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Optimal Transboundary Water Diversion: The Case of the Senegal River

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Abstract

This paper ascertains the costs and benefits of diverting water from the Senegal River. Two scenarios are compared to the status quo of inaction: the social planner and the competitive scenarios. Although these two scenarios yield positive present values of net benefits, the social planner scenario would use smaller quantities of water while providing the highest net benefits to society. Given that the benefits are one-sided while the costs are spread over several constituencies that share the river, it is possible for the gainers to compensate the losers, especially the farmers of flood recession agriculture identified as the main deprived group.

Key words: water, project analysis, economic development, environment management

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Introduction

Water resources shared between two or more countries form a significant portion of the world's fresh water. Although the efficient handling of shared water resources is vitally important, there are still numerous impediments to the optimal use of these resources: conflicts of interests between co-basin States, opposing priorities on river basin issues, and externalities (Elhance, 1999; Falkenmark, 1986; Godana, 1985; Wilson, 1995; Just and Netanyahu, 1998). An economic analysis of water diversion integrating basin-wide benefits and costs may shed light on possible "win-win" negotiations resulting in positive non-zero sum games.

The Senegal River provides an interesting case study of transboundary water diversion. Shared by three countries (Senegal, Mali and Mauritania), unilateral management decisions by Senegal have forestalled cooperative agreements with neighboring riparian countries.[1]

The thrust of this article is to determine the costs and benefits of diverting water from the Senegal River. More specifically, it pursues three objectives. First, it estimates the costs and benefits accruing to different parties affected by such a water diversion. Second, it develops and implements an empirical model for determining the socially optimal level of water diversion. This solution is compared to the status quo and to a competitive market allocation of water diversion. Third, it ascertains the policy implications and alternative policy schemes that can be used to implement a water diversion program.

A Conceptual Model of Water Diversion

When two or more countries use common resources, there is potential for the existence of unidirectional or reciprocal externalities. In those circumstances, resources are inefficiently used. However, so long as costs are fully integrated and compensation is possible, full cooperation will yield efficient water diversion from the basin.

Following Becker and Easter (1999), the benefit of diverting water is given by a positive, increasing, continuous, and concave quadratic function

$$(1) \qquad B_i(w_i) = \alpha_1 w_i - \frac{\alpha_2 w_i^2}{2} \quad ,$$

where users are *i* = 1, ...n (a user *i* refers here to a country); w_i is the amount of water diverted by user *i*; $B_i(w_i)$ is the money benefit to user *i* from diverting w_i; and α_1, $\alpha_2 > 0$. The total amount of water diverted is given by

$$(2) \qquad W = \sum_{i=1}^{N} w_i \ .$$

The cost for user *i* is given by a positive, increasing, continuous, convex quadratic function. This user cost consists of the direct cost of diverting water, $DC_i(w_i)$, as well as the indirect cost, $EC_i(W)$, associated with decreasing the river stock. We assume that the effects of user *i*'s actions on its own cost function are the same as on any other user.

The direct cost function is given by

$$(3) \qquad DC_i(w_i) = \beta_1 w_i + \frac{\beta_2 w_i^2}{2} \quad ,$$

Where β_1 and β_2 are positive parameters (> 0). The external cost depends on the total amount of water diverted:

(4) $$EC_i(W) = \gamma_1 W + \frac{\gamma_2 W^2}{2} \quad .$$

Substituting (2) into (4), let $W = nw_i$ (assuming identical users) to obtain:

(5) $$EC_i(W) = n\gamma_1 w_i + \frac{n^2 \gamma_2 w_i^2}{2} \quad ,$$

where $\gamma_{1,}$ and γ_2 are positive parameters.

Assume that there exists a social planner who would decide on a basin wide policy that guarantees an optimal solution. To determine the economic optimal level of water diversion, water should be diverted up to the point where marginal benefits from diverting one unit of water is equal to the sum of marginal damages to all users in the river basin. This is equivalent to maximizing the following equation:

(6) $$\underset{w_i}{Z^s} = \sum_{i=1}^{N} \beta_i(w_i) - \sum_{i=1}^{N} DC_i(w_i) - \sum_{i=1}^{N} EC_i(W) \quad .$$

At the economic optimum, the efficient water diversion from the basin is:

(7) $$w^{s*} = \frac{\alpha_1 - \beta_1 - n\gamma_1}{\alpha_2 + \beta_2 + n^2\gamma_2} \quad .$$

Under competition, each country ignores any external costs. Thus, the solution under competition is given by:

(8) $$w^{c*} = \frac{\alpha_1 - \beta_1}{\alpha_2 + \beta_2}$$

As one would expect, $w^{c*} \geq w^{s*}$, indicating that competition results in excess diversion of water.

Estimating the Benefits of Water Diversion

Agricultural benefits constitute by far the most significant benefits from diverting water inland. The proposed project only involves directing water into Senegal and although Mauritania could in principle do the same, it would do so at a higher and practically prohibitive cost. Indeed, Senegalese agriculture is based on rainfed production and suffers dramatically from drastic water deficits. The diversion project allows farmers to pursue in two seasonal production activities rather than only one.

Consider a typical Senegalese farm producing two crops, peanuts and millet. Farmers production choices involve three net outputs (Q_i), of which the first two are outputs produced ($Q_i > 0$, $i = 1, 2$) and the third is a variable input ($Q_i < 0$, $i = 3$). In the absence of irrigation data, rainfall (R) is used as an empirical proxy and is treated as an exogenous variable.[2] Let the expected nominal output prices and the input price be defined as P_i ($P_i > 0, i = 1,..,3$) and the expected profit as Π. Using P_3 as the *numéraire* price, then the normalized expected prices of outputs are $P_i = P_i/P_3$ ($i = 1, 2$) and the normalized variable profit is $\pi = \Pi / P_3$. Following Diewert (1973) and Lau (1976), the normalized restricted profit function can be expressed as

$$\pi = a_0 + \sum_{i=1}^{2} a_i p_i + \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2} a_{ij} p_i p_j + \sum_{i=1}^{2} b_i p_i R + \frac{1}{2}\sum_{i=1}^{2} c_i p_i R^2 \quad , \tag{9}$$

where a_i, b_i and c_i are parameters and other notation is as defined above.

It is required that the above profit function be continuous, twice differentiable, convex, and monotonic for the normalized prices and the other exogenous factor. Applying Hotelling's lemma (Lau, 1976), the following system of output supply and variable input demand functions (Q_i^*) is obtained:

$$\text{(10)} \qquad \frac{\partial \pi}{\partial p_i} = Q_i^*(p,R) = a_i + \sum_{j=1}^{2} a_{ij} p_j + \sum_{i=1}^{2} b_i R + \frac{1}{2} \sum_{i=1}^{2} c_i R^2, \quad (i = 1, 2).$$

From equation (9), the shadow price of rainfall is given by:

$$\text{(11)} \qquad \frac{\partial \pi}{\partial R} = \sum_{i=1}^{2} b_i p_i + \sum_{i=1}^{2} c_i p_i R.$$

Assuming that profit is on a per hectare basis, (11) is the value of marginal of water per hectare. It is reasonable to assume that $\partial C / \partial R = 0.$[3] Consequently, (11) represents the demand for water.

Following the theoretical framework above, from equation (10) the following system of equations (including the domestic demand for millet) is estimated:

$$\text{(12)} \qquad \begin{aligned} Q_1 &= \alpha_{10} + \alpha_{11} p_1 + \alpha_{12} p_2 + \alpha_{13} R + \alpha_{14} R^2 + u_1 \\ Q_2 &= \alpha_{20} + \alpha_{21} p_1 + \alpha_{22} p_2 + \alpha_{23} R + \alpha_{24} R^2 + u_2 \\ P_2 / d &= \alpha_{30} + \alpha_{31} (Q_2 A_m) + \alpha_{32} (GDP / d) + u_3 \quad , \end{aligned}$$

where Q_1 and Q_2 are respectively the peanut and millet yield. A_m represents millet area, p_1 and p_2 are the normalized prices of peanut and (expected) millet, and the u_i's are random errors. Prices in the supply equations are deflated by the fertilizer price, while the consumer price index (*d*) is used as a deflator in the demand equation for millet. In addition, symmetry is imposed with $\alpha_{12} = \alpha_{21}$ in order to reduce the number of parameters to be estimated. The domestic demand for millet is included to account for possible price effects of changes in supply due to additional water access.

Using (12) along with (11), the change in agricultural profit from a change in rainfall is given by:

$$\text{(13)} \qquad \begin{aligned} \frac{d\pi}{dR} &= \alpha_{13} p_1 + \alpha_{23} p_2 + \alpha_{14} p_1 R + \alpha_{24} p_2 R \\ &= \alpha_0^* + \alpha_1^* R \end{aligned}$$

where $\alpha_0^* = \alpha_{13} p_1 + \alpha_{23} p_2$ and $\alpha_1^* = \alpha_{14} p_1 + \alpha_{24} p_2$.

To evaluate the demand for water, it is necessary to assess the benefits of additional amounts of rainfall. Consequently, it is important to estimate the desirable level of rainfall (R^d) from the farmer's perspective. Equation (13) can be utilized to retrieve this desirable level.

Once the desirable level of rainfall is known, one can assess the benefits of moving from actual rainfall to that desirable rainfall level. This amounts to the following integral:

$$(14) \qquad \int_{R}^{R^d} (\alpha_0^* + \alpha_1^* R)\, dR$$

It is quite simple to convert rain into a water irrigation equivalent. First, consider that 1mm of rain is equivalent to 10 m^3 of water per ha (Bousquet et al., 1997). Since irrigation is more efficient than rainfall in water distribution to crops, water can be valued at 80% of rainfall (Bousquet et. al., 1997). Thus, the amount of water equivalent to rain is given by $w = R \; x \; 10 \; x \; 0.8$. Equation (14) then becomes:

$$(15) \qquad \int_{w}^{w^d} (\alpha_0 + \alpha_1 w)\, dw$$

Note that α_0 and α_1 correspond to α_0^* and α_1^* when scaled by the rate of transformation of rainfall into water irrigation equivalence given above. The expression in (15) is the empirical approximation to equation (1), the benefits of water diversion.

Estimating the Costs of Water Diversion

One of the main components of the costs of water diversion is the investment cost for the construction of the water transportation facility (pumping stations, diversion canals, and other works). The operating and maintenance costs represent the other major component of the direct costs of diversion. The operating costs include the costs of labor, material and energy required to pump the water. The value of the land taken for the construction of canals should also be imputed even if land is publicly owned.

Besides these direct costs borne out by the project builders, it is possible that the project implementation causes collateral damages.[4] Farmers that perform flood recession agriculture in sensual Mauritania are the first victims. These farmers cultivate their plots around the river at the end of the rainy season once the flood has ceased and the river has receded. This activity usually constitutes their main source of agricultural revenue and the magnitude of this source of income depends essentially on the extent of the flooding (Salem-Murdock and Niasse, 1996).

The direct cost function, which includes operating and maintenance costs, draws from the work of Scott et al. (1985). Direct costs are determined by the rate of water flow (y) rather than by the total amount of water diverted and are represented by:

$$DC_t = \beta_0 y_t + \beta_1 y_t \quad , \tag{16}$$

where y_t is the amount of water transferred in period t.

Consider the following relationships: $W = y * \theta \;\; \Rightarrow \;\; y = \frac{W}{\theta}$, where W is the total volume of water diverted, y is the flow rate and θ is time. Then the direct cost function becomes:[5]

$$DC = \beta_0 \frac{W}{\theta} + \beta_1 \left(\frac{W}{\theta} \right)^2 \quad . \tag{17}$$

Farmers of flood recession agriculture represent the main group that suffers from external damage. There are about 100,000 ha cultivated under this production system, on both sides (Senegal and Mauritania) of the Senegal river. Revenue per ha were estimated to amount about 8,500 FCFA per ha (Crousse et al., 1991). These values were used to estimate the parameters γ_0 and γ_1 of a quadratic external cost function:

$$EC = \gamma_0 W + \gamma_1 W^2 \, . \tag{18}$$

It was assumed that external costs start taking effect at 100,000 m^3 of water diversion. At about 200 billion m^3 of water, any additional diversion would have no effect, the maximum damage being already attained. Equation (18) corresponds to equation (5) for the external costs.

Implementing Alternative Scenarios

After estimating the cost and benefit functions for water diversion, the social planner's and the competitive solutions were implemented. The results are presented considering both the rainy and the dry seasons.

Using equation (15), (17), and (18) and assuming that Senegal decides to divert water, the net social benefit (NSB) which is the empirical counterpart of equation (6) is given by:

$$\begin{aligned} Z^s_{\tilde{w}} = \{(\alpha_0 \tilde{w} + \frac{\alpha_1}{2}(\tilde{w}^2 + (2\tilde{w}w))) * A\} - \{\beta_0 \left(\frac{\tilde{w} * A}{\theta} \right) + \beta_1 \left(\frac{\tilde{w} * A}{\theta} \right)^2 \\ - \{\gamma_0 (\tilde{w} * A) + \gamma_1 * (\tilde{w} * A)^2\} \quad . \end{aligned} \tag{19}$$

where $\tilde{w} = w^d - w$ is the difference between desired and actual water, *A* is irrigated area, and other notation is as defined above.

Taking the derivative of *NSB* with respect to $\tilde{w}$ one obtains:

$$\tilde{w}^{s*} = \frac{\theta(-\beta_0 + \alpha_0\theta + w\alpha_1\theta - \gamma_0\theta)}{2A\beta_1 - \alpha_1\theta^2 + 2A\gamma_1\theta^2} \quad . \tag{20}$$

Plugging the value of $\tilde{w}^{s*}$ into (19), one obtains the optimal NSB value (Z^{s*}). The actual value of rainfall is crucial in determining the level of additional water needed and subsequently the benefits of providing this supplementary water. To take into account the uncertainty of the water supply, a Monte Carlo procedure using the mean and standard deviation of rainfall (or its water irrigation equivalent), and assuming normal distribution, generates 1,000 random numbers (rainfalls). These numbers can then be used in the calculation of the optimal water irrigation and the net social benefit.

To implement the competitive scenario, external costs are ignored and equation (19) reduces to its first two components:

(21) $$\underset{\tilde{w}}{Z^c} = \{(\alpha_0 \tilde{w} + \frac{\alpha_1}{2}(\tilde{w}^2 + (2\tilde{w}w)))*A\} - \{\beta_0\left(\frac{\tilde{w}*A}{\theta}\right) + \beta_1\left(\frac{\tilde{w}*A}{\theta}\right)^2 .$$

Maximizing Z^c with respect to $\tilde{w}$, one obtains the equilibrium level of water under the competitive situation:

(22) $$\tilde{w}^c = \frac{\theta(-\beta_0 + \alpha_0\theta + w\alpha_1\theta)}{2A\beta_1 - \alpha_1\theta^2} \quad .$$

Comparing equations (20) and (22), it is clear that $\tilde{w}^c > \tilde{w}^{s*}$, as expected. Again, using equation (22) and inserting it back into equation (21), one obtains NSB for the competitive solution. Further details on data sources and management can be found in the appendix.

Empirical Results

The estimated parameters for the system of supply equations in (12) is presented in Table 1. Nearly all the parameter estimates are statistically significant at the 5% level. The estimate for millet (α_{22}) in the millet yield equation is negative. This might signal the fact that millet is primarily consumed at the household level and is only marginally supplied to the market.

The results in Table 1 are used to evaluate the change in agricultural profit for a marginal change in the quantity of rainfall ($d\pi / dR$).[6] From equation (15), the value of the parameter estimates α_0 and α_1 are respectively 34.665 and -0.0080875 and it follows that the desirable level of rainfall (R^d) is equal to 536.57 mm. This quantity is far higher than the mean rainfall $\overline{R}$, which is approximately 356.94 mm. These values correspond to the desired level of irrigated water (w^d) being equal to 4,286 m^3/ha and the mean water equal of 2,855 m^3/ha. The parameters used in the maximization of the social planner and competitive objective functions are summarized in Table 3.

Equation (19) provides the optimal net social benefit while equation (20) provides the optimal level of water diversion. The net social benefit is evaluated over 50 years and its present value is obtained using a 10% discount rate. Notice that the values of water used in the base calculation were generated randomly. The evaluation over 50 years is repeated 20 times to add to 1,000 random rainfalls. The results are presented in Table 3.

Three solutions are included for each year: the rainy season, the dry season, and the combined season (dual production). The optimal amount of additional water for the rainy season is on average 62.515 millions m^3, assuming an irrigated area of 62,069 ha.

Regarding the net social value, the results for the rainy season program are not satisfactory. Indeed, the net present value of social benefits (subtracting the investment costs) is negative at all times and is, on average, equal to –24.66 billion FCFA (Table 3). When the investment costs are excluded, the net social benefit amounts to 4.34 billion

FCFA. This outcome implies that the investment should not be made for the sole purpose of providing additional water to cover agricultural water deficits.

When the dry season is included, enabling double cropping, then the net present value is positive and reaches, on average, 15.86 billion FCFA. On the other hand, if the dry season were considered in isolation, the investment would provide positive figures around 11.53 billion FCFA. In this case, the volume of water would be approximately 224.51 millions m^3.

There is a large difference between the rainy and dry season results. This difference stems in part from the fact that the demand for additional water during the rainy season is limited and cannot justify extensive investment expenses. In addition, the assumption that the dry season activities do not cause external damage increases the likelihood of higher returns for that season.[7]

Following a procedure similar to the one outlined above, the competitive solution was obtained. This solution indicates that the optimal amount of additional water needed during the rainy season is 78.767 millions m^3, a volume greater than the quantity needed under the social planner's scenario. Although the competitive solution yields a greater volume of water compared to the social planner's scenario, its returns are lower due to higher external costs.

In contrast, because it is assumed that external costs are absent during the dry season, the present value of net social benefit is slightly higher for the competitive situation (11.63 billion FCFA) relative to the social planner's case (11.53 billion FCFA). On the other hand, when considering the whole year, the social planner's scenario becomes dominant (15.86 billion FCFA compared to 15.77 billion for the competitive case).

Conclusions

The overall objective of this paper was to determine the costs and benefits of diverting water from the Senegal River. Cost and benefit functions of water diversion were estimated taking into account external costs to flood recession farmers.

For both the social planner and the competitive scenarios, building the water diversion project for the sole purpose of supplying additional water during the rainy season would not be socially desirable. The best alternative is a system of double cropping for which water is made available during the rainy season as well as the dry season. This system requires, however, that water allocation during the rainy season be restrained to its best use, implying that monitoring costs would be incurred. Another possibility would be to make water available only during the dry season, which supposes that the infrastructure would be idle during the rainy season.

Although both scenarios give positive present values of net benefits, the social planner's scenario uses smaller quantities of water while providing higher net benefits to society. This outcome is expected because the social planner contemplates all costs including the external costs in contrast to other scenarios in which players ignore costs to their counterparts and thus pose a greater burden on society by overdrawing water.

One of the weaknesses of the project is that the benefits are one-sided while the costs are spread over the different countries that share the river. However, given the profitability of the project, it may be worthwhile to design a compensation scheme that would alleviate the costs that would eventually be imposed on other parties.

There is, however, no guarantee that any of the options described above would be applicable, given the fact that farmers in Mauritania may lose while no one in that country would gain from the project implementation. This makes it almost impossible for the Mauritanian policymakers to approve such an initiative. Unless a compensation scheme is devised to allow the Mauritanian side to share part of the gains, the status quo situation is likely to prevail.

Footnotes

[1] Since 1972 Mali, Mauritania and Senegal have initiated a cooperative agreement under the OMVS (Organisation pour la Mise en Valeur du Fleuve Senegal) treaty to manage the river basin for irrigation, energy production and navigation (OMVS, 1972). Two dams were built to regulate the river flow and prevent salt intrusion from the sea. In the early 1990s, Senegal designed a plan to divert water from the Senegal River to revitalize its fossilized valleys. This program is to cover 3,000 km of hydrological axes (Sakho, 1998; Bitondo et al, 1997). Four years after the initial decision and an experimental realization of 150 km, the program entered its active phase of implementation. At the end of 1997, Mauritanian officials protested vigorously against the Senegalese project. They argued that this program would threaten the stability of water resources and would therefore jeopardize Mauritania's interests. The government of Senegal decided to momentarily freeze the project for additional research.

[2] To assess the agricultural benefits of irrigation, one starts with the state of nature and sees how rainfall impacts agricultural production in the region under study. This process allows the determination of the desirable level of rainfall and subsequently the amount of rain deficit. This amount of rain deficit can then be converted in to a water irrigation equivalent. Finally, the agricultural benefits of having additional water through irrigation can be evaluated.

[3] It is assumed that additional costs for a marginal increase in rainfall are zero. In fact, unless there is a severe drought that makes farmers reluctant to use fertilizer, it is unlikely that cost would be influenced by marginal changes in rainfall.

[4] A potentially important cost of the project stems from its impact on the environment, including decreased wildlife habitat consecutive to lower river levels and accelerated rates of stream erosion (Okidi, 1987). Although these environmental damages are often difficult to quantify, they should not be ignored.

[5] In the empirical implementation, the parameter estimates β_0 and β_1 are scaled to take into consideration the conversion of the flow rate in m^3/s and the variable costs in FCFA. Thus, equation (17) corresponds to the conceptual equation (3) for direct costs.

[6] This marginal change initially included direct as well as market effects. In the empirical implementation, the market effects turned out to be insignificant. There are two possible explanations. First, rainfall is not crucial to millet production as compared to peanuts. Second, the role of millet in household consumption may counteract the supply effects. Calculations conducted with the direct effects alone ($\partial\pi / \partial R$) gave similar results to those with the full model. Therefore, to keep the model tractable, equation (11) was simplified to its first term and the market effects were subsequently dropped.

[7] This assumption would not persist if one considers the potential cost to navigation, the latter would mainly affect Mali especially if the OMVS partners decide to implement their navigation program. This avenue is not pursued here.

DATA APPENDIX

The Senegalese diversion project was originally conceived to include three geographical zones: the north of the peanut basin, which corresponds to the administrative region of Louga, the Central region (Fatick-Diourbel) and the South-East. This study is limited to the northern region, which represents the main component of the project.

The data necessary for the computation of the agricultural benefits represent the bulk of the regional data needed to implement this analysis. Monthly rainfall data time series were obtained from the Food and Agriculture Organization of the United Nations (FAO, 200D) and the National Oceanic and Atmospheric Administration (NOAA). These data span 1960 to 1994 and are relatively decentralized. They are organized at the department level, which facilitates aggregation over space and time.

Time series data on area cultivated and the production figures for peanuts and millet came from the Department of Agriculture of the Senegalese Ministry of Rural Development. Price series for peanuts and millet along with the price of fertilizer for the period under study (1960-1994) originated from the Senegalese Department of Statistics. The data on Gross Domestic Product (GDP) also came from this same source.

The data on investment costs for the diversion project were extracted from various preliminary studies of the Senegalese program for the revitalization of the fossilized valleys (Hydroconsult International, 1995, 1996; MEAVF, 1994). The cost parameters used in the calculation of the direct costs were obtained from Scott et al. (1985). The preliminary data used to estimate the parameters of the external costs were taken from Crousse et al. (1991).

Once the data were ready for use, three different software packages were employed to carry out the different estimation tasks. The *SHAZAM 8.0* software was used in the estimation of the system of equations (13) to determine the parameter of the agricultural benefit function. The optimization process to solve for the optimal level of water and the net social benefit were conducted with the *MATHEMATICA 4.0.2* program. Finally, the numerical solutions were carried out with *MS EXCEL 97*.

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Table 1. Econometric results of the system of supply and demand equations (GMM estimation)

		Parameter Estimates	T-ratio
Peanut Yield Equation			
Intercept	β_{10}	-0.79822	-2.1173
Peanut Price	β_{11}	0.1149E-05	2.2656
Millet Price	β_{12}	0.13153E-05	4.1290
Rain	β_{13}	0.35032E-03	2.1007
Rain^2	β_{14}	-0.26053E-07	-1.4892
Millet Yield Equation			
Intercept	β_{20}	0.34571	2.1545
Peanut Price	β_{21}	0.13153E-05	4.1290
Millet Price	β_{22}	-0.26261E-05	-6.2451
Rain	β_{23}	0.15382E-03	2.2858
Rain^2	β_{24}	-0.16698E-07	-2.2791
Millet Price equation			
Intercept	β_{30}	0.15640E+06	17.564
Area times Yield	β_{31}	-0.46213E-01	-4.3813
GDP/d	β_{32}	-41.942	-9.3156

Table 2. Parameters Used in the Maximization of the Objective Function

Benefits	Direct Costs	External Costs	Water (m^3)	Area (ha)
$\alpha_0 = 34.665$	$\beta_0 = -24.643$	$\gamma_0 = 2.8813$	$w^d = 4286.22$	$A = 62{,}069$
$\alpha_1 = -0.0080875$	$\beta_1 = 877{,}168.4$	$\gamma_1 = -2.5\text{E-}09$	$\overline{w} = 2{,}855.529$	
	$\theta = 10{,}368{,}000$		$\sigma_w = 789.404$	

Table 3. Present Value of Net Social Benefits from Alternative Scenarios (millions FCFA)

Statistics	Social Planner's Scenario			Competitive Scenario		
	Rainy Season	Dry Season	Combined Seasons *	Rainy Season	Dry Season	Combined Season
Mean	-24,662	11,527	15,865	-24,865	11,630	15,765
St. Error	207	0	207	208	0	208
Median	-24,451	11,527	16,076	-24,660	11,630	15,970
Mode	N/A	11,527	N/A	N/A	11,630	N/A
St. Deviation	924	0	924	928	0	928
Minimum	-26,185	11,527	14,342	-26,397	11,630	14,233
Maximum	-23,201	11,527	17,326	-23,405	11,630	17,225
Sum	-493,239	11,527	317,298	-497,292	232,602	315,310
# Scenarios **	20	20	20	20	20	20

* The combined season results are not the sum of the two seasons because the investment costs are subtracted only once.

** Each scenario is simulated 20 times for a 50 year series.