A QUANTITATIVE MODEL FOR THE MANAGEMENT OF A SAHELIAN LAKE IN THE SENEGAL BASSIN : THE LAKE OF GUIERS

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ABSTRACT

The lake of Guiers is fed by the Senegal river which is regulated by two recently operational dams. Its maximal area amounts to 300 km^2 and its water capacity to 800 millions of m^3. The users of the water are and will be numerous : irrigation, drinking water production and water adduction to Dakar through a 230 km open canal. The total annual demand and the evaporation losses will exceed the lake capacity.

A new model has been developed which calculates the inflow from the Senegal river required to ensure the water demand and to impose an important annual variation of the water level : this is important for the save keeping of the traditionnal recession-zone crops and in order to try to limit the growth of the aquatic plants and their negative direct and indirect effects. The model calculates the daily water balance of the lake, based on its evaporation (studied for 14 years), on the water demand in general and for the different types of crops and their distribution during the year. Various simulations of the water management of the lake are proposed.

INTRODUCTION

Lake Guiers belongs to the lower valley of the river Senegal (left-bank defluent). As a result of successive projects, the lake has become a large multi-purpose reservoir for irrigation and drinking water and should, in the future, supply water to the Dakar conurbation. The Figure 1 shows the area surrounding lake Guiers.

On average, the lake is 50 km long and 6 km wide, with a depth of around 2 m. Its volume fluctuates strongly throughout the year, depending of evaporation and pumping. The regional climate is typical of the

Sahel : hot and dry, with irregular rains amounting to between 250 and 300 mm per year.

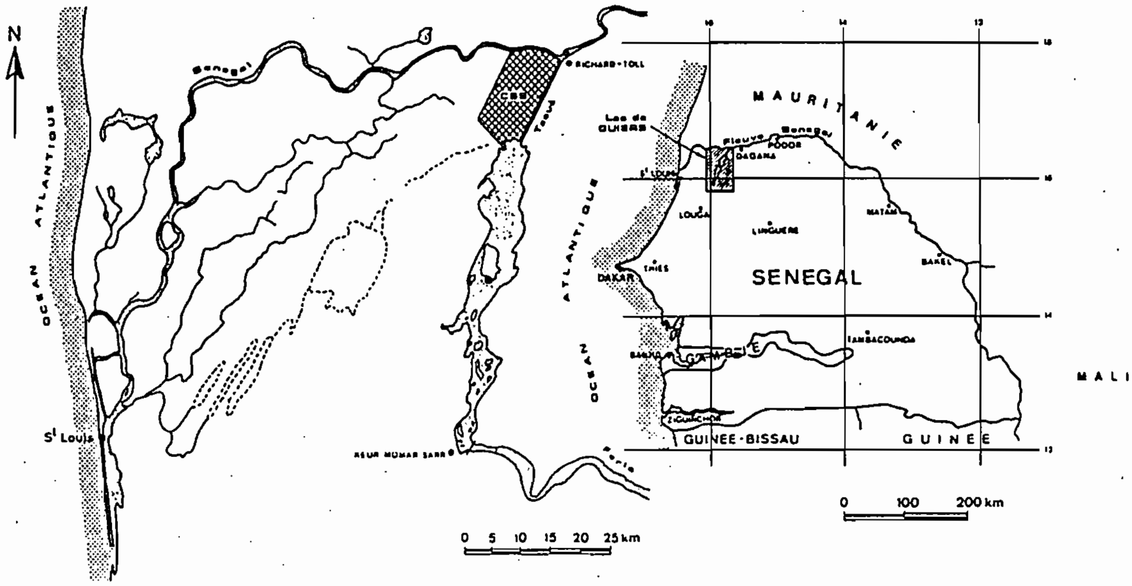
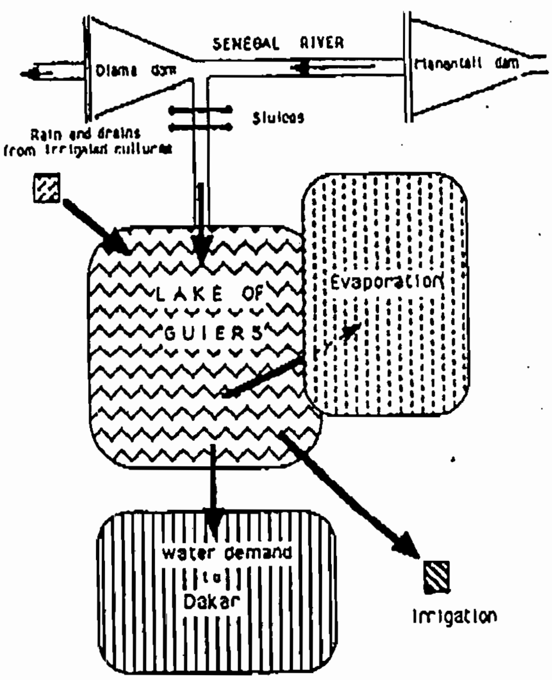


Figure 1. Location of lake Guiers in West Africa

Figure 2.



There are now two dams on the river Senegal : the Manantali dam in the upper catchment area regulates flow and the Diama dam near the mouth of the river prevents the low of salt-water upriver. Lake Guiers now has a reliable supply of water and its depth can be regulated via the straight canal connecting it with the Diama reservoir (Fig. 2).

Figure 2 is a diagram of future water demand on the lake. The two sluices on the canal between the river and the lake makes its possible both to regulate the supply of water to the lake from the river and to choose whether to irrigate the sugar cane fields from the river.

FUTURE WATER MANAGEMENT PROBLEMS

The future management of lake Guiers will be a complex task for a number important of reasons :

- there are many users with different priorities and supply requirements : irrigated crops, traditionnal low-water crops, pumping thresholds...

- the water requirement for the futur century is very large and amounts to nearly twice the lake's volume : drinking water plant, irrigated sugar-cane plantations and the canal supplying water to Dakar (2 million inhabitants).

The water management scheme involves managing the canal between the river and the lake (using sluices) taking into account the fact that sufficient water is available throughout the year in the Diama reservoir. Management priorities have yet to identified.

THE LAKE'S WATER BALANCE

The first stage was to ascertain the water balance of lake Guiers as precisely as possible in order both to analyse it and to quantify certain parameters that cannot determined directly such as evaporation (Cogels et al., 1990)

Monthly water balances were calculated over the 14-year period from 1976 to 1989. During this time, all quantifiable parameters were measured, i.e. rainfall, outflow, volumes pumped, volumes released from and into the lake. The lake's area and volume are also known, and are calculated from the water level. Evaporation, the unknown parameter of the balance, was estimated for the 168 months of the study. Figure 3 shows the monthly average taken over the 14-year period.

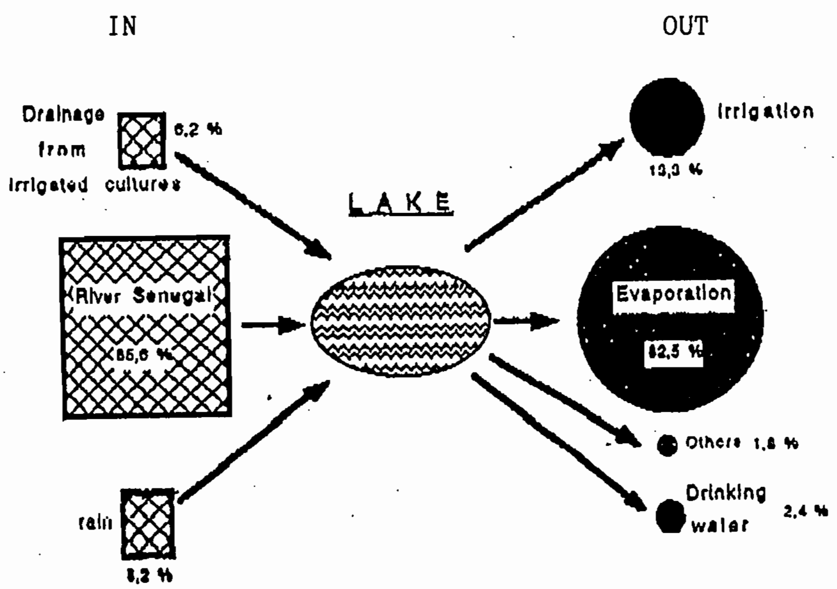


Figure 3. Mean annual water Balance of the lake (1976-1989)

Table 1 indicates the monthly evaporation of the lake. Its standard deviation *s* is low and shows that the interannual repetition of the lake's evaporation is remarquable. The interannual average approximates 2,29 meters.

Table 1 : Monthly and annual evaporation of the lake (1976/1989).

	mm/day	s (mm/day)		mm/day	s (mm/day)
Jan	5,02	1,15	Jul	5,65	0,60
Feb	5,81	1,22	Aug	5,55	0,63
Mar	6,34	1,04	Sep	5,76	0,68
Apr	7,46	0,86	Oct	7,63	0,66
May	7,91	0,81	Nov	6,22	0,91
Jun	7,20	0,67	Dec	4,86	0,79
year	**total (m)**	**mm/day**	**year**	**total (m)**	**mm/day**
1976	2,18	5,96	1983	2,58	7,06
1977	2,19	6,01	1984	2,45	6,72
1978	2,24	6,13	1985	2,23	6,11
1979	2,14	5,87	1986	2,41	6,61
1980	2,39	6,53	1987	2,28	6,24
1981	2,23	6,10	1988	2,18	5,98
1982	2,30	6,31	1989	2,31	6,33

Figure 4 indicates the mean annual evaporation of the lake on the 1976-89 period. The result is very similar with those recorded on others sahelian lakes like Tchad or Bam in Burkina (Gac, Cogels 1981/1982; Pouyaud, 1980; Roche, 1979).

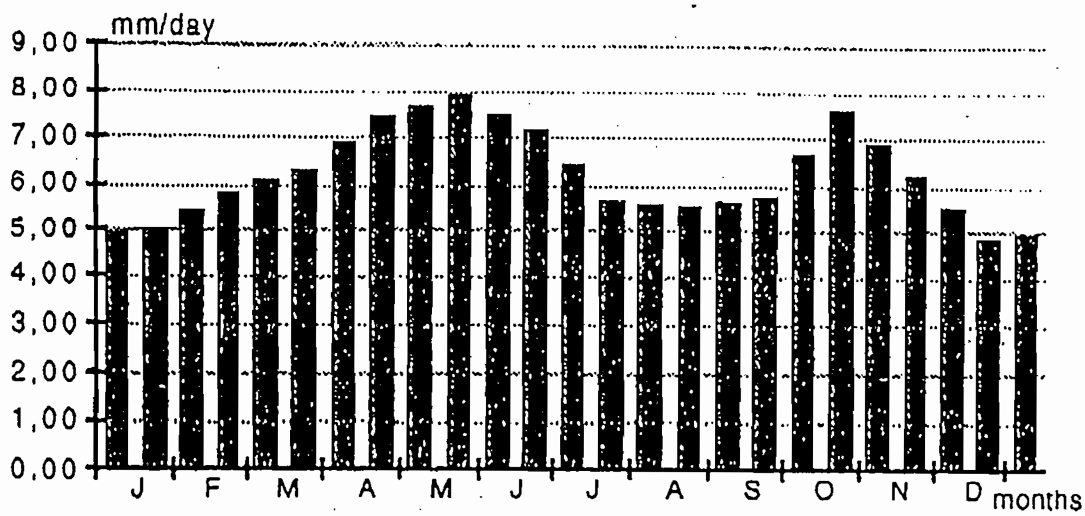


Figure 4. Mean evaporation of the lake (1976/1989)

THE WATER MANAGEMENT MODEL

An estimate of the daily variation of evaporation was made on the basis of these monthly averages for 1976/1989 (Cogels et al. 1991). Under the sahel climate, the annual evolution of the evaporation may be considered to be reccurent from year to year like all the climatic parameters involved (wind speed, air saturation deficit and incident radiation) (Riou 1975; Dacruz Evora 1990).

The theoretical model

The new model is derived from the earlier water management model for the laked presented in 1982 (Cogels, 1984) and takes into account the new conditions. It is now possible to calculate the amounts of water required from the Diama reservoir to meet the needs of users around lake Guiers, around Diama and in the lower part of the Senegal river valley. The model is in fact a forecast of the lake's water balance :

$$V = V_1 - V_2 = V_{in} - V_{out}$$

V_1 et V_2 are the volume of lake at times 1 and 2
V_{in} et V_{out} are influx and outflux

hence $$V_1 - V_2 = Q_a + Q_b + Q_c - Q_d - Q_e \qquad (1)$$

Q_a : (rainfall in mm for day n).(area of the lake S for day n)
Q_b : inflow draining from the sagar cane fields north of the lake
Q_c : inflow from the river via the Diama reservoir
Q_d : daily evaporation estimated on the basis of water balances
Q_e : total volume taken from the lake (irrigation, drinking water)

In this form, the equation allows us to calculate the variation of the lake's water level on the basis of the different influx and outflux components. It may also Written :

$$Q_c = V_2 - V_1 + Q_e - Q_a - Q_b + Q_d \qquad (2)$$

Provided the variation of the lake's water level has been decided beforehand, the equation now gives the volumes needed from the Diama reservoir in order to meet demand on the lake over a given period.

Using the model

The model is designed to be extremely flexible and will simulate any number of conditions for the purpose of managing the lake. Circumstances and alternatives are numerous, and depend on hydrological, economic and agricultural citeria including :

- limiting evaporation,
- adapting the annual or seasonnal variations of the water level to the water requirements of traditionnal low-water crops and various other users,
- managing the river lake relationship on the basis of the availability of water from the Diama reservoir.

Figure 5 shows the use of the model in a relatively simple case wich involves closing the lake-river canal at certains times : there are two filling periods. When the lake is cut off from the river, the water level depends on evaporation and the amount of water used : the model calculates the variation of the water level. During the two periods when canal between the river and the lake is opened, the model calculates the lake's water requirement as a function of the water level variation that has been decided while ensuring that user requirements are met. In this respect, the volume used for irrigation is not constant : it varies according to a theoretical estimate of demand, which in turn depends of the annual needs of the different varieties of crops.

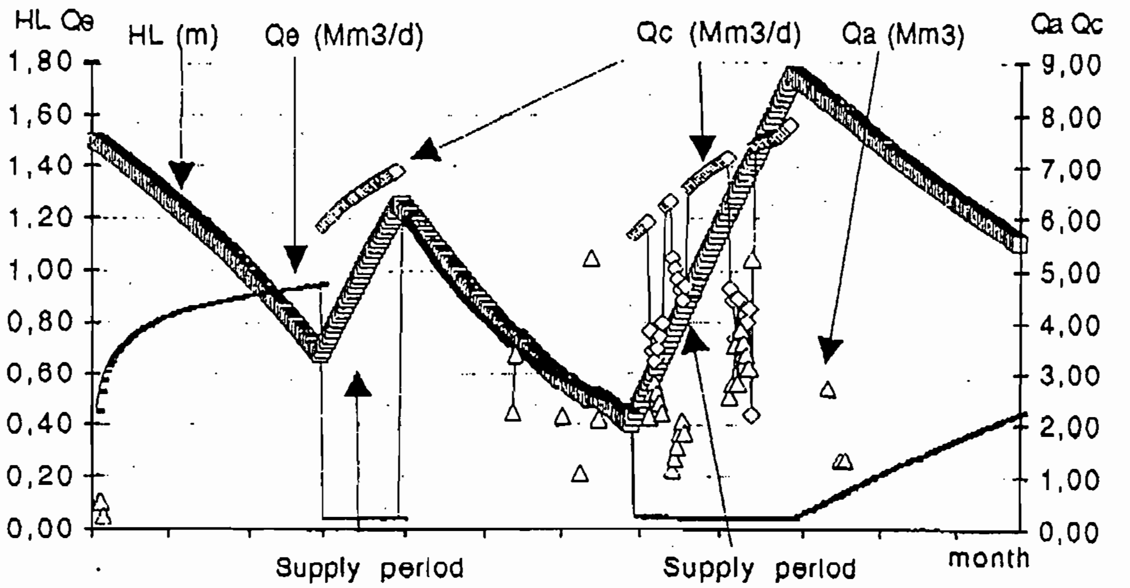


Figure 5. Annual evolution of the lake's level water and of its water requirements from Senegal river (Q_c) to assure the total theoretical needs of the users (Q_e). The mean rainfall is taken account (Qa).

CONCLUSION

The results of 14 years of study of the water balance of lake Guiers have enabled us to perfect an overall water management model based on a daily forecast of the water balance. The model has not yet to be tested under real conditions, but already enables us to simulate alternative ways of using the water and sharing it between the different users. The model is simple (approx. 1 Mb) and easy to use : the data processing hardware involved is standard and available on site. The model should contribute to the averall management of the lake-river system ; at present time, optimizing the implementation of the multi-function sluices is the main concern of the local officials.

ACKOWLEDGEMENTS

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