorates fauna habitat. It accelerates erosion and sand invasion, deteriorates land status and hence, agricultural productivity.

— Erosion and sand invasion: Erosion and sand invasion have the same effects on land status as deforestation. They are among the symptoms and causes of desertification.

— Bush fires: Bush fires accelerate deforestation and denude and expose soil to water and wind erosion.

— Desertification: Once begun, the process of desertification acts on all bioclimatic and human factors: vegetation cover, erosion and sand invasion, soil status, load capacity of livestock routes, agricultural productivity, etc.

— Invasive species: Proliferation of invasive species promotes the high prevalence of waterborne diseases. It also causes asphyxia in wetlands and deteriorates water quality through eutrophication.

The fourth criteria relates to the transboundary dimension. It involves problems that require a transboundary approach to find sustainable solutions for them. The problems covered by this criteria must have one or more of the following characteristics: (a) the problem arose or is manifest on a transboundary scale, meaning in at least two basin countries; (b) the problem manifests in a single country but its causes are external (in other words, are generated by other basin countries); (c) the problem's consequences affect environmental factors having impacts in other countries; and (d) the extent and complexity of the problem are such that pooling basin-wide resources into a transboundary plan is necessary to confront it in a sustainable way.

— Riverbank degradation: Currently this phenomenon is observed with greater intensity at the confluence between the Bafing and Bakoye (Kayes region in Mali) and the river's sources in Guinea where it manifests as headwaters degradation. If it is also proven that it is caused by the Manantali floodgates in the Kayes region, its solution will require transboundary cooperation between the basin countries since controlling Manantali floodgates is dictated by electricity production goals, flood management and maintaining sufficient flow for irrigated agriculture needs now and navigation needs in the future. The solution for headwaters degradation will depend on the promotion of sustainable agro-forestry practices. Abandoning current practices has a cost, and leading the upper basin population to steer toward other practices for the good of the downstream population will require implementation of a transboundary solidarity system.

— Degradation of fish fauna: Fish fauna migrate from upstream to downstream and from one bank to another depending on the season and their reproductive cycle. Therefore, fish resources are by nature transboundary resources.

— Proliferation of invasive species: Invasive aquatic species affect the entire basin with the exception of Guinea. *Typha*, which proliferates on the Senegalese and Mauritanian banks is now reported immediately downstream of the Manantali dam in Mali. In addition, the extent and complexity of the problem are such that no basin country acting individually can implement effective sustainable responses alone. Transboundary cooperation is a requirement here.

— High prevalence of waterborne diseases: Just like the fish fauna, waterborne disease vectors migrate along the river, and as long as there are infected pockets, all of the basin areas remain exposed.

After adding the assigned scores for each of the four criteria for each environmental problem analyzed in Chapter 2, a table organized by priority (see below) identifies three broad categories of problems:

- ☞ The most urgent problems (in other words, environmental problems raising the most concern): invasive plants, desertification and bush fires, wetlands degradation and change in estuarine hydrodynamics.
- ☞ Serious environmental problems (covering a broad range): problems related to surface water supply, deforestation, overgrazing, erosion and siltation, riverbank degradation and degradation of fish fauna.
- ☞ Major environmental problems but determined by other factors (waterborne diseases) or occurring locally and/or not necessarily needing a transboundary solution: groundwater supply and quality; water quality (pollution from mining operations); and land salinization, especially in the delta.

However, it is evident that the valence of environmental problems varies according to country and also to the specific types of ecosystems in the basin, particularly biodiversity hotspots (see 2nd part).

After this classification, the problems with the highest priority do not undergo a second causal analysis, but emphasis is placed on formulating intervention options to resolve them.

3. POSSIBLE RESPONSES TO PRIORITY ENVIRONMENTAL PROBLEMS

In terms of the Environmental Diagnostic Analysis of the basin, certain identified problems demand that urgent solutions are found due to their extent, evolution and impacts. The possible solutions proposed below result from the analysis of immediate and root causes of the considered problems but also from the analysis of governance for the basin environment. However, overall each option has its advantages and disadvantages, its strengths and weaknesses. Consequently, stakeholders must discuss the acceptability of a particular possible solution, which is possible in the development phase of the Environmental Strategic Action Plan, following this development phase of the TDA.

The list of intervention options below includes those envisaged at the national level. These conceivable actions at the national level appear in the annexes (priority action matrices in Guinea, Mali, Senegal and Mauritania). The options for actions listed below have a more marked transboundary range.

<u>Invasive species</u>

a. Given the mixed results so far in the efforts to combat invasive species such as *Typha*, the current trend aims to promote the idea that “living with” the proliferating aquatic plants is legitimate. However, pushing this rationale to the point of abandoning the control or eradication of harmful aquatic species must be avoided. It is hard to believe that the basin’s river ecosystem can reach its potential for sustainable improvement of living conditions for communities and as a host to rich biological diversity without controlling the proliferation invasive aquatic plants such as *Typha*.

b. Besides mechanical control methods and perhaps in addition to these methods, greater effort should be placed on addressing the river regime by trying to recreate a tidal range system that is as close as possible to the natural regime. In some cases, a periodic temporary dryout or substantial lowering of the water system could be justified.

<u>Desertification, overgrazing</u>

a. The OMVS should encourage member States to strengthen investments in pastoral hydraulics in the river basin so that livestock pressure is reduced along the banks of the river and its tributaries. Insufficient pastoral water points is one explanation for the high concentration of livestock along the river for most of the long dry season, leading to overgrazing, land and riverbank erosion, conflicts between farmers and herders, etc.

b. In view of intensified livestock farming, the OMVS should support the member States through improved integration of agriculture, livestock farming and forestry.

c. Using the national plans to combat desertification that exist in three of the four basin countries (Mali, Senegal and Mauritania), formulate a Senegal River Basin-wide program to combat desertification. Given its current dynamism, the OMVS should be an effective framework to implement such an action program. This also ensures that efforts to combat desertification in the basin are coordinated with those undertaken on a national level by the basin countries.

Biodiversity, wetlands and protected areas

a. The basin organisms managing water flowing from Guinea (NBA, OMVG, OMVS) should play a greater role in the efforts to restore and conserve the Fouta Djallon Massif and not leave this mission exclusively to the countries in the sub-region that until now, have struggled to mobilize the necessary means from financial partners. The OMVS should collaborate with the NBA and OMVG and take a greater part in the promotion and implementation of the GEF Fouta Djallon Massif Program, which has finalized its PDF-B phase and is in the process of searching for funding for project execution. Hence, the aforementioned basin organisms could consider auditing the PDF-B document with the intention of improving it so that greater consideration is given to the priority environmental problems as identified in the TDAs for the Senegal and Niger River Basins.

b. In collaboration with the NBA and OMVG, the OMVS should examine the feasibility of a sustainable development program for the Fouta Djallon, from the perspective of “benefit sharing,” in other words, to share the benefits drawn from managing the Niger, Senegal and Gambia Rivers with the population of the Fouta Djallon. This mechanism will provide these communities with the necessary incentive to adopt practices that protect the headwaters of transboundary rivers. The idea for a hydro-electric micro power station program that the OMVS plans to launch in the Guinean part of the Senegal River Basin is one way to put the concept of “benefit sharing” into practice.

c. While taking advantage of the fact that Guinea is now an OMVS member, efforts should be made to identify and classify wetlands in the Guinean part of the basin as Ramsar sites. The Bafing area downstream of Mamou or the Bakoun forest host rich biodiversity that could make it eligible for the Ramsar criteria. It is noteworthy that the Guinean parts of the Niger River Basin and Gambia River Basin host four and two, respectively, Ramsar sites, which was possibly facilitated by Guinea’s inclusion in the NBA and OMVG.

d. By and large, the OMVS should invite its member States, in collaboration with the relevant environmental organizations, to identify and classify new wetlands as Ramsar sites, for all sites that fulfill the eligibility criteria. This could take on the form of the similar resolution taken by the NBA under the direction of the Member States during the 7th Summit of Heads of State held in Abuja in 2002.

e. The OMVS should take on greater responsibility for proper management of the Bafing Wildlife Reserve, a reserve specifically created to compensate for habitat loss following the construction of the Manantali dam and its reservoir. The OMVS could study the relevance and feasibility of setting up a trust fund to support management of the Bafing Wildlife Reserve and implementation of its management plan. This fund could be fed through resources such as the sale of fishing rights on the Manantali reservoir or a moderate levy on electricity produced in Manantali.

f. The OMVS could also support the development and/or implementation of management plans for the Boucle du Baoulé Biosphere Reserve (currently facing financial difficulties) and the recently created Transboundary Biosphere Reserve of the Senegal River delta.

g. The Diama and particularly the Manantali reservoirs have increasingly assumed significant ecological functions but also confront common problems in wetlands. In collaboration with the relevant environmental organizations, the OMVS should implement biodiversity monitoring systems for these water systems and develop and implement appropriate management plans as needed for these human-made wetland areas.

Fish fauna

a. The OMVS Water Charter's recognition of the importance of the river's annual flooding and the need to manage the dams so that flooding is generated in the best possible conditions and as frequently as possible marks significant progress in the development strategy for the river basin. Flooding is important for flood recession agriculture but also for livestock farming, forestry, groundwater recharge and fishing. It plays an essential role in the development of fish fauna. Consequently, it is important that the needs of fish fauna, and not just those of flood recession agriculture, are taken into consideration when determining how to manage flooding.

b. The Diama dam, which does not have a fish ladder, raises a barrier that prevents fish migration between the estuary, the coastal area and the river. About 20 years after the dam's activation, it would be useful to sponsor a study on the dam's actual impact on fish fauna and the foreseeable possible corrective measures.

Change in estuarine hydrodynamics

a. Given the rapid changes in the hydrological regime of the river delta—with the combined effects of the Diama dam and the channel in the Langue de Barbarie—a monitoring system of the phenomenon should be implemented. In addition, studies should be carried out on the implications of this phenomenon on ecology and the development of the lower valley and delta, taking into consideration the various possible scenarios for changes in the current dynamics.
b. Based on the results of these studies, appropriate measures will be defined and implemented to alleviate the foreseeable impacts caused by changes in the delta's hydrological dynamic.

Problems linked surface-water supply

a. Although current demand for freshwater—in terms of the level of actual use—only exerts a limited pressure on available resources, it is important to better understand and anticipate the foreseeable impacts of climate change on the Senegal River regime. It will be beneficial to develop and implement a strategy based on the obtained knowledge to strengthen the level of preparation and adaptation to climate variability and change in the Senegal River Basin.

Riverbank degradation

a. Along with foreseeable responses from the countries directly involved, Mali in particular (see Priority Solutions Matrix in the Annex), in-depth studies are urgently needed to better understand the causes for the acceleration and amplification of the riverbank erosion process. Specifically, this will concern examining the hypothesis of a possible link between water management in the Manantali dam and the riverbank degradation process in the reach downstream of this dam.

Water pollution

a. Due to the international character of the Senegal River and the legitimacy of its mission to manage the Senegal River Basin (a mission reinforced by the Water Charter, adopted in 2002), the OMVS must play a greater role in protecting the river's water quality in the face of heightened pollution risks.

b. The OMVS should strengthen its support to member States in their efforts to improve the drainage systems of irrigated areas (for example, the project to construct a drainage canal in the delta on the right bank of the Senegal River lower valley and delta).

c. In addition to efforts concerning the Diama and Manantali reservoirs that have been realized or planned, the OMVS should allocate the required means (perhaps in collaboration with relevant national services) to control water quality in the river in the rest of the basin where there are possibilities of water contamination from agricultural, industrial and mining activities in the basin.

d. The OMVS and its member States should initiate public education and awareness-raising campaigns, but also training for local communities and collectivities in managing water pollution problems. This intervention could support the ongoing efforts within in the framework of the Public Participation Component of the GEF-SRB Project.

e. The OMVS, in collaboration with the member States, should commit to implementing appropriate measures to discourage and prevent pollution and lean toward effective implementation of the "polluter-payer" principle. Since the member States have acceptable jurisdiction to confront water pollution at the national level and also through the ratified conventions, the effort should be focused on harmonizing national systems and especially their effective application.

f. To achieve the goal to protect river water from pollution, the OMVS must support a network of water-quality control laboratories with the appropriate equipment and the necessary autonomy to ensure reliability of control results.

Waterborne diseases

a. The high prevalence of diseases is the result and one of the symptoms of the degradation of the health of the basin's biophysical environment; restoring this environment can resolve many of the basin's current problems involving human and animal health. One priority solution to the prevalence of bilharzia, malaria and diarrheal diseases consists of combating invasive plants and river water pollution.

b. Besides this, possible classic solutions to the types of health problems arising in the valley remain necessary. They concern: community health education; the diagnosis and treatment of sick people, particularly by strengthening healthcare infrastructure and epidemiological monitoring; preventive measures such as the promotion and use of impregnated mosquito nets; improved availability of drinking water for communities and access to sanitation; and larva treatment in infected areas.

Other priority problems

Solutions on a national level are recommended in order to respond to problems posed by deforestation, bush fires, erosion and siltation. Even for the environmental problems covered above, possible solutions on a national level will complete those suggested on a basin level.

ANNEX 1. CONTACT PERSONS

ANNEX 1.1. CONTACT PERSONS DURING THE REGIONAL SYNTHESIS PHASE

Country	First and Last Name	Title and Institution
GUINEA		
	Alarény DIALLO	Ingénieur des Eaux et Forêts, Consultant national ADT-Guinée
	El Hadj Alpha Oumar SOW	Chef de Division / Ministère de l'Agriculture et de l'élevage
	Mamadou Lamine BAH	Cellule Nationale OMVS / Guinée – Ministère de l'Hydraulique et de l'Energie
	Mamadou Saliou DIALLO	Président- Coordinateur de Programmes / Guinée – Ecologie (ONG de Protection de l'Environnement)
	Ibrahima CAMARA	Spécialiste Développement Rural USAID/Guinée
	Boubacar CAMARA	Chef Section DPA/DNE, PNFT/CNC
	Dr Amadou Cherif BAH	Chef Service Etudes et Planification à la Direction Nationale des Eaux & Forêts Ministère de l'Agriculture de l'Elevage et des Forêts
	Seydouba SYLLA	Directeur National – Direction Nationale du Génie Rural – Ministère de l'Agriculture, de l'élevage et des Eaux et Forêts
	Jean LAPIERRE	Conseiller Technique Principal – programme de renforcement institutionnel à la Direction Nationale des Eaux et Forêts (ISP-FS)
	Atigou BALDE	Coordonnateur, Convention Ramsar – Ministère Hydraulique/ Energie – Direction Nationale de la Gestion des Ressources en Eaux (DNGRE)
	Souleymane SOW	Directeur National Hydraulique
	El Hadj Alpha Oumar SOW	Chef de Division, Aménagements Hydro-agricoles – Directeur National du Génie Rural
	Dr Daouda DIALLO	Enseignant – Chercheur, CERE
	Dr Mamdou I Ouattara	Coordonnateur Programme Massif Fouta Djallon, Bureau de Coordination Internationale de l'Union Africaine
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Country	First and Last Name	Title and Institution
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	Mountaga DIALLO	Directeur Technique SOGEM

Country	First and Last Name	Title and Institution
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	Brahim SALL	Directeur – SIDER Consult - Ing. MBA
	Matthieu BERNERDON	Conseiller Technique – UICN Afrique de l'Ouest – Bureau de Liaison – Mauritanie
	Dr Mokhtar FALL	Directeur – Ministère du Développement Rural et de l'Environnement – Direction de l'Elevage
	Amadou BA	Chargé de Programme – UICN Afrique de l'Ouest – Bureau de Liaison – Mauritanie
	Oumar COULIBALY	Directeur – Ministère du Développement Rural et de l'Environnement, DAR
	Amadou Diam BA	Conseiller Technique – Ministère du Développement Rural et de l'Environnement – Parc National du Diawling
	Pierre ESTRADE	Ingénieur, Topographe, Géomètre, Expert foncier – Agilis Mauritanie
	Youssoufa KAMARA	Directeur des Relations avec les Usagers – OMVS/SOGED
	Mamédy SACKO	Directeur Général – OMVS/SOGED
	Sidi Mohamed OULD DIDI	Directeur Administratif et Financier – OMVS/SOGED
	Saleh Ould SIDI MOHAMED	Expert National/GEF/OMVS/BFS (CNS)
	Alassane GUISSE	Directeur des Etudes Techniques (DET) - SONADER
	Mohamed Lemine OULD BABA	Coordonnateur UICN - Mauritanie
	Amadou DIAMBA	Conseiller Technique, PND
		Directeur PND
SENEGAL		
	Amadou T. DIAW	Directeur Laboratoire d'Enseignement et de Recherche en Géomatique.
	Dr Assize TOURE	Directeur Technique – Centre de Suivi Ecologique (CSE)
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	Matar DIOUF	UICN - Sénégal
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	Dior MBACKE	Expert charge de la Composante 5 OMVS/GEF-BFS
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	Mamadou SAMAKE	Expert chargé de la Composante 3 (ADT-PAS)
	Djibril SALL	Coordonnateur Projet GEF/BFS
	Malamine DIATTA	Hydrologue OMVS
	Mamadou M. SYLLA	OMVS
	Gora NDIAYE	Ingénieur – Hydrologue DGPRE
	Lamine NDIAYE	Expert SIG, SOE OMVS
	Cheikh MBOW	Enseignant-Chercheur, Laboratoire d’Enseignement et de recherche en Géomatique (LERG), ESP

ANNEX 1.2. STAKEHOLDERS DURING THE NATIONAL TDA PROCESS

COUNTRY	STAKEHOLDERS	
	First and Last Name	**Structures**
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	M. Sao SANGARÉ	Section Analyse et traitement des données - Ministère Hydraulique et Énergie
	M. Djiramba DIAWARA	Division Foresterie Rurale - Ministère de l'Agriculture et de l'Élevage
	M. Lankan TRAORÉ	Division Économie et Législation Forestière - Ministère de l'Agriculture et de l'Élevage
	M. Alpha Tougué DIALLO	Section Enquêtes et programmation des points d'eau - Ministère Hydraulique et Énergie
	M. Ibrahima Sory CAMARA	Division Pêche Continentale – Ministère Pêche et Aquaculture
	M. Cécé Alexis LOUA	Division Planification et Réglementation Énergétiques - Ministère Hydraulique et Énergie
	M. Cheick Fall CISSOKO	Direction Nationale de l'Énergie - Ministère Hydraulique et Énergie
	M. DABO	SEG - Ministère Hydraulique et Énergie
	M. Boubacar CAMARA	Direction Nationale de l'Élevage - Ministère de l'Agriculture et de l'Élevage
	M. Emmanuel Rolland MALANO	Prévention et Lutte contre les maladies – Ministère de la Santé Publique
	M. Momo SOUMAH	Service National des Sols - Ministère de l'Agriculture et de l'Élevage
	M. Aboubacar OULARÉ	Aires Protégées - Ministère de l'Environnement
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COUNTRY	STAKEHOLDERS	
	First and Last Name	**Structures**
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	M.Oumar Bodié BAH	Cellule Nationale de Coordination du Projet GEF/OMVS/BFS
	M.Oumar DIANE	Assistant Comptable du Projet GEF/BFS
	Mme. Augustine TOURE	Cellule Nationale de Coordination du Projet GEF/OMVS/BFS
	M. Mory CHERIF	Cellule Nationale de Coordination du Projet GEF/OMVS/BFS
	M. Daouda CAMARA	Cellule Nationale de Coordination du Projet GEF/OMVS/BFS
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	M. Fodé Luncény CAMARA	Ministère de l'Environnement
	M. Boubacar CAMARA	MAEEF / DNE
	M. Aliou CAMARA	MAEEF/DNEF
	M. Souleymane KOUROUMA	SGCD / Mali
	M. El Hadj Boubacar Hottia DIALLO	SGCD / Mamou
	M. Mohamed Abou YOULA	MHE / DNH
	M. Alarény Gongoré DIALLO	Consultant Indépendant
	Moussa DOUMBOUYA	Inspecteur Régional Agriculture
	M. Amirou DIALLO	CERE / Université de Conakry
	M. Forè CAMARA	CLC / Tougué
	M. Mamadou Dinah DIALLO	ENAE-Tolo/Mamou
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	Marcel BEAVOGUI	Radio Rural
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	M. Youssouf CAMARA	GEF/ Cellule Nationale OMVS - Ministère des Mines, de l'Energie et de l'eau
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COUNTRY	STAKEHOLDERS	
	First and Last Name	**Structures**
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	Mme Djénéba COULIBALY	Comité Local de Coordination (CLC) Kati
	M. Bakoye BA	Adjoint Chef SLACAER
	M. Drissa Zou COULIBALY	Comité Local de Coordination (CLC) Yélimané
	M. Dialla SISSOKO	C/Sce PIA
	Dr. Kariba TANGARA	Comité Local de Coordination (CLC) Kita
	M. Diatigui DIARRA	Comité Local de Coordination (CLC) Kolokani
	M. Boubacar O. TRAORE	Comité Local de Coordination (CLC) Koulikoro
	M. Drissa COULIBALY	Comité Local de Coordination (CLC) Diéma
	M. Aly KARABENTA	Comité Local de Coordination (CLC) Kéniébé
	M. Abraham SOGOBA	Cellule Nationale OMVS - Ministère des Mines, de l'Energie et de l'eau
	M. Djigui NIAKATE	Radio Kouroukan-Kita
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	M. Ibrahima Hamma TRAORE	Préfet de Kita
	M. Mamadou Moustaph SISSOKO	Président Conseil de Cercle
	M. Nampaa SANOGHO	Consultant
MAURITANIA	M. Brahim OULD BAH	Cellule Nationale OMVS
	M. Saleh OULD SIDI MOHAMED	GEF/ Cellule Nationale OMVS
	M. EL GHOTOB	GEF/ Cellule Nationale OMVS
	M.Mohamedou SOW	GEF/ Cellule Nationale OMVS
	M.Hamidou BA	GEF/ Cellule Nationale OMVS
	M.Mahmoud KONE	GEF/ Cellule Nationale OMVS
	M; SID'AHMED	GEF/ Cellule Nationale OMVS
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	First and Last Name	**Structures**
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	M.Med LEMINE ZEBAH	Comité Local de Coordination (CLC)- Bababe
	M.Hamoud CHEIKH	Comité Local de Coordination (CLC)- Bogué
	M.Med SALEM	Comité Local de Coordination (CLC)- Keur
	M.Sid'Ahmed OULD BAH	Consultant
	Mme. Marième BEKAYE	Consultante
	M.Djibril SARR	DAT
	M.Ahmed HAMOUD	DE
	M.Issmail AHMED	OPS
	M.MALOUMDINE	SA
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	M. Fodé Sarr	Direction Régionale Développement Rural Saint Louis
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	M. Sidy Fall	DAIH (Dir Amlén. Infrast. Hydroagricoles) SAED
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	M. Landing Mané	DDAR (Direction Développement & Amén Rural) SAED
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	M. Ibrahima Aly SOW	SDDC
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ANNEX 2 . BIBLIOGRAPHY

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