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case study Senegal River

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1 Background of the study case

1.1 The Senegal River Basin

The Senegal River Basin is located in West Africa and occupies an area of roughly 483'200 km^2. The entire basin, including the upstream catchments is drained by the 1'083 km-long Senegal River and its tributaries. The area of the river basin accounts for about 1.6% of the African continent and lies within the territory of four different countries: Guinea, Mali, Mauritania and Senegal.

The basin is divided into three distinct regions. The upper basin which lies in the mountains of Mali, the middle valley, which forms the 500 km long borderline between Senegal and Mauritania, and the delta in the lower valley where the Senegal River discharge into the Atlantic Ocean. The delta is about 80 km long and consists of numerous estuaries which form a complex canal system.

1.2 Rivers and discharges

The Senegal River is the second largest river in West Africa. It is formed by the confluence of two smaller rivers, the Bafing and the Bakoye, which occurs near Bafoulabé in Mali, about 1,083 km from the Atlantic Ocean. Downstream of Bafoulabé the river flows north-westward crossing the arid lands of western Mali. About 200 km further downstream the Falémé River gushes into the Senegal River. From this point on the Senegal River forms a natural border between Mauritania and Senegal flowing westwards toward the Atlantic Ocean (See Figure 1).

All three main tributaries of the Senegal River (Bafing, Bakoye and Falémé) have their sources in the Fouta Djallon Mountains of Guinea and in the south-western part of Mali. Several other small tributaries, originating in Mauritania, discharge as well into Senegal River. One of them, the Karakoro River, enters the Senegal River at more or less the same point as the Falémé River. About 200 km further downstream the Gorgol River enters the Senegal River. Total annual discharge leaving Guinea is estimated at about 8 km^3. This annual discharge increases by the inflow of numerous tributaries up to 20 km^3 by the time the river reaches the meeting point of Mali, Mauritania and Senegal.

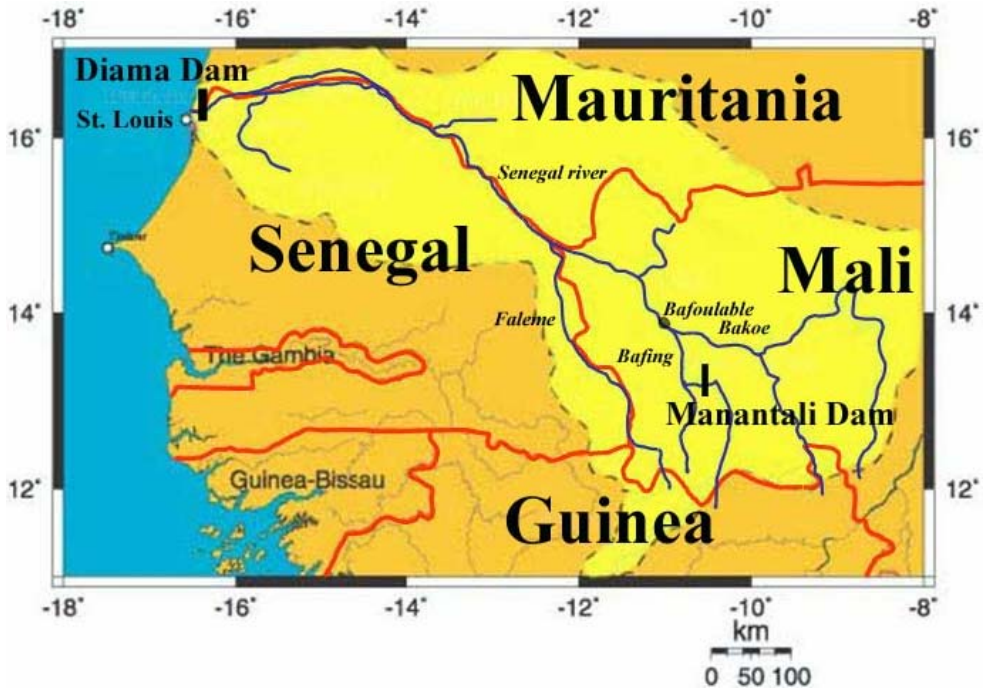

Figure 1 Senegal River Basin (yellow) shared by the four countries: Guinea, Mali, Mauritania and Senegal; the main tributaries and the positions of the two dams Manantali and Diama.

1.3 Hydrology

The flow rate of the river depends mainly on the rainfall in the upper basin in Guinea (about 2'000 mm/year, see Table 1). In the valley and the delta, rainfall is generally low and exceeds rarely more than 500 mm/year. During the drought years of the 1970s, there was significant less precipitation. The climatic regime in the basin can be divided into three seasons: a rainy season from June to September, a cool and dry season from October to February, and a hot-dry season from March to June. This creates a high-water period during which flooding occur between June and October. During this high water period the river overflows its banks and floods the broad alluvial plain of the middle valley. This enabled farmers to grow crops during the dry season, after the waters have receded and the low-water period had started. In areas of low rainfall, the river's annual flood was a necessity to life.

Country	Total area of the country (km^2)	Area of the country within the basin (km^2)	As % of total area of basin (%)	As % of total area of country (%)	Average annual rainfall in the basin area (mm)		
					min.	max.	mean
Guinea	245'857	29'475	6.1	12.0	1'120	2'100	1'475
Mali	1'240'190	139'098	28.2	11.2	455	1'410	855
Mauritania	1'025'520	242'742	50.2	23.7	55	600	270
Senegal	196'720	71'866	14.9	36.5	270	1'340	520
For Senegal basin		483'181	100		55	2'100	550

Table 1 Senegal River Basin: areas and rainfall by country.

Nevertheless, the inter-annual irregularity of the Senegal River also imposed severe threads to the local population in the basin. For a long time the inter-annual flood irregularity posed a major problem for the valley, as it decreased the potential for guaranteed agricultural production. The arable land area that could effectively be farmed after the flood varied between 15'000 ha and 150'000 ha, depending on the magnitude and duration of the flood.

Exceptionally high water levels caused widespread devastation in 1890, 1906, and 1950. Conversely, the years with extremely reduced water flow were also disastrous, since they did not yield a sufficient agricultural production in the valley. Most recently the drought of 1972-1973 was particularly devastating for the populations and the economy of the riparian region. During the low-water discharge period, from November to May or June, no significant rainfall occurred, and the river discharge and that of its tributaries gradually decreased. The particularly low water level during the dry season resulted in a deep intrusion of the ocean's salted waters into the riverbed. During the 1970s a saltwater wedge penetrated more than 200 km upstream of Saint-Louis.

To address the problems associated with the significant inter-annual variability in rainfall and water flow of the Senegal River, three of the four main bordering countries (Mali, Mauritania, and Senegal) agreed to establish a joint river management program.

2 River management

2.1 Organisations

The first institutions to develop the Senegal River Valley were created during the colonial period. In 1963, shortly after independence, Guinea, Mali, Mauritania, and Senegal signed the Bamako Convention for the Development of the Senegal River Basin that declared the Senegal River to be an "International River" and create an "Interstate Committee" to oversee its development. In 1968, the Labe Convention created the Organisation of Boundary states of the Senegal River (OERS - *Organisation des Etats Riverains du Sénégal*) to replace the Interstate Committee, broadening the field of sub regional cooperation. In 1972 the "Organisation pour la *Mise en Valeur du fleuve Sénégal* (OMVS), a river management organisation, was created replacing the OERS which broke up after the withdrawal of its fourth member, Guinea. The new organisation involved three riparian countries: Mali, Senegal and Mauritania.

2.2 The 1972 Treaty

Parallel to the establishment of the OMVS an international convention concerning the status of the Senegal River was signed by the three riparian states. The objectives of the convention were to promote cooperation among the riparian States of the Senegal River in the management and development of its resources. The provisions made in the convention can be summarized in four points:

(a) Projects for agricultural or industrial exploitation likely to modify the characteristics of the river appreciably to be implemented only with prior approval of the contracting states (art. 4);

(b) Joint programme of work for the coordinated development and rational exploitation of water resources to be defined by OMVS (art. 8);

(c) Joint projects to be carried out by management agencies (art. 15), and coordinated by the Office of the High Commissioner (arts. 19 and 20);

(d) The organization to be governed by a Council of Ministers, assisted by a Standing Commission to define principles and procedures for sharing the waters of the river, and an advisory Inter-State Committee for Research and Agricultural Development.

In the year of its founding, OMVS started its aims as being: to provide a secure and steadily improving livelihood for the inhabitants of the river basin and neighbouring areas; to safeguard as far as possible the ecological balance of the river basin; to make the economies of the member states less vulnerable to climatic conditions and external factors; and to accelerate the economic development of the member countries by the intensive promotion of region co-operation.

In 1973 it announced its program, based on the construction of two dams: one upstream at Manantali in Mali which would retain the waters of the Bafing; and one at the mouth of the river, which would stop salt water entering the delta and lower valley. The programme included three components. The first was irrigation schemes on the Senegalese bank of the river, overseen by the State development corporation for the river, the *Société d'Aménagement et d'Exploitation des terres du Delta du Fleuve Sénégal* (SAED). The second was navigation (the river was to be made navigable between Saint-Louis and Kayes throughout the year). The third was energy with the construction of a hydro-electric power station at the foot of the Manantali Dam.

Two private holding companies are now responsible for the management, operation, and maintenance of the dams. The *Société de Gestion et d'Exploitation de Diama* (SOGED, or the Diama Dam Management Company) and the *Société de Gestion de l'Energie de Manantali* (SOGEM, or the Manantali Energy Management Company) were created in 1997, and are located in Mauritania and Mali, respectively.

There are several other organizations within OMVS that have various responsibilities regarding the dams. The OMVS Regional Documentation Centre is located in Saint-Louis and processes and archives the many documents and data related to the activities of the OMVS, mostly administrative materials. It also provides access to these materials currently only in paper form, and hosts and maintains the OMVS web site, where a directory of its archived documents is being made available.

In 1998 the OMVS created the *Programme d'Attenuation et de Suivi des Impacts sur l'Environnement de l'OMVS* (PASIE, or Environment Impact Mitigation and Monitoring Program), which conducts environmental impact mitigation and monitoring activities related to the development of the dams. It receives financing from the World Bank and the African Development Bank, as well as France and Canada. PASIE consists of six programs focused on mitigation of construction impact and monitoring; appropriations and right of way for transmission lines; reservoir management; environmental health; and monitoring, coordination, and communication.

National planning bodies have been created with the task of working out post-dam guidelines. In Senegal, this is the *Comite National de Planification, de Coordination et de Suivi du Developpment de la Vallee du Fleuve Senegal* (National Planning, Coordinating and Development-Promoting Committee for the Senegal River Valley or CNPCS) and its executive department, the post-dam group. In Mauritania, the Ministry of Hydraulics and Energy in charge of the Supporting Technology Office which itself plays a consultant role on the interministerial post-dam committee.

The OMVS's fundamental conventions of 1972 as well as the Senegal River Water Charter signed in May 2002 establish a legal and regulatory framework, which clearly states that river water must be allocated to various uses. However the water resource is not allocated to riparian states in terms of volume of water to be withdrawn, but rather to use as a function of possibilities. The available water should be managed in a way to adequately supply the following sectors: agriculture, inland fishing, livestock raising, fish farming, tree farming, hydroelectric energy production, urban and rural drinking water supply, health, industry, navigation and the environment.

2.3 Costs and benefits

Two key funding principles of the OMVS model were: the recognition of the international status of the Senegal River by all riparian states (Senegal, Mali, and Mauritania); and the equal regard to the interests of each riparian states through rigorous criteria ensuring an equilibrate sharing of the development costs and benefits of the agreed programme. For this second principle Mauritania bears 22.6% of the costs of common infrastructures, receives 33.6% of the 375'000 ha of the land for irrigation in the agreed development programme and 15% of anticipated power generated. Mali bears 35.3% of the cost, receives 52% of the all energy generated and is the main beneficiary of the navigation programme. Senegal, which receives 42% of irrigated land and 33% of the energy generated, assume more than 42% of the costs. OMVS model has generated approx. one billion US dollars for the implementation of part of its programme (Manantali and Diama Dam projects).

3 The dams

The first to be completed (in 1986) was the Diama Dam, located 27 km upstream from the city of St Louis (Senegal) (see Figure 2). The primary goal of this dam was to stop the dry-season intrusion of sea water along the river bed. During the drought years saltwater would penetrate over 100 km inland, making the entire delta unsuitable for agriculture use (Gac 1986 a & b).

The second storage dam is located at Manantali in Mali and was completed in 1988 (both dams were inaugurated in 1990). Manantali lies 1,200 km upstream from the river mouth (see Figure 3), on the Bafing, the main tributary of the river, which supplies approximately 60% of the annual flow of the Senegal River in a reservoir. It's a reservoir, theoretically capable of stocking 11'000 km^3 of the strongly seasonal rainfall on the Fouta Djalon Mountains in Guinea. The water can then be gradually released over a longer period than the natural flood. Total cost of the dams was estimated at 600 million $US. The two dams should provide enough water to achieve the following development objectives:

- Regulate the river's discharge at a rate of 2'500 m^3/s during the rainy season (in August and September), in order to enable the traditional flood-recession farming;

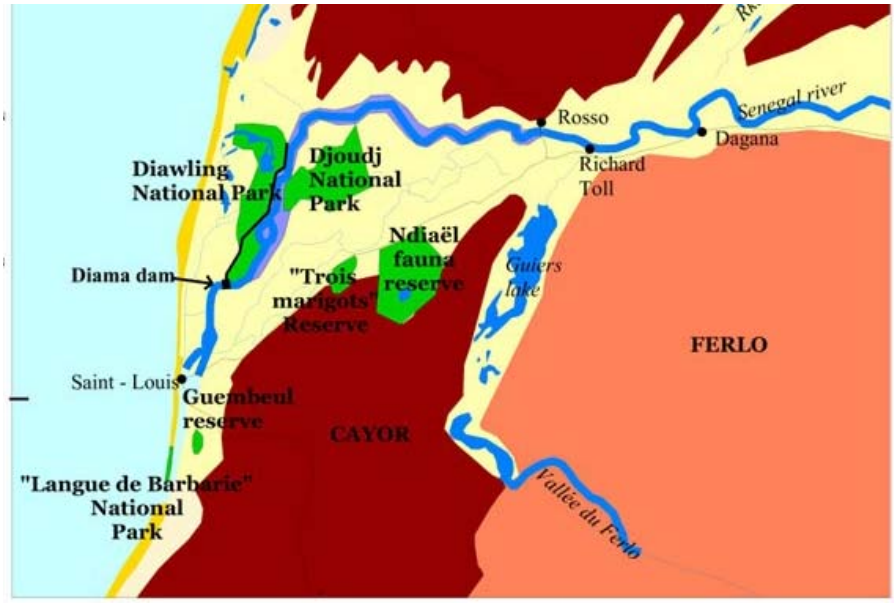

Figure 2 Location of the Diama Dam

- Regularization of river flows to 300 m^3/s at Bakel;
- Irrigate 300'000 - 400'000 hectares of former floodplain with two crops a year, especially for rice production;
- Produce hydropower (800 GWh per year), guaranteed 9 out of 10 years;
- 1'500-km transport line network to assure energy delivery to interconnected networks in the three member states;

- Make the river navigable all year round between Saint Louis at the river mouth and Ambibédi in Mali (about 900 km upstream). This part of the project also includes construction of a river port in Saint-Louis and seven smaller ports upstream.

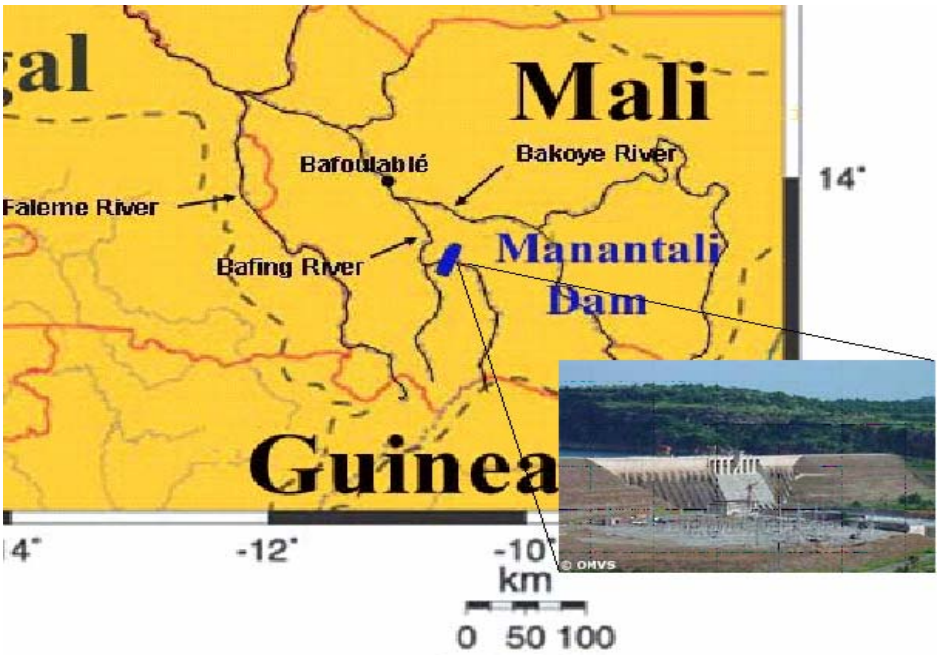

Figure 3 Location of Manatali Dam

The overall goal of these objectives was to improve the livelihoods of people living in the basin. In addition, people outside the region should be supplied with electricity, the agricultural production should be increased, and access to the sea should be facilitated.

These objectives, however, are still far from being realized. Today, the flow of the Senegal River is regulated primarily to serve the interests of irrigated agriculture, since the electric turbines at Manantali are not yet working. Water release from the dam has been haphazard, at least from the perspective of those who live in the valley. One thing is clear, though: the annual floods that formed the basis of a productive pre-dam recession system have been significantly altered.

4 Socio- economical conflict

The construction of the dams created unexpected environmental, social and economical problems which partly resulted in violent conflicts.

Before the Manantali Dam was equipped with turbines for hydropower traditional farming seemed to be a minor concern to the water managers controlling the discharge rates in the river. It was expected that all traditional farmers would convert into irrigational agriculturists in time. The main goal of OMVS was to maximise yields of the harvest market and gains through hydropower activities. To achieve this goal conditions for financial loans were loosened, to facilitate local farmers the transition from traditional farming to irrigational agriculturists.

In fact only foreign farmers with enough wealth could satisfy the conditions for getting loans in order to establish large-scale farming in the area, leaving the poorer local farmer on their own. However the rich farmer's only interest in the region was getting easy access to lucrative loans. As soon as they got hold of the money they disappeared, leaving behind a crooked ´death certificate' instead of repayments. The period of the arrival of the newcomer's resulted in violent interethnic conflicts.

Ethnic disputes in the region preceded the arrival of the newcomers in the river valley. Because these violent outbreaks, also referred to as "Les Evénements", coincided with the completion of the dams, many believe that there exists a direct link between the two events (Adams, 1999, Horowitz 2001, etc.). In 1989, the killing of sedentary Senegalese farmers by nomadic Mauritanian herdsmen in the river valley triggered the ethnic conflicts. In Senegal's capital Dakar 100 to 150 Moorish shopkeepers were killed and 10'000s of Mauritanians fled from Senegal to Mauritania. Also in Mauritania's capital Nouakchott, hundreds of black people were killed. And about 70'000 flood-recession farmers fled from the Mauritanian side of the river to Senegal. The military of the two countries engaged in armed skirmishes, and nearly went to war over the conflict (Bosshard 1999). According to Bosshard, the ruling Moors in Mauritania took advantage of the situation and expelled the flood-recession farmers to Senegal in order to make room for large-scale irrigation schemes. People mostly belonging to the elite Moorish society later exploited these irrigation schemes. On the other hand most large-scale irrigation schemes were constructed in the Lower Valley where population densities were relatively low and where little flood-recession farming took place before dam construction (Adams, 1999).

5 Success-Failure

Thousands of days of work and millions of dollars have been invested in development plans for the Senegal River Basin. Clearly, the landscape of the basin has changed forever. It is neither possible nor feasible to return to life as it was before the dams.

The OMVS proposed 375'000 ha of pumped irrigation, navigation from the ocean to Kayes, 800 GWh/yr electricity 9 years out of 10, flood mitigation, maintenance of flood recession agriculture in transition to irrigated agriculture, and control of saltwater intrusion at Diama.

After so much hard work by so many people, it is important to distinguish between the successes and the failures of the efforts.

5.1 Irrigation

Irrigation development has been slower than planned, with only 131,000 ha irrigated by 1998, and only half of that area being cropped on average. The average production of rice does not exceed 3 tonnes per ha per year instead of the projected 12 t per ha per year. Moreover, as the delta was a marine bay that gradually filled in with sediment over the last few thousand years (Monteillet 1988), there is an underlying hypersaline groundwater sheet at about 1 m below average sea level stretching to over 200 km inland. Current irrigation practices, usually without drainage systems, seem unsustainable because of increased soil salinity (Boivin *et al.* 1995) and large tracts have already become permanently improper for agriculture (JICA- Sonader 1997).

The rate of expansion of irrigated agriculture and total production are still far below set targets. For example, in Mauritania, of some 50'000 hectares equipped for irrigation at great cost, only about 15 000 are cultivated annually. This low rate of conversion to irrigation has incited the OMVS to extend the artificial support to the natural flood. Releases from Manantali during the natural flood season have allowed traditional recession agriculture in the floodplains to continue to some extent. Though technically hampered, mostly by the lack of reliable recent rainfall and hydrological data from the upper basin, this compensatory measure has certainly attenuated the negative impacts of the dam on the quality of life of the traditional sedentary agriculturist communities.

5.2 Hydropower production

Hydropower production at Manantali dam, planned to be fully operational by 1992, was inaugurated in 2001 with the transmission line only for Mali's capital Bamako. As the economic viability of this sector seems beyond doubt, it is likely to rapidly expand with high tension lines supplying the two other capitals, Dakar and Nouakchott within the following few years. It is important to note that the

dams were built with loans and that hydropower production at present seems to be the only possibility for reimbursement.

With the start-up of the hydropower production the Senegal Valley Project has entered a new phase for the partitioning of water use and some difficult choices may have to be made. For efficient electricity production water levels in Manantali will have to be high and most of the peak demand in the capitals will probably be for air conditioning in the hottest months. Will there be enough water to both sustain the artificial flood and produce hydropower? Little comfort can be taken from the official OMVS documents concerning the impacts of power production (OMVS 1997), that seem mostly concerned with the local impacts of the power lines. It is to be feared that, given the generally disappointing results of the agricultural development and the very shaky economic basis of the navigational sector, the riparian countries will be 'forced' to reimburse the loans, contracted for the building of the hydraulic infrastructure, almost entirely from the sale of electricity. This may compromise the continued support of the artificial flood, which, though officially justified only by the needs of recession agriculture, has at least partially satisfied the more general water needs of the multifunctional floodplains.

5.3 Navigation

Improvement of navigation facilities has not been implemented. Donor agencies have so far been reluctant to take up the investments needed for improving the navigability and for building the associated harbour infrastructures. This happened in spite of OMVS having already lowered the project's ambitions several times. Mali, whose part of the basin has virtually no exploitable floodplains, expected its main benefits of the project from this sector and the slowness of its implementation is creating frustration.

Further nuisances linked to the construction of the dams are explained in the following sections.

5.4 Diama Dam

The ecosystem in the Diama dam area traditionally varied from nearly fresh, during the wet season, when the rain fed flood inundated the zone, to brackish, during the dry season when salt water from the ocean intruded into the delta. With the construction of the dam the ecosystem was divided into a permanent fresh water ecosystem upstream of the dam while the area downstream of the dam changed into a hyper saline area throughout almost the entire year. As a consequence the area downstream of the dam transformed from rich wetland into a salt desert.

During the 1970's small village-level irrigation schemes developed rapidly in the valleys. The small dams in the surroundings of Diama Dam cut off former floodplains and estuaries, preventing seasonal flooding during rainy season. This led to devastated rain fed corps and reduced the area of flood recession farming (see also the section on agriculture further down).

Blocking the migration route for the fishes, the dam caused the total disappearance of mullet fishes in the river upstream the impoundment.

The invasive weed problem arises soon after the Diama Dam became operational in 1988.In the area upstream the dam proliferation of *Salvinia molesta* occurred. These are very invasive and eutrophication has begun in some places in the valley and the delta. Anthropogenic pollution was caused by the discharge of industrial and agricultural chemicals into these environments.

Other problems arise from increased competition for agricultural land and firewood because of the erosion of the slops or river banks.

Meanwhile the changes in the ecosystem downriver of the dams caused a proliferation of *Typha australis*. Within 10 years the *Typha australis* proliferated so strongly that irrigation systems were clogged. The hyper saline groundwater (heritage of the original marine bay) and the increasing soil

salinity (also due to the altered discharge rate) have led to the devastations of large tracts of agricultural land. Consequently the production of rice remained at about 1/3 of the projected 12 t/ha per year.

5.5 Manantali Dam

When it was built (in 1980s) the dam call a "poster child of bad dams" put an end of one thousand years of successful flood-recession farming, create a major economic impacts for downstream farmers, fishers and herders, ground water resources and riverine forests, and turn an area with a low incidence of water-born disease into one of the worst-infected in Africa (Pottinger, 1997).

On the whole, less has been achieved than had been hoped for. As of the end of 1999, the electric power turbines had not been installed at Manantali. Under current plans, the power that is eventually generated will be exported from the valley to larger cities.

Irrigation has been costly and far below levels anticipated. And not a single vessel has passed through the boat lock at Diama since it was completed in 1986. The following sections focus at the repercussions felt throughout the basin.

5.6 Further negative side effects of the dams

5.6.1 Agriculture

In the agricultural sector, on top of the salinisation and loss of fertility, production has been hampered by the important increase in the population of granivorous birds. It is thought that this population explosion is linked to the permanent availability of fresh water, which has eliminated the important dry season mortality. Another factor may have been the creation of inaccessible breeding and resting areas in the tens of thousands of hectares of former floodplains invaded by aquatic weed (*Typha domingensis)*.

Another issue linked to the previous one is the change in land tenure linked to the change in agricultural practice. Traditionally, the parts of the floodplain that had been under water for 45 days at least could be cultivated without any other intervention but planting seeds when the waters receded. Fertility was maintained by the clays and silts that sedimented from the flood water, and by the dung left by animals that had grazed the floodplains during the dry season. Though the productivity per hectare rarely exceeds 1 ton per year, the low labour and capital input and the hundreds of years of experience transmitted through the generations made this exploitation system rather performant, especially for the rural poor. Even now, sedentary agriculturists that have converted to rice farming continue to practice recession agriculture as an extra source of food security whenever the floods released from Manantali allow. A major problem is that the land available for this sustainable type of agriculture is insufficient, not only because of population growth and reduction of flood height but also through the change in land ownership structure. Many of the best soils have been converted to large-scale irrigation plots and concomitantly their ownership has 'moved out of the valley'. This has in some cases led to serious social conflicts (Crousse 1991, Ba 1991).

5.6.2 Fisheries

In the pre dam area fishermen have concentrated their efforts on catching fishes trying to regain the permanent waters of the river bed after the floods have withdrawn from the floodplains. In the delta area fish catches were estimated to vary around 30'000 tonnes during this epoch. Today however, almost the entire production has been lost subsequently. In the Diama Reservoir fishing is seriously hampered by the dense stands of *Typha* and aquatic fern (*Salvinia molesta)*. Only in the Manantali Reservoir catches seem to have increased, although this does not compensate the losses in the valley.

5.6.3 Pastoralism

In the pre dam epoch nomadic pastoralism was the dominant traditional exploitation system. During rainy season the herds moved away from the river to nutritious pastures avoiding diseases in the flooded valleys. However, today the permanent presence of stagnant fresh water has favoured the development of parasitic diseases affecting livestock, especially liver flukes. They have a major impact on livestock's productivity and herders have to keep livestock from entering the infested waters and provide drinking water away from the river's edge.

5.6.4 Forestry

The wood from the floodplains is termite-resistant and therefore used as building material. Furthermore it provides excellent firewood and charcoal. After the construction of the dams the most of the forests retrograded or disappeared because of lack of water or water logging. Forests downstream of the Diama Dam were affected strongest because of high tides that used to ride up the river, deflected on the dam. The hyper saline water of these floods left a thick salt crust behind, destroying almost the entire initial flora. The hyper saline floods had also a devastating affect on the perennial grass (*Sporobolus robustus*), which is used in mat waving. The exploitation of *Sporobolus robustus* was the main sources of income of the local women.

Most of the original habitat of species that used to occupy the seasonal pools in the floodplains, which was used locally as a cereal substitute and for its pharmaceutical properties, is now covered with *Typha*.

5.6.5 Human health

As mentioned some economic areas (agriculture, fishing, livestock raising) experienced a drop in productivity, compared with productivity during the first year after the dams were filled. This decline led to decrease in income and, therefore, a decrease in the standard of life for the local population.

However, the most serious problem that the basin has to face since 1993/94 is the impact of the dams on the public health. Parasitic diseases in the valley (schistosomiasis, malaria, and Rift Valley fever) have reached epidemic proportions because the changed water regime of the basin provides ideal habitats for snails and mosquitoes. Before the dam was built at Diama in 1985, no cases of schistosomiasis were reported at Richard Toll, the largest irrigated region along the river. Because the upstream movement of saline water is blocked, the snails that host schistosomiasis parasites now thrive in the salt-free river and irrigation canals. By 1987, 80 percent of stool samples were showing infection with intestinal schistosomiasis, a particularly debilitating form of the disease.

A field survey between 1988 and 1989 for randomly chosen 1,000 subjects of all ages reveal a prevalence rate of 60% for intestinal bilharzia (Talla 1992).

Cholera outbreaks, which used to occur typically only during the rainy season, seem to have become quasi endemic.

The increase in schistosomiasis result from the creation of bodies of fresh water such as irrigation canals and pounds, that breed disease-bearing snails previously controlled by seasonal fluctuations and salt inflows. The mortality rate caused by water-related disease calculated in 1997 was 8'000 per year and was estimated that adequate measure to manage flows from the dams could reduce the number of deaths by 2'500.

5.6.6 Food production

Since the dams were finished a decade ago, useful floods have occurred only rarely, and irrigated farming has expanded only modestly, with far higher costs and lower yields than had been anticipated. Consequently, food production in the Senegal River valley has declined. Increasing numbers of young

men have emigrated to seek jobs in Senegal's cities, other West African countries, and Europe and North America. As a result, the burden of agricultural labor is increasingly borne by women, children, and the elderly. Many households now depend on remittances from absent members to buy food they no longer produce. The resultant decline in nutrition has left the population even more vulnerable to respiratory and parasitic diseases. Malnutrition is most noticeable among women and children, as well as ethnic minorities.

5.6.7 Irrigation costs

To date, irrigation in the Senegal Valley has not performed well. Constructing perimeters is costly. Maintaining them (for example, pump and canal repair and land leveling) translates into high recurrent costs. After several years, yields commonly decline because of salinization, which results in the phenomenon known in the valley as irrigation itinerate.

5.6.8 Drinking water

Because of reduced flooding, shallow aquifer recharge has declined and wells have dried up. Some people are forced to travel long distances to draw water directly from the river and marigots, with attendant health and sanitation risks. Others have drilled expensive boreholes to tap the deep aquifer. Providing several hundred thousand Middle Valley residents with new, safe, and reliable sources of potable water will be costly.

5.6.9 Displacement

Dam construction forced the displacement of 10,000 villagers in the valley. The people were forced from their homes and farms upstream from the Manantali Dam, where an 11'000 km^3 lake has formed. They were resettled onto lands downstream from the dam and in new villages along the rocky margins of the reservoir. At present, the relocated population is as poor as it was before the move, if not poorer. Although a USAID-supported effort did an exemplary job in getting the resettled involved in selecting new village sites, some people worry that the new lands will prove inadequate for livestock and proper fallowing. There is also concern that conflict will arise between the resettled and host populations over access to land.

Downstream, smallholders have lost their land and trouble has flared over land. Non-valley natives in Mauritania, anticipating large external investment in irrigated pump schemes on the floodplain, obtained control over riverine land by evicting the smallholders who had been living on it, forcing at least 70,000 people to cross the river into Senegal, where they live in precarious conditions in camps.

5.6.10 Social cohesion

Social relations are never static. As time passes, an inevitable evolution of groupings takes place. This certainly has been the case since the dams were completed. Those ethnic groups and countries best able to take advantage of irrigated farming and changes in land value have done so. For them, the dam investments have been a success. But looking at the region as a whole, it is hard to argue that the dams have advanced social cohesion. On the contrary, as the overall productive capacity of the floodplains has declined, formerly amicable relationships among ethnically distinct farmers and herders have become contentious, as groups are forced to compete for access to scarce resources. In a number of instances, competition has escalated into violence. Where the flood allowed a succession of mutually reinforcing productive activities (such as fishing, herding, and farming) the absence of useful floods generates social conflicts that are too readily, and mistakenly, interpreted as reflections of ancient tribal tensions.

5.6.11 Income

Each effect noted above captures a dimension of the change that has occurred in the region. In the end, perhaps the most important criteria for assessing the change is the overall change in household

incomes. USAID's research in the Senegal River Valley on the economic value of the traditional production system demonstrates that the succession of flood-recession farming, herding, and fishing generated an economic return that surpassed the returns from irrigation, when all the costs of land, labor, and capital are taken into account. The average annual value of output per hectare of inundated floodplain was 28,550 to 57,434 FCFA for recession cultivation of sorghum, 70,000 FCFA for fish, and 35,000 FCFA for livestock, totaling 133,550 to 162,400 FCFA (in post-1994 francs). Irrigation, even if double-crop irrigation were sustainably carried out on the floodplains, has not proven capable of providing this level of net returns to individual farming families. Indeed, World Bank studies show traditional production systems to be more economical than hydro power production.

6 Recent mitigation efforts

In 1997, OMVS started to collaborate with the World Bank to develop a **Global Environment Facility** GEF project for the Senegal River Basin. After a series of consultation a technical programme has been elaborated that focuses on establishing a viable integrated resource management strategy that focuses on water, biodiversity and environment. The programme focuses on establishing a series of activities at national levels that together form a cohesive strategy for the river basin. However, so far insufficient attention has been given to the need for a wide consultation and participation of all stakeholders for the implementation of a sustainable management of the Senegal River Basin. It is essential that the people living in the basin are sufficiently informed about the water resources management policy of OMVS, especially the management of the up-stream Manantali Dam. This obviously has much to do with the flood characteristics created by the water releases that largely affect the agricultural, domestic and natural environment. Secondly, a sustainable basin management needs to incorporate a full knowledge of the environmental conditions within the basin. Invasive plant species, seasonally severe pollution and serious waterborne diseases are just some of the aspects that need to be dealt with.

In June 1997, despite serious environmental and socio-economical concerns raised by a host of critics, the World Bank approved a US$38 million loan to help finance installation and operation of the Manantali Dam's turbines. The bank was not a lender for the original construction of the dam.

In May 2003 the World Bank's Board of Executive Directors approved a $46 million IDA credit to assist the Government of Senegal in creating the conditions to stimulate private investment, through an improved investment climate, greater private participation in economic activities and policy sector reform. The project is thus expected to make important incremental contributions towards Senegal attaining the eight percent GDP growth called for in the Government's poverty alleviation program. The credit is on standard International Development Association (IDA) terms, with a maturity of 40 years, including a 10-year period of grace.

As part of the international community's support to the Senegal River Basin Authority, the OMVS, the World Bank Board of Executive Directors approved in October 2003 the implementation of the Senegal River Basin Water and Environmental Management Project.

This is the first regional water and environment management project within the Senegal River Basin. According to Ousmane Dione (World Bank Team Leader) the project has a total cost of US$ 21.20 million, funded in part by a US$ 7.25 million grant from the Global Environment Facility (GEF), with additional contributions from several development partners including the African Development Bank, the French Government, the Government of the Netherlands as well as the OMVS and the four national governments. The GEF is the largest single source of funding for the global environment. GEF brings together 176 member governments, leading development institutions, the scientific community and a wide spectrum of private sector and NGOs in support of a common global environmental agenda.

7 Conclusions

In response to the exceptionally high water levels which caused widespread devastation in 1890, 1906, and 1950 and the historic droughts of the early 1970s, the governments of Senegal, Mauritania, and Mali searched for ways to improve management of water resources in the region. The three governments created the Senegal Valley Development Authority (Organisation pour la Mise en Valeur du Fleuve Senegal [OMVS]) to oversee river basin development planning and implementation. Extensive investments in water management were made, in particular through the construction of the Manantali Dam on the Bafing River in Mali and the Diama salt-intrusion barrage between Senegal and Mauritania near the mouth of the Senegal River. The dams were built in the 1980s to expand irrigated farming along the Senegal River and in the delta, to generate electricity for urban and industrial development, and to make the river more navigable. From the total costs estimated at 600 million US Dollars, no money were allocated for research in order to predict negative environmental, social and health impacts that appeared very quickly after the opening of the two dams.

Nearly 30 years later, water management in the basin has changed dramatically and irrevocably. Enormous efforts have been made by the governments in the region and their partners. Some of these efforts have paid off in improved livelihoods. Others have failed. Today, new investments worth hundreds of millions of dollars are poised to further influence the well-being of those who live in the basin.

Moreover, the initial goals in the three main compartments of the programme (conversion from flood recession farming to irrigated agriculture, river navigation throughout the year and hydro-electric power production) were not achieved. Enormous unforeseen problems were created by the construction of the dams. The unexpected problems occurred mainly in sectors which were not taken into account during the initial phase of the planning. Especially severe environmental and social problems, directly linked to the construction of the dams, hamper large parts of the economy along the river.

Social and environmental problems do not seem to be the result of opposed interest between the riparian countries. Rather the lack of foreseeing research and investigation during the initial phase of the program seem to be the cause for the negative effects observed. As a consequence, the main conflict situations are rather of social and environmental nature than being an international conflict between two sovereign countries.

Only in 1997, OMVS started to collaborate with the World Bank to develop a GEF (Global Environment Facility) project for the Senegal River basin. After a series of consultation a technical programme has been elaborated that focuses on establishing a viable integrated resource management strategy that focuses on water, biodiversity and environment. The programme focuses on establishing a series of activities at national levels that together form a cohesive strategy for the river basin. However, so far insufficient attention has been given to the need for a wide consultation and participation of all stakeholders for the implementation of a sustainable management of the Senegal River Basin. It is essential that the people living in the basin are sufficiently informed about the water resources management policy of OMVS, especially the management of the up-stream Manantali Dam. This obviously has much to do with the flood characteristics created by the water releases that largely affect the agricultural, domestic and natural environment. Secondly, a sustainable basin management needs to incorporate a full knowledge of the environmental conditions within the basin. Invasive plant species, seasonally severe pollution and serious water borne diseases were just some of the aspects that need to be dealt with.

The absences of Guinea in the organisation constitute a great handicap for the OMVS, simply, because of lack of information and knowledge on the Guinean upper basin, main catchment area of the Manantali Dam. Just in 1997 the Republic of Guinea and OMVS signed a protocol for cooperation and start to attend the OMVS meetings as an observer.

Within the next year or two, a Water Charter will be established to govern how the Senegal River's water resources will be used in the future. This booklet provides information to facilitate an open and informed discussion on the future of the Senegal River Basin. A great deal of effort has been spent gathering information about options for river management. Too often, however, debates over these options have taken place in distant cities among people who do not represent the full range of stakeholders. And not all of the existing information has been used to the full extent possible. The process of optimizing the water resources of the basin will work only if everyone concerned (from government planners to the rural people who live and work in the basin) has access to the information generated in earlier studies and takes part in the decision-making process.

7.1 Numerical evaluation

As the discussion in section 5 shows, the success or failure of the efforts conducted by the OMVS depends on a variety of different factors. Since all of the sectors discussed are negatively affected by the construction of the two dams, it can be concluded that up to today the water management failed to achieve its goals. None of the objectives of OMVS were adequately reached but many unforeseen problems have been created by its actions. Most disappointingly, the standard of living for the local population has declined since the construction of the dams. But to what extend have the efforts failed? A quantification of the success of the efforts conducted in the Senegal Basin is appended in the appendix. In this section only the effectiveness of the water management will be quantified and shortly commented. For this purpose the actual situation, the situation in absence of international efforts (situation without the implementation of OMVS) and the best imaginable outcome under an effective water management have to be compared and quantified regarding their success. The three situations have to be scaled on a scale of 1 to 10, where 1 signifies a minimal success and 10 a maximal success.

Best imaginable outcome or Collective optimum (CO):

Ideally extreme flooding and droughts would be prevented and water level in the river would be stabilized, agricultural production would be increased, river navigation would be possible and hydropower production would lead to extra income for the riparian states. By definition the success of this scenario is 10.

Outcome in the absence of international efforts (NR):

Occasional severe flooding and drought would appear, jeopardizing the entire basin. However the traditional lifestyle would be conserved. NR was given the value 5 since it seems that local people and environment have adapted to the natural state of the river to ensure a decent living during period's without severe hydrological events.

Present situation (AP):

The present situation has been described in detail above. Considering all the nuisances mentioned the present situation was graded with the value 2.

Effectiveness score:

The Effectiveness score describes the efficiency of the water management plan. Its value is calculated by a simple arithmetic formula using the values of the CO, NR and AP:

$$Effectivness\_score = \frac{AP - NR}{CO - NR}$$

Using this formula a negative effectiveness of –60% is determined for the Senegal Case. The negative Effectiveness score reflects the fact that the situation before the construction of the two dams was better than the present situation. The efforts of the water management have had an undesired negative outcome resulting in a situation, which in an overall view is worse than the original state.

8 Coding Sheet

OUTCOMES-SUCCESS-FAILURE	CODING OBJECT 1 (Conflict, Approach)	VARIABLE DEFINITION (change if not sensible!)	Explanation (short, more detailed in text)
REGULATORY OUTPUT			
International treaty	1	yes, no	To promote cooperation among the riparian States of the Senegal River Basin in the management and development of its resources.
Are treaty provisions specific in terms of goals and implementation?	4	1 (vague) - 5 (very specific) scale	Provisions made in the convention: (a) Projects for agricultural or industrial exploitation likely to modify the characteristics of the river appreciably to be implemented only with prior approval of the contracting States (art. 4); (b) Joint programme of work for the coordinated development and rational exploitation of water resources to be defined by the Organization (art. 8); (c) Joint projects to be carried out by management agencies (art. 15), and coordinated by the Office of the High Commissioner (arts. 19 and 20); (d) The organization to be governed by a Council of Ministers, assisted by a Standing Commission to define principles and procedures for sharing the waters of the river, and an advisory Inter-State Committee for Research and Agricultural Development.
Is there a dedicated international organization	1	yes, no	In 1972, the OMVS ("Organisation pour la Mise en Valeur du fleuve Sénégal"), a river management organization, was created. The organization involved 3 riparian countries (Mali, Senegal and Mauritania) and replace the Organization des Etats Riverains du Sénégal (OERS).
IMPLEMENTATION			
To what extent have riparian governments enacted legislation or other domestic measures to implement international commitments?	4	1 (none) - 5 (very much) scale	Treaty was singed and founding was implemented, however side effects have not been considered

PROBLEM SOLVING			
What is the collective optimum (CO)?	10	1-10 scale	Ideally extreme flooding and droughts would be prevented and water level in the river would be stabilized, agricultural production would be increased, river navigation would be made possible, hydropower production would lead to extra income,
What would the outcome have been in the absence of international efforts (NR)?	5	1-10 scale	Occasional severe flooding and drought would appear, jeopardizing the entire basin - traditional lifestyle would be conserved
What is the present situation (actual performance, AP)?	2	1-10 scale	Unforeseen problems occurred, but initial goals were achieved only partially: flood plain ecosystem destroyed - traditional farming impossible - eutrophication and blooming of water plants- decrease in fishing -increase water borne diseases- delays in hydropower and river navigation plans -
Effectiveness score = (AP-NR)/(CO-NR)	-0.6		Conclusion: efforts were unsuccessful
Sensitivity score = 1/(CO-NR) = d(effectiveness score)/dAP	0.20		
EXPLANATORY VARIABLES			
NON-REGIME INFLUENCES			
Geographical/hydrological:			
Number of countries involved	3	1-?? Scale	There are 3 riparian countries involved: Mali, Senegal and Mauritania. Guinea, recently became a member with an observer status
Area of river/lake basin	483200	km^2	

Asymmetry in terms of riparian land area in river/lake basin	8.229508197	% of largest riparian country in river basin / % of smallest riparian country in river basin (0-1 scale)	Guinea (6.1%), Senegal (14.9%), Mali (28.2%) and Mauritania (50.2%)
Issue-characteristics:			
Extent to which damage caused by individual riparian countries is exported to other riparian (average)	3	1-5 scale	Mali exports almost 90% of the negative effects coming from the Manantali Dam to Senegal and Mauritania - the negative effects of the drama dam are more or less evenly distributed between Senegal and Mauritania
Is the problem an upstream-downstream negative externality problem?	3	1-5 scale	The problems, which occur from the Manantali dam in Mali, are concentrated downstream. For Diama dam, the problems, which occur, are as well upstream, as downstream.
Is the environmental problem scientifically well-understood?	4	1-5 scale	Negative effects of the dams were not anticipated or underestimated (human health degradation, degradation of ecosystem, fishing decrease and agriculture problems have only been considered understood once they appeared)
How easy/hard is monitoring of compliance with international commitments?	5	1-5 scale	Commitments can be monitored easily - however implementation lies below the expectations
Is the environmental problem predominantly a point-source or a diffused-sources problem?	3	1-5 scale (1-point source; 5-diffuse source)	Dams are local, however the negative effects are spread over the entire valley
Economic and political conditions:			
Average level of development of riparian countries	10.43	mean of GDP	16.2 billion Senegal; 9.8 billion Mali; 5.3 billion Mauritania
Economic development gap between riparian countries	0.33	GDP of poorest / GDP of richest riparian country	GDP Mauritania (5.3)/GDP Senegal (16.2) = 0.33
What is the level of economic integration among the riparian countries?	15	average trade among riparian countries as % of their GDP (1-100%)	Senegal and Mali are members of the West African Economic and Monetary (UEMOA) with trading program, which represent 15% of GDP. Mauritania is member of only Economic Community of the West African States (ECOWAS) formed my UEMOA states and several others countries including Guinea and Mauritania. No trade program between Mauritania and Senegal or Mali.

What is the level of political integration among the riparian countries?	4	1(very bad) - 5 (very good) scale	All three riparian countries are members of OMVS. The relations are generally good.
How closely are the riparian countries affiliated in foreign policy?		correlation of voting in UN General Assembly	All three riparian countries are members of several international organizations: Organization of the African Unity (OUA); United Nations Organization (UNO); International Monetary Fund (IMF) and the World Bank. The relations are generally good.
General environmental awareness in the riparian countries	2	1-5 scale	3 for Senegal and Mauritania (new environmental lows, international funds for environment). 1 for Mali, which is less suffering from environmental problems.
Is the riparian country that suffers most from the problem economically/militarily more or less powerful than the countries) primarily responsible for damages?		average GDP+MilExp polluter countries) / average victim country (0-1 scale)	Responsibility for present problems lies by all three countries evenly; Senegal has the highest GDP, however it suffers also a high part of the negative effects
REGIME DESIGN			
Single-issue management or integrated river management?	2	1 (clear-cut single issue m.) - 5 (clear-cut integrated m.) scale	At the beginning focus was laid only on flood and drought management and hydropower production - almost no regards were laid on ecological, health, social and cultural aspects
Extent of third party funding (e.g. World Bank...)	2	1 (no 3.party funding) - 5 (full 3.party funding) scale	For the original water management no third party funding - for restoration of an intact environment at the present most of the funding comes from the world bank
Extent of NGO involvement		1 (none) - 5 (extensive) scale	IUCN (World Conservation Union)
Are federal or local/regional government primarily responsible for implementation and funding?	federal	federal, regional/local	Probably one of the causes for the poor results: local concerns have been neglected in the past
Are liability rules or other legal instruments used in implementation?	no	yes, no	No one can be held responsible for the present problems in the Senegal basin - however several organizations have the responsibility regarding the operation of the dams

Is the respective river management authority well organized and funded?	3	1 (bad) - 5 (good)	Funding and organisation seem to be well organised, however implementation of commitments encounter several problems (delays, unexpected negative side effects etc.)
Legally binding agreement or politically binding action program approach (hard vs. soft law)?		leg. Binding, action program	Treaty is a hard law - however implementation seems to be rather soft
How are the management costs and benefits allocated?	3	1=concentrated costs, diffused benefits; 2= concentrated costs and benefits; 3=diffused costs and benefits; 4=diffused costs and concentrated benefits	Mauritania bears 22.6% of the coast of common infrastructures and receive 33.6% of the 375,000 ha of the land for irrigation in the agreed development program, and 15% of the anticipated power generated. Mali bears 35.3% of he coast, receive 52% of the all energy generated and is the main beneficiary of the navigation programme. Senegal, which receive 42% of the irrigated land and 33% of the energy generated, assume more than 42% of the coast.

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