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Valorization of water resources in Senegal for economic, social and sustainable development

Cheikh Faye[1*] and Sidy Dieye[2]

[1]Department of Geography, U.F.R. Science and Technology, UASZ, Laboratory of Geomatics and Environment, Ziguinchor, Senegal.
[2]Department of Geography, Faculty of Letters and Human Sciences, UCAD, Dakar, Senegal.

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Senegal has a rich and diversified hydrological potential. The bulk of surface water reserves are located in the basin's rivers Senegal and Gambia, whose waters originate from the Fouta Djallon massif. Alongside these large rivers, there are smaller rivers (Casamance and Kayanga) and small watersheds with temporary flows. Groundwater resources are also an important part of Senegal's water heritage. Unfortunately, water resources are now threatened by anthropogenic actions of diverse origins (extensive agriculture, mining, illegal fishing, bushfires, domestic use along watercourses, etc.) and the adverse effects of climate change. Also, inadequate water management policies increase the water scarcity and are often not conducive to sustainable water resources management. The impact of water shortages is felt on all socio-economic activities (particularly in the agriculture sector, which is the main user of water in the country), but also in the supply sector water. Thus, for several decades, the Senegalese government has pursued a water control policy aimed at providing water users in sufficient quantities and of appropriate quality according to their usage. In order to correct the heavy trends in water resources sector and to satisfy various demands, Senegal has for some years been committed to a national policy for integrated water resources management (IWRM) and an action plan focusing on taking into account cooperation on shared watersheds.

Key words: potential, water resources, climate change, integrated management, sustainable development.

INTRODUCTION

Freshwater is a vital resource for life. It is essential for the survival of natural ecosystems and for human activities. Until the mid-twentieth century, water was considered inexhaustible wealth that each user could appropriate, own and exploit according to their needs (Honegger and Tabarly, 2011). A strategic resource for man and a former

*Corresponding author. E-mail:cheikh.faye@univ-zig.sn.

subject of conflict, water remains difficult to manage for the common good (Petit, 2015). Men, to satisfy their vital needs, use water for their different economic activities. This situation has led to a sectoral and competitive use of the resource, a management that is at the root of many problems such as conflict, deterioration of water quality and environmental problems, unequal distribution and the decline in water resources (Batcho, 2008).

Water is considered a factor of national integration (Roman and Buchs, 2016). Since early civilizations, humans have relied on water management infrastructure. Dams, river control structures and water supply canals were important objects of state activity in ancient Egypt as well as in China, Mesopotamia and, more recently, in the south. west of the United States. These objects tend to be rooted in the principles of supply management: providing more water to meet demand or anticipate growth in demand. However, alongside attempts to provide more water, it has coexisted with the idea that the growing demand for water must ultimately be limited (Crow-Miller et al., 2017).

The combined effects of population growth, rising incomes and urban expansion will lead to an exponential increase in water demand, while the supply of resource will become more erratic and uncertain (Camara and Bangoura, 2017). Without immediate action, water will become like the rice self-sufficiency project. Many projects, particularly in the field of water management and rice production are in sight or about to be implemented to reinforce the dynamics of agricultural development of the bank left of the Senegal River (Senegal River valley) and in the Anambé Basin. Unlike rice cultivation, which is still traditionally practiced in lowlands (rainfed rice), irrigated rice cultivation is less of a problem than it is because it is done in managed areas with more or less control irrigation (FAO, 2008). In Lower Casamance, the technique of anti-salt dykes for the practice of rice cultivation encounters significant problems following the decrease in rainfall which ensures less and less soil leaching.

Without immediate action, water will become a scarce resource in areas where it is abundant today. The impact of water scarcity will be felt on all socio-economic activities, including agriculture, health, energy and income (Olivier, 2016). In the face of these multiple problems that do not guarantee the sustainability of water resources and environment, water resources are increasingly limited and vulnerable (Sinarinzi, 2010). They are limited by a variety of factors such as climatic conditions, unequal distribution of rainfall, the shared nature of the resource, high population pressure, and poor water control. In order to cope with them and to establish a rational management of water resources, the assessment of water availability is a fundamental step.

In Africa, water is the leading vector of childhood diseases; more than 70 to 80% of diseases on the continent are related to poor water quality. Also, the resource is unequally distributed geographically. For the World Bank, the scarcity of water exacerbated by climate change could lead some regions of the world to experience a GDP decline of around 6%, cause migration and trigger conflicts (Camara and Bangoura, 2017). In addition, there are imperfections in water management, focusing on the development of new sources rather than better managing existing ones, and sectoral approaches to water management that lead to the development and uncoordinated management of the resource (CAP-Net, 2005).

In Senegal, the potential for water resources (surface and groundwater) is significant and the availability of renewable water is currently estimated at around 4747m^3 / inhabitant/year (CONGAD, 2009). However, the issue of water has become a national concern given the range of issues facing the sector: scarcity, randomness of rainfall, vulnerability of water resources, disparity in their spatial distribution, current or emerging conflicts, their exploitation and overexploitation, degradation of their quality, inequity in access to water resources between zones, social groups, different socio-economic activities, etc. (Ministry of Hydraulics / DGPRE, 2007). The water crisis can be explained both by the absolute lack of physical availability, poverty and inadequate water management policies. This water scarcity is thus considered as a crisis of the adjustment between produced resources and end-uses (Buchs, 2014) and requires the establishment of policies capable of solving water problems (Crow-Miller, 2015).

Faced with the urgency of moving to new forms of water management, Senegal has been keen to comply with the recommendations of World Summits (Rio-Dublin in January 1992 and Johannesburg in August 2002). The water resources management and monitoring throughout Senegal are supported by the Directorate of Management and Planning of Water Resources (DGPRE). In the process of water management nationwide, the state plays a privileged role. It is he who puts in place the appropriate legislative tools favoring the decentralization of the management of resources, decrees the watershed as a priority territory for water management and allows the development of local consultation spaces (Francis, 2016).

According to Linton (2014), water should be viewed in a situated way as resulting from the social and ecological interactions involved in a "hydrosocial cycle". Water management tends to be reduced to a biological and hydrological perspective or to that of politics and public action (Strang, 2004) whereas it makes sense in the historical perspective of the interactions between

environment and society (Aspe and Jacque, 2012). According to this idea and in the context of the management of water resources for achieving the Sustainable Development Goals (SDGs), this article examined the development of water resources in Senegal with a view to economic and social and sustainable development.

MATERIALS AND METHODS

Data and information from the institutions involved in water management were used. Among the institutions and ministries concerned, there is the Ministry of Hydraulics and Sanitation, the Ministry of Environment and Sustainable Development, the Directorate of Management and Planning of Water Resources, the National Agency of Civil Aviation and Meteorology, the National Agency for Statistics and Demography, the Organization for the Development of the Senegal River, the National Water Company of Senegal ... Some semi-structured interviews were conducted with key players in the institutions to complete the analysis of water management. The data comes mainly from the documentary/policy reviews of the selected institutions, in order to better understand the subject. Institutional documents, progress reports and institutional water resource management libraries have been used to develop a deeper perspective on water policy. The analysis focused on themes analyzing the links between water resources management and sustainable development.

RESULTS AND DISCUSSION

Context of water resources in Senegal

The Republic of Senegal, located on the extreme western tip of the African continent, covers an area of 196722 km². Its population is 13 508 715 inhabitants (ANSD, 2013). The coastal country with 700 km of Atlantic coastline, Senegal is located between 12.5° and 16.5° north latitude and 12° and 17° west longitude. Given the variations in rainfall in space and time, in Senegal, from south to north, there are three climatic domains, namely the southern Sudanian, northern Sudanian and Sahelian domains, each domain having two variants (coastal and coastal) a continental) (Faye et al., 2017).

Located in the tropical zone, Senegal has a Sudano-Sahelian climate with an annual rainfall ranging between about 1250 mm in the South to just over 200 mm in the North. This climate is marked by an alternation between a rainy season and a dry season. The rainy season, which is the monsoon period, extends roughly from June to October with a peak in August-September. The rain varies degressively depending on the latitude. The dry season that lasts from November to June is marked by the presence of a hot and dry wind: harmattan.

Water is needed to meet consumption needs, including agricultural, domestic and industrial, and non-consumer needs that include use in waterways (navigation, fishing, salinity control and dilution of pollution). Ecological protection and preservation of wetlands. For good planning, development and use of water resources, a proper assessment of available water resources is essential but difficult (Nadira and Shixiang, 2018). In Senegal, water really becomes a scarce resource during the dry months of the year that often correspond with the maximum water demand.

The potential of Senegal's water resources (surface and groundwater) is important. Three rivers originating in Guinea (Senegal, Gambia and Kayanga rivers) irrigate a large part of the country. Senegal has a rich and diversified hydrological potential. Most of the surface water reserves are located in the basins of the Senegal and Gambia rivers whose waters come from the Fouta Djallon Massif in the Republic of Guinea (Sané, 2015). Alongside these two large rivers, there are smaller rivers characterized by intermittent flows. These are Casamance, Kayanga with its main tributary Anambé, Sine, Saloum and coastal creeks (Figure 1). A number of listed lakes and ponds complete this hydrographic network; the most important being: the Guiers Lake, the bolongs of the estuaries and the ponds of the Niayes region of the northern coast and Ferlo.

Groundwater has always been an essential component of Senegal's water supply, but even more so since the beginning of the drought. The country has four four (04) major aquifer systems corresponding to the main geological formations: the superficial aquifer system (reserves estimated at 50-75 km²); the intermediate aquifer system (reserves estimated at 100 km²); the deep aquifer system (estimated reserves between 300 and 500 km²); the aquifer system of the basement (weak reserves).

The total renewable water resources (surface water, groundwater, inland and external waters) are estimated at 38.97 km3 / year in 2014 (FAO, 2016). The surface renewable water resources are estimated at 36.97 km3 / year and the internal renewable water resources in the order of 25.8 km3 / year, which is an index of dependence of 33.8%. Unfortunately, Senegal's water resources today are threatened by the extent of drought and climate change.

The total volume of renewable groundwater available is estimated at 3.5 km^3 / year. This groundwater is the main source of reliable and safe drinking water supply in rural areas and in many cities, for irrigation of thousands of hectares of arable land and for livestock watering. Many mines and industries also depend on groundwater for their supplies. In 2000, withdrawals from water resources amounted to 1,591 million m3, of which 1,435 million for agriculture (93%), 98 million for communities (4%) and 58 million for industry (3%) (FAO, 2016). The irrigation

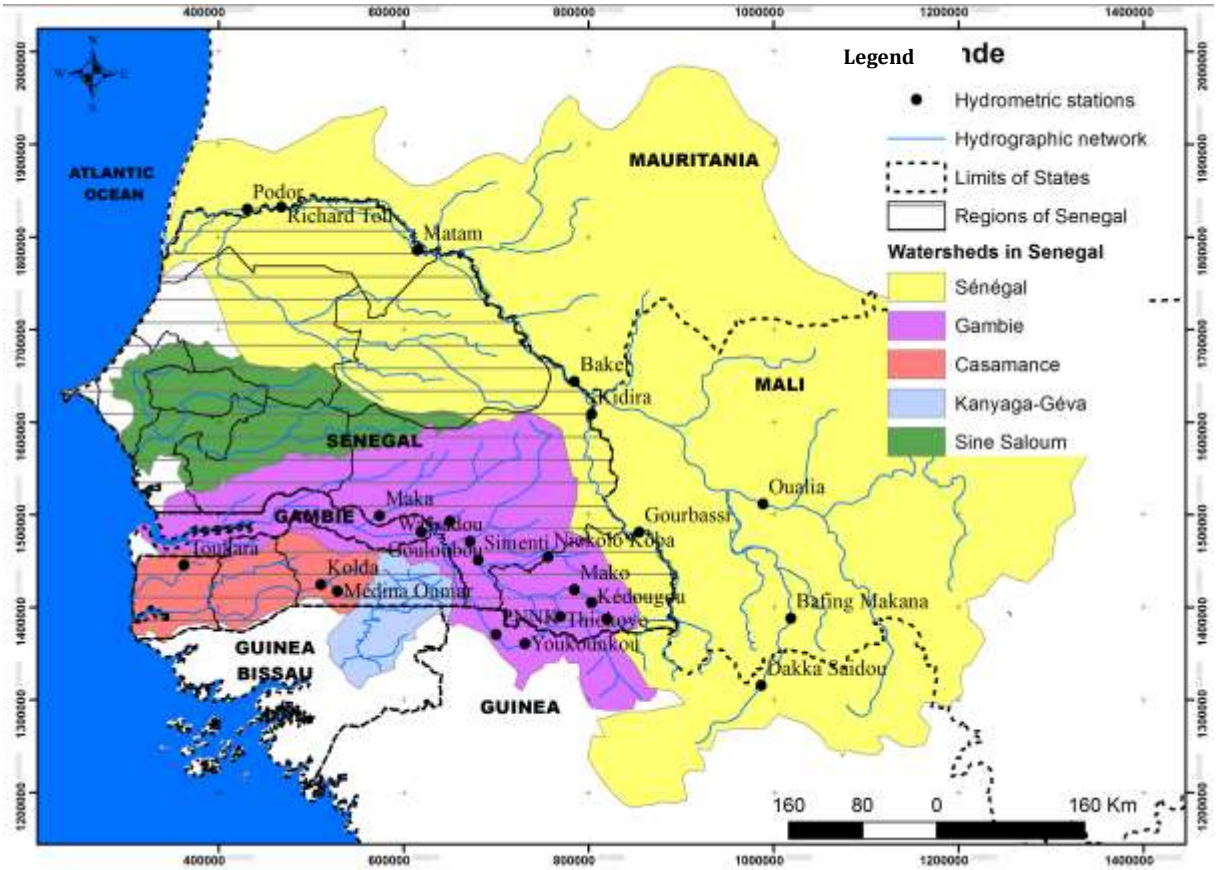

Figure 1. Watersheds draining the Senegalese territory.
Source: DGPRE.

potential varies, according to different estimates, from 160 000 ha to more than 640 000 ha. In 2014, total removals are estimated at 2.22 km^3 / year in Senegal. Given the considerable potential of water reserves in the country, the exploitation index is relatively low (5.75%).

In Senegal, social development leads to an increasing demand for water. Water plays a central role in most national planning initiatives, such as agricultural development, energy security, tourism and recreation, mining, industry and municipal water supply (Mwendera and Atyosi, 2018). Demographic and urban growth is putting a lot of pressure on available water resources, often limited in dry saoson. According to FAO (2016), per capita renewable freshwater resources (in m^3) are steadily decreasing. They thus went from 11612 m^3 in Senegal in 1958-62 to only 2576 m^3 in 2013-2017. These results show the evolution of the country towards a situation first of water stress (below 1700 m^3/ inhabitant / year) and then of water shortage (below 1000 m^3 / inhabitant / year). Senegal is also not far from a water vulnerability situation (below 2500 m^3 / inhabitant / year). This finding may be of concern because water consumption is increasing exponentially in relation to population growth in the riparian countries of the Senegal River Basin. The logical outcome of such a situation could be competition for the resource (Boinet, 2011). Senegal could seek to reduce its own uncertainty about the water resource by making arrangements on the rivers that cross its territory, for a better water availability of the users, without making use of the force to safeguard the interests of other riparian countries on this issue of national security (Descroix and Lasserre, 2003). Although the country has rivers of great water (more than 26 billion m3 per year), large areas, previously crossed by rivers, have become almost completely without surface water as a result of drying rivers (Sané, 2015).

Water resources management in Senegal

The Dublin meeting in 1992 identified four universal principles governing sustainable water management

(GWP, 2005):

1) Freshwater is a finite and vulnerable resource, essential to sustaining life, development and theenvironment;
2) Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels;
3) Women play a central role in the water supply, management and safeguarding;

Water has an economic value in all its competing uses and should be recognized both as economic and social good.

For the Sustainable Development Goals (SDOs), SDG 6 on sustainable water management is subdivided into several targets (Water Solidarity Program, 2016): (i) Universal access to drinking water; (ii) Sanitation and hygiene for all; (iii) Improvement of water quality; (iv) Rational use of water; (v) Integrated water resources management; (vi) Protection and restoration of ecosystems. To achieve this goal (SDG 6) by 2030 in Senegal, a national monitoring framework has been set up by the Coordination and Monitoring Unit for Water and Sanitation Programs (Ndour, 2016). Like most African states, Senegal's challenges in water sector stem from the need to provide safe drinking water to achieve SDG 6, by maintaining cooperation in basin management cross-border hydrographic surveys (OMVS, OMVG), continuing to develop hydropower (Manantali dam), by satisfying an increasing demand for water for different uses (industrial, mining, agriculture, navigation, recreational activities), by preventing the pollution of water, by managing water in the context of climate change.

In Senegal, the water resources management is based on a set of regulatory texts, conventions and hydraulic schemes (such as the major hydraulic schemes of the Senegal River Valley). To ensure sustainable and shared management of water potential at the national and sub-regional levels, the country has had in recent years a national policy of integrated water resources management and in the elaboration of an action plan favouring the taking into account of cooperation in shared watersheds (Ministry of Hydraulics / DGPRE, 2007).

Use of water resources in the agricultural sector

In Senegal, agriculture is a sector at the heart of its economy, and as such, it is a priority for the political authorities because it occupies 2/3 of the active population. The agriculture sector is the main user of water in the country. With the intensification of irrigated agriculture, water requirements have increased. In 2002, water withdrawals amounted to 2221 million m^3, of which 2065 million for agriculture (93%) (FAO, 2016). Table 1 shows the distribution of water withdrawals from the agricultural sector in Senegal in different areas (DGPRE, 2016).

As part of the rice self-sufficiency project, many projects, particularly in the field of water management and rice production are in sight or at the beginning of implementation to reinforce the dynamics of agricultural development of the bank. left of the Senegal River (Senegal River valley) and in the Anambé basin. Unlike rice cultivation, which is still traditionally practiced in lowlands (rainfed rice), irrigated rice cultivation is less of a problem than it is because it is done in managed areas with more or less control irrigation (FAO, 2008). In Lower Casamance, the technique of anti-salt dykes for the practice of rice cultivation encounters significant problems following the decrease in rainfall which ensures less and less soil leaching.

At the level of the Senegal River valley, the irrigable potential is 240 000 ha and the developed area is 119 640 ha. To achieve self-sufficiency in rice, the pace of implementation of hydro-agricultural development is increased. In this context, 23,691 ha of new development and 18,830 ha of rehabilitation are underway in the valley (Diouf, 2017). The Anambé basin has also been the subject of hydro-agricultural development since 1978 with the construction of the Niandouba (1997) and Confluent (1984) dams. The revival of the agricultural and particularly rice rhythm in the irrigated perimeter of the Anambé basin has always been a major concern of the State of Senegal to better cope with the food and socio-economic crisis. Over the winter season 2016, over 3700 ha were planted in the landscaped perimeter and concomitantly several valleys are developed in the area, such as the valley of Témento, Saré Wogna ... (Mballo, 2017). In the Dakar area, the development of hill dams and the reuse of treated wastewater by the Cambérène station should help to strengthen the water supply for market gardeners.

Despite its strong potential, Senegalese agriculture remains dependent on rainfall and recent studies have shown that rainfall has decreased overall by 35% in quantity with a decrease in the duration of the rainy season and a decrease in the frequency of days of rain between the period 1950-1965 and the period 1970-1995 (Diagne, 2000). Nowadays, there is an accelerated and continuous degradation of the production potential with the result that yields fall. If current warming trends continue, the performance of Senegal's agriculture would be more affected, as rising temperatures combined with lower rainfall would exacerbate the plant moisture deficit that would affect agricultural yields and production (MEPN, 2006). To remedy this, the State of Senegal has

Table 1. Water withdrawals from the agricultural sector in Senegal.

Designation	Quantity of water withdrawn (m^3)	Proportion %
River Valley Area (North)	1 345 050 000	73.27
Delta River Area (North)	194 441 107	10.59
Niayes areas	228 268 000	12.43
Casamance area	50 000 000	2.72
Other	17 942 701	0.98
Total	1 835 701 808	100

Source: DGPRE, 2016.

recently given priority to small-scale irrigation, which should be developed and extended on the basis of economic profitability criteria, while large and medium-scale irrigated schemes will have to be rehabilitated and consolidated.

Hydropower in Senegal

To diversify its energy resources, Senegal is giving increasing importance to hydropower. Despite the high potential, the implementation of hydroelectric dams is hampered by the financial means required to achieve them (hydroelectric works are very expensive). Hydroelectric production remains not only low compared to potential (in 2012, the hydroelectric production mainly from the Manantali dam amounted to 276 GWh for a hydroelectric potential of the Senegal River estimated at more than 4000 GWh / year) but shared (Senegal has production sharing agreements with Mali and Mauritania). Beyond the Manantali dam, other hydroelectric dams like Felou, with a capacity of 60 MW, allowing residents of the riparian states of the Senegal River to benefit from a stable, reliable and cheap electricity source.

Due to the increase in energy demand by 60% by 2050, all the dams that will be implemented by the Senegal River Development Organization (OMVS) and the Gambia River Development Organization (OMVG) will help to exploit the potential of 2 000 MW suffering. Already in 2015, with the commissioning of the Kaleta hydroelectric dam in Guinea, it is 20% of the energy produced that Senegal will receive and 48% of the energy of Samba Ngalou whose completion is expected in 2018. Only this potential is still under-exploited (only 17% being exploited).

This clean, sustainable and competitive energy is an important potential both in Senegal and in other African countries. However, hydropower supplies only 11% of the country's energy needs and most of it comes from the Manantali dam which sells 33% of the energy it produces in Senegal, or 66 MW, while the Félou dam offers 25% of its energy to the country.

Guinea, as a Party to the United Nations Framework Convention on Climate Change (UNFCCC), has made a commitment at COP21 to increase the number of renewable energy sources, including hydropower. However, given the deterioration of the main watersheds (The basins of Senegal and Gambia) due to anthropogenic and climatic factors, if appropriate measures are not taken, this hydropower production may be compromised.

Water use in the diet

The coverage or overall rate of access to drinking water, according to the 8th annual joint sectoral review of 2014 of PEPAM, is estimated at 90.4% at the end of December 2013. This high proportion of access to drinking water hides, however, disparities by place of residence. According to the said review, drinking water coverage is 98% in urban areas compared to 84.1% in rural areas, a difference of more than 14% between the two environments in terms of access to drinking water (ANSD, 2015). Moreover, an analysis of the results of the census of population (2013) according to the source of supply reveals that in 73.8% of cases Senegalese households use the tap to obtain water (16.3% of which is at the public tap). In urban areas, this proportion is 88% (of which 9.3% is on the public tap) compared with 57.1% in rural areas (of which 24% is on the public tap). This record remains mixed, however, because of important regional disparities; while in rural areas the level of equipment has increased considerably, quantitative and qualitative efforts still need to be made.

In urban areas, most of the water produced is distributed in Dakar. However, water supply in urban centers has deteriorated significantly due to (i) the expansion of cities, (ii) insufficient equipment, (iii) low productivity and (iv) shortcomings in the internal management of the company in charge (Camara and Bangoura, 2017). Beyond the Keur Momar Sarr and Ngnith treatment plants, which draw water from the Guiers Lake, produce around 170 000 m^3/d and supply

the drinking water supply system in the Dakar region at a rate of 45%, groundwater (pump wells/boreholes) are the main sources of drinking water supply in urban and rural areas.

For almost a decade, Dakar's drinking water supply has been characterized by strong demand, which is due to population growth, the establishment of new economic development hubs (Diamniadio, Lake Rose, Diass) and tourist centers in the Small Coast. The current production capacity of 421,000 m^3 / d is very insufficient compared to water needs estimated at around 659,000 m^3 / d in 2025 in the Dakar-Thiès-Mbour / Small Coast triangle zone. In 2013, for the entire urban perimeter conceded to SONES and operated by SDE, the peak consumption reached 328,000 m3 / d for an installed capacity of 331,000 m^3 / d, which reflects an important tension between supply and demand, frequently affecting the continuity of service in several districts of Dakar and its suburbs. This voltage exposes the power system to major dysfunctions in case of disturbances in production.

In Senegal, the total number of days in the year during which the drinking water service was provided continuously is estimated at 97.0% in rural areas in 2012 against 97.6% in 2013, an increase of 0, 6%. According to PEPAM, the major renewal operations of the dewatering equipment have made it possible to improve the situation of the availability of motorized rural boreholes. From 2006 to 2007, the proportion of motorized rural boreholes available increased from 93 to 88%; a 5% drop in percentage over this period. On the other hand, over the period from 2010 to 2013, the rate of availability of motorized rural drilling fell from 86.4 to 97.6%; a significant gain of 11.2% (ANSD, 2015).

On the basis of the statistics stabilized in December 2013 in relation to the SDE and SONES and relating to the water intakes actually invoiced, access by private connection, which constitutes the sector's preferential option for service provision, globally very satisfactory with a rate of 89.4% for the entire perimeter. This ratio is maintained at 100% for urban Dakar, 88.2% for the peri-urban and rural area of Dakar and 79.2% for other urban centers. The overall access rate has almost stabilized with 98% for the entire area covered; the other urban centers show a result of 91.2% for the same indicator. Despite improvements in drinking water coverage, the sector still faces the following problems: (i) pollution risk (especially in agglomerations), (ii) limited water production and treatment capacity compared to demand, (iii) weak extension of the distribution network, (iv) technical losses and high commercial fraud, (v) unavailability of installed capacity due to lack of maintenance or fuel and inappropriate institutional and legal frameworks of the sector (African Water Facility, 2012).

Degradation factors of water resources: Case of the Senegalese part of the Senegal river basin

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 km^2. The Senegal River basin is occupied by a large plain that extends from the feet of the Fouta Djallon Mountains to northern Senegal (Saint Louis Region). The Senegal River is formed by the meeting of Bafing and Bakoye in Bafoulabé in Mali. The Senegal River basin is generally divided into three entities (OMVS, 2008): the upper basin, the valley and the delta (Figure 2).

The upper basin goes from the sources of the river (Fouta Djallon) to the confluence between the Senegal River and Falémé. As for the valley, it goes from the confluence of the river Senegal-Falémé to the traditional limit of the rise of the salt tongue (Rosso Mauritania) and the Rosso Mauritania delta at the mouth of the river. The Senegalese part of the Senegal River Basin is made up of the left bank of the Senegal River which is made up of part of the Falémé (high basin), the valley and the delta.

The Senegal River passes through four distinct climatic zones: "Guinean" (very humid), "Southern Sudan" (humid), North Sudan (semi-humid) and "Sahelian" (semi-arid). The rainfall gradient remains very strong, of 1500 mm/year in its Guinean part against only 200-250 mm/year in the northern part for an annual average of 550 mm/year. This rainfall contrast which characterizes the basin is somewhat attenuated by the fact that the river transfers annually billions of m^3 of water (OMVS and HYCOS, 2007) from the heavily watered regions of the high basin to the arid Sahelian regions of the valley and delta. This particular device explains the great richness of the biophysical environments of the basin as well as the great diversity of the production systems of the 3.5 million people living in the basin. Two major pressures in recent years have been on the basin's water resources: (a) natural pressures (climate variability and change); (b) pressures from anthropogenic sources (dams, rapid population growth and various productive activities). These pressures have impacted the natural environment of the basin and its ecological diversity (OMVS, 2008).

Natural factors

Climatic changes cause the rise of temperature, disturbances of the rainfall regime and a rainfall deficit that can reach 36.4% below the current normal by 2050 and 40.4% around 2100, with significant impacts water resources and the main socio-economic sectors of the country (Camara and Bangoura, 2017). Although the Senegal River Basin still constitutes a sort of backbone of the economy of riparian societies but also a crossroads of

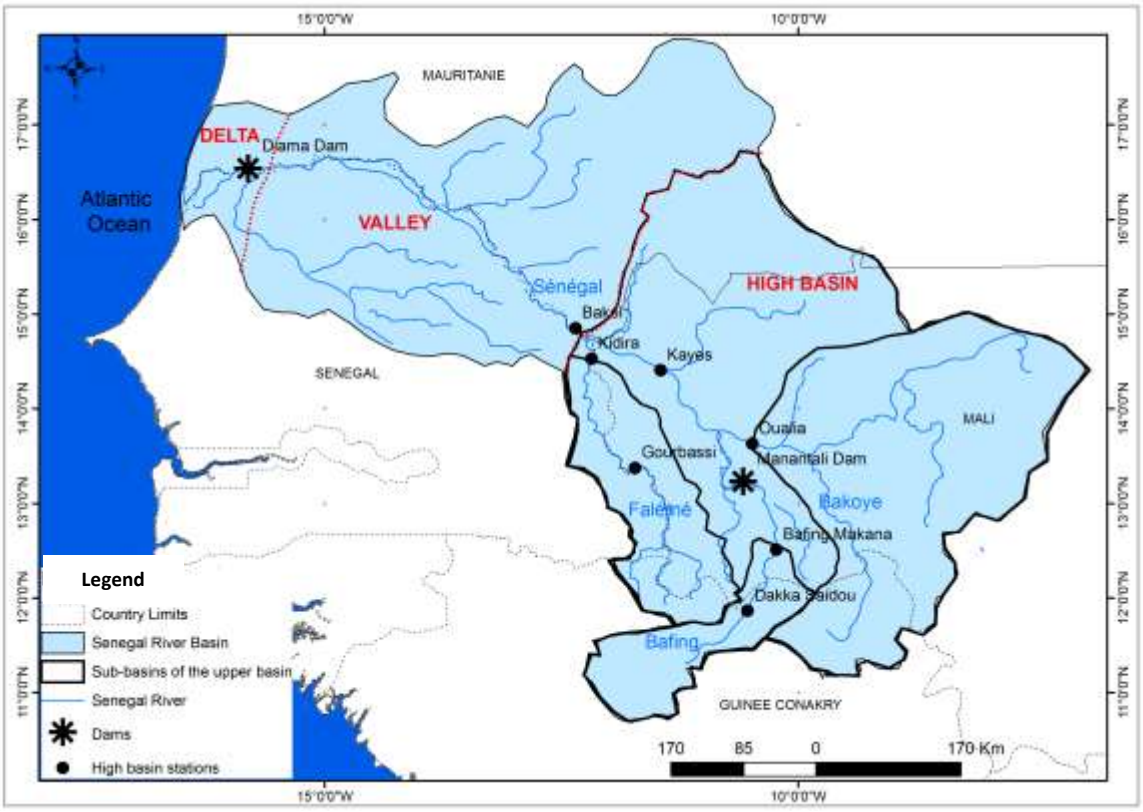

Figure 2. Situation of the Senegal River basin.

remarkable biological diversity, it has been threatened since the 1970s by drought and today by climate change. The drought strongly influences the hydrology of the river, which results in a decrease of the flows since the beginning of the 1970s. Compared to the period 1950-1969, the flows during the period 1970-2004 show an average decrease of 52, 5% (from 36.7% for Bafing in Bafing-Makana to 63.2% for Bakoye in Oualia) (Faye et al., 2015a). These different studies (Faye, 2015 ; Faye et al., 2015a ; Faye et al., 2015b), showing the effects of climate change on changes in the hydrological regime of the Senegal River, indicated a decrease in flow rates at the level of different basin stations, evoking the appearance of a break observed around 1970.

Anthropogenic factors

The impacts of human activities (development, rapid population growth and various productive activities) related to the exploitation of resources for the satisfaction of daily needs of populations are sometimes negatively manifested on the whole of the natural resources of the basin. Extensive agriculture is characterized by excessive clearing, slash-and-burn agriculture, agricultural nomadism, and erosion, soil depletion and loss of biodiversity. Extensive livestock farming is characterized by transhumance, shoreline trampling, bushfires, conflicts between farmers and pastoralists, and so on. It causes biodiversity loss and erosion. Mining (traditional activity and gold panning) puts pressure on ecosystems and their resources. It reduces the vegetation cover and influences the water quality and availability. Exploitation of gold under current conditions (leaching technique with cyanide or mercury and tailings ponds) poses enormous risks of pollution (infiltration and contamination) of water resources in the basin.

The Environmental Transboundary Analysis (ERA) done during the PDF-B phase of the GEF project (OMVS, 2008) indicated a priority level which is established as follows: the most urgent environmental problems (invasive plants, desertification and fire bush degradation, wetland degradation, modification of estuarine hydro-dynamics), serious environmental problems (surface water availability problem, deforestation, overgrazing, erosion and silting, degradation of riverbanks and fish

fauna) and environmental problems important (waterborne diseases, availability and quality of groundwater, water quality due to pollution from mining, salinization of land in the delta). With the implementation of major developments built to mitigate the effects of climate variability and change, many problems can be summarized as changes in water quantity and quality, groundwater pollution, drainage and recurrent diseases are noted (OMVS, 2011).

Indeed, with OMVS developments, the development of mining activities (extraction and washing with mercury release) and a large consumer agriculture of fertilizers and pesticides has led to biological and chemical waters pollution of the Senegal River. (WWAP, 2003). This degradation has resulted in the disruption of biodiversity at the basin level and the deterioration of fauna and flora (Sène, 2009). The loss of natural functions resulting from the drying up and direct destruction of the freshwater ecosystems of the Senegal River is one of the main factors contributing to the rapid degradation of hydrological resources in the basin (Awaïss, 2003).

Institutional factor

At the institutional level, several actors intervene directly or indirectly in the water sector in Senegal. Based on the differences in responsibilities, these actors in Senegal are divided into centralized management actors (Ministries, Superior Council of Water, Technical Committee of Water, National Partnership of Water of Senegal, National Society of Waters of Senegal ...), deconcentrated and decentralized (Regional Divisions of Hydraulics, Wells and Drilling Brigades, Hydrological Brigades, Drilling Management Committees, Youth and Women's Associations ...) and Conventional (OMVS cells, ECOWAS, Universities, IRD ...). These different actors, with competing interests, do not have the same motivations: for example, some may only be interested in the protection of water resources and others in improving socio-economic conditions in a basin (agriculture, breeding, fishing, gold mining, mining, trade, tourism ...).

The multiplicity of actors is a source of dysfunction of the water management system and therefore a major constraint for the rational management of water. One of the major difficulties is the poor distribution or even the fragmentation of skills between actors and the lack of coordination between the structures and services responsible for implementing policies in the countries with which Senegal shares its basin. Added to this are the problems of legitimacy between political and administrative actors and the risk of duplication in actions. In addition, rivers such as Senegal and Gambia being cross-border rivers, a parallel intervention by the actors of states crossed by their basins only accentuates the problems of coordination and sharing of skills (Faye, 2013). Faced with this lack of coordination, the sectoral resource management is wasteful. The situation, reinforced by the embryonic nature of Senegal's commitment to the Integrated Water Resources Management process since April 2010, most often leads to conflicts of use between the different actors. In addition, few programs target the sustainable management of national basins such as Casamance, Sine and Saloum.

Legal factor

On the legal and regulatory level, the water resources regulation is defined through the Law No. 81-13 of March 4, 1981, on the Water Code and Law No. 83-05 of January 28, 1983, on the Code of Water. the environment, thus laying down the legal regime for water, the conditions for the use of natural resources and the protection against adverse effects on water. By putting in place a large volume of legal instruments in the management of water resources, the legislator has shown the awareness and the desire to appropriate and control this fundamental environmental issue for social well-being. This legal framework deals mainly with problems relating to the water supply of populations and defines the applicable legal regime for the protection of water resources. Although Senegal has developed many water laws and policies, their application remains difficult in the face of different water issues. However, the strict enforcement of regulations for the environment and water in Senegal is mandatory.

Water resources management strategy

Water resources management and services that have been in the past and, in most cases, continue to be based on the separate sectoral administration of the different resource uses (GWP, 2003) has shown its limitations. The practices of this fragmented water management have not provided sustainable livelihoods (Murenga, 2003) and have implied high economic, social and ecological costs for human societies and environment (Kouam-Kenmogne et al., 2006). With the increasing scarcity of water resources, effective and efficient management of water resources is a major challenge.

With a view to the proper implementation of the sectoral water and sanitation policy, Senegal has adopted certain regulatory texts and conventions, such as Law 81-13 of 4 March 1981 on the Water Code. This Code lays down the provisions for good water

management, especially in the health and pollution control fields. The essential principle is that of the public domanial of the waters, which makes this resource a common good to all. It is on this basis that a good planning of the resources, their good management and their equitable distribution between the different uses, and their attribution to each according to their needs in the framework of the strict respect of the general interest is based. It will be necessary to wait 17 years to know the applications relating to the authorizations of construction and use of works of collection and rejection, with the decree 98-555 of June 25, 1998. The decree 98-556 of June 25, 1998, as for to him, applies the provisions of the Water Code relating to the water police. Finally, Decree 98-557 of 25 June 1998 establishes a Higher Water Council (FAO, 2016).

Although water policy was put in place by the authorities in the early years of independence, it was mainly from the 1980s that water resources management planning process was accelerated with the introduction of water resources several programs in place: the short-term emergency program (1988 to 1990); the medium-term interim program (1990 to 1998); the long-term program (1998 to 2029). Thus, the sectoral policy letter for water and sanitation in urban and rural areas was drafted with the objective of ensuring the water availability and quality in urban and rural areas. Indeed, it concerns in particular: "to set up and guarantee sustainable management of Guiers Lake, whose importance for the urban water sector is vital; to improve the quality of water offered to rural users of the Groundnut Basin, at a reasonable cost for users; to identify alternative water resources for market gardening irrigation in the Niayes area; to strengthen the quality of data and monitoring analyzes of water resources "(MAH et al., 2005).

Given the position of Senegal (downstream position compared to the States with which they share basins), the water resources management methods taken by these states upstream (Guinea, Mali) will inevitably have impacts in Senegal. These international implications add to Senegal's burden of responsibility for the sound management of its resources in the current context of climate change. This is where the joint management of international rivers through the creation of sub-regional organizations is of great importance (Organization for the Development of the Senegal River (OMVS) and Organization for the Development of the Gambia River (OMVG).

Finally, achieving the Sustainable Development Goals first requires an appropriate strategy for the water resources sustainable management. To this end, the definition and implementation of IWRM have several levels: national and sub-regional (cross-border). For example, Senegal, in implementing the Johannesburg Summit's recommendation on sustainable development, has in recent years adopted an Integrated Water Resources Management Action Plan (IWRMAP) through a participatory process of water management of all users (domestic, productive, ecological and in situ) and actors (centralized, decentralized, deconcentrated and conventional) of water resources. It has also embarked on the elaboration of an action plan that favours taking into account cooperation in shared watersheds (in particular the Senegal and Gambia rivers basins). If at the national level the IWRMAP is implemented by the DGPRE, at the sub-regional level, (in particular at the level of the Senegal and Gambia rivers basins), it is elaborated by the OMVS and the OMVG which have implemented an integrated water resources management program (PEPAM, 2014).

Conclusion

This article examines the value of water resources in Senegal with a view to economic, social and sustainable development. Although the water resources potential (rainwater, surface water and groundwater) is important, the issue of water has become a national concern given the range of issues facing the sector: scarcity, random nature of rainfall, water resources vulnerability, disparity in their spatial distribution, degradation of their quality, inequity in access to water resources. Human activities (development, rapid population growth and various productive activities) that are not respectful of the environment and the adverse effects of climate variability and change contribute to an accelerated degradation of these resources and the decline of the country's water availability.

To reverse this trend and be in line with the Sustainable Development Goals (including SDG 6), it is necessary to adopt and implement sustainable water resources management strategies across the country. These strategies must take into account: the improvement of the access and the service in drinking water, the reinforcement of the protection of the aquatic sources, the mobilization of important concessional funds through the Technical and Financial Partners for financing of the sector, the management of hydrological forecasting and monitoring systems at watershed scale, the application of the Water Code, the preparation of work plans for watershed groups, the strengthening of collection and basic data processing.

Faced with the urgency of moving to new forms of water management, Senegal has been keen to comply with the recommendations of the World Summits (Rio-Dublin in January 1992 and Johannesburg in August

2002). As a result, widespread awareness both at the level of institutions concerned and at the level of public, as well as the promotion of subregional and regional cooperation, will contribute to the water resources sustainable management nationally and cross-border. In addition to the actions undertaken by national and sub-regional actors (through the implementation of the IWRMAP), specific actions for the mobilization and securing of water resources are also undertaken by public bodies such as the Guiers Lake Geneva Office. (OLAG) and the Agency for the Promotion of National Hydrographic Network (APRHN). These strategic initiatives include enhancing the resource potential to meet the diverse demand for water.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Agence Nationale de la Statistique et de la Démographie (2013). Recensement Général de la Population et de l'Habitat, de l'Agriculture et de l'Elevage (RGPHAE) Rapport provisoire, mars 2014. 36 p.

Agence Nationale de la Statistique et de la Démographie (2015). Situation Economique et Sociale du Sénégal Edition 2013 14 p.

Aspe C Jacque M Eds (2012). Environnement et société Natures sociales Paris, Versailles : Editions de la Maison des sciences de l'homme, Editions Quae. 279 p.

Awaïss A (2003). L'Initiative Bassin du Niger (IBN): développement durable et gestion intégrée d'un grand fleuve Afrique contemporaine /2 (206):179-203.

Batcho KA (2008). Analyse de la contribution de la gestion intégrée des ressources en eau (GIRE) dans la résolution des problèmes environnementaux liés à la gestion de l'eau dans l'espace CEDEAO Rapport de projet personnel, master spécialisé, 2iE. 34 p.

Boinet E (2011). La Gestion Intégrée des Ressources en Eau du fleuve Sénégal : bilan et perspectives Université Paris Sud XI, Mémoire de stage, Faculté Jean Monnet-Promotion 2011. 75 p.

Buchs A (2014).Comprendre le changement institutionnel Régimes et crises du mode d'usage de l'eau en Espagne (XIXe-XXe siècle), Revue de la régulation, n° 16 https://journalsopeneditionorg/regulation/10925

Camara S, Bangoura A (2017). Valorisation des ressources en eau en Guinée en vue d'un développement économique et social durable. Journal of Water and Environmental Sciences1 (Numéro spécial COP22):106-114.

CAP-Net (2005). [Cap-Net - 24 Juillet 2005 - 23 04 2011 Disponible sur : - http://wwwarchivecapnetorg/iwrm_tutorial/mainmenuhtm

CONGAD (2009). Livre bleu « L'eau, la vie, le développement humain » Rapport pays: Sénégal, Document de consultation fourni par SENAGROSOL CONSULT. 72 p.

Crow-Miller B (2015). Discourses of deflection: The politics of framing China's South-North Water Transfer Project Water Alternatives 8(2):173-192.

Crow-Miller B, Webber M, Molle F (2017). The (re)turn to infrastructure for water management ? , Water Alternatives, 10(2):195-207.

Descroix L, Lasserre F (2003). L'eau dans tous ses états : Chine, Australie, Sénégal, Etats-Unis, Mexique et Moyen-Orient, Ed L'Harmattan, Paris 351 p.

DGPRE (2016). Rapport phase pilote du suivi des indicateurs de l'ODD6 de l'initiative GEMI au Sénégal Rapport final, Ministère de l'Hydraulique et de l'Assainissement, DGPRE, décembre 69 p.

Diagne M (2000). Vulnérabilité des productions agricoles au changement climatique au Sénégal Direction de l'Environnement et des Etablissements Classés- Programme d'Assistance des Pays-Bas sur les Changements Climatiques NCCSAP Ministère de la Jeunesse, de l'Environnement et de l'Hygiène Publique, Sénégal 36 p.

Diouf W (2017). Contribution: le Sénégal peut-il être autosuffisant en riz en 2017? Disponible sur: http://wwwdakaractucom/CONTRIBUTION-le-Senegal-peut-il-etre-autosuffisant-en-riz-en-2017_a77883html

Facilité africaine de l'eau (2012). Plan stratégique 2012-2016 Vers l'eau pour tous à l'horizon 2025.

Food and Agriculture Organization (FAO) (2008). Aperçu du Développement Rizicole, Sénégal Brochure produite par la Division de la production végétale et de la protection des plantes (AGP) de la FAO en collaboration avec le bureau sous régional de la FAO pour l'Afrique de l'Ouest 10 p.

Food and Agriculture Organization (FAO) (2016). Site web AQUASTAT Organisation des Nations Unies pour l'alimentation et l'agriculture Site consulté le 21/05/2017 Disponible sur: http://wwwfaoorg/statistics/fr/

Faye C (2015). Impact du changement climatique et du barrage de Manantali sur la dynamique du régime hydrologique du fleuve Sénégal à Bakel (1950-2014) Bulletin de la Société Géographique de Liège: BSGLg 64:69-82.

Faye C, Sow AA, Ndong JB (2015b). Étude des sècheresses pluviométriques et hydrologiques en Afrique tropicale: caractérisation et cartographie de la sècheresse par indices dans le haut bassin du fleuve Sénégal Physio-Géo 9:17-35.

Faye C (2013). Evaluation et gestion intégrée des ressources en eau dans un contexte de variabilité hydroclimatique: cas du bassin versant de la Falémé Thèse de Doctorat, Université Cheikh Anta Diop de Dakar 309 p.

Faye C, Diop ES, Mbaye I (2015a) Impacts des changements de climat et des aménagements sur les ressources en eau du fleuve Sénégal: caractérisation et évolution des régimes hydrologiques de sous-bassins versants naturels et aménagés Belgeo 4:1-22.

Faye C Ndiaye A Mbaye I (2017) Une évaluation comparative des séquences de sècheresse météorologique par indices, par échelles de temps et par domaines climatiques au Sénégal Journal of Water and Environmental Sciences 1(1):11-28.

Francis R (2016). L'eau dans les pays en développement Retour d'expériences de gestion intégrée et participative avec les acteurs locaux Éditions Johanet 416 p.

Global Water Partnership / Comité Technique (TEC) (2003). La Réduction de la Pauvreté et la GIRE Première édition, TEC background papers (8):50.

Honegger A, Tabarly S (2011). La "gestion durable des ressources en eau" dans le bassin du Rhône, de la théorie à la pratique Université de Lyon, UMR / CNRS 5600 EVS) pour Géoconfluences 12 p.

Kouam-Kenmogne GR, Mpakam HG, Ndonwy SA, Bopda SLD, Ekodeck GE (2006). Gestion intégrée des ressources en eau et objectifs du millénaire pour le développement en Afrique: Cas du Cameroun, VertigO - la revue électronique en sciences de l'environnement, 7 (2) Disponible sur URL: http://vertigorevuesorg/2319

Linton J (2010). What is water? The history of a Modern Abstraction Vancouver : University of British Columbia Press, 333 p. https://curve.carleton.ca/system/files/etd/4570d131-bfce-4c83-aaa9-2d2bcb64068f/etd_pdf/a37d3ae4e286deb22f765aa6be2470b3/linton-whatiswaterthehistoryandcrisisofamodernabstraction.pdf

Mballo I (2017). Projet d'autosuffisance en riz et développement des aménagements hydroagricoles du bassin de l'Anambé (Kolda)

Mémoire de Master 2, Université Assane Seck de Ziguinchor, Département de Géographie, 128 p.

Ministère de l'Agriculture et de l'Hydraulique, Ministère de la Prévention,

de l'Hygiène Publique et de l'Assainissement, Ministère de l'Economie et des Finances (2005). Lettre de Politique sectorielle de l'Hydraulique et de l'Assainissement en milieu urbain et rural, mars P 6.
Ministry of Hydraulics/DGPRE (2007). Plan d'Action de Gestion intégrée des ressources en eau du Sénégal Global Water Partnership West Africa 61 p
Ministre de l'Environnement et de la Protection de la Nature (2006). Plan d'Action Nationale pour l'Adaptation aux Changements Climatiques République du Sénégal 84 p.
Murenga K (2003). The Impact of Integrated Water Resources Management (IWRM) on Poverty Alleviation 4th WaterNet/Warfsa Symposium: Water, Science, Technology and Policy Convergence and Action by All, 15-17 October 2003, 7 p.
Mwendera E, Atyosi Y (2018). A review of water storage for socio-economic development in South Africa. Journal of Water Resource and Protection 10(03):266.
Nadira SA, Shixiang L (2018). The current situation and sustainable development of water resources in Bangladesh. American Journal of Water Science and Engineering 4(1):9-15.
Ndour N (2016). Etat d'avancement du processus de suivi de l'ODD6 de l'initiative GEMI au Sénégal Conférence internationale sur les Objectifs de Développement Durable (0DD): Quel agenda pour le Sénégal? 12-13 octobre 2016, Dakar, Sénégal 14 p.
Olivier P (2016) .Un conflit de l'eau inédit en Inde Les guerres de l'eau auront-elles lieu? Disponible sur: http://wwwpartagedeseauxinfo/Une-conflit-de-l-eau-inedit-en-Inde
OMVS and HYCOS (2007). Renforcement des capacités nationales et régionales d'observation, transmission et traitement de données pour contribuer au développement durable du bassin du Fleuve Sénégal, Une composante du Système Mondial d'Observation du Cycle Hydrologique (WHYCOS), Document de projet préliminaire 53 p.
OMVS (2008). Projet FEM/Bassin du fleuve Sénégal, 2008 Plan d'action stratégique de gestion des problèmes environnementaux prioritaires du bassin du fleuve Sénégal, Version finale 133 p.
OMVS (2011). SDAGE du fleuve Sénégal Phase 3, annexes, version finale 181 p.
Petit S (2015). Au fond de l'eau : histoires sociales et représentations environnementales d'un bassin versant agricole », Territoire en mouvement, revue de géographie et aménagement pp. 25-26,
Programme d'eau potable et d'assainissement du Millénaire (2014). Feuille de route, POST-OMD, 2014-2025:52.
Programme Solidarité Eau (2016). Les services d'eau et d'assainissement dans les objectifs de développement durable Document de travail, Version octobre 39 p.
Roman P, Buchs A (2016). La pénurie en eau est-elle inéluctable ? - Une approche institutionnaliste de l'évolution du mode d'usage de l'eau en Espagne et au Maroc, PIE Peter Lang 331 p.
Sane M (2015). Note sur les ressources en eaux du Sénégal: zones potentielles pour le transfert d'eau Directeur de l'hydraulique, République du Sénégal 8 p.
Sène AM (2009). Développement durable et impacts des politiques publiques de gestion de la vallee du fleuve Sénégal: Du régional au local », VertigO - la revue électronique en sciences de l'environnement [Online], 9(3) disponible sur: http://vertigorevuesorg/9221
Sinarinzi E (2010). Enjeux et Défis dans la gestion des ressources en eau et de l'Assainissement de base: le rôle des Parties Prenantes Forum pour l'Eau et la Sécurité Alimentaire: FESA du 17 03 2010, Bujumbura, Burundi 23 p.
Strang V (2004). The meaning of water Oxford: Berg Publishers 274 p.
WWAP (2003). "Senegal river case study", in Premier rapport du Programme Mondial pour l'évaluation des ressources en eau (WWAP).