Communication présentée à
la 5ème Conférence Inter-Régionale sur l'Environnement et l'Eau (ENVIROWATER 2002)
EIER-ETSHER, Ouagadougou, 5-8 novembre 2002.

The quest for integrated and sustainable water management in the Senegal River Valley

P. Fraval[a 1], J-C. Bader[b], L. K. Mané[c], H. David-Benz[d], J-P Lamagat[e], O. Diop Diagne[f]

[a] *Water resources engineer & economist - International Water Management Institute (IWMI), c/o WARDA, BP 96 St-Louis, Senegal*

[b] *Hydrologist - Institut de Recherche pour le Développement (IRD), Maison des sciences de l'eau, 240 av. E. Jeambrau, 34000 Montpellier, France*

[c] *Remote sensing specialist - Société Nationale d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal et des Vallées du Fleuve Sénégal et de la Falémé (SAED), BP 74 St-Louis, Senegal*

[d] *Agricultural economist - Centre de Coopération International en Recherche Agronomique pour le Développement (CIRAD) Institut Sénégalais de Recherche Agronomique (ISRA), BP 240 St-Louis, Senegal*

[e] *Hydrologist, Institut de Recherche pour le Développement (IRD), BP 1386, Dakar Hann, Senegal*

[f] *Economist & consultant - West Africa Rice Development Association (WARDA), BP 96 St-Louis, Senegal*

Abstract

Based ex post economic analysis of water uses and on hydrological modelling in the Senegal River Valley, this paper highlights the shortcomings of unilateral approaches to water management and argues for a holistic, multi-scale analysis that simultaneously addresses productivity, profitability and sustainability and integrates stakeholders' strategies and capabilities. It suggests that the Manantali dam be managed so as to create an artificial flood of limited extent and enable traditional water uses since the level of competition they exert on more productive modern water uses is low.

Key words

Senegal River; integrated water resources management; economic analysis; hydrological modelling; sustainability; irrigated agriculture; hydropower; rural development.

Introduction

The development of the Senegal River Valley, with over 300,000 hectares of suitable land for irrigation, good agro climatic conditions, freshwater available all year long thanks to the regulation of the 11 billion m3 Manantali reservoir, should, as former Senegalese President Abdou Diouf expressed it in 1984, "*have made the dream come true for three Sahelian countries*[2] *wishing to push back beyond their frontiers the spectrum of hunger and malnutrition*"[3]. In 2002, 15 years after the erection of the Manantali and Diama dams and massive investments in irrigated agriculture to rationalize the utilization of water from the Senegal River, even though famine situations have not reappeared, the gap between what was then planned and the actual situation is wide.

Based on ex-post economic analysis of irrigated agriculture on the Senegalese bank of the floodplain and on hydrological simulations of the basin, this paper shows how the combined effect of various hydrologic and socio-economic factors makes it difficult to achieve sound integrated water resources management. It argues the case for the implementation of an artificial flood, limited in size but

---

[1] corresponding author
[2] Mali, Mauritania and Senegal, Member States of the Senegal River Basin Authority OMVS
[3] cited by Barry, 1985

delivered regularly, on a yearly basis. This allocation pattern would be an acceptable compromise between productivity, profitability and sustainability, three inseparable dimensions to assess and guide water management and allocation. It would indeed take into account locals' actual strategies, capabilities and constraints and, from the perspective of competition over water resources, would not jeopardize hydropower, expected to produce significant macroeconomic benefits, and farmer managed irrigated agriculture, also a productive use but which sustainability is not ensured.

Integrated water resources management: defining terms

The concept of "integrated water resources management" is very popular. It is *"a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."* (Global Water Partnership, 2000) This common definition implies that water is usually used by competing activities, that its "value" varies across these activities and that the benefits to the environment are in general opposed to the aggregated benefits to the society, called "social welfare". Beyond this definition, the question remains of how to practically allocate water in an integrated manner. What is the value of water across uses, across groups of users? Does it depend upon their subjective judgment or is there a standard to measure it, rank uses and allocate water accordingly, once and for all? What time scale should be considered to measure values? What does "allocate" mean when intended users might not utilize the water allocated to them? Rather than proposing a comprehensive IWRM theory, this paper just claims that water development and allocation should be simultaneously guided according to three dimensions: productivity, profitability and sustainability.

Productivity refers primarily to productive uses but is a relevant concept for some unintentional uses, such as alluvial forests that provide fuelwood in the Senegal River floodplain. It is important to distinguish between the partial productivity of one input (such as water), *it being assumed that the other inputs are available*, and the overall productivity of factors that measures the ratio between the value of output and that of inputs used in a given combination. The highest overall productivity is achieved from the optimal combination of factors. If many factors are required (credit, water, labor, fertilizers, collective organizational skills, etc…) and their availability is uncertain, it is less likely to reach it. Generally speaking, seeking a high productivity in agriculture is legitimate in Sahelian countries, where hunger and malnutrition remain a concern.

The basic notion of benefits minus costs that defines **profit** is actually relative and depends upon which group and which costs and benefits are considered. It can be farmers involved in irrigated agriculture, a sector of the economy or the entire nation. It varies in particular according to whether farmers' own labor is valued as a cost, subsidies and depreciation are accounted for in the equation.

For **sustainability**, we suggest a minimalist definition: a sustainable use of water simply lasts over time. Implicitly, it means that the resources required for this use remain available. The whole system is sustainable if they remain available for all uses. We are not only talking about natural resources (fertile soils, water) but all resources. The stock and/or flow of resources does not matter as long as it is always available.

These three concepts cannot be addressed in a binary way (sustainable / not sustainable, profitable / not profitable) and the position of the cursor might change with time and circumstances. An activity that is not considered profitable by those who directly implement it is very unlikely to be sustainable and to evolve as planned, no matter how profitable and productive it was assessed ex ante at the level of society. A new irrigation scheme supplied to Sahelian farmers with a dedicated team of extension officers during the first two years of operation and naturally rich soils will certainly be highly productive and profitable for these farmers, at least during the initial phase. The same scheme five years later, with a proportion of farmers who didn't pay the irrigation fee (without being sanctioned), impoverished soils not enough supplemented by chemical fertilizers rendered more expensive by the removal of subsidies is not as profitable and productive as it used to be and the reasons to keep it going (that is to ensure its sustainability) are weaker than before. This example, not that hypothetical, illustrates the interdependence between the concepts presented above.

The case of the Senegal River Valley

The hydrological pattern of the Senegal River and the dams

The Senegal River is the second largest perennial water course in the Sahel and in West Africa. Virtually all the water flow is due to a 4 months rainy season that occurs in the green upper basin (figure 1), some 1.500 km away from the mouth of the River. This results in the hydrological pattern represented by the plain line in figure 2, characterized by a very high seasonal but also interannual variability. The natural discharge of the river is very low most of the year (minimum average monthly discharge of 9 m3/s in May) except for a peak during the rainy season (maximum average monthly discharge of 3,320 m3/s in September) when a natural flood occurs that inundates the depressions of the very flat *floodplain* between Matam and Dagana during a few weeks or months. This does not occur in the *delta*, which is protected from floods by general dykes. As a result, *all flood related water uses are found only in the floodplain*. On average, the Bafing, where the Manantali dam was erected in 1987 brings 40 to 60% of the annual flow, the rest being supplied by the uncontrolled tributaries (Falémé and Bakoye). The Manantali dam can be operated so as to retain water or release more than the natural flow. The Diama dam, constructed at the same period in the delta prevents tidal water to flow upstream into the river bed. Yearly rainfall between Matam and Saint-Louis is very low (below 500 mm) and erratic, which does not allow regular and secured rain fed agriculture.

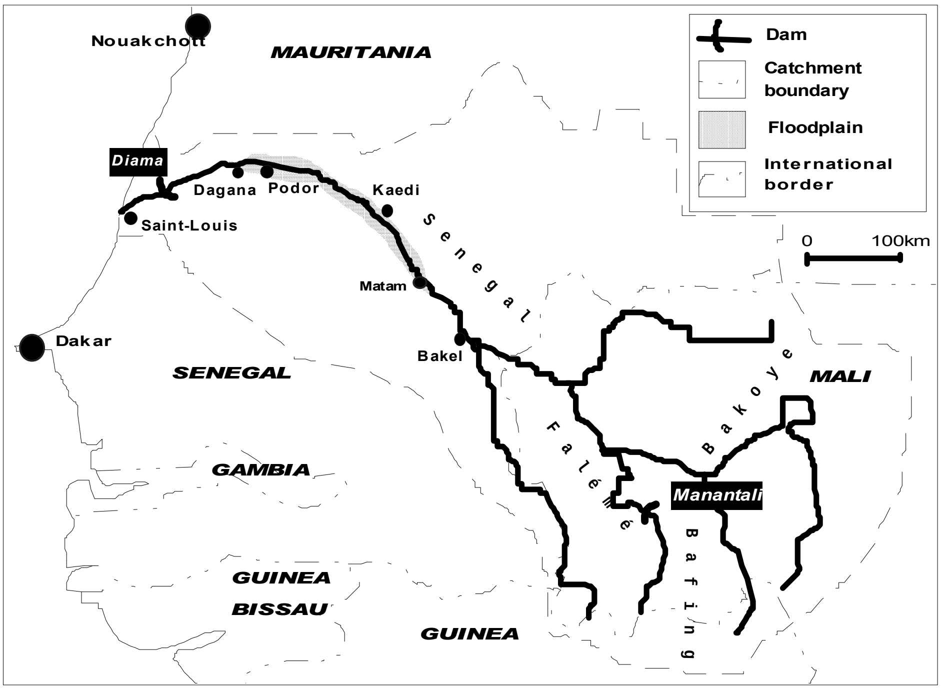


Figure 1: map of the Senegal River Basin

Description of water uses

A variety of water uses are found on either side of the Valley (Mauritania in the north and Senegal in the south). Some are traditional and pre-existed the infrastructures. Modern ones were introduced as part of the overall planning process of water resources development. Mali has no direct economic interest in downstream uses.

- <u>pump based irrigated agriculture</u>: over 125,000 ha (40,000 in Mauritania and 85,000 in Senegal) have been developed on both banks of the valley, starting from almost zero in the sixties. The area is composed predominantly of smallholder village based schemes of less than 50 ha, particularly in the floodplain. A large majority of schemes were constructed or rehabilitated with donations from international donors. Investment costs usually range between US$ 1,500 and US$ 6,500 per hectare developed. Rice is the main crop and is grown almost only during the rainy season, but cultivation of vegetables (onion and tomato) is increasing during the dry season. Rice yields are fairly high on average (4 to 5 tons/ha) but very variable among farmers. The current cropping intensity (CI)[4] on both banks is around 60%. In Senegal and to a lesser extent in Mauritania, the management of schemes has been transferred to farmers organizations during the 90's.

- domestic water supply: in addition to local villages, some water is supplied to Dakar and Nouakchott, respectively the capital cities of Senegal and Mauritania for domestic purposes.
- flood recession agriculture: in the clay depressions of the floodplain, sorghum and other crops have been extensively grown for centuries. This production system is highly irregular, because dependent on the extent and duration of the annual flood: between 1950 to 2000, it has covered from less than 20,000 to over 300,000 ha in the entire floodplain ! Sorghum and the other crops grow exclusively on the residual moisture brought by the flood (which must therefore last 25 days minimum). The average yield is 600 kg/hectare (Mané and Fraval, 2001). This is by nature a profitable use for farmers since they don't use any fertilizers: whatever is harvested is a profit.
- livestock breeding: the flood provides pasture during the dry season for the livestock that stays permanently in the floodplain.
- hydropower: in 2002, hydropower production will start at Manantali. *The objective of OMVS is to generate at least 800 GWh / year on average* to partly supply the capital and major towns of the three member States. Hydropower is the only use that makes it easy to recover part of the capital and running costs faced by OMVS, by selling power to national electricity companies. The contribution to national electricity consumption will be significant and lead to reduced oil imports, with a positive macroeconomic impact. Hydropower will primarily benefit urban dwellers. Because it is starting, the Manantali dam has not yet been managed for hydropower.
- environmental uses: in addition to the Djoudj and Diawling, two large bird sanctuaries located on either bank of the Delta, whose freshwater needs are very low, fishing, forest regeneration, groundwater recharge are environmental positive externalities of the flood with a direct influence on floodplain residents' livelihoods. Quantifying the benefits and the water demand of such uses is virtually impossible.
- commercial navigation on the Senegal River is so far a "non existent" use, although frequent until a century ago, and supposed to bring major benefits in initial economic assessments. It still requires high investments for infrastructure and private operators ready to engage in fluvial transport. This use, supported by the landlocked Mali, is currently highly hypothetical. This is why it is not considered any further in this paper.

It must be emphasized that there is no clear frontier between water users' groups. **A large majority of households in the floodplain are simultaneously involved in irrigation and recession agriculture** (Ministry of Agriculture of Senegal, 2000).

Water supply and demand

The figure 2 represents the water demand for the existing uses and the supply, represented by the discharge measured at Bakel over the 1990-2000 period, during which Manantali has been operational.

4 ratio between the area cultivated each year and the area developed considered functional. Two full agricultural seasons corresponds to a CI of 200%

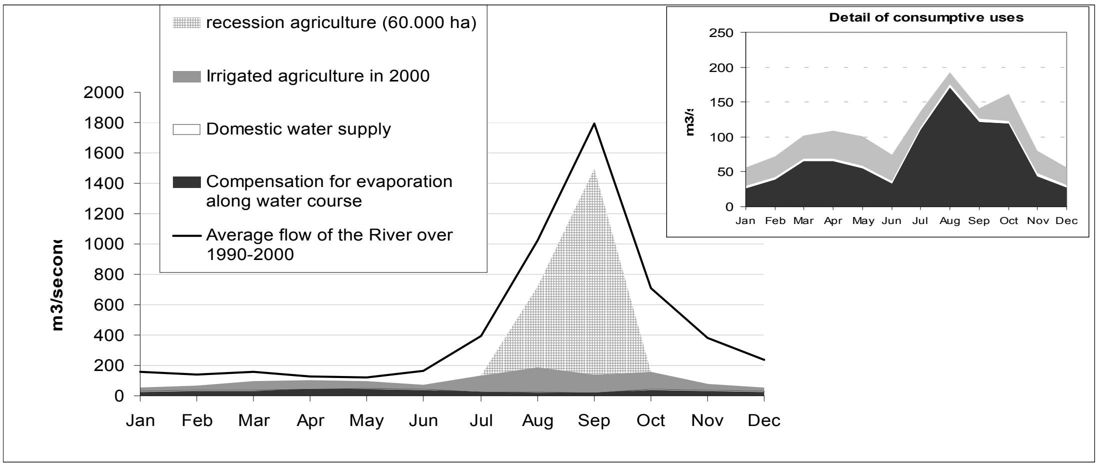


Figure 2: water demand and supply in the Senegal River Valley, month by month

Recession agriculture, a non consumptive use, punctually requires a lot of water: 4.5 billion m3 (20 to 30% of the annual average flow of the river) over a 40 days period to enable the cultivation of 50,000 ha, brought partly by Manantali, partly by the uncontrolled tributaries. Irrigated agriculture is the largest consumptive use but its demand has been stagnating over the last 7 years due to the low cropping intensity. However, during the hot and dry months of April and May, the situation is tight if we compensate for evaporation in the river bed (an option OMVS is considering in order to raise the water level to reduce pumping costs). Including evaporation into the demand would increase it by 50 to 60% for these dry months. The only way to cope with more irrigation in the dry season is to release water from Manantali. With less than 5 m3/s, the withdrawal for cities is and will remain small and easy to fulfill in the future. Hydropower does not consume any water. Navigation requires a continuous discharge to raise the overall level of the river: depending upon the size of barges, this discharge varies between 100 m3/s and 360 m3/s (SCP et al, 2000).

A long history of water resources planning

Valuable resources awaiting development

The objective of developing the abundant water and land resources in the Senegal River Valley started in the years 1920 and has been carried by OMVS since its creation in 1972. Until the late eighties, studying *"the optimal rate for irrigation development and the constraints to reduce to the minimum the transition period during which water should be released from the (future) Manantali reservoir to allow recession agriculture*" (OMVS, 1980) was on OMVS agenda together with hydropower generation and navigation although no resources were yet available to construct the required investments. In the years 1990, things evolved: while the "*development of a diversified and intensified irrigated agriculture in the valley with a targeted cropping intensity of 160% (including 60% in the dry season)"* is still a major target (although the initial objective of 375,000 hectares developed has been revised), OMVS considers *"reservoir releases that favour floods and the associated uses and preserves the ecological equilibrium in the valley"* (OMVS, 2000). Traditional water uses have now gained acceptance, at least qualitatively.

Actual vs. planned situations: the divergence

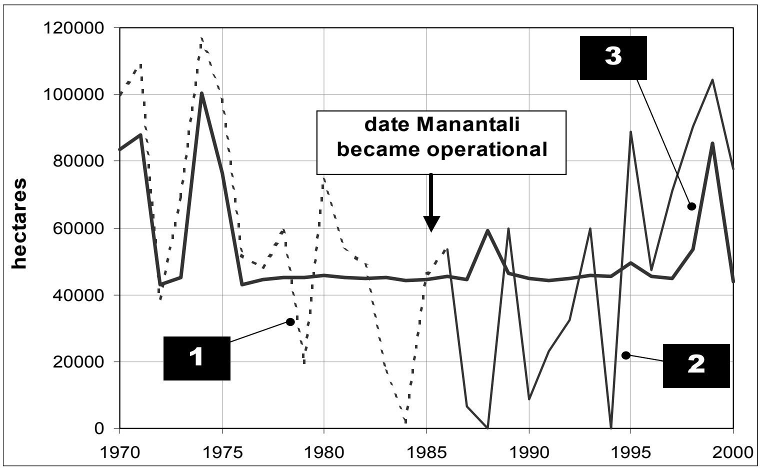
OMVS at basin level, Senegal and Mauritania at national level, have gone through the exercise of water and rural development planning, including economic ex ante analysis. *"A high level of uncertainty affects numerous factors that have a direct impact on the future effects of the project, whether physical, technological, sociological and economic"* wrote Inglès in 1995 on reviewing past OMVS planning documents. This comment also applies to the PDRG (GERSAR et al, 1991), pillar of rural development planning on the Left Bank of the Senegal River Valley. Over the 1990 decade, the only achieved and even exceeded prediction was investments in irrigation: in Matam and Podor, international donors spent US$ 88.5 millions on the construction or rehabilitation of some 11,000 hectares of public schemes, against US$ 82.5 millions planned… but for an expected area of 18,000 hectares. The actual cropping intensity is 3 times lower than planned, and so are the gross benefits derived from irrigated agriculture and its contribution to food needs. This doesn't mean that planning is useless ; instead less ambitious but more achievable objectives should be targeted, even if it reduces the overall internal rate of return.

Competition between uses and water management options

Competition between water uses concerns water and farmers' labour allocation.

Hydropower vs. recession agriculture and other flood related uses

In the short run, the only real competition over water is between hydropower and the uses associated with the flood, including recession agriculture, which water demand is well characterized. Maximizing hydropower would require keep a relatively high water table in the reservoir, which is not compatible with releasing a lot of water in the middle of the rainy season, when the reservoir is refilling. This competition issue was long argued outside a sound scientific framework. Tools are now available to optimize in a dynamic, statistical and comprehensive way water releases from the reservoir so as to obtain a predetermined hydrograph[5] at Bakel that provides suitable conditions for the cultivation of a given area under recession agriculture while predicting the resulting hydropower production (IRD, 2001). A set of simulations of the reservoir management over the driest period of last century (1970-2000) has been carried out using the Simulsen program designed by IRD (IRD, 2001). The objective was to see, in case the dam had operational at that time, what area under recession agriculture could have been **guaranteed each year** by adequate releases while reaching the OMVS hydropower target of 800 GWh per year on average. For this simulation, all other water current demands have been considered, except navigation. Results show that it could have been possible to cultivate at least 45.000 hectares each of the 30 years (and 52,500 hectares on average) while generating on average 96% of the hydropower minimum threshold. There is thus no competition between recession agriculture and hydropower generation in the short and medium term, as long as we don't try to maximize the latter. Moreover, such a management pattern would have dramatically reduced the irregularity of the inundation and associated uses, as shown in figure 3.



1 *is a simulated approximation of the* ***real situation*** *under natural flow conditions that prevailed before the dam was erected (1970-1986)*

2 *represents the* ***real situation*** *after the Manantali dam was erected (1970-2000)*

3 *represents a* ***simulated situation*** *if the dam had been operational from 1970 on and managed with an objective of 45.000 ha cultivated each year. (1970-2000)*

Figure 3: area under recession agriculture on both banks of the River under various scenarios

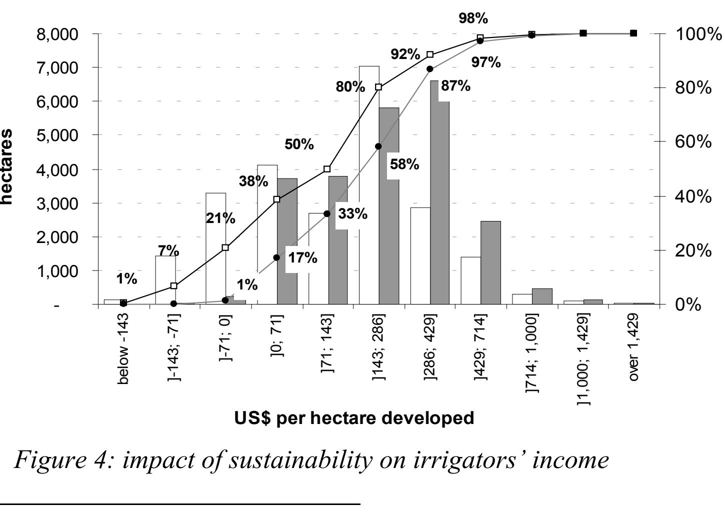
Recession vs. irrigated agriculture

For a total production cost of US$ 450 per hectare that includes pumps renewal and scheme maintenance, *provided best agricultural practices are followed*, even with a single cropping season, farmers could get 7.5 tonnes/ha of paddy and a net income of US$ 470 per hectare[6] (Haefele et al, 2000). These are impressive figures compared with the modest yield of recession sorghum. At first sight, it seems surprising that local people in the floodplain did not enthusiastically give up recession agriculture for irrigated agriculture. This would also have brought benefits to all the local economy

[5] the hydrograph represents the flow at a certain point of the river as a function of time
[6] this is composed of the return to family labor and the net profit to farmers

through induced value added (maintenance, credit, inputs, services suppliers) and to the national economies through an increased hydropower production. It is misleading to compare production systems (yield, income, resource use, production costs) on a per hectare basis potential and one needs to look at actual practices. The reason for the apparently reversible wide scale adoption of irrigated agriculture by floodplain's residents is that they are risk adverse. They will preferably engage in activities that are little labor and inputs intensive, non risky and that guarantee a minimum output to feed their family, rather than in risky activities with high production and transaction costs, even though they are more productive and profitable on paper. And this is more or less what characterizes irrigated rice in numerous schemes of the Senegal River floodplain. Subsidies on inputs have been lifted, public extension services have shrunk and not been replaced by "the private sector", credit is not easily available, the suppression of trade barriers has eased imports of Asian rice that makes it difficult for some to market their paddy, the social hierarchy of the local ethnic group has adverse effects on global efficiency in the fields (Diemer and van der Laan, 1987). The fortuitous but actual conjunction of all these factors acts as a disincentive for many irrigating farmers, hence the low cropping intensity and the low rate of cultivation during the dry season. Irrigation by itself is not a problem: during drought years, smallholder village based schemes were extremely popular and productive, but the circumstances were different and even now, some farmers who specialized in irrigation make substantial profits but they are few.

Unlike recession or rain-fed fields, irrigated plots not only cost a lot in investment but if the scheme is too degraded, it permanently loses its ability to produce, unless it is rehabilitated. *Sustainability is therefore a vital issue for irrigated agriculture*. It implies that schemes remain functional over time through timely replacement of pumps and other devices, and sufficient maintenance of canals, drains… In theory, the origin of resources does not matter as long as they are available. But now, because of State budget restrictions, farmers are expected to bear the cost of sustainability. A crucial question is: if they did so, what income would be left to remunerate household labor and for profit, *under the prevailing conditions of costs, efficiency, yield, cropping intensity* ? In other words what would be the *sustainable household income* (SHI) as opposed to the *non sustainable household income* (NSHI) represented by the average situation found today in the floodplain ? To shed light on this question, an economic model has been designed and applied to the 685 non abandoned irrigation schemes in the Matam and Podor departments covering some 23,000 hectares developed[7] over the 1998-2000 period. Data on cultivated and harvested areas for each crop, each season and each scheme extracted from SAED's database was combined with results from socio-economic surveys of irrigated agriculture (SAED, 1999; Huat and David-Benz, 2000; David-Benz and Bâ, 2000) that give actual figures on yields, production costs for the various crops - and on a study on maintenance costs (BRL, 2000) that enables to reconstitute the *sustainable cost of irrigation* for each scheme, based on its characteristics (location, type, cropping intensity…).



The household income derived from irrigated agriculture ***per hectare developed and per year*** *has been computed for each scheme, both in the sustainable and non sustainable situations, been estimated. The entire area developed is classified based on that criteria.*

number of hectares within HI category (sustainable)

number of hectares within HI category (non sustainable)

The left scale gives the cumulative percentage

Figure 4: impact of sustainability on irrigators' income

[7] the sample is composed of 289 small private schemes covering 24% of the total area, 12 large schemes covering 28% of the area and 384 community-based schemes covering 48% of the area.

After the model, in the sustainable situation, the HI would be negative for 21% of the area developed (and 31% of schemes), which means that the "average farmer" on those schemes would cultivate at a loss. In the current non sustainable situation, in 99% of the schemes, the HI would be positive. The average SHI per hectare developed is US$ 163, that is 36% less than the NSHI. From another angle, shifting to the sustainable situation would reduce the contribution of irrigated agriculture incomes to cereals' requirements of irrigators' households (Sourisseau, 2000) from 75% to 49% in Podor, 57% to 27% in Matam. Aware of this situation, the Senegalese State has just set up collective maintenance funds (*restricted however to public schemes, 75% of the area*). However, the State's planned contribution (SAED, 2001) for the Matam and Podor departments is only half of the sum of what farmers save currently and both added represent only half of the US$ 1.73 millions required in cruising speed. These worrying figures are explained by the low cropping intensity that automatically raises the share of maintenance and renewal costs (fixed costs) in the total production cost. Complementary to this strictly financial analysis, a recent survey of 20 community based irrigation schemes highlights the rapid degradation of schemes and the passivity of farmers' organizations to prevent it, both in terms of repairs and financial organization (Larbaigt, 2001). Since farmers will not drastically improve their practices (cropping intensity, efficiency) nor accept that the irrigation fee more than doubles, the sustainability of irrigated agriculture based strictly on farmers resources is not insured.

The competition between both production systems with regards to labor allocation and decision process, often noted by anthropologists is confirmed by a statistical analysis: over the last 25 years, the area flooded in year N (which is correlated with the sorghum produced in March of year N+1) has a significant negative influence on the cropping intensity for cereals in irrigation schemes for the rainy season of year N+1. It is thus reasonable to say that a large number of farmers will plant recession sorghum if a good flood enables it.

Why favor the artificial flood

Hydropower and irrigated agriculture[8] are the only ways for OMVS to at least partly recover its investments. There is no point obtaining anything from other activities that benefit from the flood, that is indirectly from the reservoir management: recession agriculture, fishing, cattle. It is therefore tempting for OMVS to manage the dam so as to avoid the artificial flood, allowing it only once in a while for environmental purposes. Would it be a good solution? Yes from the point of view of cost recovery and profitability at national and supranational level. No because the constraints that affect irrigated agriculture are out of reach of decision makers of all levels, and lifting only one (by preventing recession agriculture) would perhaps result in a strange and certainly not optimal situation where the two major agricultural activities present in the floodplain would decline: irrigated agriculture by lack of resources devoted to maintenance and recession agriculture by lack of water. Such a scenario would probably accelerate emigration, whereas one of the objectives of PDRG was to reverse it (GERSAR et al, 1991). Furthermore, if the participatory dimension of integrated water resources management (GWP, 2000) is not here just to look nice, we can hardly imagine options that would be opposed to their direct intended beneficiaries.

Create an artificial flood of limited extent to enable recession agriculture would be seen by some as a step backward. They would be wrong. *Without being the ultimate solution*, it appears a reasonable strategy that OMVS should consider seriously, now that tools are available to implement it. Past agricultural research has shown that with a US$ 35 per hectare urea application (more than ten times less than what farmers currently spend for irrigated agriculture), sorghum yield could reach 1,200 to 1,500 kg per hectare in farmers' conditions using local varieties (Mané and Fraval, 2000), which, even with a small size flood, would bring about 90 kg of cereals per person for the Matam and Podor population each year, and probably the same on the Mauritanian bank. Widespread intensification of recession agriculture is more likely to succeed if the inundation occurs regularly, ideally each year,

[8] to a lesser extent given the low rate of recovery of the per cultivated hectare OMVS tax.

although the hydrological risk cannot be reduced to zero and there might be a succession of dry years that don't make it possible. So far, recession agriculture has been conducted traditionally without any inputs, but the low production cost, combined with the "risk" that the financial flow toward irrigation dries up, make it worth trying. Favoring recession agriculture would certainly divert some farmers from irrigated but not those who really are market oriented. We should therefore consider irrigation (both rice and market oriented vegetables) and recession agriculture as complementary in the floodplain, which, as far as the Senegalese side is concerned, still has a negative cereals' balance.

Conclusion

A new ex ante economic analysis is currently being conducted by OMVS. Its objective, as hydropower is about to begin, is to select water management scenarios for the future. The selection criteria are hydraulic - how to satisfy future demands - and, in a second phase, economic - what is the overall internal rate of return of the acceptable hydraulic scenarios. Whereas a realistic economic analysis should not ignore the constraints faced by irrigated agriculture (in particular by computing a reasonable cropping intensity), we can fear that, as usual, "per hectare figures" that describe potential performances will be extrapolated, thereby sweeping out of the analysis all these constraints and creating a bias in favor of irrigated agriculture. There should be no confusion between pessimism and realism: since the management transfer of irrigation schemes, there are very few incentives left to shape the behaviors of thousands "responsible" farmers towards a productive, sustainable and profitable agriculture. These are in sole command. This does not mean that it will never be the case in the future. As in the past, irrigation in the valley, a costly but fragile common heritage, will continue relying on outside resources for some time. A tricky but essential mission for decision makers will be to credibly inform irrigating farmers that from now on, breaking with past habits, they will gradually reduce these resources and that farmers will have to count more and more on their own capacities.

We also must highlight the limits of the approach that would seek the maximization of the society's overall economic benefits. Even if the loss in hydropower from favoring the flood was much higher than the benefits derived from the flood itself, this would not justify the policy of hydropower maximization accompanied by the compensation of losers: how to identify and compensate tens of thousands people scattered along the river? Moreover, valuing hydropower benefits is an awkward task: the uncertainty attached to the flow of the river and the fact that power cannot be stored would recommend that some of the existing electricity plants that supply the three countries be kept in working order, even though in an average situation, they could be permanently stopped; this involves maintenance costs (this time for power stations) that must be accounted for in the equation. The temptation to unilaterally favor hydropower is high for OMVS. Donors, although they have linked their financial support to the energy project to an environment friendly water management, are more than happy to see OMVS at last generate its own economic resources and could well not be very fussy in the future.

By managing the Manantali dam so as to create a regular flood of medium size, OMVS would not solve all the water management problems in the Senegal River Valley. It would nevertheless give the opportunity to tens of thousands of farmers to produce their cereals at a low cost without affecting hydropower production, as long as the objective is to reach a threshold and not maximization. It could limit the potential for increasing irrigated agriculture during the dry season, but the current rate of utilization is so low, especially for rice, largest "per hectare" water consuming crop, that tensions over the resource will not arise right away. Moreover, if average hydrologic years come back (after the drought of 1970-1990), part of the hydropower will be produced during the dry season, which should contribute to release the constraint.

This multidisciplinary research, far from revealing the "optimal" water allocation in the Senegal River Valley, claims that there are only satisfactory allocations that are flexible enough and simultaneously address productivity, profitability, and sustainability in a pragmatic manner, taking into account capabilities and strategies of all stakeholders. It also shows that we cannot avoid an analysis of the past to make achievable plans for the future.

Bibliography

Barry, B. 1985. Le royaume du Waalo. Le Sénégal avant la conquête (Postface). Karthala. Paris.

BRL Ingénierie, 2000. Etude pour la mise en place de fonds de maintenance des aménagements hydroagricoles dans la vallée du fleuve Sénégal. Phase 3 – Rapport final : dossier d'instruction du fonds. Tome 2 : annexe coûts (édition provisoire).

David-Benz, H; Ba, D, 2000, L'oignon dans la vallée du fleuve Sénégal: une filière en emergence. In : Legoupil JC, Dancette C, Godon P, Maïga IM et Ndiaye KM ed. Pour un développement durable de l'agriculture irriguée dans la zone soudano-sahélienne. PSI/WECARD-CORAF, 2000 : 188-213.

Diemer, G. ; van der Laan, E. 1987. L'irrigation au Sahel. Karthala CTA.

GERSAR/CACG, Euroconsult, Sir Alexander Gibb, SONED-AFRIQUE, 1991. Plan directeur de développement intégré pour la rive gauche de la Vallée du Fleuve Sénégal. République du Sénégal, avril 1991.

Global Water Partnership, 2000. Integrated water resources management. TAC Background paper n°4. Technical Advisory Committee.

Haefele, S.M.; Johnson, D.E., Diallo, S., Wopereis, M.C.S., Janin, I. 2000. Improved soil fertility and weed management is profitable for irrigated rice farmers in Sahelian West Africa. Field Crop Research 66 (2000) - 101-113.

Huat, J ; David-Benz, H, 2000. La tomate d'industrie au Sénégal : performances de la production et enjeux pour la filière. In : Legoupil JC, Dancette C, Godon P, Maïga IM et Ndiaye KM ed. Pour un développement durable de l'agriculture irriguée dans la zone soudano-sahélienne. PSI/WECARD-CORAF, 2000 : 167-187.

Inglès, J. 1995. la trajectoire de l'OMVS au travers de la succession des logiques de développement du fleuve Sénégal: quel schéma d'évolution pour une organisation institutionnelle de gestion d'un hydrosystème dans les pays en voie de développement ». Unpublished internal ORSTOM report.

Institut de Recherche pour le Développement (IRD), 2001. Programme d'Optimisation de la Gestion des Réservoirs de l'OMVS. Phase 3 tome 1 : crue artificielle et cultures de décrue. Tome 2 : Manuel de gestion du barrage de Manantali.

Larbaigt, F. 2001. La gestion de la maintenance dans les périmètres irrigués villageois de la Moyenne Vallée du Fleuve Sénégal. MSc thesis. ENGEES, IWMI, WARDA.

Mané, L.K.; Fraval, P. 2001. Suivi par télédétection des cultures de décrue dans la Vallée du Fleuve Sénégal en saison froide 2000/2001. SAED-IWMI-WARDA report.

Organisation pour la Mise en Valeur du Fleuve Sénégal. 1980. Etude socio-économique du bassin du fleuve Sénégal – rapport spécial – Esquisse du plan directeur des périmètres de première génération (horizon 1990). OMVS, 1980.

Organisation pour la Mise en Valeur du Fleuve Sénégal. 2000. Programme d'optimisation de la gestion des réservoirs. Termes de référence de l'analyse coûts-bénéfices OMVS, 2000.

République du Sénégal, Ministère de l'Agriculture et de l'Elevage, 2000. Recensement national de l'agriculture 1998-99. FAO, September 2000.

SAED, 1999. Analyse technico-socio-économique sur les exploitations agricoles de la vallée, résultats d'enquêtes auprès d'un échantillon d'exploitants agricoles dans la vallée du fleuve Sénégal 1993-1996

SAED, 2001. Mise en place de fonds de maintenance des aménagements hydroagricoles dans la vallée du fleuve Sénégal – Protocole d'accord entre les représentants de l'Etat et des usagers. SAED official document.

SCP, C&B, Senagrosol, 2000. Programme d'optimisation de la gestion des réservoirs. Volet analyse coûts-bénéfices – simulation des scénarios dossier D besoins de la navigation. OMVS, octobre 2000.

Sourisseau, J-M. 2000. Les stratégies de diversification des revenus sur les grands aménagements hydro-agricoles sahéliens. Les cas de l'Office du Niger et du delta du fleuve Sénégal. PhD thesis. Paris X University.