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ー持続可能な生態系サービスを目指してー

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-Toward Sustainable Ecosystem Services-

平成30年

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Water availability and demand under climate change and population growth in Lake Guiers, Senegal

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ABSTRACT

During the last three decades, increasing population, changing patterns of water demand, and concentration of population and economic activities in urban areas has pressurize Senegal's freshwater resources. To overcome this deficit, Senegal turned to the exploitation of Lake Guiers. It is the sole water reservoir in the country and its water is use for irrigating crops and sugar refinery, as well as a drinking water resource for urban centres. To address the challenges that climate change and population growth poses in Lake Guiers water resources, it is necessary to consider its potential impacts on different dimensions of water resources. In this study, future water availability and demand has been modelled under scenarios of climate change and population growth until 2030, based on the representative concentration pathways (RCPs) 4.5 and 8.5 by applying the Water Evaluation And Planning System model (WEAP). The results show that the pressure on Lake Guiers's water resources will increase, leading to greater competition between agriculture and municipal demand site. Decreasing inflow due to climate change will aggravate this situation. WEAP results offer basis to Lake Guiers water resources manager for an efficient long-term planning and management.

1. INTRODUCTION

In Senegal, the supply of drinking water to satisfy population needs is one of the biggest issue. To overcome deficit on water supply, Senegalese authority turned to the exploitation of the Lake Guiers. It is a shallow reservoir located on the right bank of Senegal River, between latitudes 16°23'N and 15°55'N, and longitudes 16°12'W and 16°04'W. The Lake Guiers is mainly fed by Senegal River through Taouey canal (Figure 1). Its water is used for irrigating crops (90,000 ha) and as a drinking water resource for urban centres (165,000 m3/days for a population of 5 Million inhbts).

In the last decades, the Lake Guiers basin was subject to several changes. These changes concern socio-economic factors like growth of population and increased agro-industrial farming as well as hydrological changes in the Senegal River basin and the impacts of climate change.

Despite all these emerging issues, there is limited knowledge of the Lake's resources and how it might respond to global changes. Statistics on water use and supply are sparse and incomplete. There has been little assessment of the impacts of climate change and population growth in Lake Guiers which has much relevance for the formulation of climate adaptation policies. Many studies carried out in the Lake Guiers [1]-[2] provided only qualitative information. The lack of observations and studies limits our understanding of the dynamic relationship between the resources of the Lake and climate change and demographic change. In the future, increasing water abstraction will cause problems for downstream riparian communities and ecosystems [3], not only at the local, but also the national scale. The high spatial and temporal variability of water resource availability and its uneven spatial distribution and the further stress on this resource due to population growth, means that Lake Guiers water supply is at risk [4]

Therefore, this study aims to assess water availability and demand in Lake Guiers under scenarios of climate change and population growth until 2030, based on two IPCC scenario: the representative concentration pathways (RCPs) 4.5 and 8.5. To achieve research objective, we apply the Water Evaluation And Planning System model (WEAP).

2. METHOD

2.1 Data Set: We used hydrological data (discharge), climate data (Pmm T°C Etpot), and water demand and population growth rate. For scenarios analysis we use 2 IPCC scenarios: RCP 4.5 and RCP 8.5. Data are from CORDEX (Coordinated Regional Climate Downscaling Experiment) with 50km x 50km gridded and a length period of 2002-2030; 2051-2100

2.2 Water Evaluation and Planning System (WEAP): The main program that was used is WEAP, a management

program that is focused on the optimal distribution of water supply. WEAP is developed to combine water management and watershed hydrology [5]. The structure of demand and supply sites is created. Lake Guiers was characterized by the storage capacity, the initial storage and the netto Evaporation (ET_{net}).

The demand sites each got their annual water use rate by an activity level that means the population, the number of livestock or for agro industrial activities, the expand of cultivated land in hectares.

3.3 Scenario analysis**:** Three main scenarios have been developed on the basis of the current account year 2005 and the reference period from 2006-2030. The following Table 1 shows the structure of the scenarios created in WEAP.

The first scenario assumed the climate change in two of the RCP scenarios. The second scenario in WEAP is a growth scenario including the Lake Guiers region as well as the capital Dakar. The third scenario was created to test in which time the water in the reservoir will be exploited without a refill. It is based on the climate change scenarios and the growth scenario.

Table 1 Structure of the scenario created in WEAP

Current Account (2005)			
Simulation period (2006-2030)			
1	**Climate change scenario RCP8.5 or RCP4.5**		
Change in ET_{net} following change in RCP8.5 or RCP4.5			
2	**Growth scenarios on the basis of climate change scenario RCP8.5 or RCP4.5**		
Et_{net}	Population growth Implementation of introduced projects		
3	**Water supply from reservoir, Lake Guiers**		
ETnet	Population growth	Implementation of projects	Stopped inflow from Taouey canal

3. RESULTS

3.1 Water supply

The modeled stream flow in Taouey Canal into Lake Guiers show a distinct variation throughout the year representing the influence of Senegal River. Furthermore Figure 2 illustrates the distinct increase in inflow from 2006 - 2030 in both scenario RCP 4.5 and RCP 8.5 compare to current account year. The increasing differences between the two combined scenarios are very slight.

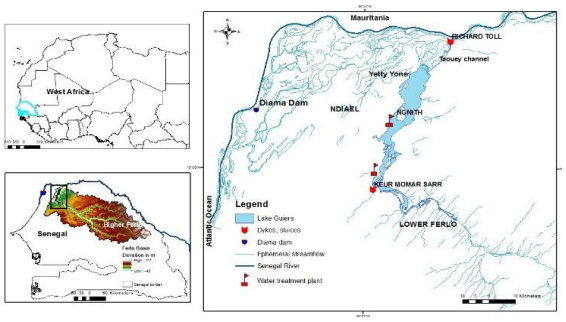

Fig. 1 Study area: Lake Guiers

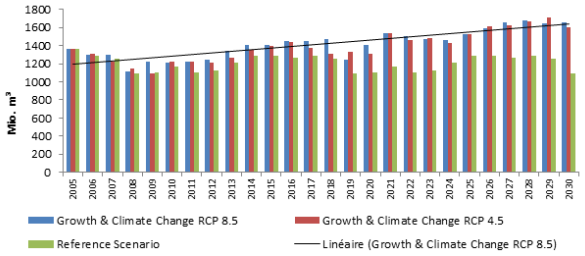

Fig. 2 Annual stream flow in Taouey Canal under RCP 8.5 and RCP 4.5 scenarios

3.2 Reservoir

It was tested, in case of a limitation of inflow (4,177,274.8 m^3/day) from the Senegal River, how long the water stored in the reservoir (655,616,099.3 m^3) will be sufficient when all projects are implemented. The water supplied by the reservoir (Figure 3) will not suffice for more than twenty months in RCP 4.5 scenario and nineteen months in RCP 8.5.

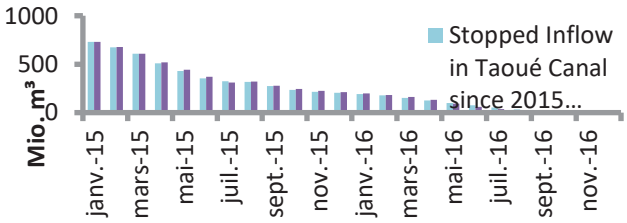

Fig. 3 Storage Volume in Lake Guiers with stopped inflow beginning in January 2015, combined scenarios of growth and climate change RCP 4.5 and RCP 8.5.

3.3 Water availability and demand

The total water demand (Figure 4) of the different demand site types is increasing throughout the study period and in all of the applied scenarios. Hereby, RCP8.5 shows the highest growth rates.

Results show that CSS (Sugar cane refinery), the biggest agro-industrial units, water demand is the highest. In 2005, it was estimate to 175 million m^3 and by 2030 the demand

will increase up to 25% in total. Furthermore, Senhuile, the second big agro-industrial units and private irrigation (others agro-industrial units) will face an increasing water demand by 2030. It was estimated that their demand will increase up to 20%.

For domestic demand the water demand in Dakar was estimate to 70,810,000 m^3 in 2005. This demand will increase up to 116,800,000 m^3 /year by 2030.

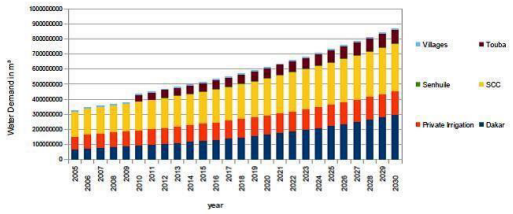

Fig. 4 Total water demand per user type in m^3

Unmet demand (Figure 5) is found in all scenarios, however, its amounts vary. Some demand sites will suffer unmet demand due to their dependency of Taouey canal which in turn depend on the inflow from Senegal River

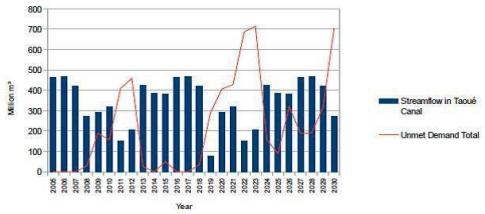

Fig. 5 Annual streamflow in Touey canal and Total Unmet demand

4. DISCUSSION

Like most of modelling tools, WEAP requires a large number of input data. Therefore, it faces uncertainties and constraints. One of the limits of the model is that it has not a quality assurance module [6]. Therefore, the challenge for a user applying WEAP model is to identify errors and to judge of the model results accuracy.

Data input uncertainties and constraints apply to both water supply and water demand data. The CORDEX data (spatial resolution 0.25°; rasta data) has been used for simulating evapotranspiration. The modelled demand might be underestimated as we don't take account to ground water data, livestock watering, industrial water demand, due to the lack of data availability.

Water availability and water supply situation could be ensured and achieved by using different management methods. Taouey canal should be adjusted in order to mitigate or anticipate unmet demand. In addition to increasing the reservoir capacities, other efficiency measurements should be applied: Adopt a basin approach, taking into account the adjacent ecosystems. Another efficiency measure is to establish water laws and allocations. This option imply water pricing and other market-based incentives to motivate further improvements in water use efficiency in agriculture dominated by private agro-industrial unit. Water evaporation mitigation is also another efficiency measure that could be used. Reducing the amount of water lost to evaporation would improve water security for Lake Guiers and lead to increased irrigation production. Substantial research and commercial testing on practical methods to reduce evaporation in a reservoir were completed recently [7] [8]. These methods use new technologies. Some of these new technologies are cost efficient solution to reduce evaporation each year and to maintain the highest quality drinking water.

5. CONCLUSION

The results show that the available amount of water in the reservoir is potentially high enough to satisfy users demand. However, the scenario analysis with WEAP reveal potential conflicts about water shortage. These shortages occur in both climate scenarios RCP 4.5 and RCP 8.5 with the decreasing of Taouey canal inflows. To ensure water security supply this research recommend to integrate the results in a DPSIR as an analyzing tools to help water resources managers to mitigate or anticipate future impacts.

REFERENCES

[1] S. Diop, S. Wade, and M. Tijani, 'Analysis of MERIS data for assessing the water quality in lake Guiers (Senegal): preliminary results', no. 1, 2008.

[2] S. Sane, 'Contrôle environnemental de la production primaire du lac de Guiers au Nord du Sénégal', 2006.

[3] P. Speth, M. Christoph, B. Deikkrüger, and M. Bollig, Impacts of global change on the hydrological cycle in West and Northwest Africa. Berlin; Heidelberg: Springer-Verlag, 127 2010.

[4] C. Faye et al. 'Lac de Guiers: Perils sur une source vitale.', Les cahiers du GREP, Dakar, p. 3,4, 2011

[5] D. Yates and J. Sieber, 'WEAP21 - A Demand-, Priority-, and Preference-Driven Water Planning Model', International Water Resources Association, vol. 30, no. 4, pp. 487-500, 2005.

[6] D. Juizo and R. Liden, 'Modeling for transboundary water resources planning and allocation', Hydrol Earth Syst Sci Discuss., vol. 5, pp. 475-509, 2008.

[7] S. Solomon et al., 'Contributions of Stratospheric Water Vapor to Decadal Changes in the Rate of Global Warming', Science, vol. 327, no. 5970, pp. 1219-1223, Mar. 2010.

[8] L. Pereira and D. C. Samuels, 'Response to Yao et al.', Am. J. Hum. Genet. vol. 85, no. 6, p. 933,