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

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Abstract

Ex-post economic assessment of water uses found in the Senegal River Valley and hydrological modelling of the operation of the Manantali reservoir that partly regulates river flows are used to compare those water uses and to discuss water allocation from the dam. Through a multicriteria analysis, the paper explores in particular the level of competition between on the one hand irrigation and hydropower, modern water uses that consume little water and on the other hand traditional recession agriculture that requires the massive release of water from the Manantali reservoir operated by the OMVS (River Basin Organisation).

The analysis is based on the actual performance of production systems, which significantly differs from planned ones. It examines their costs, benefits and constraints for various categories of stakeholders, in particular the three nations composing OMVS and the floodplain residents. The paper shows that it is possible to provide appropriate hydrological conditions for recession agriculture to occur every year without jeopardizing the historical hydropower generation target set by OMVS but that maximising hydropower generation (tempting in times of high oil prices) would definitely kill the flood. . It also reveals that recession agriculture, in spite of its low land and water productivity, suits to a large extent local farmersô constraints, whereas irrigated agriculture is faced with sustainability problems due to the difficulty to get farmers to save money for maintenance and renewal of equipment.

Through this case study, the paper argues for a multi-scale analysis that simultaneously addresses productivity, profitability and sustainability and accounts for stakeholdersô actual strategies, capabilities and constraints. Such analysis will hardly give the ultimate solution but it will at least rule out some that are seducing but the feasibility of which is jeopardized by the lessons from the past.

The research was conducted by IWMI, with financial support of the French government. It uses tools and data some of which were developed by French Government funded research-development programs: ñProgramme dôOptimisation de la Gestion des Reservoirsò (POGR), implemented by IRD for OMVS and the Senegalese component of the ñPôle Système Irriguésò (PSI) implemented by IRD, ISRA, CIRAD, WARDA and SAED.

Key words

Senegal River; integrated water resources management; water allocation; economic analysis; hydrological modelling; sustainability; irrigated agriculture; recession agriculture; hydropower; OMVS.

Introduction

The development of the Senegal River Valley, with over 350,000 hectares of suitable land for irrigation, good agro climatic conditions, freshwater available all year long thanks to the construction of the Manantali and Diama dams, should, as former Senegalese President Abdou Diouf expressed in

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1984, ñ*have made the dream come true for three Sahelian countries*[2] *wishing to push back beyond their frontiers the spectre of hunger and malnutrition*ò[3]. Between that moment and 2004, two dams were erected to regulate the uneven flow from the upper basin and to prevent sea water intrusions into the flat floodplain; significant investments were made in irrigated agriculture and dykes were constructed to rationalize the utilization of the water in the Senegal River. Nonetheless, even though situations of famine have not reoccurred, the gap between the planned benefits and the current situation is wide. Water resources were progressively developed and irrigated agriculture and hydropower have become established and coexist now with recession agriculture, a traditional production system found in the floodplain, which requires flooding to occur to maintain it and which, as planned in the years 1970, was doomed to die out as a result of total flood control at the dam level.

Decision makers in the Senegal River Valley, primarily the OMVS, (Basin Organisation and owner of the dams) have gradually embraced the Integrated Water Resources Management (IWRM) paradigm. They now claim to base their water allocation decisions on economic, social, technical and political factors and to duly consider the interests of the various stakeholders. Since the late 1990s this has led the OMVS to prepare a ñreservoir management optimization programò.

Based on ex-post economic analysis of water uses in the Senegal River Valley and on hydrological simulation of the Manantali reservoir that was developed as part of the aforementioned optimization program, this paper highlights the shortcomings of making water management and allocation choices based on theoretical / optimal planning of different water uses. Rather, it supports the idea of considering usersô actual results, capabilities and constraints. And for that, it recommends to simultaneously consider productivity, profitability and sustainability in the analysis. It warns against the one-sided, apparently convincing but definitely partial economic comparison that inevitably minimizes the ñlow input low outputò water uses such as recession agriculture.

The first section briefly presents the concepts of productivity, profitability and sustainability that are used throughout the analysis. It is followed by a description of the situation of water resources, of uses and their water requirements in the Senegal River Valley as well as the institutional arrangements made for water resources development and management. Section 3 reveals the gap between past planned development targets and actual achievements; this gap has led to progressive revisions in planning targets with a gradual appreciation by planners that recession agriculture and environmental water uses deserve greater consideration than initially thought. In section 4, the actual level of competition between water uses is assessed, not only under the angle of water demands but also under the angle of farmersôproduction choices.

From that analysis, the paper concludes that the implementation of a yearly artificial flood (through water release from the reservoir) would allow farmers living in the floodplain to practice recession agriculture (thereby covering a significant share of their food requirements), without significantly competing with hydropower production at the Manantali dam (as long as the objective for the latter is to reach a minimum average yearly power generation). Yet, in the mean time, irrigated agriculture, although it is much more productive than recession agriculture, which it was initially supposed to replace, is faced with serious sustainability problems under farmer management. The ultimate goal of the paper is to address the following question: ñif it thought to be technically possible to reach a high level of economic development and benefits by implementing a major development project, but knowing that the pre-identified pattern of conditions and events required for those benefits to materialise has a probability not to occur, should we nevertheless set target at its highest or set lower targets, likely to be reached and maintained?

Integrated water resources management: defining terms

The concept of ñintegrated water resources managementò is popular and widely promoted, at least in speeches. One of the most frequently cited definitions is ***ñ****a process which promotes the co-ordinated*

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

*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***ò** (Global Water Partnership, 2000). This implies that water is usually used by potentially competing activities, that its ñvalueò varies across these activities and that the benefits to the environment tend to contradict the aggregated benefits to the society, called ñsocial welfareò. Beyond this definition, the question remains of how to practically allocate water in an integrated and equitable manner. What is the value of water across uses, across groups of users? Does it depend upon subjective judgment or is there a standard to measure it, rank uses and allocate water in an optimal manner that would de facto be the correct one? What time scale should be considered to measure values? What does ñallocateò mean when intended users might not utilize the water allocated to them? How are costs and benefits distributed across groups once the economic and social welfare is ñmaximisedò?

Rather than proposing a comprehensive IWRM theory or revealing its vagueness and practical inapplicability in real world, like Biswas did (Biswas, 2004), this paper suggests that water development, management and allocation should be simultaneously guided by three dimensions: productivity, profitability and sustainability and be based on actual behaviour and ñperformanceò or stakeholdersô, actual costs and benefits rather than on optimal / potential ones.

Productivity refers primarily to productive uses but is a relevant concept for some unintentional uses, such as alluvial forests that provide fuel wood in the Senegal River floodplain. The productivity of a production system which requires the combination of several inputs (such as water, land and labour) measures the ratio between the value of the output and the sum of the values of these inputs in that combination. The partial productivity of one input is the ratio between the value (or quantity) of the output and that of the concerned input. Seeking a high productivity of the land in agriculture is legitimate in Sahelian countries, where food security and malnutrition remain a concern. The focus put on the productivity of the land tends to hide the fact that farmers, when they can make choices in production, make them on the basis of all factors at hand and notably the rarest ones. It should also not be forgotten that if many inputs are simultaneously required (water, labour, fertilizers) including what could be called ñnon material factorsò (stable prices, collective organizational skills, timely availability of credit, etcé) and if their availability is uncertain, productivity will be less than under optimal conditions.

The basic notion of returns minus costs that defines **profit** is actually relative and depends upon which group and which costs and benefits are considered. The group can be farmers involved in irrigated agriculture, a sector of the economy or the entire nation. Cost-benefit analysis attempts to put a monetary value on the economic flows between pre-identified groups (irrigation farmers, consumers of electricity, the national industry, etcé) resulting from a project (or in our case from a determined water allocation pattern). However, often, one of the sole indicators considered for decision making is the aggregated overall benefits at national level, which either ignores redistribution between affected groups (winners and losers) or implicitly (and often wrongly) assumes that redistribution and compensation to groups that lose in the process are ñonlyò a technical question.

For **sustainability**, a minimalist definition is suggested: 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. It does not only concern natural resources (fertile soils, water) but all resources.

These three concepts cannot be addressed in a binary way (sustainable / not sustainable, profitable / not profitable) and the balance might change with time and circumstance. An activity that is not considered profitable by those who directly implement it is very unlikely to be sustainable and to materialise as planned, no matter how profitable and productive it was assessed to be *ex ante* at the level of the nation as a whole. A new irrigation scheme ñofferedò to Sahelian farmers together with a dedicated team of qualified extension officers during the first two years of operation and rich soils will certainly be highly productive and profitable for these farmers, at least during the initial phase. In the same scheme, five years later, some farmers will have not paid the irrigation fee, soils will be impoverished and not enough supplemented by chemical fertilizers rendered more expensive by the

removal of subsidies. Such a scheme will not be as profitable and productive as it used to be and the reasons (from the point of view of farmers) to keep it going, i.e. to ensure its sustainability, are weaker than before. This example illustrates the interdependence between the concepts presented above.

Water resources and water uses in the Senegal River Valley

The Manantali dam: regulating variable flows in the Senegal River

The Senegal River is the second largest perennial river in the Sahel and in West Africa. Virtually all the flow is generated during a four months rainy season that occurs in the forested upper basin (figure 1), some 1.700 km away from the mouth of the river. This results in the hydrological pattern represented by the solid line in figure 2, characterized by a very high seasonal but also high interannual variability. The natural discharge of the river is very low for 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 *floodplain* between Matam and Dagana. The *delta* is protected from floods by a system of dykes erected since the seventies. As a result, *all flood related water uses are found only in the floodplain.* On average, the Bafing, where the Manantali dam (11 billion m^3) was erected in 1987 generates 40 to 60% of the annual flow, the rest being supplied by two unregulated tributaries (Falémé and Bakoye). The Manantali dam can be operated so as to retain water during high flows or to release more than the natural flow during the dry period. The Diama barrage was constructed at the same period near the river mouth to prevent tidal water from flowing several hundreds km upstream into the river bed, which prohibited water use for irrigation during the dry season. The Diama barrage is also used to artificially raise the level of the river in the Delta in order to reduce the cost of pumping water in neighbouring irrigation schemes.

Yearly rainfall between Matam and Saint-Louis is low (below 500 mm) and erratic, which does not allow regular and secure rainfed agriculture. Over 2.4 Million inhabitants (10% of the total population of the three OMVS countries) live on the banks of the River. They are farmers, cattle rearers and fishermen belonging to various ethnic groups: Soninke, Wolof, Toucouleur (SERES, 2005; Salem-Murdock et al, 1994).

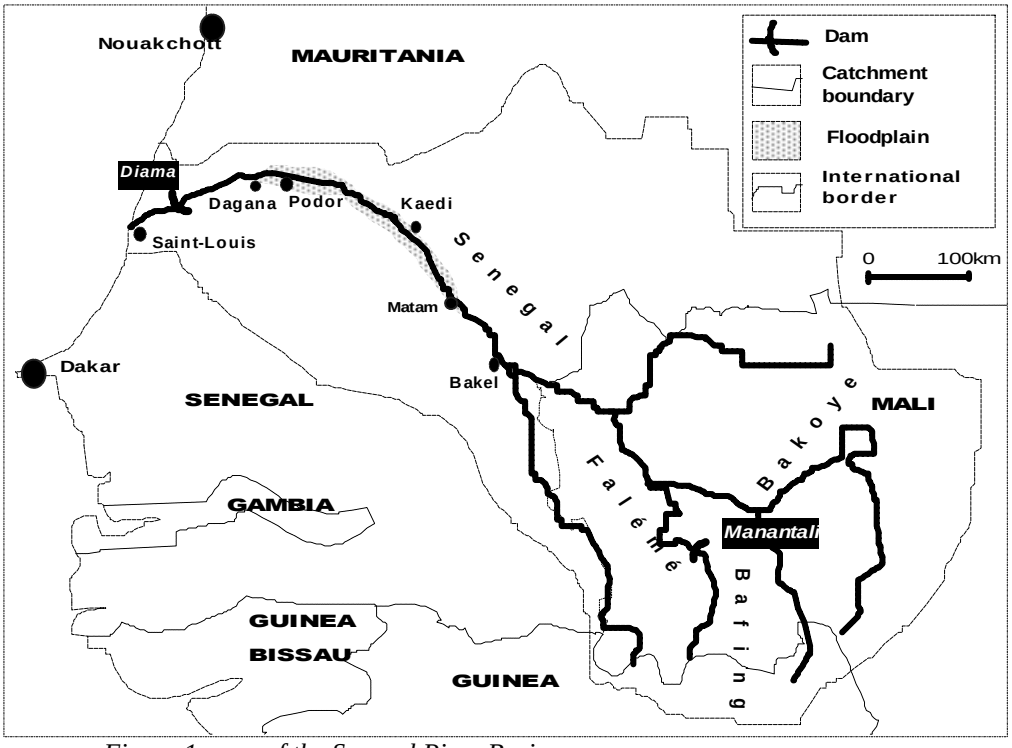


Figure 1: map of the Senegal River Basin

OMVS, an innovative institutional mechanism based on joint ownership of water management assets

OMVS was created in 1972 and its institutional features were reinforced in the 2002 Charter, which was based on the four following pillars (SERES, 2005):

- sustained cooperation between member countries, driven by equity, solidarity and equal consideration of all users of the water, including permanent navigation capacity all year long,
- joint ownership of dams and other assets (that has been the case since the creation),
- equal access to the water resource,
- equity in the sharing of costs and charges.

The dams and the hydropower plant and the transmission lines are therefore the property of the three countries that benefit in one way or another from the river, Senegal, Mauritania and Mali. The total investment cost was about 1.2 Billion USD (2005 prices) distributed as follows: 55% for Manantali dam, 13% for Diama dam and 32% for the hydropower plant and transmission lines (SERES, 2005). The last two became operational almost 15 years after the barrages. About 30% of the investment cost was as a grant or a loan that was later written off. The rest, 800 Million USD, has to be repaid over the coming decades (mostly soft loan from international donor organisations).

Whereas its initial objective in the 70s was geared towards overall economic integration, OMVS gradually decided to focus on sustainable water development, management and allocation.

Diverse water uses

A variety of water uses are found on both sides of the Valley (Mauritania in the north and Senegal in the south). Some are traditional and existed long before the dams. Modern water uses were introduced as part of a general, coordinated and ambitious plan to develop water resources promoted by the OMVS (OMVS, 1980). The OMVS represents Mali (in the upstream basin where the Manantali dam is located, and not concerned by consumptive uses), Senegal and Mauritania in the lower part.

The uses include:

- pump based irrigated agriculture: over 130,000 ha (40,000 in Mauritania and 90,000 in Senegal and a few hundred in Mali) have been developed on both banks of the valley, starting from almost zero in the 1960s. The irrigation domain is composed predominantly of smallholder village based schemes of less than 100 ha, particularly in the floodplain, whereas large schemes are located in the delta. A large majority of schemes were constructed or rehabilitated with grants from international donors with investment costs usually ranging between US$ 1,500 and US$ 6,500 per hectare developed. Rice is the main crop; it is grown almost only during the rainy season. 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 cropping intensity (CI)[4] in 2002 on both banks was not more than 60%. In Senegal and to a lesser extent in Mauritania, the management of schemes has been transferred by the State (usually public irrigation companies, such as SAED in Senegal) to farmersô organizations during the 90ôs. The Diama barrage was built in order to make dry season cultivation possible by blocking sea water intrusion.
- domestic water supply: in addition to local villages, some water is supplied to Dakar and Nouakchott, respectively the capital cities of Senegal and Mauritania to supplement other sources of drinking water. The volume is minimal.
- flood recession agriculture: in the clay depressions of the floodplain, sorghum and maize crops have been extensively grown for centuries (Barry, 1985). This production system was highly irregular because it depended on the extent and duration of the annual flood occurring in the middle of the rainy season: from 1950 to 2000, it covered a broad range from less than 15,000 ha to over 300,000

4 The cropping intensity (CI) is the ratio between the area cultivated each year and the area developed for cultivation. Two cropping seasons with the full area cultivated correspond to a CI of 200%.

ha in the entire floodplain. Sorghum grows during the dry season, exclusively on the residual soil moisture after flood recession. Due to the absence of gates to retain water in the depressions, inundation must last for 25 to 30 days minimum to store enough soil moisture. The average yield is low at 600 kg/hectare (Mané and Fraval, 2001). However it is a profitable production system for farmers since they use no purchased inputs: seeds are kept aside from the previous season, fertiliser is cow dung and labour is provided by the family. Every time the floodplain is inundated by floods, vast areas of it are systematically sown with sorghum. Whereas the annual area flooded was as erratic as the hydrology in the upper catchment (see figure 3), the Manantali dam has made it possible to better control the flood either in the sense of favouring the required floodé or of precluding it.

- livestock breeding: the flood provides pasture during the dry season for the livestock that stays permanently in the floodplain. Livestock also feeds on recession agriculture crop residue.
- hydropower: *The historical objective of OMVS was and still is to generate at least 800 GWh per year 8 years out of 10* to supply the three member States of OMVS (cited in SERES, 2005). Oddly, this figure that dates from early planning documents elaborated in the 1970s has, until recently never been explained or justified. It has however ï at least until now - remained the historical (and unquestioned) target; members participating in various negotiations over water resources and cost benefit analysis have always used that figure as if it was carved in marble. Hydropower is the only water use that makes it easy to recover part of the capital and running costs faced by OMVS, by selling power to national electricity companies. Hydropower generation started in 2003, 15 years after the dams were constructed and has since been supplying some 30% of the total electricity consumed by the three countries, which otherwise rely on thermal power stations. With increasing oil prices, this has an unquestionably positive macroeconomic impact for the three countries and notably for Mali that receives 50% of the energy but gets no other benefit from the dams.
- environmental ñusesò: the Djoudj and Diawling are two large bird sanctuaries of international significance which are located on either bank of the Delta. Their freshwater needs are very low and to some extent too much fresh water can adversely modify the natural environment. Fishing, forest regeneration, groundwater recharge are positive environmental externalities of the flood in the Middle Valley with a direct influence on floodplain residents (fishing, fuel wood). Quantifying the benefits of the flood for such uses is virtually impossible. One thing is certain though: the natural fauna and flora found are the products of past - and highly irregular - flooding events and preventing flooding would definitely impact them.
- commercial navigation on the Senegal River is a historical but now a ñvirtualò use. Restoration of navigation would require high investment costs for infrastructure, the availability of operators (private or public) that are ready to engage in river transport (as in the ñgood old timesò) as well as a minimum steady flow all year long. This use is therefore very hypothetical and is not considered any further in this paper. Ironically, in the first *ex-ante* cost benefit analysis made prior to major developments by OMVS, navigation was supposed to generate a significant share of the overall benefits of the water development (OMVS, 1980) **a**nd it still appears as a priority objective, as expressed in the 2002 Charter (OMVS, 2002).

It must be emphasized that there is not always a clear boundary between different water user groups. A large majority of households in the floodplain are simultaneously involved in irrigation, recession agriculture and cattle rearing. A significant proportion of households receive monetary transfers from migrants in Europe and the USA (Diemer, 1987); this source of income serves to a large extent as a safety net, which tends to distort farmersô behaviour towards irrigated agriculture: insufficient effort and inputs in irrigated fields may be compensated by transfers from migrants.

Water supply and demand in the valley

Figure 2 shows the water demand for existing uses in relation to supply, represented by the discharge measured at Bakel (the downstream junction of all tributaries of the river) over the 1990-2000 period, during which Manantali has been operational.

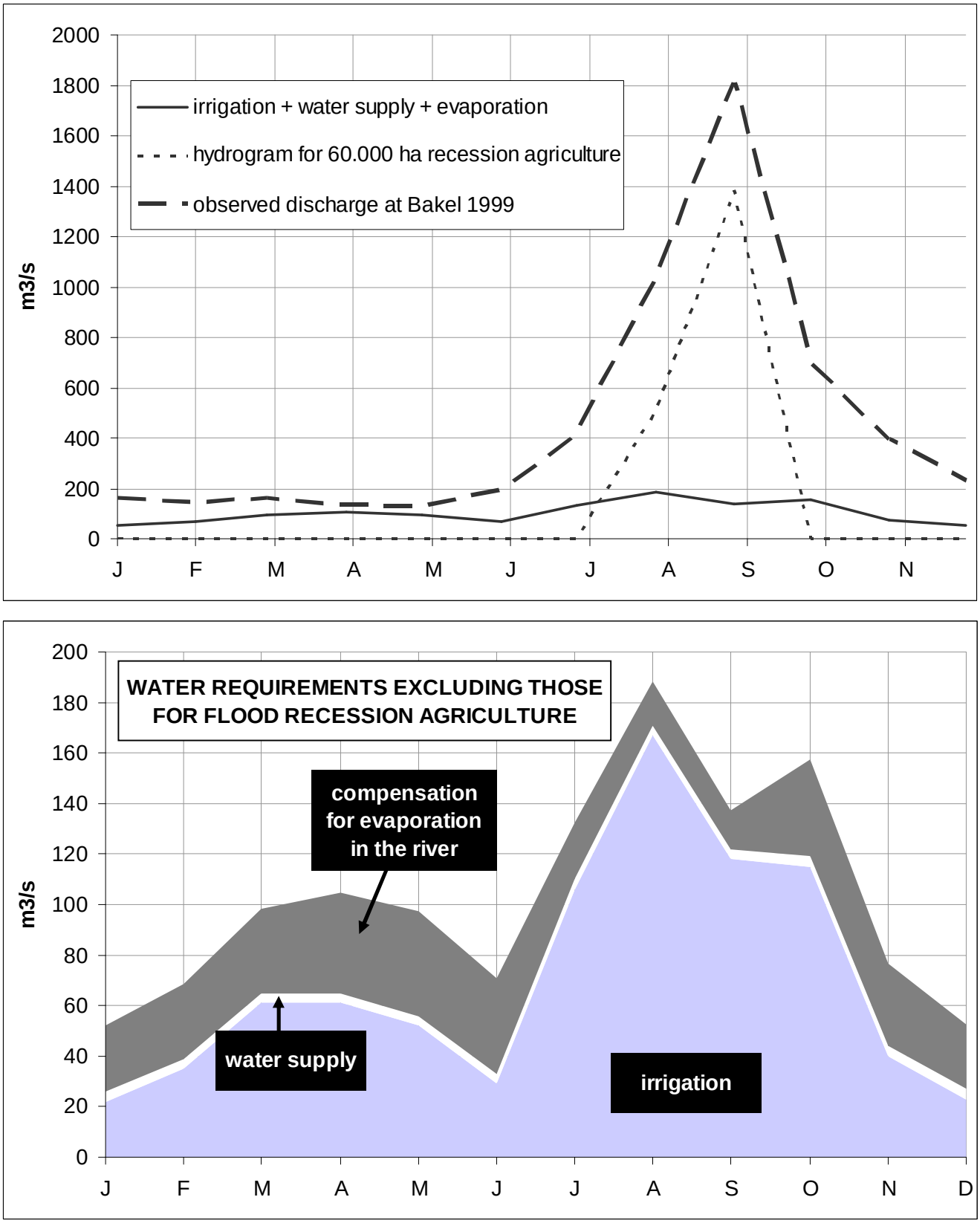


Figure 2: water requirement in the River Valley, on a monthly basis (in m3/s, with a focus on consumptive uses on the bottom chart)

Recession agriculture requires a lot of water within a short period of time: 3.5 to 4.5 bcm (20 to 30% of the annual average flow of the river) over a 40 days period to make the cultivation of 50,000 ha under current conditions possible (IRD, 2001). This water comes partly from the Manantali reservoir, partly from the uncontrolled tributaries (Falémé and Bakoye). As figure 2 shows, recession agriculture, even though it is not strictly a consumptive use is by far the major water user. The high volume is

justified by the need to keep the water level high enough in the clay depressions for a sufficient time to allow all the entire flooded soils to store enough water to be later used by sorghum and maïze over their vegetative cycle .

Irrigated agriculture is the largest strictly consumptive use. Its demand has been stagnating since 1995 due to the low cropping intensity. However, during the hot and dry months of April and May, to make water available to the few irrigation schemes that are operated in the delta, much more water must be supplied than the gross irrigation requirement in order to compensate for evaporation in the river bed: evaporation alone increases the gross irrigation demand by 50 to 60% for these dry months.

With less than 5m3/s, water abstraction for cities is and will remain small and easy to fulfil in the future.

Hydropower does not consume any water, but definitely changes the natural flow pattern. The ideal water consumption for hydropower would be a continuous water discharge all year long, in order to meet the power demand, which is fairly constant throughout the year. This water management pattern would neatly combine with 2 crops per season of irrigated agriculture in the Valley. The volume required to generate every kWh is a decreasing function of the water level in the reservoir[5] (Bader et al, 2003). Economically, it is therefore better to keep the water level as high as possible, whilst avoiding reservoir spill and guaranteeing at all times the safety of the dam as explained later on optimizing tools. Hydropower primarily benefits urban dwellers, although OMVS is promoting rural electrification in the valley (SERES, 2005).

Navigation would require a continuous discharge to maintain water levels all year long: depending upon the size of barges, this discharge would vary between 100m3/s and 360m3/s (SCP et al, 2000). As explained earlier, this water use was not considered in the hydrological simulations described later, due to the low likelihood of it happening in the coming decades.

Water allocation decision making process

Water allocation consists of determining on a yearly basis how water should be released from the Manantali reservoir. The mandate of the *Permanent Commission on Water (CPE)*, staffed by representatives of the three member states, is precisely to define the principles practice of water allocation between uses. Decisions are based on (1) an assessment of the resource (uncertain because the inflow into the reservoir is a function of the unpredictable rainfall in the upper catchment) and (2) the expression of needs by users. Some specific tools are used to guide decision, which must be the result of a consensus between the three Member States as per the internal regulation of OMVS. These tools are described later in this article. It is an oversight that recession agriculture farmers are not represented at the CPE, whereas the irrigation sector is[6].

A history of ambitious 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 1920s and has been carried on by the OMVS since its creation in 1972. Until the late eighties, studying ***ñ****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*ò (OMVS, 1980) was a priority for OMVS together with hydropower generation and navigation, although no resources were then available to construct the required investments. As far as agricultural uses of water were concerned, the key ambition was to make farmers shift from low-input low-output archaic and highly variable recession agriculture to productive irrigated agriculture focused on rice, for which the soil and climate conditions are indeed favourable. Thereby farmers would have had the means to produce enough to feed themselves and sell

[5] According to IRD, 12.2 m3 for an altitude of 187 m against only 7.2 m3 at an altitude of 208 m

[6] For Senegal, SAED, the rural development agency which was created precisely to develop irrigation in the valley, represents irrigators.

the surplus on the market. To support the entire plan, an impressive cost-benefit analysis was prepared not only to justify the rationale for changing the pattern of water use (especially the development of some 375,000 ha of irrigation) through the taming floods, but also to determine how the investment and future running costs should be shared across uses and between countries, based on the expected benefits.

In the 1990s, the agenda evolved: while the ñ*development of a diversified and intensified irrigated agriculture in the valley with a targeted cropping intensity of 160% (including 60% in the dry season)*[7]**ò** was still a major objective (although the earlier estimate of 375,000 hectares was revised downwards), the OMVS favourably considered **ñ***reservoir releases that allow floods and associated uses and preserves the ecological equilibrium in the valley***ò** (OMVS, 2000). The growing interest in recession agriculture owes a lot to a community based socio-economic research program carried out between 1987 (before the construction of the Manantali dam) and 1991 that revealed the socio-economic importance of recession agriculture for numerous households in the Middle Valley (Salem-Murdock et al, 1994).

Actual vs. planned situations: the divergence

OMVS at basin level, and Senegal and Mauritania at national level, have completed of water and rural development plans, including economic *ex-ante* analysis. **ñ***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***ò** wrote Inglès in 1995 in reviewing past OMVS planning documents, especially when realising that navigation no longer existed in the valley, 30 years after it was identified as one of the water uses that would yield the highest benefits. Inglèsô statement also applies to the PDRG (GERSAR et al, 1991), pillar of rural and water resources development planning on the Left Bank of the Senegal River Valley. Over the 1990s, the only target the PDRG attained - and even exceeded ï was the amount of money invested in irrigation schemes: in Matam and Podor regions, international donors spent US$ 88.5 million[8] on the construction or rehabilitation of some 11,000 hectares of public schemes, against US$ 82.5 millions plannedé 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.

This gap does not apply to hydropower. The profitability of hydropower generation is high, or at least would be high if the three national electricity utilities paid for the power they purchase from SOGEM, the OMVS organ in charge of Manantali. In late 2004, less than 2 years after power generation started, 7 months billing was still to be paid by the utilities (SERES, 2005). This poses the double question of risk and enforcement of contractual arrangements in water resources development economic analysis.

Competition between uses and water management options

Competition between water uses in the Middle Senegal River Valley is both a quantitative issue of water allocation and one of farmersô labour allocation and decision making process.

Hydropower vs. recession agriculture

A striking competition at first sight

In terms of competition over water resources, at face value, releasing 3.5 to 4.5 billion m^3 (between one fourth and one third of the Manantali storage capacity) in the middle of the rainy season for recession agriculture, not knowing with absolute certainty how rains occurring later in the upper basin will replenish the reservoirôs storage, appears ill-considered. Whereas the unit water requirement for one hectare of recession agriculture is about: From a qualitative point of view, there is definitely competition over water between the (partly) artificial flood required by recession agriculture and hydropower maximisation. But what is the real level of competition? This issue was long argued

[7] In 2002, it did not exceed 60%.

[8] Figures on donorsô support for irrigation investment in the Valley are derived from a comprehensive survey of their actual grants / loans, including overhead costs such as technical assistance.

outside a sound scientific framework. Tools were progressively developed to see whether it was possible to optimize in a dynamic manner water releases from the reservoir and assess the actual level of competition between water uses. This is the purpose of the POGR[9] that was carried out by OMVS.

PROGEMAN and SIMULSEN: 2 models to optimise the management of the Manantali dam

Based on satellite images and statistical analysis of the riverôs hydrology, IRD established a meaningful correlation between (1) the area inundated during a certain duration at a certain time in the season in the floodplain and (2) the shape of the hydrograph[10] at Bakel, a strategic gauging station located downstream the junction of the three main tributaries of the Senegal River. These results permit the characterisation of optimal hydrographs at Bakel over one month, corresponding to various recession crops areas of between 45,000 and 60,000 ha in the floodplain.

These hydrographs are used by the software Simulsen and Progeman (Bader & al., 2003; Bader& al, 2006) developed as part of the POGR, which aim respectively to simulate and to assist the real time management of Manantali.

SIMULSEN

This software was developed to simulate on a daily basis and run over a hydrological series of several decades (simulations made in the framework of this paper covered 1970 ï 2000) various scenarios of water release patterns from the Manantali dam. The aim of the simulations was to evaluate in what manner (from a statistical point of view) the various water uses could have been compatible with one another. It allows determine at each point in time what the level in the reservoir should be in order to fulfil the uses with a given degree of certainty.

For Manantali, the simulations made are based on the following data and parameters :

- Data: daily observed or ñrecalculatedò discharges at the Manantali site on Bafing river, Oualia site on Bakoye river and Gourbassy on Falémé river (see figure 1).;
- Parameters that enable calculate the discharge at Bakel at any point in time as a function of time and the various discharges at Manantali, Oualia and Gourbassy (Morel Seytoux & al, 1993)
- Characteristics of the Manantali dam (gatesô and turbinesô operational rules, evaporation of the reservoir)

Simulations are carried out in the framework of a number of requirements that each depicts a given objective (fulfil a water use, ensure safety of dam). These requirements are prioritised.

For hydropower generation, the objective is to generate a certain quantity of power over the year.

Rule A	To release enough water to reach that objective (800 MWh / year)
Rule B	To maintain a certain stock of water in the reservoir in order to achieve the objective the next year with a given level of certainty

Recession agriculture objective

Rule C	To release water at the appropriate time at Manantali in order to be over the optimal objective at Bakel, based on the expected contribution of uncontrolled tributaries
Rule D	To maintain a certain stock of water in the reservoir in order to achieve the recession agriculture objective the next year with a given level of certainty the next year

Objective to prevent excessive destructive floods in the floodplain and further downstream

Rule E	To keep a certain empty volume in the reservoir before the rainy season in order to be able to laminate floods with a certain level of certainty (the same year)
Rule F	To release a sufficiently small discharge from the dam so that the sum of that discharge - when it reaches Bakel - added to those of Bakoye and Faleme does not

[9] POGR, Programme dôOptimisation de la Gestion des Réservoirs (Program to Optimize the Management of the Reservoirs) funded by the French government between 1997 and 2002.

[10] the hydrograph at a certain point of the river represents the flow (m3/s) as a function of time ï see figure 2

	exceed a certain value

Parameters are chosen in order to best picture a realistic management of the dam. As an example, the decision to carry out or not the aimed hydrograph is made according to the stock of water available on August 20, date to which the operation of the gates must start to indeed achieve the targeted hydrograph. If this stock exceeds a certain threshold, the flood support is carried out. If not, the flood obtained at Bakel and thus the inundation in the floodplain will only result from the natural flows of Bakoye and Falémé, plus the low discharges released at Manantali but for hydroelectric production. Lastly, the minimal values of stock or empty volume that must be respected in the reservoir not to compromise the future achievement of the objectives, can be calculated with a specific procedure of Simulsen. They vary from year to year and depend on each objective and on the level of guarantee desired. We can see that the decision regarding massive water release for recession agriculture is at present of a ñYes or Noò nature, which is not fully satisfactory.

For each time step of the chronological simulation (daily basis), SIMULSEN first calculates the possible range of discharge which can physically be released based on the level in the reservoir at the beginning of the day and on the capacity of the damôs gates, turbines and spillway. That range becomes narrower as a result of the various requirements which are prioritised as follows: safety of the dam (in case of extreme high incoming flows); release of a minimum environmental flow; water balance of the dam (rules B, D and E in the limits of the fulfilment of the safety requirement); energy balance (rule A) and discharge propagation modelling (rules C and F). The loop (and then resulting range of discharge that can be released) stops as soon as all rules are considered by the software. However, when one of rule is not consistent with a rule of higher priority, the discharge is no more within a potential range but has a unique value which is compatible with superior rules and closest to the most compatible discharge with the rule of lower importance. Eventually, the daily discharge released as calculated is the lower limit of the range.

In addition to the daily discharge released, SIMULSEN provides the following outputs:

- Average daily level in the reservoir (as well as its distribution between what goes through the turbines and what does not)
- Daily power generation (the sum on a yearly basis has helped us compare with the historical target)
- Daily discharge at various locations on the Bafing river between the dam and Bakel (using the propagation model)

And on a yearly basis, SIMULSEN calculates the yearly area that can be cultivated under recession agriculture, as a result of the resulting hydrograph at Bakel.

PROGEMAN

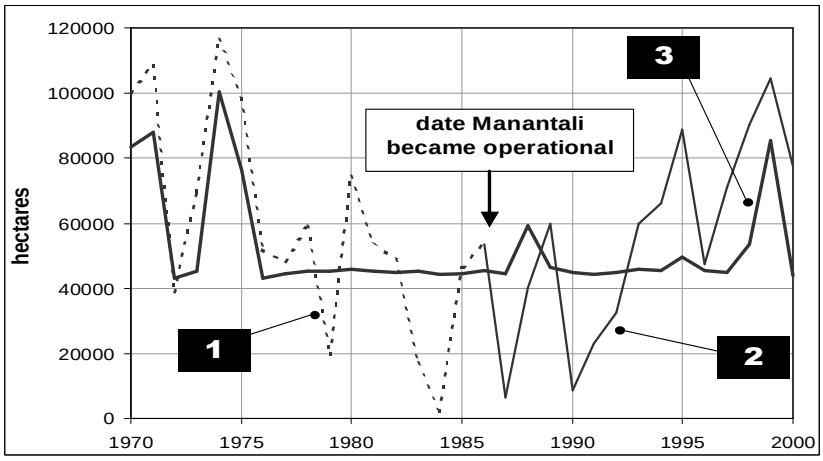
Developed for real time management of the Manantali dam, PROGEMAN software is based on the same parameters as SIMULSEN and relies on the same modelling principles. The differences between both programs are: whereas SIMULSEN is run over past hydrological series, PROGEMAN only uses actual recent data which is continuously updated and made available to the company that operates Manantali. This allows flow propagation models to be more precise than with SIMULSEN.

Levels observed at Oualia (Bakoye), Gourbassy (Falémé), Bakel (Senegal) and Bafing Makana (station which controlls the incoming discharge in the reservoir). These levels, which are known in quasi-real time thanks to radio transmission, are translated into discharge by Progeman.

While SIMULSEN needs uninterrupted series of data, PROGEMAN can operate even if lacks of data occurs, due to a breakdown of radio transmission. According to available data, it uses various methods to reconstitute the missing one (propagation starting from upstream stations, autoregression, median values).

Hydropower and recession agriculture are compatible

A set of simulations of the reservoir management over the driest period of the last century (i.e. 1970-2000) has been carried out using SIMULSEN. The objective was to see what area under recession agriculture could have been **guaranteed each year** by optimal releases and reach the hydropower target of 800 GWh per year on average. For this series of simulations, all other current water demands have been considered, except navigation as justified earlier. Results show that it could have been possible to cultivate at least 45,000 hectares in each of the 30 years (and 52,500 hectares on average) while generating on average 96% of the hydropower minimum threshold.



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 (1987-2000)*

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 with or without the Manantali dam

There is thus no real competition between recession agriculture and hydropower generation in the short and medium term, as long as the objective for hydropower is to reach a target on average and not to maximize it. If such a management pattern had been adopted, it would have dramatically reduced the irregularity of the inundation and associated uses, as shown in figure 3.

However, allocating water for recession agriculture reduces the profitability of hydropower

In a recent evaluation of the French support to OMVS (SERES, 2005), two drastically different scenarios (tested with SIMULSEN) are compared. In Scenario A, the artificial flood from Manantali is not an objective. Under this scenario, recession agriculture would statistically occur only 1 year out of 4 on 45,000 hectares and 8 years out of 10 on 7,000 hectares only. The annual hydropower production would be 850 GWh on average. Scenario B consists of allowing the artificial flood every year by setting a low ñrelease levelò in the reservoir. This would enable the cultivation of 45,000 hectares 8 years out of 10 and 20,000 hectares 9 years out of 10. The average power generated would be only 750 GWh, i.e. 100 GWh less than with the first scenario. By implicitly considering Scenario A as the ñnormalò one, due to the unit cost differential for hydropower production between the scenarios and due to the necessity to compensate for the 100 GWh difference by producing from a thermal power station (the unit production cost of which is much higher), the ñpro-floodò Scenario B results in ña loss to the hydropower sectorò estimated at 8 Billion FCA every year, which is approximately 15.7 Million USD[11], i.e. a 410 USD loss per hectare of recession agriculture in scenario B (SERES, 2005).

How does this compare with the net benefit made by recession farmers? Based on a yield of 700 kg/ha, on recession sorghum prices in local markets and on the fact that production costs are close to nil, the net benefit per hectare would fluctuate between 70 and 110 USD/ha. This means that at best, allowing recession agriculture on 45,000 ha 8 years out of 10 would result in an annual loss to society (i.e. the 3 countries) of (45,000 ï 7,000) X (410 ï 110) = 11.4 Millions USD. No matter how objective and irrefutable these figures are, the mere fact of making that comparison implicitly presents water management scenario A - that basically condemns the artificial flood and recession agriculture - as the

[11] exchange rate for year 2005 used by SERES: 510 CFA = 1 USD

ñbase oneò. It is logically the one that power producers and macroeconomists would definitely prefer, especially in a situation of high oil prices and increasing power consumption of the countries.

Another way of looking at this result would be to say that it is better to pay recession farmers for giving up recession agriculture due to restricted flooding, by an amount that would be at least equivalent to what they would earn if they had cultivated successfully. How to compensate such farmers is another question. Giving them cash every year has so far never been proposed. It is perhaps because of the cumbersome distribution (how much to whom) to members of a very hierarchical society where ñslave to masterò relationships are still very common (Schmitz, 1994; NôGaïde, 2003). This, as well as the moral failure some could see in having to make monetary transfers to farmers against no work (some kind of ñmoney for NO workò) explains why the first planners in the seventies wanted to simply replace recession agriculture by modern productive irrigation. The question of the competition between these two agricultural systems is presented next.

Recession vs. irrigated agriculture

It has been shown earlier that some 45,000 to 52,000 hectares of recession agriculture would be possible each year while reaching the ñtargetò for hydropower production. That area is far from being small if compared to the 65,900 hectares cultivated under irrigation along the Senegal River Valley - out of 137,000 hectares developed since the sixties[12] (SERES, 2005).

ñPer hectareò or ñregion basedò comparison between recession agriculture and irrigation

For a total production cost of US$ 450 per hectare that includes pump renewal and scheme maintenance, provided best agricultural practices are followed, even in a single cropping season, farmers could get 7.5 tonnes/ha of paddy and a net income of US$ 470 per hectare[13] (Haefele et al, 2000). These are impressive land productivity figures, compared with the modest yield of recession sorghum (10 times lower). In addition, as revealed in figure 4, the gross value of product generated by the three production systems found in the floodplain shows that irrigated agriculture is by far the highest and steadiest contributor to that value. At first sight, it seems therefore surprising that local people in the floodplain did not enthusiastically give up recession agriculture for irrigated agriculture. This would also have brought benefits to the entire local economy through induced value added (maintenance of schemes, credit, inputs supply and other service suppliers). Moreover, due to water control, as shown in figure 4, the income obtained from irrigation is much more regular than that of recession agriculture.

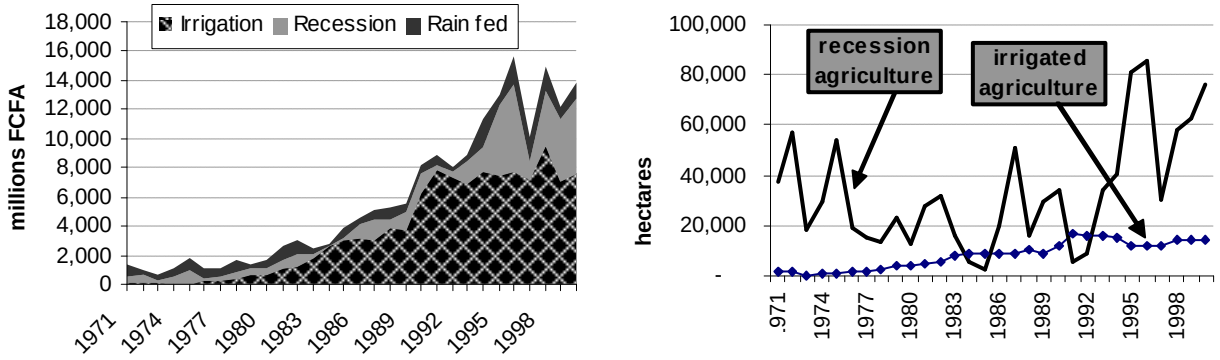


Figure 4: (Left) contribution of irrigated, recession and rain fed agriculture to overall agricultural value in Podor and Matam areas between 1971 and 2000 (at market prices) ï (right) hectares cultivated for recession and irrigated agriculture

[12] Figures for the year 2002

[13] The net income is composed of the return to family labour plus the net profit to farmers

Determinants of floodplain residentsô interest in production systems is not the ñper hectare benefitò

It is misleading to compare production systems (yield, income, resource use, production costs) only on the basis of the theoretical per hectare potential. Real long term performance (costs, benefits, risks), as opposed to spot ñper hectareò measurements, and the role of the production system in the householdôs overall budget and labour allocation decisions must be considered to try to explain how farmers consider and adhere to this or that economic activity (Sourisseau, 2000).

For many floodplain residents, the interest (i.e. the willingness to invest and work) in irrigated agriculture is reversible. As many poor farmers in the developing world, they preferably engage in activities that are least labour and input intensive, low risk and that guarantee a minimum output to feed their family, rather than in activities characterised by high production, organisational and transaction costs, marketing risk, even though such activities are potentially more productive and profitable. To a large extent, pump-based irrigation in the Senegal River floodplain corresponds to the latter description. Subsidies on agricultural inputs have been lifted; public extension services have shrunk and not been replaced by the private sector; credit is not easily available; the removal of trade barriers has increased imports of Asian rice that sometimes makes it difficult to market local rice. The combination of these factors acts as a strong disincentive for many potential irrigators. This explains the low cropping intensity, particularly during the dry season. Irrigation of itself is not a problem: during drought years in the seventies, smallholder village based schemes were extremely popular and productive, but the circumstances were different and few alternatives were available to them in order to survive. Even now, some farmers who have specialized in irrigation make substantial profits but they are few and tend to be the ones with large land holdings (that allow economies of scale) and a certain marketing power.

Unlike recession or rain-fed fields, irrigated plots not only require high investment (from US$ 1,500 to US$ 6,500 per hectare developed) but if a 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 requires 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 and a tangible weariness among donors to fund yet more rehabilitation, farmers are expected to bear the cost of sustainability. Well, can they do it? This is examined next.

A model to assess the sustainability of irrigated agriculture

The capability and willingness of farmers to pay for the sustainability of irrigated agriculture (maintenance and renewal of pumps under the form of a ñmaintenance feeò) is addressed through the following question: if they do so, what income is left to remunerate household labour *under the prevailing real conditions of costs, efficiency, yield, cropping intensity*? In other words what is the *Sustainable Irrigation Income* - which supposes that farmers pay the maintenance fee - as opposed to the *Unsustainable Irrigation Income* for the irrigation schemes found today in the floodplain? To shed light on this question, an economic model (Ndiaye et al, 2002) has been developed and applied to the 685 functional (not abandoned) irrigation schemes in the Matam and Podor departments, altogether covering some 23,000 hectares[14]. Average area cultivated and harvested (from 1998 to 2000) for each crop, each cropping season and each scheme were extracted from SAEDôs irrigation database. They were combined with results from extensive socio-economic surveys of irrigated agriculture (SAED, 1999; Huat and David-Benz, 2000; David-Benz and Bâ, 2000) that provide actual reliable figures on yields, production costs for the concerned crops. Maintenance costs are those used in a specific study on maintenance costs (BRL, 2000) implemented n order to check the feasibility of a collective maintenance fund and from scheme level surveys (Larbaigt, 2001). All these data enabled to calculate

[14] 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.

the *cost of sustainable irrigation* for each scheme, based on its characteristics (location, type, cropping intensityé).

The model calculates an average irrigation scheme budget for 3 types of schemes (large public schemes, small private schemes, community-based schemes) based on the actual area cultivated for each crop as computed in SAED database. It is illustrated in figure 5 below.

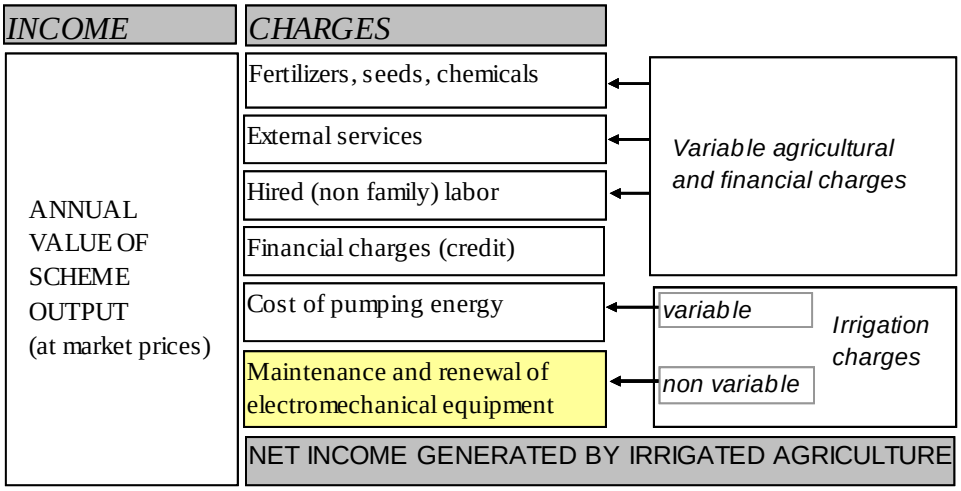


Figure 5: components of an irrigation scheme budget

The key variable of the model is the Net Sustainable Irrigation Income (NSII) on a per developed hectare basis, for each irrigation scheme. It supposes that farmers pay for the maintenance of the scheme and the renewal of electromechanical equipment, which are mostly fixed costs, whether or not the scheme is cultivated. If the NSII is negative, this means that the farmers in that scheme would ñon averageòcultivate at a loss due to the fact that the charges exceed their income.

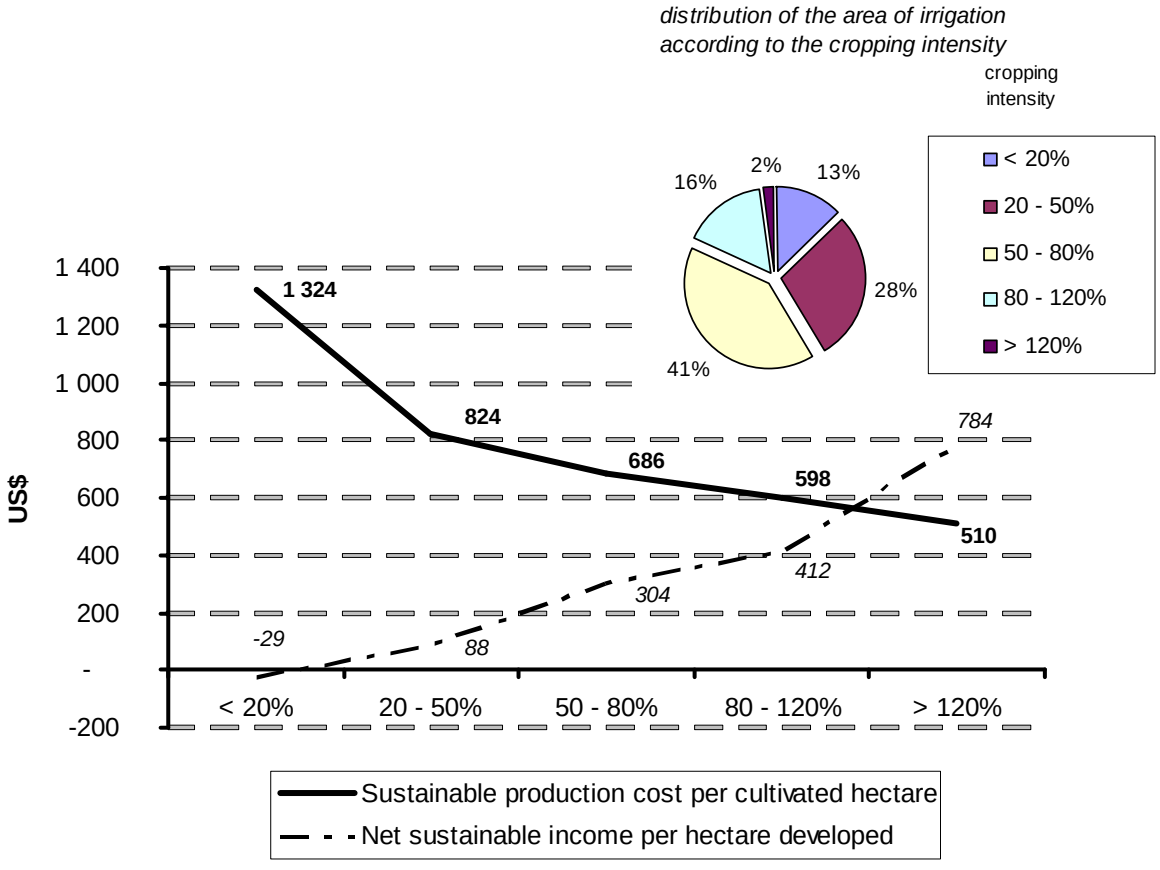


Figure 6: the cropping intensity: a key variable that explains farmersô income and production costs under sustainable conditions

The farmersô income derived from irrigated agriculture has been computed on a per hectare developed and per year basis for each scheme, using an access based program, both in the sustainable and unsustainable situations. The entire area developed is classified based on this criteria.

Figure 7 shows a distribution of the total irrigation area developed across classes of ñper hectare incomeò under sustainable situation (dark line) and unsustainable situation (grey line). The right scale is the cumulative percentage (sustainable situation is represented by the dark line and the unsustainable one by the grey line).

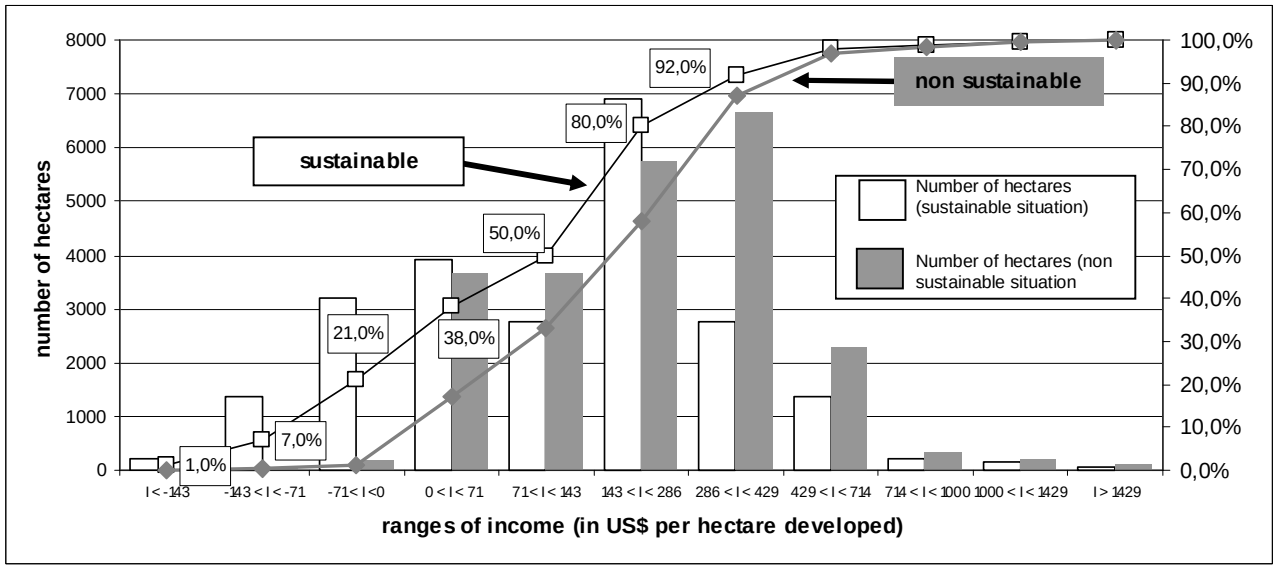


Figure 7: impact of irrigation sustainability on farmersô income

The model indicates that, in the sustainable situation (if farmers paid what is considered appropriate for maintenance and renewal), the income would be negative for 21% of the total area developed (which means that the ñaverage farmerò on those schemes would cultivate at a loss) and lower than 143 US$ per hectare and per year for half of the area,. In the unsustainable situation (no fee for maintenance and renewal accounted for in the production cost), in 99% of the schemes, the income would be positive. The average SII per hectare developed is US$ 163, which is 36% less than the NSII.

Based on average yield figures, population data in the Podor and Matam provinces and on food requirements, shifting from an unsustainable to the sustainable situation would reduce the contribution of incomes derived from irrigation to cerealsô requirements of irrigatorsô households from 75% to 49% in Podor, 57% to 27% in Matam.

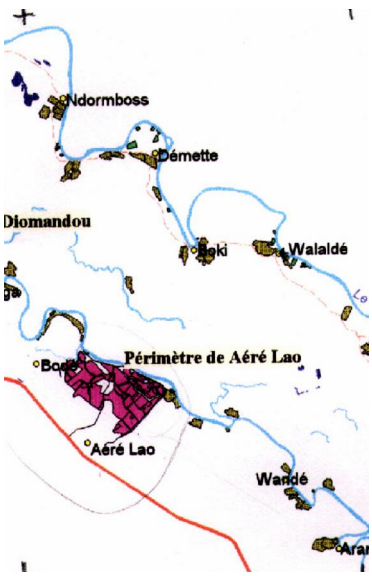
The Senegalese State was in the process of setting up collective maintenance funds for public schemes (75% of the area) in 2001. However, the Stateôs planned contribution (SAED, 2001) for the Matam and Podor departments schemes was only half of what farmers save currently and both together represent only half of the US$ 1.73 millions required to cover the maintenance and renewal costs. These worrying figures are mostly explained by the low cropping intensity that automatically raises the share of maintenance and renewal costs (fixed costs) in the total production cost (see figure 6).

Complementary to this strictly financial analysis, a survey of 20 community based irrigation schemes highlights the rapid degradation of schemes and the passivity of farmersô organizations to prevent it, both in terms of repairs and financial organization (Larbaigt, 2001). Without a drastic improvement of their practices (cropping intensity, efficiency) and a two fold increase in the average irrigation fee to reach sufficient financial resources devoted to maintenance and renewal, the sustainability of irrigated agriculture based strictly on farmersô resources cannot be achieved.

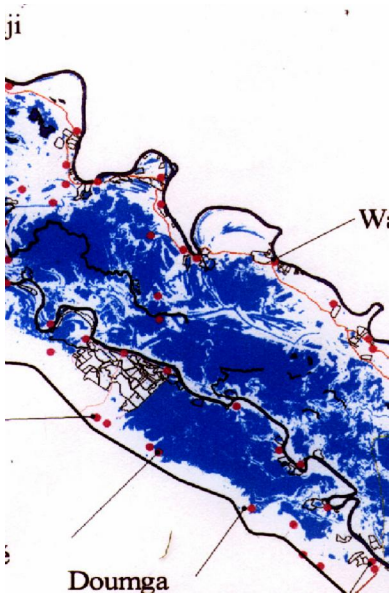
One could valuably argue that irrigated agriculture directly or indirectly creates many chains of value added (inputs provision, pump supply and repair, transporters, consultants, NGOs, etcé). The problem though is that all these induced economic activities will always depend on the existence of irrigation schemes, viz on their sustainability.

A correlation between the flooded area and the next yearôs cropping intensity in irrigation

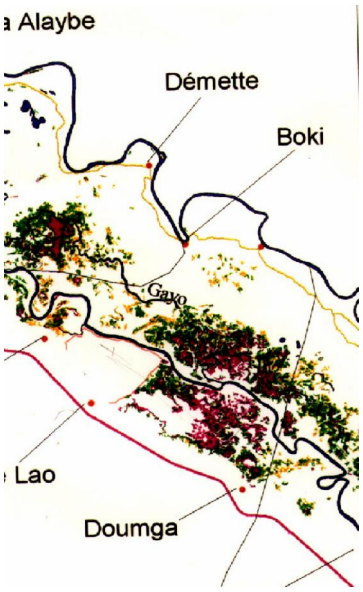
Figure 8 shows a set of GIS and/or Remote sensing maps of the same location in the floodplain at different times of the year in 1999. It reveals the closeness of irrigation projects (which are protected by dykes) and clay depressions where recession agriculture is cultivated in an extensive manner.



In purple, the Aere Lao irrigation scheme supplied by pumps from one branch of the Senegal river



The same area inundated (except the irrigation scheme protected by dykes) during the rainy season of 1999



And in January 2000: most of the flooplain is covered with recession sorghum sown thanks to the flood

Figure 8: Farmersô responsiveness to large inundations in the floodplain

A competition between irrigation and recession agriculture with regards to priority setting and decision making process has been observed many times by anthropologists at micro-level (Salem-Murdock et al, 1994). Analysis at micro level explains that, if a large area is flooded, a significant number of farmers located in the floodplain will plant recession sorghum and maize in October and harvest it in March or April and, because their granary is full at that moment, tend to grow less rice during the next rainy season for which irrigation preparation starts at that moment.

In the research, an econometric test has been made over a 25 year period (1976-2001) by testing to what extent the cropping intensity for cereals in irrigation schemes for the rainy season of year N+1 is dependent on the area flooded in year N (which is a proxy for the recession sorghum harvested in March of year N+1). For that, the equation $\log (CI_{N+1}) = \breve{U} \log (Area_N) + \mathring{U}_{N+1}$ was tested using the Fischer test. $\breve{U}$ is the correlation parameter to be estimated ($\breve{U}$ is the elasticity of CI against the area). The model is valid and indicates a negative elasticity of 10%. In clear, the larger the area inundated (and thus cultivated with sorghum), the smaller the will (and the need) of the farmers to invest time and money in irrigation the next season.

Intensification of recession agriculture, first or second best option ?

Intensification of recession agriculture is more likely to succeed if the inundation occurs regularly, ideally each year. So far, recession agriculture has been conducted traditionally without any inputs, but the low production cost of intensification combined with the ñriskò that public / donor investments or operational subsidies toward irrigation continues shrinking, make it worth considering for OMVS and other decision makers intensify recession agriculture. Past agricultural research (Sapin, 1971) has shown that with a US$ 35[15] per hectare urea application (more than ten times less than what farmers currently spend on irrigated agriculture), recession sorghum yield could reach 1,200 to 1,500 kg per hectare (twice the average current yield) using local varieties (Mané and Fraval, 2000). With a flood

[15] The amount of urea indicated in the paper quoted has been priced at current prices.

allowing 45,000 ha on both banks, of which 30,000 are on the left bank, this would provide about 90 kg of cereals per person to the Matam and Podor population each year. This is half of the 150 to 200 kg/year/person of cereals to cover minimum needs (based on UN food requirements ratios). Complementary to the use of urea, it is possible to equip recession agriculture depressions or groups of depressions with gates that just need to be closed when the water has reached its maximum level in order to control the duration of the inundation locally, and which would therefore allow release of significantly less water from the dam during the artificial flooding. Figures are not available but it would be worth assessing the plausible impact on the hydropower sector under such conditions. Ironically, as shown before with the econometric analysis, favouring recession agriculture by allowing more regular flooding to occur would negatively influence the attractiveness of some farmers of the floodplain for rice irrigation

Finally, how should water be managed at the Manantali reservoir?

The hydropower temptation, in a context of asymmetric information

Hydropower and irrigated agriculture are the only water uses that can be charged by OMVS to at least partly recover investment and running costs (operation and maintenance of the Diama and Manantali dam and of dykes in the delta, and OMVS budget). It is indeed impossible in practice to request people involved in activities that result from the flood, i.e. indirectly from water releases from the reservoir, to pay for the investment: recession agriculture fishing, cattle, etcé In addition, as has been shown before, the money spent by farmers on irrigation does not cover the cost of schemes sustainability, all the more so the cost of the initial investment. Besides, Water Users Associations are reluctant to pay and poor enforcement mechanisms are in place. All in all, it is only hydropower that allows OMVS to gradually reimburse the 800 Millions USD left for the investment and the running costs.

Hence, it appears tempting for OMVS, which has for so long depended upon donor support, to generate more resources internally by managing the dam so as to maximise hydropower, i.e. to circumvent the artificial flood, allowing it at best only once in a while for environmental purposes, as Nature randomly did before the dams. It would definitely be a good solution from the point of view of cost recovery and profitability at national and tri-nation level. It would not be so positive at local level in the Middle Valley because the constraints that affect irrigated agriculture are beyond the reach of decision makers of all levels. Lifting only one (by wiping off recession agriculture) would perhaps result in a peculiar and certainly not optimal situation where the two major agricultural activities present in the floodplain would decline: irrigated agriculture through lack of financial resources spent on maintenance and low profitability (let aside the case of few communities that would absolutely need to rely on irrigation but for subsistence purpose and would find the resources as they did in the 70s and 80s in times of drought), 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).

The fact that, among the direct stakeholders concerned with water allocation, only ESKOM (the private company that operates the Manantali dam and produces hydropower) fully understands the details of the computerised programs developed for the management of the Manantali dam (SERES, 2005) and the lack of representation of stakeholders ñspeaking forò (not to say representing) recession agriculture in the ***ñ****Permanent Water Commission****ò*** creates an obvious distortion in favour of hydropower generation. It is very likely that, during a specific year, if ESKOM did not implement the targeted hydrograph even though the water level in the reservoir would reach or exceed, the ceiling set to do it, it would be difficult for anyone to challenge ESKOM.

In addition, donors, although they have linked their financial support for the energy project to environmentally friendly water management practices, are more than happy to see OMVS at last generate its own income and may well not be so fussy in the future.

The limits of economic cost-benefits analysis.

A new *ex-ante* economic analysis was being conducted for OMVS as a complement to the Reservoir Management Optimisation Program (SCP et al, 2000) at the time of this research. Its objective was to help select water management scenarios for the future. The criteria for selecting preferred dam management scenarios were primary hydraulic - how to satisfy future demands - and, in a second phase, economic - what is the overall internal rate of return associated with the acceptable hydraulic scenarios. A more realistic economic analysis should not ignore the constraints faced by irrigated agriculture (in particular by computing a reasonable cropping intensity, realistic production costs, etcé) instead of the usual, ñper hectare figuresò that describe potential performance and create a bias in favour of so-called productive water uses.

There should be no confusion between pessimism and realism: since transfer of irrigation schemes to farmer management, there are very few incentives left to shape the behaviour of thousands ñresponsibleò farmers towards a productive, sustainable and profitable agriculture. 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 to rely on outside resources for some time. A tricky but essential mission for decision makers will be to credibly inform irrigators that, from now on, breaking with past habits (such as general cancellation debt, 100% donor funded rehabilitation of schemes), farmers will have to count more and more on their own resources and skills. And the challenge remains for them to recreate the local economy that is necessary for agricultural production in irrigation schemes to: existence of readily available artisans who can maintain and repair pumps while making a living out of it (otherwise by definition, they would not exist) inter-schemes organisation for marketing rice at a better price, private extension services,...

One should also point out the limits of the approach that would seek the maximization of the societyôs overall economic benefits. Even though the benefits to hydropower resulting from a restriction of floodwater are much higher than the agricultural benefits derived from the flood itself, this would not justify the policy of hydropower maximization accompanied by the compensation of losers simply because it is practically not feasible: how to identify and compensate tens of thousands people scattered along the river?

Water management decisions result from stakeholdersô visions of development?

Water management options in the Senegal River Valley are being analysed through a variety of sometimes opposed visions of ñdevelopmentò. Whereas the land, water and climatic conditions are optimal for highly productive agriculture, to create an artificial flood to enable recession agriculture and other minor uses is definitely seen by many as a sign of backwardness and wastage of resources. This engineering and economic vision is expressed in terms of inputs, assets, potential, markets. It either ignores the complexity of social constraints, although they are well documented (Hugon, 1993), or considers that they can always be overcome with some adjustments and side measures. On the other end of the spectrum, there will be people to authentically believe that whatever is traditional, natural, community-based is good by nature and should not be affected in any way. People from this category would both criticize the construction of the Manantali dam and take the side of recession farmers, not realising that it is the Manantali dam that provides the opportunity for more stable recession agriculture in that it allows more frequent flooding than under natural conditions. It is difficult to say whether either view is right or wrong, as the respective perceptions and positions are more the results of values than of an objective analysis of facts and figures.

The facts are the following: 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 an opportunity to tens of thousands of farmers to produce their cereals at a low cost without significantly affecting current hydropower production targets. 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, the most water consuming crop, that tensions over the resource will not arise right away. Moreover, SIMULSEN has shown that, if hydrological conditions went back to the long

period average (after the drought of 1970-1990), the antinomy between reaching the hydropower threshold and allowing an annual artificial flood would be even minimised.

This multidisciplinary research, far from revealing the ñoptimalò 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.

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