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WEIGHT OF TRANSFORMATIONS AND MAJOR DRIFTS RELATED TO MAJOR RIVER WATER PROJECTS IN AFRICA : CASE OF THE MANANTALI DAM ON THE SENEGAL RIVER BASIN

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ABSTRACT

This article deals with the weight of major developments or hydroelectric works in the development of the Senegal River Basin. He is interested in the positive and negative consequences resulting from the installation of the Manantali dam. This dam is the only major dam in the world that is declared a joint dam, financed, operated and jointly managed. The methodology is based on the collection of information from secondary sources and available statistics (books and Internet). Thus, it required dialogue and consultation between Senegal, Mali and Mauritania, through the Organization for the Development of the Senegal River (OMVS). However, it has long since been built into controversy even before its construction began in 1982 and it was flooded in 1988. The results show that: first, the benefits of Manantali Dam are flood prevention and surface water availability, power generation, navigation, aquaculture, ecological protection, development-based restocking, food self-sufficiency, water transfer and supply in neighboring countries, irrigation, etc ; on the other hand, the disadvantages of dam are the impacts on environment (waterborne diseases and proliferation of aquatic plants), the effect on local culture and traditional economy, the sedimentation, etc. From the point of view of the impacts the Manantali Dam shows proof that there are more advantages than disadvantages. Thus, it could well be compatible with an ethic of sustainable development and the preservation of ecological balances.

Keywords: Manantali dam, environmental impact, flood prevention, electricity production, ecological protection

INTRODUCTION

The creation of the organization for the development of the Senegal River (OMVS) was driving force that allowed the start of implementation of a common policy and a regional development program of interest to Senegal, Mali and Mauritania. The basis of this program is the construction of the Diama and Manantali dams. The Manatali dam is a multiple-purpose dam that stores 11 billion cubic meters of water and whose function is to regulate the flow of the Senegal River with a view in particular to the development of agricultural production by irrigation in all seasons, low-cost electric power generation and the development of waterway from the mouth of river to the city of Mali. Associated with the Diama dam, the Manantali dam ensure optimal annual and multi-year management of water resources in the Senegal River (African Development Bank, 1994).

Pre-investment studies for the development of resources in the Senegal River Basin had been undertaken in 1964 with UNDP funding. These studies led to the classification of sites, the most interesting to develop, including the site of Manantali. These studies were continued in 1976 by the detailed pre-project studies of the Manantali dam, carried out by a consortium of consultants called "Groupement Manantali", with funding from the Federal Republic of Germany. They were approved in 1979 by the Ministers Council of OMVS States. The bank had to participate with other donors in the financing of the project of this dam, which were completed in 1990, and which is the object of this article. This dam constitutes with that of Diama, the first works of the development program of OMVS.

Several politicians, scientists and engineers have participated for many years in construction of the Manantali dam on the Bafing in 1987 (Figure 1) and the Manantali hydroelectric power station in 2002. This dam has a total production capacity of electricity of about 800GWh / year, thanks to an installed capacity of 200 MW (OMVS and FEM, 2008). The Three Gorges Dam is the largest hydroelectric facility in the world by capacity. One of the main reasons for the construction of the Manantali dam was the fight against the drought of the 1970s and 1980s, which led to a decline in the flow (Faye, 2013). Initially, the construction of the Manantali dam (1982-1988) had three objectives : to develop irrigated agriculture in Senegal, Mauritania and Mali (all members of OMVS); to provide these countries with electricity they need; to make the Senegal River navigable (Dickmann *et al.,* 2009).

Large hydraulic developments escape, in their realization and their evolution, the logic of their designers and know as well unexpected drifts as expected, these drifts can be positive or negative, happy or dramatic (Bethemont, 2009). As with all technological implementations, the Manantali dam has advantages and disadvantages (OMVS, 2002 ; Ndiaye, 2007). This paper focuses mainly on the advantages and disadvantages of the Manantali Dam, with a particular focus on environmental impacts.

Presentation of the study area

A river on a new era

The Senegal River is the second largest river in West Africa. It is 1800 km long and its basin covers an area of 300,000 km2 (Figure 1). From the South, the Senegal River crosses different types of climates (Guinean, Sudanian, Sahelian) before sinking through the semi-arid and arid areas of the North where it gets very low rainfall. The average annual precipitation of the basin is estimated at 550 mm / year (OMVS and FEM, 2008). The Senegal River Basin is located in the western part of Africa between latitudes 10 ° 30 'and 17 ° 30' North and longitudes 7 ° 30 'and 16 ° 30' West. The Senegal River is formed by the meeting of Bafing and Bakoye in Bafoulabé in Mali. The Bafing, its main component, carries the dam of Manatali. The Senegal River thus formed by the junction between Bafing and Bakoye, receives the Kolimbiné then Karokoro on the right and Falémé on the left, 50 km upstream of Bakel. The Senegal River basin is generally divided into three entities (OMVS, Project FEM / BFS, 2008 ; OMVS and FEM, 200808): the upper basin, the valley and the delta.

Since the early 1970s, the Senegal River Basin has been characterized by chronic rainfall and water deficits, setting it up in a major ecological crisis. Increasing demand for water from upstream countries in basin (Guinea and Mali), coupled with the impacts of climate change on watercourse, has affected the availability of water resources for downstream countries (Senegal and Mauritania). According to the OMVS Observatory of the Environment Service (SOE, 2003), flow in Bakel has decreased by more than half between the 2 halves of the last century and between the last 2 quarters of the century. Climate change has affected the multiple characteristics of water resources (quantity and quality) and has produced a systemic crisis that can affect activities.

The attempts to adapt the riparian states of the Senegal River Basin are based on the establishment of a regional cooperation framework under the supervision of the Organization for the Development of the Senegal River (OMVS) which resulted in implementation of a large regional infrastructure program. Thus, in the last decades, the Senegal River Basin has been the subject of interventions and hydro-agricultural developments that have profoundly modified its natural regime (OMVS and FEM, 2007): the Bafing dam at Tolo, the Mafevol dam at Dounkimaggna (Guinea), the Manantali dam, reservoir and power station (in Mali), the Foum Gleita dam and the left bank dam between Diama and Rosso (in Mauritania) , the Richard Toll dam bridge over the Taouey, the digging of the Taouey canal, the construction of the dyke between Bango and Rosso, the Diama dam, the left bank dam between Diama and Rosso (in Senegal). Today, the Félou dam on the Bafing is in progress and the construction of the Gouina dams on the Bafing below Manantali and Gourbassi on the Falémé is envisaged.

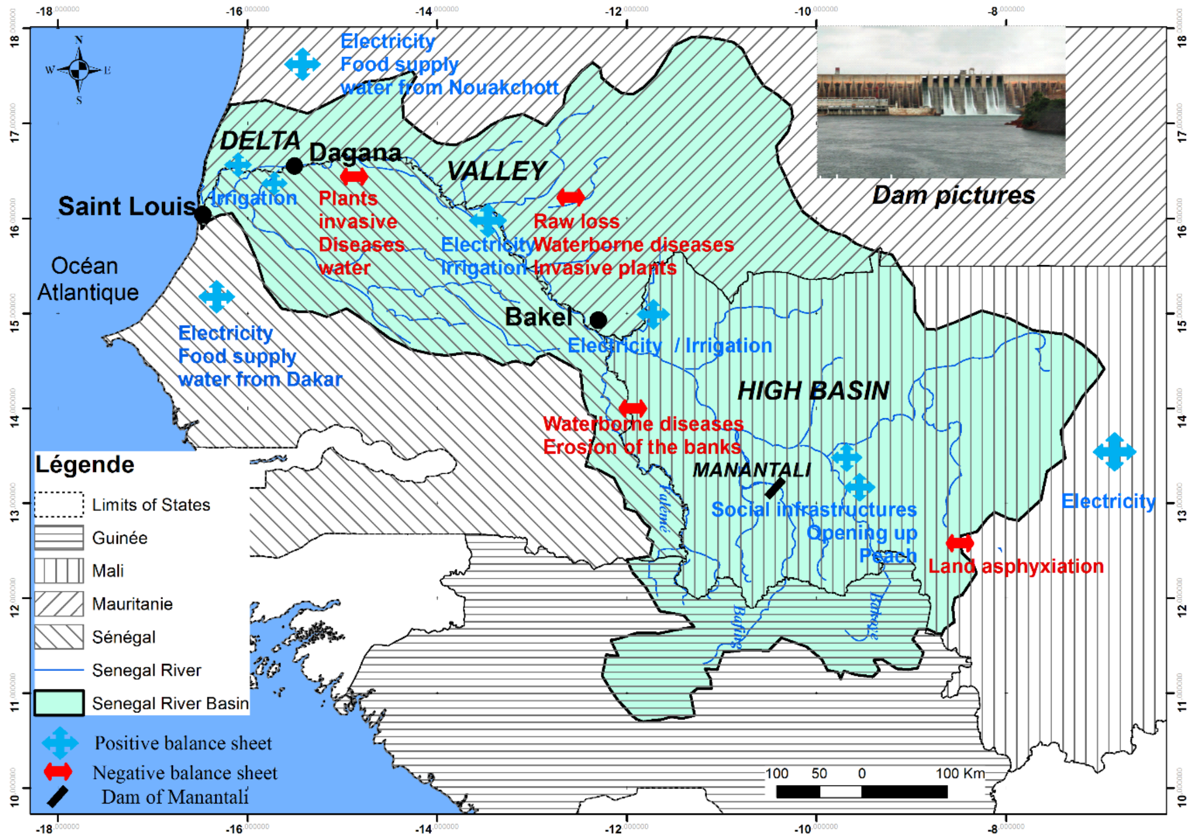

Figure 1: Senegal River Basin: Perceptions of the program's balance sheet according to the basin areas and the riparian countries of river (Source: Ficatier and Niasse, 2008 modified)

The Manantali Dam

The Manantali Dam is located on the Bafing River, the main tributary of the Senegal River, 90 km upstream from Bafoulabé (Figure 1). Built between 1982 and 1988, the Manantali Dam consists of a 1,460 m long dike and a height of 66 m at foundation. At IGN 208 meter filling level, its reservoir has a capacity of 11.3 billions m^3 and covers an area of 477 km² (International Office for Water, 2009). At its minimum level of exploitation (187 m IGN), the reservoir has a volume of 3.4 billions m^3 and covers an area of 275 km². The Manantali dam regulates the flow of the Senegal River and allows to irrigate a potential of 255 000 ha of land and eventually will have to allow the river navigability for about 800 km from mouth. Added to this is a power generation function (Badier *et al.*, 2003 ; Ficatier and Niasse, 2008). To this end, a 200 MW power plant and a network of 12 transformer substations and approximately 1650 km of 225.150 and 90 kv high-voltage transmission lines, interconnected to the networks of Mali, Mauritania Senegal (Dickmann *et al.*, 2009).

MATERIAL AND METHODS

This article is based on data from bibliographic research, field observations and semi-structured interviews with stakeholders. The combined approach of data collection (on the issues of dams) is preferred here. It consisted primarily of a consultation of unpublished documents (works, reports, memoirs, theses, articles ...) which are of great interest for this study. This in-depth review of the literature has allowed us to collect various available data and information on the impact of the Manantali and Diama dams, and in areas where similar studies have been conducted. Other data used on this article come from the database of the Directorate of Management and Planning of Water Resources (DGPRE) and the Organization for the Development of the Senegal River (OMVS).

RESULTS AND DISCUSSION

In the downstream Senegal River, the consequences of the Manantali Dam, in concert with the Diama Dam, were quickly demonstrated by post-dam work (Michel *et al.*, 1993 ; Duvail 2001 ; Kane 1997).

The main advantages of the Manantali Dam

The Manantali Dam is a multi-use project that offers many enormous benefits such as flood prevention and surface water availability, power generation, navigation, aquaculture, ecological protection, and restocking on development, food self-sufficiency, water transfer and supply in neighboring countries, and irrigation.

The fight against floods

The river development factor is certainly an element of a rare versatility with its positive and negative aspects. In this respect, monitoring and management of the Senegal River waterbody is essential to reduce the negative effects of flooding (Republic of Senegal, 2000). The alluvial plain along the middle and lower reaches of Senegal contains many activities. Nevertheless, before the dam was put in place, it was most vulnerable to floods, which were very frequent. As part of flood risk management in the valley, alert ratings were established from Bakel to Saint Louis (the Bakel warning is 10 m). In addition to these warnings, the propagation time of Bakel flood wave in Saint Louis is also estimated. This monitoring system makes it possible to manage floods all along the Senegal River (OMVS, 2014). With the capping of natural floods, the Manantali dam reduces the impact of floods. Thus, it ensures the safety of people and their property in downstream areas. In general, floods in the Senegal River valley and delta have generally dissipated with the good filling of the Manantali Dam.

The availability of surface water

To characterize the Manantali dam impact on water availability, annual and monthly module at Bakel station is analyzed (Figure 2).

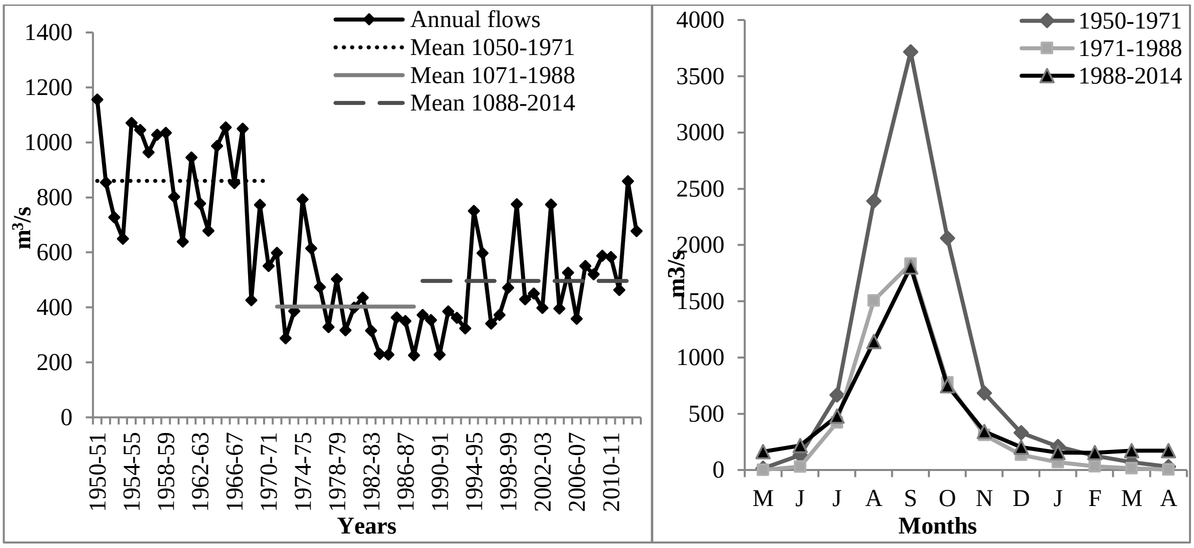

Figure 2: Evolution of annual and monthly modules at Bakel station

In past (SOE, 2003), the inter-annual hydrological situation of the Senegal River was irregular (variability of floods and low flows ...) and source of many handicaps in the valley (high flood damage, low water flow, variability cultivated areas after receding, food insufficiency of the populations of basin...). Following the years of drought (1970s and 1980s) during which flow of the Senegal River was not significant enough, the dam installation caused a permanent flow in river. These developments (dams and related developments) have resulted in profound changes in river's hydrological regime, as well as in the biophysical and socio-economic environment of the basin (Ficatier and Niasse, 2008). Today, following the construction of the Manantali hydraulic structure, the fresh water availability in sufficient quantities and guaranteed all year round has led to the improvement of lake filling conditions (Lake Guiers and the lake Rkiz), natural parks (Djoudj Park, Diawling Park), depressions and other wetlands, groundwater recharge, increased irrigation capacity, etc. (OMVS, 2002 ; Ndiaye, 2007).

Electricity generation

The full capacity production of the Manantali power station is to reach 540 GWh, on average over several years, transferred to the high-voltage lines of East and West systems. The expected average annual supply rate has been largely exceeded, with the three utilities receiving an average of about 740 GWh per year (+ 37%). Capacities are fully exploited. According to the OMVS High Commission, the electricity price is only 35 FCFA per kW, while the thermal costs in the Member States, between 100 and 200 FCFA KW, resulting in a huge difference because OMVS does not need to indebt states. The supply of reliable energy at an acceptable price is still a priority for the development of manufacturing and trade. The energy distribution among the beneficiaries is made according to the following distribution key : 52% for Mali, 15% for Mauritania and 33% for Senegal (Ndiaye, 2003). The objective is as much to improve the quality of national electricity grids as to make substantial savings in relation to the production of thermal energy (Boinet, 2011).

Manantali Energy Management Company (SOGEM) is an international entity in charge of Manantali's hydroelectric assets. Its contractual partner, Eskom Energy Manantali (EEM), has only three customers: Mali's Energy (EDM) of Mali, National Electricity Company of Senegal (SENELEC) and Mauritania's Electricity Company of Mauritania (SEMELEC). The three national electricity companies have energy situations that would have been much worse in the absence of the Manantali dam and the hydropower component of the project may appear as a "success story" (Dickmann *et al.*, 2009). This renewable energy project is of the paramount importance to region, especially in the face of soaring oil prices and the reduction of greenhouse gases that have further strengthened its soundness. In the perspective of future production deficits, the Manantali energy project proved to be more than relevant. In general, the overall relevance of energy component is quite acceptable and the Manantali plant will play an increasingly important role.

Navigation

Anxious to make the sub-regional area benefit from major mining potential, certain asset of the agricultural sector and immense possibilities for the exchange of goods, OMVS has set itself the task of giving new impetus to the Integrated Multimodal to Transport System (SITRAM). Navigation is the first part of integrated development project. Goal is to ensure the development of trade (between basin states and internationally), but also to open up Mali by giving access to the Atlantic Ocean (D'Armaille, 1992). Navigation component will also facilitate exploitation of the immense mineral wealth of the basin, the exchange of goods and services as well as the mobility of populations. SITRAM is expected to allow sustainable airworthiness on the Senegal River over 905 km between Ambidédi and Saint-Louis, after a consequent development of the river channel, the construction of river port of Ambidédi and sea-water port of Saint-Louis, the construction of a dozen ports of call. The implementation of SITRAM should boost river navigation and meet the expectations and concerns of economic actors at local, national and regional levels (OMVS, 2014). The completion will significantly improve navigation conditions on the river upstream of dam, with the expanded shipping channel, and a reduction in transportation costs.

Aquaculture

The 1460 m lenght and 66 m hight at the foundation leads to the formation of a huge reservoir of 11.3 billions m^3 for 500 km^2. This reservoir contains more nutritious and warmer water in surface layer for the development of fish (Niasse, 2007). Today, the reservoir of Manantali shelters a sufficient quantity of fish. With catches around 1300 tonnes per annum for an estimated potential of 3000 tonnes / year (Breuil, 1996) and 17000 tonnes / year (COYNE *et al.*, 1996), Manantali is the third fishing zone for Mali (with a production of 27 kg of fish per ha), totally landlocked country (Laë *et al.*, 2004). Beyond the Manantali reservoir, the raising of low water levels and the maintenance of a larger volume of water in minor river bed, in some secondary branches and in lower parts (Guiers Lake and R'KizLake) have allowed the development of more varied species and the survival of larger fish (Ndiaye, 2007). The fish fauna thus seems to have increased since the dams came into operation, resulting in increased catches by fishermen (AGRER *et al.*, 2003) and fishing communities from all areas.

Ecological protection

The dam has filled wetlands, lakes or ponds such as Djoudj, Guiers Lake (Senegal) and Diawling (Mauritania). The economic value and ecological functions of flood plains are now better appreciated. The fresh water availability in sufficient quantity throughout year not only leads to the development of activities (agriculture, domestic needs, agribusiness) but also the recharge of water table and wetlands (OMVS, 2002). This has resulted to the reappearance of wildlife and the regeneration of vegetation cover. In terms of water management, the reservoir will regulate the water storage and ensure the population needs. Dam acts as a guardian for the protection and improvement of environment and ecologically sustainable development of the Senegal River Basin (Le Goff *et al.*, 2005). Thus, it can enable the OMVS to ensure as much as possible the ecological balance in the basin, make the economies of three Member

States less vulnerable to climatic conditions and external factors and accelerate their economic development by the intensive promotion of cooperation (Meublat, 2001). The dam would therefore be conducive to improving environmental conditions (Skinner *et al.*, 2009).

Repopulation focused on development

Overall, the evaluations showed positive results in the short term. Displaced populations have benefited from projects as their access to drinking water, health and education has improved significantly (Skinner *et al.*, 2009), as has dam from Kandji in Nigeria cited as an excellent example of successful resettlement (World Energy Council: WEC, 2003). Some 10,000 inhabitants of 46 villages and hamlets located on the current site of the dam and reservoir of Manantali had to be relocated. This has led to the construction of 30 villages, 250 km of tracks to major traffic arteries, 4500 housing, 148 boreholes and social infrastructure (schools, clinics and warehouses). Similarly, transitional food aid and compensation for these populations have been put in place. A total of 120,000,000 CFA francs were disbursed between 1986 and 1987 (Dickmann *et al.*, 2009).

The resettlement of the Manantali Dam populations in Mali has been described as a technical feat (Ficatier and Niasse, 2008). Positive aspects of resettlement process include: the increased compensation for displaced households; the construction of quality housing respecting local architecture; the creation of quality social infrastructures (schools, modern water points, health centers); the creation of roads and roads to open up the reception areas and make the inter-village exchanges more fluid; the employment of some members of populations resettled in the dam sites, etc.

Irrigation and food self-sufficiency

Irrigation component is perhaps the most ambitious of the three components of the integrated development project. Its goal is to create an irrigable potential of 375,000 ha (mainly for rice monoculture), including 240,000 ha for Senegal, 120,000 ha for Mauritania and 9,000 ha for irrigated potential ha for Mali (Boinet, 2011). The construction of the Manantali Dam is one of the responses of the governments of Senegal, Mali and Mauritania to address the major challenges of water management to meet national irrigation needs. It thus allows the regulation of natural flows, variable according to seasons and years, and provides an important irrigation potential. It is thanks to the construction of this dam that it is possible to envisage that irrigated agriculture can lead to food self-sufficiency (Skinner et al., 2009), and more generally, to optimize development in three countries concerned.

There is a shift towards diversification and an increase in agricultural production linked to the setting up of dams on the regional scale of the valley (Séne, 2009). From 1987 (after dams). There is an expansion of diversification with three groups of agricultural products (SAED, 2001): rice cultivation, agro-industrial sectors (tomato, maize, sorghum, cotton and groundnuts), horticultural sectors (onion, sweet potato, okra, etc.

An increase in cereal self-sufficiency through irrigated agriculture in the three countries requires efficient production at the macroeconomic level of rice, maize, wheat, sorghum, tomatoes, cane sugar and other crops (vegetables and fruits for example). This involves exploiting new irrigated land in Senegal, Mauritania and, in part, Mali. In the river valley, irrigation concerns, on the one hand, 9800 ha of industrial crops (sugar cane, tomatoes), and on the other hand, 125 000 ha of exploited perimeters with a very low rate of intensification (55% instead of the theoretical 200% of a double generalized crop) and mostly sown in rice (Badier *et al.*, 2003). In 2006, valued irrigated land represented 54,700 hectares in Senegal (alternative scenario: 56,900 hectares), 20,350 hectares in Mauritania (alternative scenario: 28,700 hectares) and 3,000 hectares in Mali (Dickmann *et al.*, 2009).

In addition to the agricultural production recorded during rainy season, dam allows the development of off-season crops due to the water availability throughout year and flood recession crops thanks to the floods generated by this dam. At local level, these forms of culture play an important role in improving the living conditions of populations by ensuring their production throughout the year.

The transfer and supply of drinking water in neighboring countries

Problems with drinking water supply and sanitation are a major concern of the OMVS authorities. Faced with the network of drinking water supply and sanitation infrastructure below the needs of population, significant investments are made by Member States and populations. The commissioning of the Manantali dam and the consequent availability of water ensured the supply of drinking water to the capitals of the riparian countries (Dakar and Nouakchott), which benefited greatly from the OMVS program (Julien, 2006). Dam promotes economic development through the provision of drinking water (AEP) and the preservation of the environment. Indeed, the supply of drinking water and sanitation is an absolute necessity that is the basis of any other socio-economic activity. Some drinking water supplies have already been made or secured (eg Dakar from theGuiers Lake and Nouakchott from the Diama reservoir). These various donor projects have been or are only possible with the availability at this resource.

Throughout the valley, the contribution of dam construction is important for the transfer and supply of drinking water in neighboring countries. Dams therefore provide drinking water for several cities, including two capital cities (Le Goff *et al.,* 2005). The city of Dakar has long taken more than 80% of its water needs from drilling in quaternary sands near the coast. However, these aquifers are currently overexploited (with increasing risks of salinization) and contaminated, particularly by nitrates, because of insufficient control of discharges in peri-urban areas (Faye *et al.,* 1998). To remedy this, water from Lake Guiers was put to use through a 250 km long pipeline to cover a daily consumption that is sharply rising due to population growth (Sow, 1996).

The main disadvantages of the Manantali dam

Although the utility of dams is not questioned (Barbier *et al.,* 2009) in intertropical countries whose rivers, while having honorable annual discharges, are subject to wide seasonal and interannual variations, their erection implies a set of irreversible changes (Bethemont, 2009). Despite the importance of benefits, the Manantali Dam has its own drawbacks, the main ones of which are examined.

Negative impacts on the environment

The impoundment of the Manantali and Diama dams, as well as the resulting developments (embankments, hydro-agricultural developments, etc.) have had negative impacts on the functioning of certain ecosystems in the basin. These impacts are numerous and quite diversified and boil down to changes in water quantity and quality, groundwater pollution, drainage and recurrent diseases. In addition, soil erosion has increased, causing bank collapse and landslides.

By modifying water quality and altering the hydrological regime, water control interventions (dams and expansion of irrigated land) have led to the proliferation of aquatic invasive plants such as Typha, Salvinia, etc. (SOE, 2005; AGRER *et al.,*2003). The setting up of hydro-agricultural works (mainly the Diama and Manantali dams) during the 1980s, by modifying the physicochemical characteristics of the river's water, resulted in the disruption of biodiversity in the 1980s basin level and the fauna and flora deterioration (Séne, 2009).

The Typha, by its strong development, causes the obstruction of canals and thus contributes to the siltation of the rivers; which risks reducing the irrigable potential. In addition to having a negative impact on fishing activity, Typha offers breeding grounds favorable to the development of anopheles (responsible for malaria) and also mollusc (intermediate host of the parasite responsible for bilharzia). The stagnation of surface waters and the proliferation of harmful aquatic species such as Salvinia molesta and water hyacinth on these bodies of water pose threats to Djoudj and Diawling parks by compromising the reproduction of migratory birds.

Other problems emerge from the growing competition between the farmland and use of firewood. Increasing erosion is occurring as lowland and riverbanks are deforested. The promotion of modern agricultural activities comes at the cost of massive use of chemicals that lead to soil acidification. The water quality deterioration takes the form of chemical pollution (pesticides, herbicides, insecticides, etc. resulting from human activities), microbiological pollution (domestic and industrial discharges into the waters of basin), suspended solids, solid wastes (from various human activities).

Studies also show that hydro-agricultural developments have a negative impact on the health of populations (Verhoef 1996, Mulato 1993). The setting up of the Manantali dam and the development of irrigated agricultural activities are accompanied by an upsurge in waterborne diseases. The main water-related diseases in the Senegal Valley are malaria, schistosomiasis and diarrheal diseases. With the advent of dams, the highest prevalence of malaria would be due to the fact that not only the anopheles that transmit this disease

(Anopheles gambiae) has become the best vector, but also another subspecies of anopheles (Anopheles funestis), one of the most important transmitters, is strongly present in the area since 1999-2000 (OMVS and FEM, 2007).

Invasive species also affect the ecological stability of the Senegal River Basin as well as productive activities (agriculture, fishing, livestock) and the health of populations with the high prevalence of waterborne diseases.

The effect on local culture and traditional economy

In the Senegal River Valley, hydro-agricultural development policy has favored transition from subsistence farming based on rainfed crops and recession combining livestock and fisheries with irrigated agriculture whose development induces marginalization at other activities (livestock and forestry in particular). Indeed, by regulating Senegal's river regime, the river's waters management by OMVS poses a threat to the traditional economy of populations. This first break from customary tradition was merely a prodrome to changes that were otherwise traumatic for local populations (Bethemont, 2009).

One of important issues is how the Manantali Dam management has affected the flooding conditions of alluvial plain that has shrunk due to the capping of river floods at Bakel and therefore the practice of recession culture. On the basis of a period of observations and empirical studies over ten years, Rasmussen *et al.* (1999) identify two factors to explain the deterioration of the conditions of the practice of flood recession culture from the 1970s. (a) the drought of the 1970s and 1980s; (b) the Manantali Dam. Various studies (Rasmussen *et al.*, 1999 ; IRD, 2001) indicate the negative impact of Manantali management on recession agriculture in middle and lower valley, by reducing the total volume of water that should have been available to flood floodplain under normal conditions.

Added to this is the drop in yields. For example, some of farmers who use recession lands think that yields have become lower. Some people think that this drop in yields is due to the fact that silt transported by the river has become less important. Following this logic, much of solid load that used to transported by theriver is now deposited in the Manantali reservoir. Studies have shown that there is a decrease in the amount of silt carried by the Senegal River into the valley and delta because there is an accumulation of silt in the Manantali reservoir.

In relation to fishing, the hydrological failure linked to the poor flooding of the floodplain and the cessation of runoff in certain areas weakens the traditional fishing system and makes fish capture uncertain (Taïbi *et al.*, 2007). The fish fauna of lower delta has also been strongly affected, which has resulted in reduced catches by fishermen (mainly estuarine species) accompanied by a change in the nature of species (Diawara, 1997). The proliferation of water hyacinths and other aquatic plants has also disrupted many fish species (Magrin and Seck, 2009). Transition from a brackish medium of variable salinity to a permanent freshwater environment also has negative effects on fauna and flora, leading to a break in biological balance and aquatic ecosystem. Alteration of ecosystems has resulted in the disappearance of most activities, including the collection of Sporobolus for mats, the harvest of Nymphea lotus or pods of Acacia nilotica used for skin tanning (Duvail, 2001).

Sedimentation

Sedimentation is one of major problems that have been identified and associated with dams. In fact, excessive sedimentation can block valves, which can cause dam failure under certain conditions (Zhang, 2014). Estimates have been made and revealed that the Senegal River will add low levels of silt in the reservoir on average per year. SOGEM officials confirm that the current rate of siltation of the Manantali reservoir is negligible, which is consistent with the extreme clarity of the reservoir water (Ficatier and Niasse, 2008). However, over an extended period of time, silt will continue to accumulate behind the walls of dam, and as a result, may contribute to the blockage of turbines, gateway. In addition, the lack of silt downstream would contribute to other problems. If the progressive accumulation of silt upstream induces eutrophication of reservoir and therefore a degradation of water quality, downstream, on the other hand, water is no longer naturally enriched by these silts and farmers are obliged to buy fertilizers and other pesticides to fertilize their land.

An impact study (Gannett Fleming *et al.*, 1980) estimated 530 000 tonnes of annual suspended solids reservoir content, with 50% of particles less than 0.002 millimeters in diameter. In addition, study predicted that the Manantali Reservoir, once turbined, would degrade water quality downstream for about 7 km, causing losses in fish productivity and posing a threat to human health. The current situation of reservoir (examinations made for a large part of the year) is characterized by a reduction in the vertical mixing of water (Ficatier and Niasse, 2008). Dissolved oxygen level decreases with depth and becomes virtually zero at the bottom of reservoir in April, while at surface it is around 6 mg / liter.

Other disadvantages of dam

Other negative impacts of developments are noted. The OMVS indicates the reduction of habitats for terrestrial fauna and nesting islands of certain species, the reduction of grazing spaces, the undermining of the banks in the upper basin where terrain is much more rugged, the degradation of cultivated land, modification of the hydrodynamic characters of estuary with the reduction of the phenomenon of "hunting effect"(OMVS, 2002). The decline in fishery resource has had serious consequences for ornithological fauna with a sharp reduction in the number of migratory birds in national parks (Taïbi *et al.*, 2007). It is also important to note the problem of communities whose lands are drowned in structures and large agro-industrial perimeters, and which have little or no compensation (Forget, 2009). In addition, the evictions of relocated developments and sometimes even endowed with some arable plots, are at the expense of other village communities holding customary rights (Brondeau, 2009), which inevitably implies strong tensions between old and new occupants. The implementation of the dam and the expansion of irrigated perimeters have disrupted customary osmosis between Senegal and Mauritania (Seck *et al.*, 2009), shared the same ethnic groups between two states, clouded border and often led to various disputes.

CONCLUSION

The surface waters of Senegal River are a primary resource for riparian countries. This aquatic resource has always attracted a lot of attention and men have been constantly looking for ways to control it through improvements. The construction of the Manantali dam is undoubtedly one of the greatest technological achievements of OMVS. However, as with any technological development, there are advantages and disadvantages to the physical and human environment of countries concerned. On the one hand, the benefits of the Manantali Dam are flood control, electricity generation, surface water availability, navigation, aquaculture, ecological protection, development-oriented resettlement of people, water transfer and supply, and irrigation. On the other hand, the dam disadvantages are environment impact, effect on local culture and economic activities, sedimentationn, etc. From the point of view of environmental impacts, the Manantali dam shows proof that it has more advantages than disadvantages. Thus, carefully weighing the pros and cons, we can say that the Manantali dam is an ecologically feasible achievement, despite the disadvantages.

Despite the existence of a significant distortion between the persistence of policies generating major development and the unanimous affirmation of ecological principles that condemn them, some major problems in riparian states plead in favor of the Manantali dam: high population growth; very marked reduction in rainfall and mean river flows; chronic under-nutrition and risk of famine; problems of access to drinking water; rapid progression of desertification. It is precisely in response to these problems and their impacts that the major development program for the Senegal River Basin has been designed. The Manantali dam, the Diama dam and the other related works (embankments, irrigated perimeters) have together changed the hydrological regime and the quality of river's water, permanently affecting the physical environment and socio-economic activities in area.

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