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Research Article

EXAMINATION OF WATER STORAGE IN THE SENEGAL RIVER BASIN FOR A SOCIO-ECONOMIC DEVELOPMENT OF DOWNSTREAM RIVER COUNTRIES

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ABSTRACT

The water resources of the Sahelian countries bordering the Senegal River Basin (Senegal, Mali and Mauritania) are limited and unequally distributed. To overcome the unequal distribution of water resources and to manage floods and drought in the Senegal River basin, billions of cubic meters of water are currently stored in dams, first of Manatali. The paper reviews current water storage capacity in the Senegalese, Malian and Mauritanian parts of the Senegal River Basin. Data from a list of dams recorded in the Senegal River Basin were used to analyze the country's water storage capacity in the basin. The water storage capacity is highest in the Malian part and the lowest in the Mauritanian part. The results also show that while it is clear that countries, through the OMVS, have invested heavily in the development of water storage infrastructure, there is potential for additional infrastructure development. However, since the Senegal River is transboundary, riparian countries must continue to develop additional storage taking full account of their ecological requirements and international obligations.

Keywords: Water Storage, Water Infrastructure, Dams, Water Use, Irrigation

INTRODUCTION

The water resources of the Sahelian countries bordering the Senegal River Basin (Senegal, Mali and Mauritania) are highly variable. The Senegal River, the second largest river in West Africa, is formed by the meeting of Bafing and Bakoye in Bafoulabé, Mali. Its catchment area, which is 300,000 km2 wide, is generally divided into three entities (OMVS, 2008): the upper basin, the valley and the delta (Fig. 1). The Senegal River crosses four distinct climatic zones: "Guinean" (very humid), "Southern Sudan" (wet), North Sudan (semihumid) 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 pluviometric contrast which characterizes the basin is somewhat attenuated by the fact that the river transfers annually billions of m3 of water from the heavily watered regions of the high basin to the arid Sahelian regions of the valley and the delta (OMVS and HYCOS, 2007), which explains the great richness of the biophysical environments of the basin and their great diversity.In Senegal, the climate is Sahelian, characterized by a rainy season whose duration gradually decreases towards the north (June-October in the south, July-September in the north) and a dry season (November-June). The average rainfall in the territory is 687 mm / year. This average is subject to strong interannual variations, it also hides significant geographical disparities since rainfall ranges between 1500 mm / year in the south and 200 mm / year in the north. The climate is marked by arongevapo transpiration, close to 2000 mm / year.

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BP 523 Ziguinchor (Senegal). Between 1960 and 1980, isohyets of mean annual rainfall moved 120 km to the south. Since 1986, with the exception of 1991-92, recorded rainfall appears to have returned to the 1960s level throughout the country (FAO, 2016). For Mali, the Sudano - Sahelian climate is characterized by the alternation of a wet rainy season (June to September) and a dry season lasting between five and nine months (from October to November to May-June). The average rainfall (280 mm / year) decreases from south to north, which divides the country into four major agro-climatic zones: the pre-Guinean zone (rainfall greater than 1,200 mm); the Sudation zone (rainfall between 600 and 1,200 mm); the Sahelian zone (rainfall between 200 and 600 mm); the desert zone (rainfall less than 200 mm). A general tendency for isohyets to migrate nearly 200 km to the south over the last 30 years is a result of chronic drought since the 1970s (FAO, 2016).For Mauritania, the climate, Saharan in the north and Sahelian in the south, is generally hot and dry. The rainy season, which largely conditions agro pastoral production, is very irregular in time and space. It generally extends over a period of four months, from June to September (wintering), according to a north-south gradient ranging from a few millimeters to 450 mm / year in the Guidimakha region. Most of the country receives a rainfall of less than 300 mm / year. During the last fifteen years, two major droughts have been recorded in 1984-85 and 1991-92 (rainfall is 35 to 70 percent below average) (FAO, 2016).Water withdrawals vary by country. In Senegal, water withdrawals in 2000 amounted to 1,591 million m3, of which 1,435 million for agriculture (93%), 98 million for communities (4%) and 58 million for agriculture. (3%). In Mauritania, in 2000, water withdrawals were estimated at 1,698 million m3, of which 1.5 billion for agriculture (88%), 150 million for domestic use (9%) and 48 million for industry (3%).

In Mali, current withdrawals from the irrigation sector are in the order of 5.0 km3 in 2006, or 96.4 percent of the total withdrawal (MEA, 2010), and come almost entirely from surface water resources and almost entirely over a six-month period. In addition, the livestock supply of water takes about 0.075 km3, the industry 0.004 km3 and Communities 0.107 km3 (2% of the total) in 2006. The freshwater resources of these three countries are largely replenished by rainfall. Factors affecting the availability and distribution of water resources in the Senegal River Basin include: extremely variable climatic conditions; population dynamics; environmental issues related to water such as the need to maintain ecosystems; economic development; and political and socio-cultural issues such as food security in the basin (Mwendera and Atyosi, 2018).These countries bordering the Senegal River Basin (Senegal, Mali and Mauritania) have been members of the Organization for the Development of the Senegal River (OMVS) since 1972, in addition to Guinea since 2006, managing the waters of the Senegal basin for electricity generation, agriculture, navigation and ecosystem maintenance. As part of the OMVS agreements, the management of the Manantali dam guarantees a minimum flow of water at the border between Mali and Senegal and ensures the sharing of water stored between Mali, Senegal and Mauritania. Thus, a master plan for the development of the Senegal River (SDAGE) describing sectoral schemes has been put in place and attempts to promote sustainable and concerted development of the watershed (OMVS, 2009).As water-poor countries, the Sahelian countries bordering the Senegal River Basin (Senegal, Mali and Mauritania) have, for many years, invested in water storage in order to increase the availability of water for their socio-economic and environmental needs. However, the questions raised are: is the current storage capacity sufficient to meet the development needs of these countries? How is the water storage capacity at the Senegal River Basin? Do these countries, as part of the OMVS, have the potential to develop additional water storage infrastructures? The paper reviews the current water storage capacity of Sahelian countries bordering the Senegal River Basin (Senegal, Mali and Mauritania) with the aim of trying to answer these key questions.

DATA AND METHODS

This work is based on two parts: data collection and document analysis. For data collection, a multidisciplinary literature search and semi-structured interviews were conducted with stakeholders. The scientific articles were searched in different databases to cover a series of published documents (books, reports, dissertations, theses, articles, etc.) on the issues of water storage by dams and its role in management integrated water resources in the Senegal River Basin. This in-depth review of the literature has enabled us to collect various data and information available on the implemented and planned developments for water storage in the Senegal River Basin and in basins where similar studies have been conducted. This information was supplemented by the study of the FAO reports including its AQUASTAT platform, national official documents and statistical data of the Senegal River Development Organization (OMVS), the Directorate of Management and water planning. Resources (DGPRE), The Department of Hydraulics and other departments. Finally, to complete the database, interviews were conducted with some institutional and non-institutional actors on the issue. The use of these interviews allowed to survey respondents' opinions and to clarify their interpretation of the problems. Other sources of data included consultants' reports, strategic planning documents, laws and policy documents in the riparian states of the Senegal River. A number of consultant studies have been completed for the study area and this rich database is available for review. These reports verified the interview data. The search method produced a rich database available to process the subject.

RESULTS AND DISCUSSION

Availability of water

The amount of water available, as reported by FAO (2016), is presented in Table 1. The total renewable water resources (surface water, groundwater, inland water and external waters) in 2014 vary according to the three countries. They are estimated at 120 km3 / year in Mali against 38.97 km3 / year for Senegal and 11.4 km3 / year for Mauritania. In Mali, superficial renewable water resources are estimated at 110 km3 / year and internal renewable water resources of about 60 km3 / year is a dependency index of 50%. This importance of superficial renewable water resources can be explained by the availability of water in the Niger River. In Senegal, 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 is an index of dependency of 33.8% In Mauritania where the availability is the most 11.1 km3 / yr represent 97.4% of the total water resources and consist mainly of the Senegal River and its tributaries, and the reservoirs of dams scattered in the southern and central parts of the territory. For internal renewable water resources, they represent only 0.4 km3 / year, indicating a very high dependency index with 96.49% (Table 1). Total removals are estimated at 2.22 km3 / year in Senegal. Given the considerable potential of water reserves in the country, the exploitation index is relatively low (5.75%). Groundwater is the main source of reliable and safe drinking water supply in rural areas and in many cities in Mali; in Senegal and Mauritania for irrigating thousands of hectares of arable land and for livestock watering. Many mines and industries also depend on groundwater for their supplies. The total volume of renewable groundwater available is estimated at 20 km3 / year in Mali against 3.5 km3 / year for Senegal and 0.3 km3 / year for Mauritania. For the Senegal River, inflows, although important, are also variable with a strong interannual irregularity and are of the order of 20 km3 in average year for 41 km3 in 1924 (wet

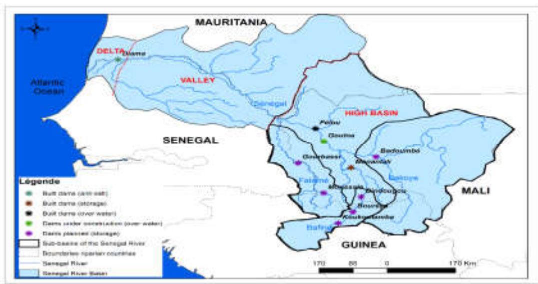

Fig. 1.Situation of the Senegal River watershed

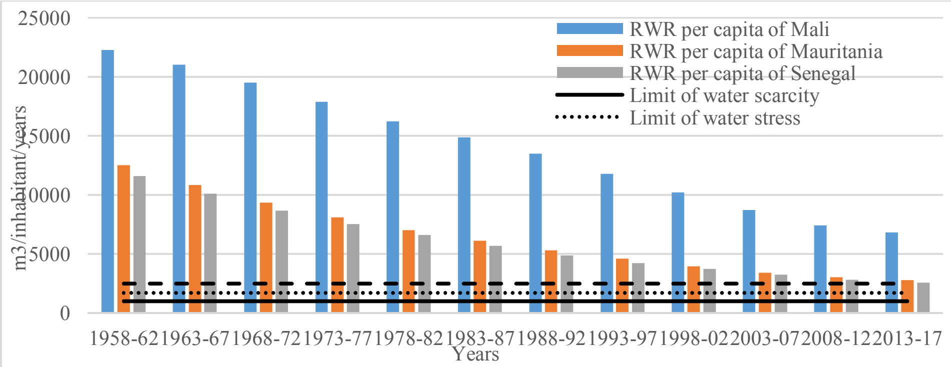

Fig. 2. Evolution of total renewable water resources per capita between 1958-62 and 2013-17 for the three countries (Source: FAO, 2016)

Renewable Water Resources (RWR)	Senegal		Mali		Mauritania	
	value	%	value	%	value	%
Total domestic RWR (km3 / year)	25.8	66.2	60	50.0	0.4	3.5
Total external RWR (km3 / year)	13.17	33.8	60	50.0	11	96.5
RWR superficial: total (km3 / year)	36.97	94.9	110	91.7	11, 1	97.4
Total underground RWR (km3 / year)	3.5	9.0	20	16.7	0.3	2.6
Total RWR (km3 / year)	38.97	100	120	100	11.4	100
Dependency index (%)	33.8		50		96, 49	
Total RWR for capita (m3 / year / hbt)	2853		6818		2,802	
Total samples (km3 / year)	2.22		5.19		1.70	
Farming index (in%)	5.71		4.33		14.9	
Total capacity of dams (km3)	0.25		13.79		0.5	
Total capacity of dams per capita (m3 / inhabitant)	16.52		783, 5		122.9	

Table 1. Renewable water resources available in 2014 for the three countries (Source: FAO, 2016)

year) and only 6.15 km3 in 1987 (dry year) (CONGAD, 2009).Following the climatic deterioration that hit the Sahel, average inputs of the Senegal River fell to 13 km3 per year. The large volumes of water drained by the rivers that cross these countries, like the Senegal River, make it possible to meet the requirements of the users concerned. As shown in Table 1, total removals are estimated at 5.19 km3 / year in Mali, 2.22 km3 / year in Senegal and 1.70 km3 / year in Mauritania. Given the considerable potential of water reserves in these countries, the exploitation index is relatively low and is 4.33% in Mali, 5.75% in Senegal (Faye *et al.*, 2019) and 14.9% in Mauritania At the level of the three, social development leads to an increasing demand for water. Water plays a central role in most of these national planning initiatives, such as agricultural development, energy security, tourism and recreation, mining, industry, and municipal water supply (Mwendera and Atyosi, 2018). The demographic and urban growth of these countries puts a great deal of pressure on the often limited water resources available in these countries. According to the AQUASTAT database (FAO, 2016), renewable freshwater resources per capita (in m3) continue to decrease between 1958-62 and 2013-17 in the three countries. They went from 22301 m3 in Mali, 12538 m3 in Mauritania and 11612 m3 in Senegal in 1958-62 to only 6818 m3 in Mali, 2802 m3 in Mauritania and 2576 m3 in Senegal in 2013-17. These results show the trend of these different ones towards a situation first of water stress (below 1700 m3 / inhabitant / year) and then of water shortage (below 1000 m3 / inhabitant / year). Countries suchas Senegal and Mauritania are also close to a situation of water vulnerability (below 2500 m3 / inhabitant / year).This observation may be worrying 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). Each country in the basin could seek to reduce its own uncertainty regarding the water resource by regulating the flow of the river on the portion that crosses its territory, by the construction of large dams in particular, most often to the detriment of water resources, other riparian riparian countries, which could paralyze peace in the area. Therefore, for countries like Mauritania, which depend on 96.49% of allogeneic resources (ie water coming from outside its territory), the use of force is possible to safeguard the interests of the country on this issue of national security. (Descroix and Lasserre, 2003).

Shared water systems

Most of the freshwater resources in sub-Saharan Africa are located in transboundary watercourse systems and shared river basins. The management and protection of these shared basins is necessary through a strong commitment to regional collaboration, which is noted in the Senegal river basin with the organization for the development of the Senegal River (OMVS) . The Senegal river basin and its tributaries is a hydrosystem that covers an area of 289000 km2. This basin is shared by four states: Mali (53.5%); Mauritania (26%); Guinea Conakry (11%)

Sub basins	Area (km2)	Riparian countries	Country surface in the basin	
			Area (km2)	% Relative to basin
Bafing Sub-Basin	2200 0	Guinea	-	-
		Mali	-	-
Bakoye Sub-Basin	85600	Guinea	-	-
		Mali	-	-
Falema sub-basin	28900	Guinea	3600	12.5
		Mali	13800	47.8
		Senegal	11500	39.7
Senegal River Basin	289000	Guinea	31000	11
		Mali	155000	53.5
		Senegal	27500	9.5
		Mauritania	75000	26

Table 2. Situation of sub-basins of the Senegal River between the territories of riparian countries

and Senegal (9.5%) (Table 2). Like the Senegal River, the Falémé basin straddles Mali (over 13,800 km2, or 47.8%), Senegal (over 11500 km^2, or 39.7%) and Guinea Conakry (over 3600 km2). or 12.5%) (Faye, 2013). Basins of bafing (22000 km^2) and Bakoye (85000 km2) are shared between Mali and Guinea.The objective of the OMVS, the organization of the Senegal River Basin, is to establish a global vision of the development of the Senegal River Basin incorporating the various sectoral objectives that are hydroelectricity, navigation, development of the Senegal River Basin drinking water and sanitation, transport, rural development, mining and industry, based on a thorough analysis of the basin's water resources and the ecosystems that depend on them (Faye, 2019a). As shown in Table 3, the riparian countries are interested in different ways in the major components of the OMVS program (irrigation, energy production and navigation) (Niasse, 2004).

Country	Hydroelectric power	Irrigation	Navigation	Recession agriculture
Mali	high	Low	Very high	Low
Mauritania	Very high	Very high	high	high
senega	Very high	Very high	high	high

Table 3. Riparian countries' priorities in relation to the components of the current OMVS program

Mauritania and Senegal remain the two riparian states whose dependency factor, which represents the total share of water resources produced outside their borders, remains the highest in the basin. In fact, unlike Mali and Guinea, which are bordering the Niger River basin and have relatively abundant water resources, the Senegal River remains the only source of fresh water in Mauritania and Senegal, which harvests around 90 % of agricultural development in the basin (Thiam, 2016).The OMVS has thus adopted a series of joint management instruments and the development of shared water resources of the Senegal River. As the water resources of the Senegal River constitute a relatively large share of the total external water resources of the riparian countries, their sustainable management requires cooperation. Through this cooperation, OMVS has been able to develop cross-border hydraulic infrastructures to improve the lives of the populations of the region. Each of the OMVS member countries has an obligation to respect its commitments by cooperating with its neighbors in the management of ernational waters in the interest of regional economic integration, peace and security.

Water use in the three countries

Water withdrawals vary by country and sector of activity, although irrigated agriculture is the largest consumer of water in the three countries. In Mali, current withdrawals from the irrigation sector are in the order of 5 billion m3 in 2006, or 96.4% of the total withdrawal (MEA, 2010), and come almost entirely from the water resources of the country, surface area (Table 4).

Sampling in millions of m3	Mali		Senegal		Mauritania	
	Value	%	Value	%	Value	%
Irrigation + Breeding	5075	97.9	2065	93.0	1500	88.3
Municipalities	107	2.06	98	4.41	150	8.83
Industry	4	0.08	58	2.61	48	2.83
Total water withdrawal	5186	100	2221	100	1698	100

Table 4. Water use by major economic sectors in these countries (Source: FAO, 2016)

In addition, the livestock supply of water takes about 75 million m3, the industry 4 million and the communities 107 million (2.06%) in 2006. In Senegal, in 2000, the water resources levies were rose to 2221 million m3, of which 2065 million for agriculture (93%), 98 million for communities (4.41%) and 58 million for industry (2.61%) (Table 4). For Mauritania, in 2000, water withdrawals were estimated at 1,698 million m3, including 1,500 million for agriculture (88.3%), 150 million for domestic use (8.83%) and 48 million for industry (2.83%) (Table 4).

Impact of climate change on water resources

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), climate change is expected to have an impact on the level and variability of rainfall in Africa. Climate change has a potentially significant impact on both the availability and the water needs of the riparian countries of the river. Likewise, it modifies the hydrological systems and water resources of the Senegal River Basin and reduces the availability of water. The monitoring of the evolution of the flow coefficients at the multi-year, seasonal and monthly scales over the period 1960-2014 is a good illustration of the changes in flow dynamics and changes in hydrological regimes (Faye *et al.,* 2015). . Thus, over the period

1960-2014, the rupture noted in 1971 on the coefficients of flow and relating to a decrease of the flow in all the basin, is linked to the drought and to the strong signal of the climatic change. Rising temperatures and increasing variability in precipitation will generally affect surface water, which will increase drought in some areas and cause flooding in others. The likely effect is greater evapotranspiration and more stress on the arid and marginal areas of the basin. The current scenarios for predicting climate change on water resources in the countries bordering the Senegal River raise many questions because water is a determining factor for multiple human activities such as agriculture, electricity generation, or the supply of drinking water. These climate change prediction scenarios indicate that climate change will have the effect of either a gradual decrease in flows by the 2030 horizon to 2090, or a gradual increase in flows over the basin (Bodian et al., 2013). What is certain is that climate change is likely to lead to more intense and variable weather events, and will likely lead to more intense and prolonged periods of drought and flooding. Jointly managed Senegal River water resources are at the center of climate adaptation strategies, and improved and extensive water storage capacities create buffer zones for periods of water scarcity (WWAP, 2015; Faye, 2019b).

Water storage infrastructure

Investment in water infrastructure

The lack of storage infrastructure has significant negative impacts, especially in a drought-prone region where water is insufficiently stored (Mwendera and Atyosi, 2018). Water storage facilitates the supply of water for domestic and industrial use, irrigation for sustainable agriculture, generation of hydroelectricity, creation of infrastructure and jobs, promotion of ecotourism through fishing, canoeing and tourism Natonal Borders, which represents a sharp increase in the income of local and national governments (Mashinini, 2010).Investment in infrastructure for the development and distribution of water resources has shown significant human and macroeconomic benefits. Drops and droughts (WWAP, 2009).

Country	Costs assumed	Benefits withdrawn
Mali	35.3%	- 52% of hydroelectric production - opening up thanks to the navigation pane
Mauritania	22.6%	- 15% of hydroelectric production - 33.6% of the 375,000 ha of land made irrigable
Senegal	42.1%	- 33% of hydroelectric production - 64% of the 375,000 ha of land made irrigable

Table 5. Key of distribution of costs and benefits (Source: SOFRECO et al., 2011)

Investment in improving water storage and water management are essential elements of any water reduction strategy poverty. The role of dams and reservoirs in sustainable development has been recognized in several declarations: World Summit on Sustainable Development in 2002; Beijing Declaration on Hydropower and Sustainable Development in 2004; Dams and Hydropower for Sustainable Development in Africa in 2008 and Ministerial Declarations of the Fifth and Sixth World Water Fora (2009/2012) (ICOLD-ICID-IHA-IWRA, 2012). Water is a vital resource for society.For the distribution of investment costs and operating costs between riparian states, it is done according to a "key" (Table 5) on the basis of the benefits derived from these common works by each of them (Article 12 of the convention of the Common Works). This slice, limited to consultation alone, consists of allocating water quotas to riparian states for the implementation of national development plans for their respective portions of the river (SOFRECO et al., 2011).

Large dams in the Senegal River Basin

In order to overcome the unequal distribution of water resources and manage the floods and drought in the basin, the riparian states within OMVS have invested a lot of money in the construction of dams that currently store billions of m3. Based on data from OMVS on dams, there is a vast program of development of water control works (Table 6). Considered as first-generation works, the Diama and Manantali dams and their ancillary works have allowed a sufficient availability of fresh water and guaranteed all year round, a development of agricultural activities and a restoration of natural environments .
The Manantali dam therefore allows the storage of 11.3 billion m3, the energy production of 800 GWh / year, the regularization of the flow of the river at 300 m3 / s at Bakel, the irrigation capacity of 255 000 ha in combination with the Diama dam, navigation in the river ... (Bedredine, 2014).After the construction of the so-called first generation structures, the OMVS envisages the gradual completion of other hydroelectric works (Table 6). Since 2012, it has undertaken major hydroelectric dam construction projects, the aim being to increase energy supply and totally control the waters of the basin (Thiam, 2016). The Félou dam, which is currently operational, and the Gouina dam, which are in the construction phase, are two structures constructed on a run-of-river basis and therefore have no water storage capacity. In contrast, other projects in the Senegal River Basin will be dams with water storage capacity (Badoumbé, Boureya, Moussala, Gourbassi ...). Among these project storage facilities, some are in the funding research phase (Koukoutamba, Boureya and Gourbassi) and others in research and identification (Badoumbé).

Water storage capacity

Improved water resources management and water storage capacity make the economy more resilient to external shocks, such as variability and drought, and thus provide a stable and sustainable basis for productivity and food production and industry (Mwendera and Atyosi, 2018). Riparian States, in the framework of the OMVS, continue to develop a large amount of water storage infrastructure, which needs to be further increased in order to improve the water storage capacity in the basin. This storage capacity is of 11300 million m3 at the Manantali dam and will be of the order of 10,000 millon m3 for Badoumbé, 5500 millon for Boureya, 3600 millon for Koukoutamba, 3000 millon for Moussala and Maréla, 2100 millons for Gourbassi and 2000 millons for Bindougou. These various facilities will have to store nearly 23 billion cubic meters of water, and thus achieve almost total control (more than 97%) of flows in the Senegal

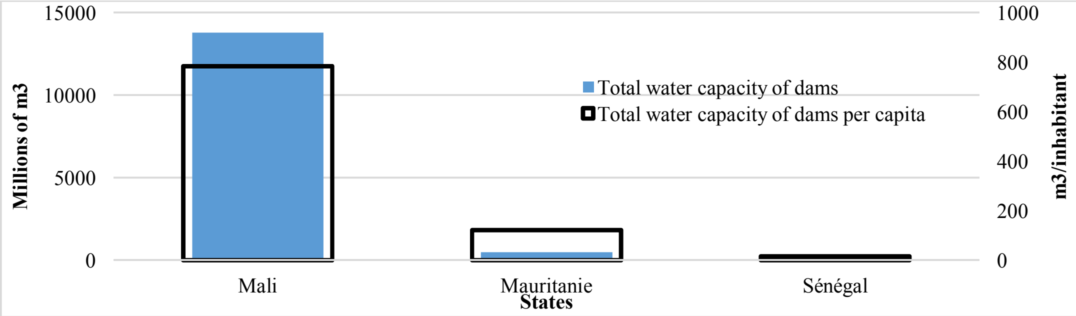

Fig. 2. Total storage capacity of dams and per person at the level of the three countries

Country	Barrage	Watercourse	Storage capacity (m³ cubic meters)	Installed Power (MW)	functions
Mali	**Manantali**	**Bafing**	**11300**	**200**	**Hydroelectricity + Regulation**
	Félou	Senegal	0 (over water)	70	hydroelectricity
	Gouina	Senegal	0 (over water)	140	hydroelectricity
	Musala	**Falémé**	**3000**	**30**	**Hydroelectricity + Regulation**
	Bindougou	**Bafing**	**2000**	**49.5**	**Hydroelectricity + Regulation**
	Boudofora	**Bakoye**	**to be determined**	**30**	**Hydroelectricity + Regulation**
	Marela	**Bakoye**	**3000**	**21**	**Hydroelectricity + Regulation**
	Badoumbé	**Bakoye**	**10000**	**70**	**Hydroelectricity + Regulation**
Guinea	**Koukoutamba**	**Bafing**	**3600**	**280**	**Hydroelectricity + Regulation**
	Boureya	**Bafing**	**5500**	**160**	**Hydroelectricity + Regulation**
	Balassa	Bafing	0 (over water)	180	hydroelectricity
Senegal	**Gourbassi**	**Falémé**	**2100**	**30**	**Hydroelectricity + Regulation**

Table 6. Dams built and dams projects in the Senegal River Basin and their storage capacity

River, doubling the storage capacity of Manantali and Diama gathered (Thiam, 2016). At the national level, Mali has the largest storage capacity (13790 million m3), followed by Mauritania (500 million), while Senegal has the lowest storage capacity (250 million). For the total capacity of dams per capita, it is estimated at 783.5 m3 per capita in Mali, 122.9 in Mauritania and only 16.52 in Senegal (Fig. 2). As for the planned storage facilities, the most important water storage capacity will come from the Malian part of the basin, with 29,300 million cubic meters against 2100 million for the Senegalese part of the basin. In the Mauritanian part of the basin, no dam project is planned (Table 6). In addition to investments in water storage infrastructure, riparian states must support national rainwater harvesting programs.

Water storage for adaptation to climate change

The impacts of climate change on water resources and developments in the Senegal River Basin include the difficulties of filling reservoirs and the resulting economic consequences, overfilling and the consequences of spills (this was the 2003 floods), the drying up of water points associated with the river, land degradation, the rapid degradation of vegetation cover, the drop in agricultural production that could lead to food insecurity, the severe degradation of high-altitude ecosystems, ecological importance (Fouta Djallon massif, source heads, loss of forest resources, loss of plant and animal biodiversity ...). Water storage (in all its forms) has a key role to play in sustainable development and adaptation to climate change. By providing abuffer, the storage of water reduces the risk of flooding by flood control and drought by supporting low flows. Thus, it offsets some of the potential negative impacts of climate change, thereby reducing people's vulnerability (McCartney and Smakhtin, 2010). Water storage can improve both water security and agricultural productivity (Mwendera and Atyosi, 2018). Each of the riparian countries, through the OMVS, has developed a climate change adaptation strategy based on the reduction of risks and vulnerabilities, in collaboration with the actors of the sector and neighboring riparian countries, and seeks to share the resources , technology and learning to coordinate a regional response. The underlying principles are to build resilience and reduce vulnerability to climate-related impacts of climate change. The strategic actions for adaptation and mitigation of climate change in the Senegal River Basin are among others (OMVS, 2016):

• The preservation of the current heritage: Manantali, Diama, Félou;

• Further development: Koukoutamba, Gourbassi, Bouréya, Balassa, Badoumbé, micor-central, etc. ;

• Close monitoring of fragile ecosystems;

• The development of irrigated agriculture;

• Building HC's capacity to deal with the effects of climate change: information management, better resource management, etc.

• Support for local development to limit emigration

Water storage for multiple uses

High intra-annual variability and multi-year droughts in the 1970s and 1980s characterized the hydrology of the Senegal River Basin, which justifies the need for considerable storage capacity to ensure reliable water supply during periods of deficient flows. . The purpose of water storage includes: water supply for domestic use, industry, livestock and irrigation, hydropower generation, flood and drought protection, fishing and aquaculture, transport, cropping and recession grazing sites, sinks for pollutants, biodiversity-based tourism, landscapes or sports activities, cultural and religious uses and sites of biological diversity (Gray and Sadoff, 2006). A major challenge in water resources planning is to ensure a harmonious integration of water supply for domestic use and water for other purposes leading to economic production, especially in rural areas. Water for domestic supply in rural areas is used for domestic purposes such as cooking, laundry, vegetable gardens, watering of reserves and small businesses (Mwendera and Atyosi, 2018). In the Senegal River Basin, water is stored for multiple purposes, including: irrigation for food production; fisheries; energy production; industrial water supply; mining; the supply of drinking water; flood management and drought mitigation; environmental services. The main areas of development associated with the storage structures in the Senegal River basin are, in order of importance, the production of hydroelectricity, irrigated agriculture, navigation and other activities such as water supply, fishing, livestock and ecological needs **(Fig. 3).** One of OMVS's strategies for the development of water infrastructures is to develop water storage infrastructures, especially large storage dams, for multi-use use, including economic and social.

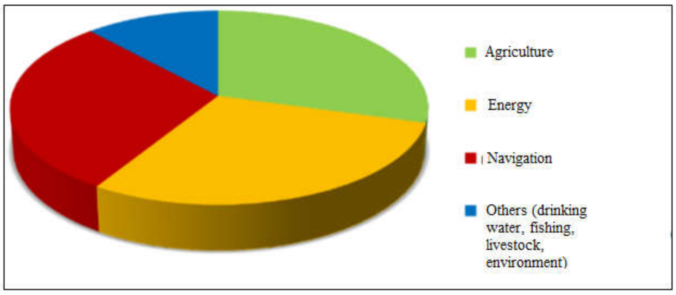

Fig. 3. Areas of water development associated with storage facilities

Hydropower

The current generation of electricity represents 16% of the basin's production capacity. However, the basin has a hydroelectric potential necessary to meet the needs of its populations. That is why, since 2012, OMVS has undertaken major hydropower dam projects to increase energy supply and totally control the water of the basin (Thiam, 2016).

Navigation

Another major objective of the commissioning of the Manantali dam is to create an uninterrupted waterway (12 months / 12), from Saint-Louis to Kayes in Mali for a total distance of 900 km. To date, there is no concrete plan for the development of navigation on the Senegal River Basin. Navigation is currently very limited in the basin, and there is a desire to expand this area. To this end, it is planned to build a navigable channel 55 m wide between the towns of Ambidédi (43 km downstream from Kayes in Mali) and Saint-Louis at the mouth of the river (OMVS 2009). . Although a non-consumptive demand, navigation still requires a minimum draft of 300 m3 / s at Bakel.

Other uses

AEP: The weight of abstractions for the EAF in the basin is low compared to the available water volumes on the river, while the rate of access to drinking water of the riparian countries of the river remains very low. To date, the surface waters of the basin are confined to supplying the growing urban population of the cities of Conakry, Bamako, Nouakchott and Dakar. Since AEP is the only priority demand on the basin, the OMVS has set the minimum conditions for the management of the catchment structures in order to guarantee the permanent availability, present and future, of the resource for domestic use. Mines: The mining resources of the river remain very little exploited limiting themselves to the mines of Mali. These weaknesses can be explained by the constraints linked to the permanent availability of water, energy and means of transport. The current water needs of the mining sector represent less than 5% of the water volumes available in the basin. The completion of the future river navigation project would propel the mining sector, which could in the long term be among the development poles of the basin.The water storage infrastructure also facilitates the watering of livestock and the preservation of ecosystems, hence the establishment of an Observatory of the Environment.

CONCLUSIONS

Water storage capacity per person is often cited as an indicator of water security and a measure of the development of large- and small-scale water infrastructure (SIWI, 2004). A well-stocked water storage infrastructure Planned and well managed is important for providing safe and secure water supply to households, agriculture and industry. Improved water storage capacity and water security are particularly needed in climatic zones characterized by low rainfall and high rainfall variability, such as Mali, Senegal and Mauritania. One of the goals of water storage in the Senegal River Basin is hydropower generation. Hydropower is a renewable energy source for which there is still significant development potential. The benefits of renewable electric power are evident not only for the economy, but also for sustainable development. The electricity supply that allows for heating, cooking and lighting is not only a great advantage for activities of daily living, but also an essential input for agriculture and a series of small-scale production activities, which are an important component of rural and urban economies. In the basin, stored water is essential to all aspects of life. It supports families and communities, but also agriculture and economic productivity. Indeed, virtually all sectors of the economy depend on water. The need for water storage to support socio-economic development in the riparian countries of the Senegal River can not be overestimated. OMVS therefore plans to invest in hydraulic infrastructure to support economic development through an infrastructure development and management strategy. While it is clear that the countries, under the OMVS, have invested a lot in the development of water storage infrastructure (Manantali, Diama, Félou), there is potential for the development of additional infrastructure in the Senegal river basin that OMVS plans to exploit in the future (dam projects of Koukoutamba, Gourbassi, Bouréya, Balassa, Badoumbé). There is therefore potentially water available in the Senegal River system that should be exploited by the construction of additional storage facilities, existing dams can not capture and control all potentially available water. It is obvious that the riparian countries of the Senegal River have the potential to increase their water storage capacity. However, since the Senegal River is cross-border, these countries need to develop additional storage taking full account of their ecological characteristics.5.

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