13

ECONOMICS OF DAMS AND IRRIGATION IN THE UPPER NIGER

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13.1 Introduction

The Poverty Reduction Strategy Paper (PRSP) of Mali constitutes the sole framework for Mali's development policies and poverty reduction strategies (GoM 2002). This influential document highlights the need to exploit the country's hydroelectric and hydro-agricultural potential, in the order of 5,000 GWh/annum and 2 million hectares, respectively. A review of the PRSP by the International Development Association (IDA) and the International Monetary Fund (IMF) confirms this, stating that "further development of Mali's untapped hydrological potential is a critical need, as it directly addresses one of Mali's core vulnerabilities, that of the temporal and spatial variability in rainfall, as well as the uncertainty of climatic conditions" (IDA & IMF 2003).

Although Mali's hydroelectric and hydro-agricultural potential has yet to be fully realised, it is widely questioned whether the costs and benefits of such mega-investments are properly estimated. Besides the economic feasibility (i.e. direct costs and benefits) of additional dams, it is still unclear what the indirect effects of hydroelectric and hydro-agricultural schemes are on downstream beneficiaries of rivers.

The overall aim of this Chapter is to support decision making at basin level with regard to management and construction of dams and irrigation schemes in the Upper-Niger in relation to food security and ecological conditions in the downstream Inner Niger Delta. This is achieved by conducting an extended cost benefit analysis (CBA) for the main economic sectors addressed in the previous chapters.

The Chapter is structured as follows. The methodology underlying the cost benefit analysis of dams and irrigation schemes in the Niger River basin is explained in Section 13.2. The valuation of the direct costs and benefits of the Office du Niger, Sélingué and the Fomi dam is conducted in Section 13.3. The indirect costs and benefits of the four scenarios are estimated in Section 13.4. The indirectly affected sectors include agriculture, fisheries, livestock, transport and biodiversity. In Section 13.5, the extended cost benefit analysis is conducted. Conclusions are drawn in Section 13.6.

13.2 Methodology

In estimating the costs and benefits associated with dams in the Niger River basin we are not taking a novel approach. Cost-Benefit Analysis (CBA) is an indispensable economic tool in any large infrastructure project. Dams are no exception. Traditionally, a CBA was performed using a limited set of parameters. In most cases the costs were restricted to the direct capital investment, construction costs and operational costs. Likewise, only direct (measurable) benefits, such as power generation, irrigation benefits and tourism were taken into account. Nowadays, social and environmental effects are increasingly considered in the planning of dams, through the application of an extended CBA. This analysis requires economic valuation of indirect costs and benefits (Aylward *et al.*, 2001).

Several extended CBA studies have been carried out in the past. The World Commission on Dams (WCD 2001) investigated eight projects in detail. Two of these are situated in Africa: (1) the Orange River Development Project in South Africa; and (2) the lake Kariba dam in Zambia and Zimbabwe. A third interesting study in Africa, which was commissioned by IUCN, focussed at the effects the Maga Dam on the Waza-Logone floodplain area in Cameroon (Loth 2004). These studies have been described in more detail in Annex IX.

Cost benefit analysis of dams

Like any other large infrastructure project, dams require large investments in the planning and construction phase. Investments take the form of financial capital as well as technology and human resources. In comparison with initial investment costs, operation and maintenance costs for dams are relatively low. Besides initial investments and operational costs, large dam projects often have significant impacts on society and the natural environment, representing an additional cost to the project. The best example of social impacts caused by large dam projects is the displacement and resettlement of inhabitants of the flooded area. Whereas resettlement used to be overseen in the planning phase in the past, at present resettlement costs are increasingly budgeted in project planning. Environmental impacts associated with dams include reduction in wetland habitat and restricted fish migration. As with social impacts, the costs of mitigating environmental impacts are included in project planning more than in the past.

Estimation of direct costs

Costs for dam construction projects vary significantly as a result of site characteristics. It is therefore difficult to give a general overview on the costs. Based on the World Commission on Dams (WCD, 2001), which conducted a large survey on the costs of dams throughout the world, we attempt to summarize general findings. As indicated above, direct costs for dams can be divided into 4 main categories: (1) construction costs; (2) resettlement costs; (3) environmental mitigation costs; and (4) operation and maintenance costs (O&M).

Table 13.1. Subdivision of Environmental costs according to size of hydropower project. Source: WCD 2001.

Project size	Type of Cost (US$1991)			
(installed capacity)	Capital	Study	O&M	Reporting
<1MW	$134,500	$21,700	$5,124	$5,900
1-10 MW	$233,900	$153,200	$25,420	$11,800
10 - 50 MW	$1,511,300	$452,800	$33,000	$31,200
50 - 100 MW	$1,266,200	$1,084,000	$9,600	$500
>100 MW	$50,569,000	$307,000	$1,439,400	$176,700

Construction costs are the major component of total project costs in most cases. Construction costs refer to the building of the dam itself as well as all related elements, such as turbines, canals, irrigation schemes etc. The base cost estimates are corrected with a 10-15% to cover unforeseen costs and are subsequently corrected for inflation over the construction phase. Costs depend mainly on the physical setting of the project, with considerable variance in costs caused by differing local geology, making it difficult to give a generalization of construction costs. A study by Head (1999) gives a range of US$1,000 to US$3,000 per KW of generated electricity for hydropower projects, while Ljung (2000) provides a range of US$1,500 - US$2,250 per KW.

In the past, the displacement of people and loss in livelihood resulting from reservoir flooding was not considered in project planning. Recently, resettlement and income restoration (jointly called 'resettlement costs') have gained increasing attention in project design. Direct compensation of those affected is also being included in the design. Gutman (1993) found that estimated resettlement costs were typically overrun by 40%. Resettlement costs can amount to between zero and 25% of total project costs, depending on the local demographic situation.

Dams can have large environmental impacts. To counter negative impacts, mitigation measures are often included in dam design. Examples are fish migration systems, habitat restoration and artificial flooding of wetlands. Environmental mitigation costs are subdivided into study costs, capital costs, operation and maintenance costs and reporting costs. Table 13.1 shows an overview of these costs for hydropower projects in the USA.

One of the attractive features of large dam projects is the relatively small share of operational costs once the construction is completed. On average, these costs amount to only 1-3% of the total project costs. For irrigation projects these costs are generally higher due to high maintenance costs of the irrigation network. Oftentimes, the costs are covered by charging user fees for irrigation.

A major issue with dam projects worldwide remains the, at times, enormous cost overruns. For example, a study of 70 World Bank financed hydropower project shows that the average cost overrun is around 27%. Another study into multipurpose dams comes to an average of 39% over budget. A WCD study (2001) into smaller dams reports overruns of as much as 200%. The majority of cost overruns are due to unpredicted geotechnical conditions. Other causes include late delivery of materials, labour unrest, legal challenges as well as changes in dam design and natural disasters. Another major impact on economic performance of a dam is the projected time schedule in comparison to the actual construction time. Schedule slippage amounted to 80% in a survey done by the Asian Development bank in 1995. Cost overruns and schedule slippages have large implications on the performance of dam projects. Around 8 to 10% of the scheduled dams actually become financially unviable after taking into account these unforeseen overruns and slippages (Gutman 1993, OED 1996).

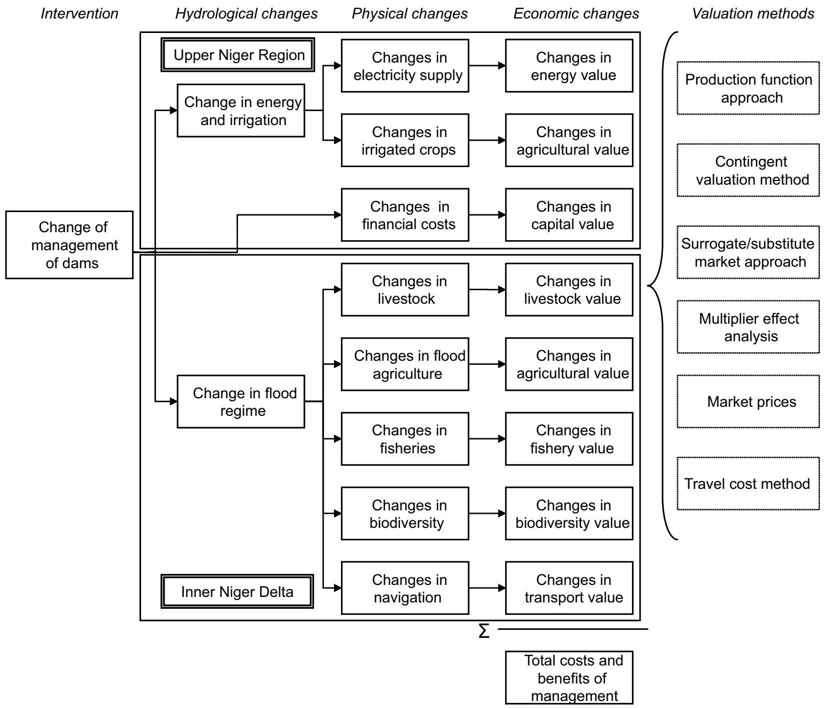


Fig. 13.1. Impact pathway of the economic evaluation procedure of management of the Inner Niger Delta, Mali.

Estimation of indirect costs and benefits

To determine the indirect costs and benefits, a wide range of information is required. A consistent way to organise this information is to pursue the sequence of underlying processes, starting with the cause of an impact, on to the physical impact and ending with the social and economic effects. This so-called "impact pathway approach" is a methodology that proceeds sequentially through the pathway, linking causes to impacts, and valuing these impacts subsequently. The framework of the impact pathway is shown in Fig. 13.1 and represents the physical and socio-economic processes resulting from the management of dams and irrigation schemes in the Niger River. The impact pathway approach proceeds in a series of methodological steps. These include:

(1) Defining the boundaries of the study: The study aims at evaluating different water management scenarios along the Niger River, with a special emphasis on the Inner Niger Delta. These scenarios include: **Scenario 0**: No dam or irrigation scheme; **Scenario 1**: Sélingué dam; **Scenario 2**: Sélingué and Office du Niger; and **Scenario 3**: Séligué, Office du Niger and the Fomi dam. Moreover, the temporal boundary of the project is set at the period 2005 to 2030. This period leaves enough time for the main environmental impacts to come into effect, while it is sufficiently short to make a reliable prediction about future developments.

(2) Identifying significant impacts: Due to practical limitations, the analysis is limited to including the most significant effects only. Inevitably, judgement must be used in deciding what is and is not significant. To judge the magnitude and significance of environmental effects, a range of criteria is identified: (a) The effect on the natural, human, chemical and physical environment depending on their relative sensitivities; (b) The location of the effect, whether within the confines of the site and beyond (local, regional, national and international scale); (c) Timing of the effect (during the construction, operational and post-operational stage); and (d) Whether the effect is reversible or irreversible. Using expert judgment in combination with these criteria, it was decided that the impacts on fishery, agriculture, livestock, transport and biodiversity can be regarded as economic activities in the Inner Niger Delta that are significantly affected.

Effects that are potentially significant, but on which little knowledge is available are the health impacts of dams. On the one hand, dams and irrigation schemes improve human health because of the increased provision of food. On the other hand, they may have a negative effect on health because the expansion of stagnant water boosts the occurrence of malaria and bilharzias. Due to the lack of information on health effects, this effect has not been included in this study.

(3) Physically quantifying the significant impacts: The evaluation of the physical effects of the management of the dams and irrigation schemes is a complex exercise. In the previous chapters, the relationship between the flooding area and the physical production levels of the individual sectors has been estimated, using the production function approach. To assist in predicting the aggregated physical consequences of the various scenarios, a dynamic simulation model has been developed. The model approximates the main effects of each scenario on the various benefit categories and evaluates the changes for the various districts (i.e. upstream and downstream). To calculate these impacts, simplifying assumptions have been adopted, such as for climatic and hydrological conditions, and future economic activities. For example, the assumed population and population growth rates used in this study are presented in Table 13.2 (data from Chapter 4).

Table 13.2. Demographic and geographic data at the Cercle level.

Cercle	Population 2004	Growth rate (%)
Tombouctou	70,177	0.08%
Gourma	67,717	-1.34%
Goundam	130,583	0.91%
Diré	84,393	0.09%
Niafunké	122,988	-0.34%
Tenenkou	127,237	1.47%
Mopti	263,719	1.54%
Djenne	155,551	1.42%
Youwarou	85,426	0.22%
Segou	494,609	2.05%
Macina	164,838	1.91%
Niono	198,749	3.28%

Another crucial assumption applied in the economic analysis is the one on climate. Fig. 13.2 shows the trends of rainfall in the Upper Niger region and in the Inner Niger Delta for the period 1926 to 2000 (data from Chapter 2.2). Both series show a clear negative trend. In the simulation model we extrapolate the trend for the study period of 2005 to 2030. The impact of this assumption is tested through a sensitivity analysis.

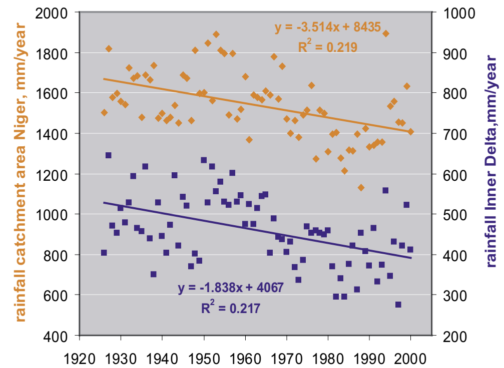


Fig. 13.2. Rainfall trends in the Upper Niger region and the Inner Niger Delta in the period 1926 to 2002.

Another important assumption underlying the model is the annual climate variations. As can be observed from Fig. 13.2, the annual rainfall in the catchment area of the Upper Niger varies between 1,100 and 1,900 mm, with an average amount of 1,500 mm. It is important to simulate these variations in the scenarios because it is generally not the average level that matters but the extremes. For example, in an extremely dry year the impact of dams have a disproportionately large effect on

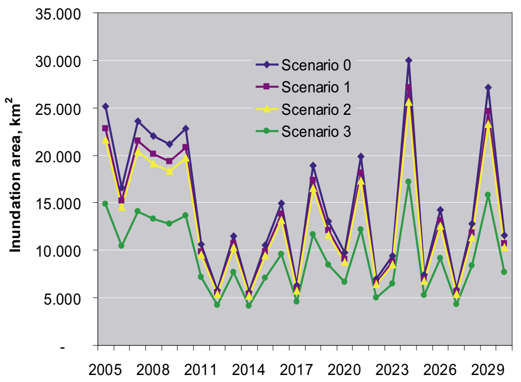


Fig. 13.3. Simulated flooding area for the four scenarios (in km²).

the economic activities in the Inner Niger Delta. Therefore, a random variation in rainfall patterns has been applied in the time series of 2005 to 2030. The maximum variation in rainfall is set at +/-20%. The impact of both short-term yearly variation and the long-term negative trend in climate change on the flooding area has been shown in Fig. 13.3.

(4) Calculating monetary values and conducting a sensitivity analysis: Having established and tabulated the full range and significance of the effects, changes are valued in monetary terms. The main impact pathways that are covered include agriculture (Chapter 8), fisheries (Chapter 5), livestock (Chapter 7), biodiversity (Chapter 12), energy supply (Chapter 2) and transport. As shown on the right-hand side of Fig. 13.1, different valuation techniques are used for these benefits. The most commonly used valuation technique in this study is the net factor income approach which estimates the value of an environmental input in production by subtracting the costs of other inputs from total revenue, and ascribes the remaining surplus as the value of the environmental input. For most of the sectors considered, statistical production functions have been estimated. These were incorporated in the integrated model simulating the four scenarios. The main welfare indicator of the model is the net-benefit of each scenario, which expresses the overall welfare level minus the financial costs of the dams and irrigation schemes. A sensitivity analysis was conducted to test the robustness of the final outcome, in relation to a number of crucial parameters such as climate change, biodiversity and the discount rate. More information on the valuation techniques applied in economic studies on wetlands is provided in Appendix XI.

As shown in Fig. 13.1, another important dimension of the impact pathway approach is the spatial allocation of welfare. Besides having an impact on the absolute level of welfare in Mali and Guinea, establishing dams in the Upper Niger region is likely to generate a transfer of economic benefits from one region to another. The model has therefore been designed at the district level so that a distinction can be made between benefits that occur in the Inner Niger Delta (i.e. livestock, agriculture, fisheries, biodiversity and transport) and those that are generated in the upstream region (i.e. electricity and irrigated crops).

Box 13.1.

Definition of costs and benefits

In the field of CBA often ambiguity may arise with regard to the exact definition of costs and benefits. The main basis for the demarcation of costs and benefits in this study is the stakeholders' perspective. In this study, 'costs' only refer to those direct financial effects that are relevant for the decision-maker who is directly responsible for the financial feasibility of the investment. These values are internal or private to the investment decision. An example of costs in this study is the investments of constructing and maintaining the dams. 'Benefits' are referred to as those effects that arise external to the direct domain of the financial decision-maker. The value of benefits can be both negative (e.g. decline of fisheries in the Delta) and positive (e.g. increase of revenues from irrigation schemes).

13.3 Costs

The cost benefit analysis of the three man-made structures in the Upper Niger is some-what unusual because it compares the Office du Niger irrigation zone and the Sélingué dam, which were established a long time ago, with the Fomi dam, which is yet to be built. To make a fair comparison, we consider a future time period of 2005 to 2030, in which we assume all dams can be active and subsequently generate benefits. However, the cost side of the analysis is more complicated because, as opposed to the investments in the Fomi dam, the initial investments in Office du Niger and the Sélingué dam have already been made. These 'sunk costs' can therefore not be avoided by future decisions.

The presence of sunk costs does not imply that Office du Niger and the Sélingué dam are free of costs. Despite the fact that the initial investments were sometimes made decades ago, the dams still require maintenance and operational expenditures. In addition, the dams consumed capital that could have been spent on alternative economic activities in Mali (i.e. opportunity costs) and therefore need to be valued accordingly.

In valuing the capital costs the following assumptions have been made. First, the capital stock is assumed to depreciate by 0.5% per year. Of the rehabilitation costs made in the past, we assume 25% of it to be additional investments in fixed capital (e.g. roads, canals, turbines). Moreover, in the early stages of operation of the dam and the irrigation scheme, the operational and maintenance (O&M) costs are assumed to be 2% of the value of the capital stock (WCD 2001). Due to increased failure and wearing of the infrastructure, this fraction increases by 1.25% per year. Therefore, the more recently the dams and irrigation schemes have been established, the lower the O&M costs. For example, the present O&M costs of Markala barrage and the Sélingué dam are assumed to be respectively 4.21% and 2.73%.

International funding agencies and national donors covered most of the investments in dams and irrigation schemes in Mali. In the case of Office du Niger, for example, the French Government covered the initial investment costs while the French and the Dutch Ministries of Development Cooperation funded most of the rehabilitation costs. The World Bank also provided substantial funds to rehabilitate the Markala dam and its irrigation area. It is not clear whether, and how much, interest is actually being paid by Office du Niger and the Sélingué dam. Yet, even if the funds have been provided as a grant and organisations of both dams do not actually pay interest for these funds, the capital still represents a scarce good and therefore should be valued accordingly. After all, the same funds could have been invested in other economic activities. Therefore, we assume an opportunity cost of capital of 8% of the actual capital stock.

Sélingué

Limited information is available on the financial costs of the Sélingué dam. As shown in Table 13.3, an initial investment of around €53.4 million was made in the period from 1980 to 1982 for the construction of the Sélingué dam and associated infrastructural works. In 1993 Energie du Mali received a credit of US$ 4.8 million for rehabilitating the hydroelectric scheme. This was followed by the Sélingué Rehabilitation Project, which ran from 1996-2002, requiring funds of the amount of US$ 34.2 million. The goal of the rehabilitation project was to increase the thermal capacity of the system, overall capacity building and the establishment of a long-term institutional framework. This brings the total investment costs to more than € 92 million, assuming an exchange rate of 1 between US$ and the Euro.

Office du Niger

Table 13.4 shows the investments that have been made in the past 80 years. These estimates include the costs of the construction and rehabilitation of the dam itself as well as the development of the irrigation area, which presently measures around 70,000 hectares. As mentioned before, the irrigation area is expected to expand further by another 40,000 ha by 2030. The cost of the expansion of the irrigation area is estimated at €2,300 per hectare. On the basis of projections provided by experts, it is assumed that the irrigation area will grow by approximately 1,500 ha per annum.

Table 13.3. Financial costs of Sélingué dam (in €).

Year	Initial Investment	Rehabilitation by Energie du Mali (funded by IDA)	Rehabilitation by World Bank and European Development Bank	Total costs
1980-1982	53,361,793			
1993		4,800,000		4,800,000
1996-2002			34,210,000	34,210,000
Total	53,361,793	4,800,000	34,210,000	92,371,793

Table 13.4. Financial costs of Office du Niger (in €).

Year	Initial Investment	Rehabilitation by French & Dutch	Rehabilitation by World Bank	Total costs
1919-1920	2,700,000			42,700,000
1945	161,000,000			161,000,000
1979		3,030,000		3,030,000
1979-1983			4,500,000	4,500,000
1985		43,770,000		43,770,000
1988		23,400,000		23,400,000
1989-1992			9,000,000	9,000,000
1989-1997			48,800,000	48,800,000
1993		23,900,000		23,900,000
1995		20,780,000		20,780,000
1996		4,990,000		4,990,000
Total	163,700,000	119,870,000	62,300,000	385,870,000

Source: Schreyger (2002), Slob(2002).

Fomi dam

The construction of the Fomi dam was initially considered several years ago. Therefore, most of the background information originates from the late nineties (Agence Canadienne pour le Développement International 1999). Still, limited financial information is available. The 42 meter high dam is expected to produce 374 GWH per month and is scheduled to provide irrigation to almost 30,000 ha of cultivable land (UNIDO 2004). Similar to the Office du Niger, the costs of the irrigation area are estimated at €2,300 per hectare. It is assumed that the irrigation area will develop over a period of 15 years, gradually expanding by 2,000 ha per year. The construction period of the Fomi dam itself will take 44 months. Table 13.5 shows the limited financial information available.

Table 13.5. Initial investment costs estimated in 1999 (in million 1999 US$).

Cost item	Detailed cost estimate by SNC
hydraulic works	199
transmission infrastructure	62
engineering & management	27
Total costs	288

Source: Agence Canadienne pour le Développement International 1999

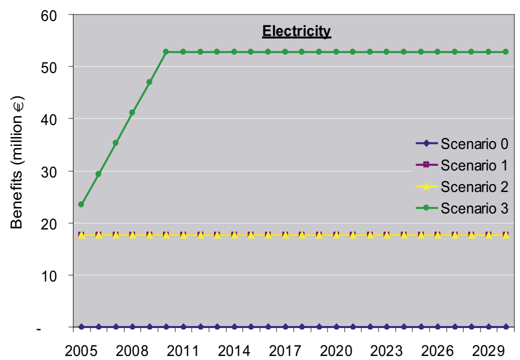


Fig. 13.4. Predicted revenues from electricity production for the four scenarios.

Electricity

Theoretically the installed capacity of the Sélingué hydropower plant is 47.6 MW. This means that the plant could produce 34.8 GWh per month under the condition that all four turbines are available and the reservoir is full. In reality the maximum generated energy was around 25 GWh per month, which is around 70% of the theoretical value. The specified firm energy of 18 MW corresponds to about 13 GWh per month (more details in Appendix II). This is the average estimate that is applied in this CBA. The Sélingué power plant is expected to produce a stable supply of electricity over time. The value added of one kilowatt-hour is FCFA75. The exchange rate applied for the FCFA against the euro is 660. Because the Fomi hydropower plant is scheduled to have a maximum installed capacity of 90 MW at full head, we assume that the power production is twice as big as Sélingué: 26 GWh per month. It will take 6 years for the Fomi power plant to be in full operation. The same value of one kilowatt-hour is assumed. Fig. 13.4 shows the pattern of revenues from electricity supply.

13.4 Benefits

A number of economic activities downstream are heavily affected by management interventions in the dam and irrigation regimes upstream. This Section focuses specifically on these indirect costs and benefits.

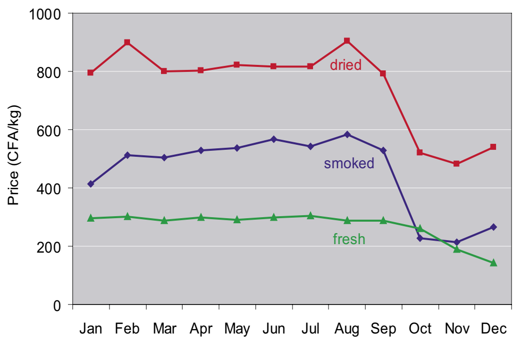


Fig. 13.5. Seasonal fluctuations of fish price for different types on the basis of data from the period 1972 to 2002 (FCFA/kg). Source: OPM-annuals.

Fisheries

The fishery sector is one of the leading economic activities in the Inner Niger Delta (Chapter 5). The economic value of the fishery industry varies due to fluctuations in catch levels as well as variations in the fish price. Fig. 13.5 shows the monthly variation of the price in the different types of fish production based on the average for the period of 1998 to 2002. One possible explanation for the seasonal fluctuation is the level of catch, which is also seasonally dependent. The flooding season causes a significant decline in the overall catch. The catch triples during the dry season. Monthly variations are not taken into account in the simulation model. Therefore, the average value of fish is estimated at FCFA 500 per kg (source: OPM-annuals).

As explained in detail Chapter 5, fisheries are heavily affected by changes in the inundation areas. Fig. 13.6 shows how the fishery sector varies over time. The short-term fluctuations are caused by the standard variation in climate conditions. Clearly, with each additional dam in operation, the fishery industry is reduced further. Therefore, scenario 0 generates the highest benefits. The difference in fish catch is particularly high during wet years.

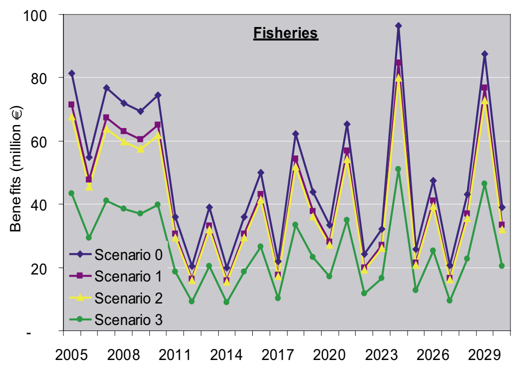


Fig. 13.6. Benefits in the fishery sector over time for the four scenarios (in million €/year).

Livestock

Livestock is valued on the basis of its meat value. It is assumed that on average 2 and 8% of the sheep and goat, and cattle is slaughtered and marketed each year (Annual reports of the Direction Générale de l'Elevage). The weight of the animals varies across the cercle, but the average weight of cattle and sheep is calculated 85 and 9 kg. The average meat price for cattle and sheep in this analysis is 600 and 400 FCFA/kg.

Fig. 13.7 shows the fluctuations of the livestock sector for the four scenarios. Several interesting observations can be made. The scenarios show less sensitivity to short-term climate fluctuations. This is the result of the ability of cattle to move to greener fields. Still, livestock is vulnerable to long-term droughts. This is demonstrated by the collapse in livestock in the period 2010 to 2013 which are modelled as extremely dry years. Another lesson from Fig. 13.7 is that in extremely wet years (i.e. 2005 to 2010) the presence of dams can actually benefit cattle, sheep and goat. This is due to the fact that livestock heavily depends on the availability of bourgou. If the water level is too high, bourgou is negatively affected, and so is the cattle (Chapter 7.3). By tempering the extreme peak flows and thus creating a more optimal bourgou habitat in extremely wet years, scenario 3 performs well in periods with abundant rain. By reducing the peak flow far beyond optimal levels in extremely dry years, scenario 3 performs poorly during the years with exceptionally little rain.

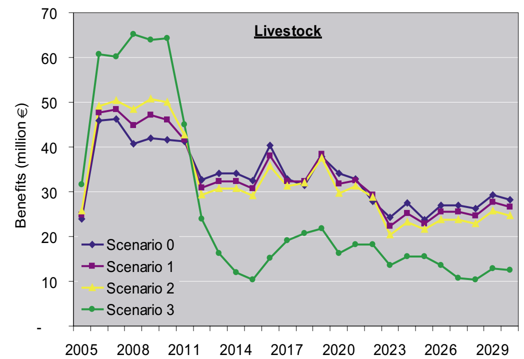


Fig. 13.7. Benefits in the livestock sector over time for the four scenarios (in million €/year).

Agriculture

The agricultural sector in and around the Inner Delta can be subdivided into irrigated agriculture (Chapter 11) and flood-related agriculture (Chapter 8). The production functions derived in these chapters have been applied in the simulation model. Despite the observed fluctuations in the price of crops, the value added of rice and other crops has been assumed to be FCFA 95,000 and 75,000 per ton, respectively.

Fig. 13.8 shows the simulated scenarios for the agricultural sector. The main contribution to agricultural production in Mali comes from Office du Niger. The present production of Office du Niger is assumed to expand by 1,500 ha per year. The other important source of rice, sorghum, and other crops in the region is expected to be the Fomi dam. Parallel to the implementation of the hydropower capacity, the irrigation fields are developed over a period of 15 years, at 2,000 ha per year.

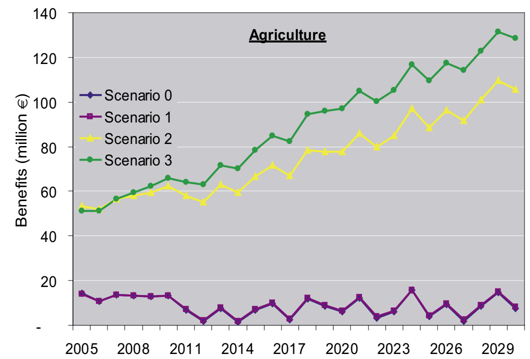
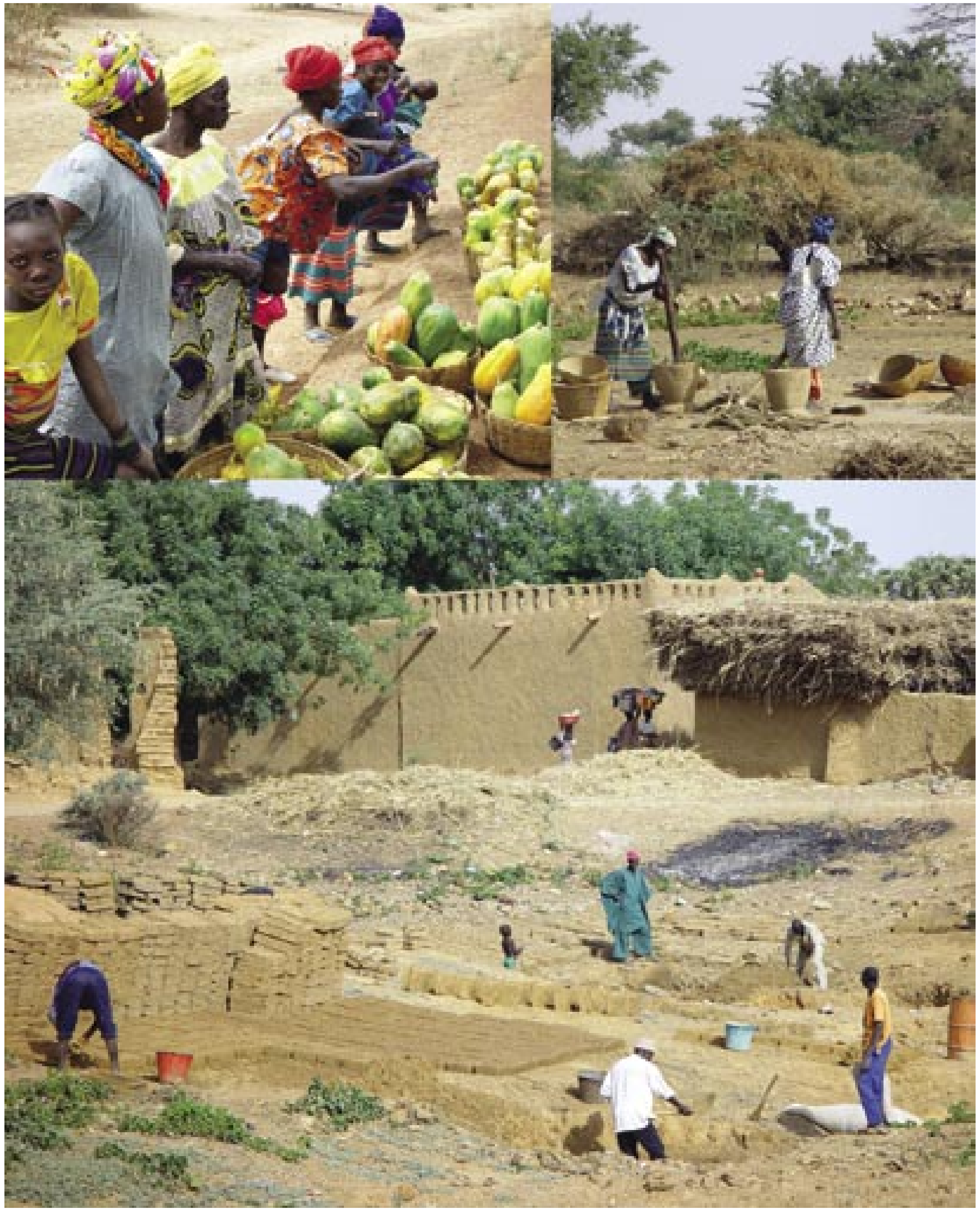


Fig. 13.8. Benefits in the agricultural sector over time for the four scenarios (in million €/year).

Transport

The Niger river plays an important role in the transport of goods and people. Particularly during the wet season, boats are the most popular means of transport in the Delta. Not only does river transport allow people and goods to reach remote places, transport by boat is also relatively inexpensive compared to road transport. As shown in Table 13.6, distances in Mali are significant.

In valuing the transport value of the Niger river,



a distinction is made between the big boats with a maximum capacity of around 400 people and 350 tons of goods and the smaller boat with a capacity of around 10-20 people and 1-5 tons of freight. Big boats need at least 3 to 4 meters of depth, while the smaller boats can still navigate at a depth of 1 meter. Table 13.7 summarises the current capacity and the economic value of the fleet of big boats. Information on the smaller boats is not readily available. Therefore we assume that the fleet of smaller boats has a similar capacity as the larger boats.

Dams and irrigation schemes have an impact on the navigation potential of the Niger River by reducing the water level in the wet season while providing additional flow during the dry season. Reducing the deep-water navigational period, specifically affects larger boats. The additional depth of the Niger in the dry season is particularly useful for smaller boats. The number of navigational days for the four scenarios at various water levels is shown in Fig. 13.9 (based on data given in Chapter 3: Fig. 3.14). Comparing Scenario 0 (no dams) and Scenario 3 (three dams), shows that the latter scenario would lead to an additional 82 days of navigation for the smaller boats while the operational season of the larger boats would be reduced by 20 days.

The results of the model simulation for the transport sector are shown in Fig. 13.10. The scenarios that perform best are the Sélingué dam and Office du Niger. These dams secure sufficient water in the dry season for the smaller boats without causing too much damage in the wet season for the larger boats. Depending on whether the year is relatively wet or

Table 13.6. Transport routes on the Niger River.

Route	Distance (in km)
Koulikoro-Ségou	180
Ségou-Macina	154
Macina-Mopti	170
Mopti-Niafunké	225
Niafunké-Diré	86
Diré-Tombouctou	85
Tombouctou-Gao	408

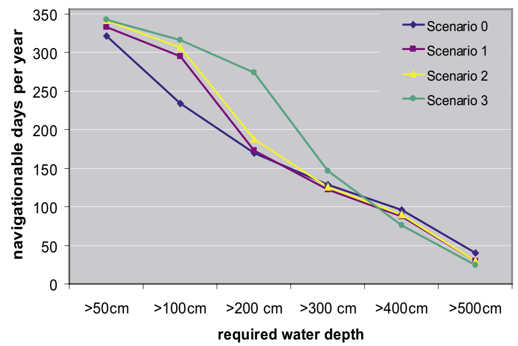


Fig. 13.9. Average seasonal variation of navigational depths at Mopti for the different scenarios based on the simulations for the period 1982-2002 (in number of days in an average year).

Table 13.7. Underlying assumptions of transport analysis for the big boats.

Data	Persons	Unit	Freight	Unit
Maximum capacity	64,613	*Persons*	34,125	*Tons*
Maximum capacity	58	*Million person-km*	31	*Million tonne-km*
Price per unit	13	*CFA/Person/km*	127	*CFA/tonne per km*
Value of transport	727	*Million SFA*	3,890	*Million SFA*

Source: COMANAV

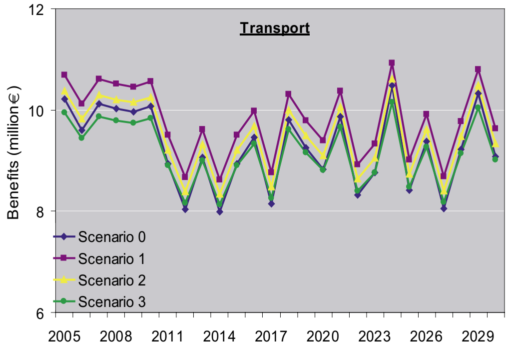


Fig. 13.10. Benefits in the transport value over time for the four scenarios (in million €/year).

not, scenario 0 (no dams) and scenario 3 (Fomi) switch position. In extremely dry years, the Fomi dam performs better in transport terms, while in wet years, the absence of dams is preferred.

Biodiversity

As explained in Chapter 12, biodiversity in the Inner Niger Delta is unique in the world. Therefore, the biodiversity in Mali also represents an economic value. To capture this value, a survey was carried out in the Netherlands in which Dutch citizens were asked about how much financial support they would give for protection of birds in the Netherlands and in sub-Saharan Africa. The results of this survey have been reported in Van Beukering and Sultanian (2005). In summary, the study shows that birds are important for many people in the Netherlands. More than a half of the 800 respondents are willing to pay for protection of bird's habitats. The average willingness to pay is estimated to be around €15 per household per year. If extrapolated across Europe, the fund available for migratory bird protection is more than €2 billion.

Given the importance of Mali as a winter residence for many European migratory birds, we assume that 1% of this amount is available for bird protection in Mali in 2005. The level of these funds is assumed to vary in relationship to the ecological value. As explained in the previous Chapter, the ecological value of birds in the Inner Niger Delta and the irrigation areas is estimated at 7,019 ecological points in scenario 0. Therefore, we fix the price of one ecological point at €3,200 (i.e. 1% of €2 billion divided by 7,019). Because the ecological score varies over time for the four scenarios, a hypothetical economic value for biodiversity can be derived. As opposed to the other sectors, the biodiversity estimate is highly hypothetical and is likely to be significantly higher or lower. However, because we consider excluding this value from the CBA more damaging than including it, we decided for the latter approach. The impact of this assumption on the final result is tested for in the sensitivity analysis (Section 13.5).

The results of the simulation modelling are shown in Fig. 13.11. Birds in the Inner Niger Delta depend heavily on bourgou. As explained in Chapter 7, bourgou does not grow well in extremely deep waters. This is the reason why scenario 2 scores somewhat better than scenario 0 in extremely wet years. However, across the full period, a situation without dams generates the highest biodiversity value. Scenario 3 leads to an extremely low value of biodiversity in the Delta. The reduced flooding surface that results from the Fomi dam forces the water birds to concentrate in limited areas which not only restricts the availability of food but also makes them more vulnerable for human exposure.

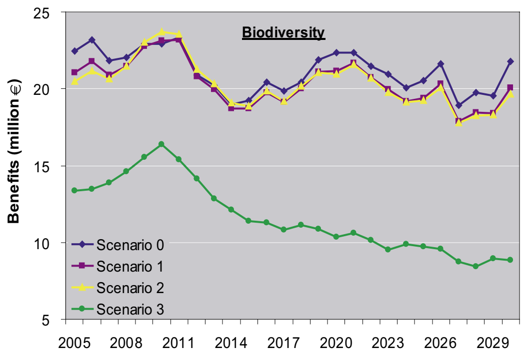
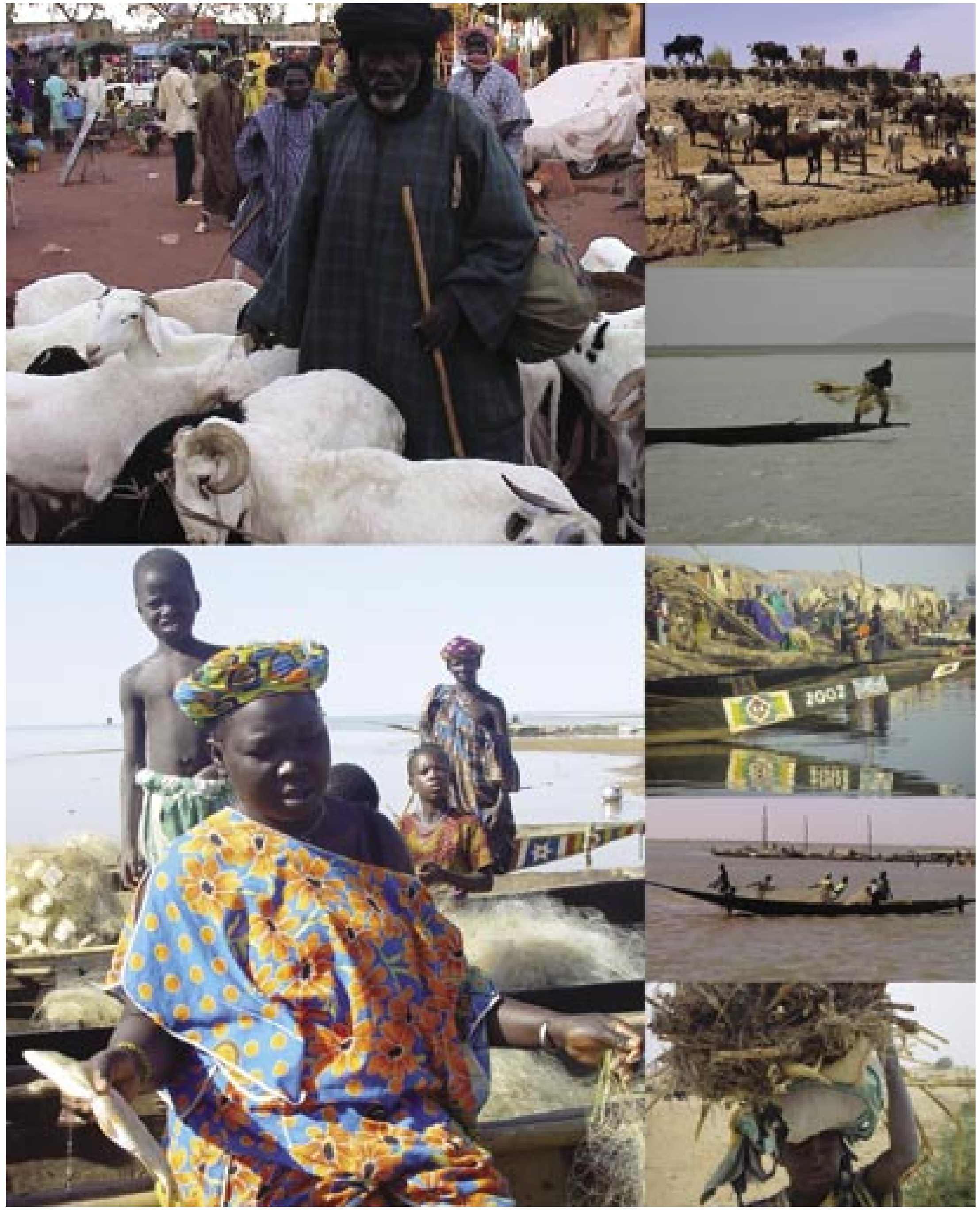


Fig. 13.11. Benefits in the biodiversity value sector over time for the four scenarios (in million €/year).



13.5 Cost benefit analysis

Benefits and costs over time

Fig. 13.12 presents the overall costs and benefits for the four scenarios over the full period of 2005 to 2030. Strictly looking at the benefits, which are shown in the upper part of Fig. 13.12, it is clear that more dams also lead to higher overall benefits. In practically each year, the benefits of scenario 3 (i.e. 3 dams) exceed the benefits of scenario 2 (i.e. 2 dams), which in turn exceeds the benefits in scenario 1 (1 dam). In other words, human intervention can lead to higher revenues for the society at large. Yet, higher benefits do not necessarily imply higher welfare levels. The cost of each scenario should also be taken into account.

The middle part of Fig. 13.12 shows the overall costs over time for the four scenarios. Not surprisingly, a similar ranking pattern arises as in the benefits graph. Obviously, 3 dams cost more than 2 dams, and 2 dams cost more than 1 dam, etc. Yet, the cost differs from the benefits in two ways. First, the difference between the scenarios is much more pronounced in the cost graph. Especially, the combination of three dams (scenario 3) requires significant investments and maintenance costs. This is mainly due to the fact that the Fomi still needs to be built while the Office de Niger and Sélingué dam are already in operation. Second, compared to the benefits, the costs are much more predictable and constant over time as they are independent of climate conditions.

The lower part of Fig. 13.12 resembles the net benefits over time for the four scenarios. Net-benefits are defined as the overall benefits minus the overall costs. The ranking of the scenarios on the basis of net-benefits is changing over time. Due to the high initial investments of the Fomi dam, scenario 3 generates low net-benefits in the first few years but these increase as soon as the Fomi dam gradually go into operation. Typically, the net-benefits of scenario 2 exceed those of scenario 3 throughout the full period. From the fluctuations of the net-benefits in Fig. 13.12, it can also be concluded that dams are particularly beneficial during years of abundant rain. During wet years the foregone benefits downstream are significantly less.

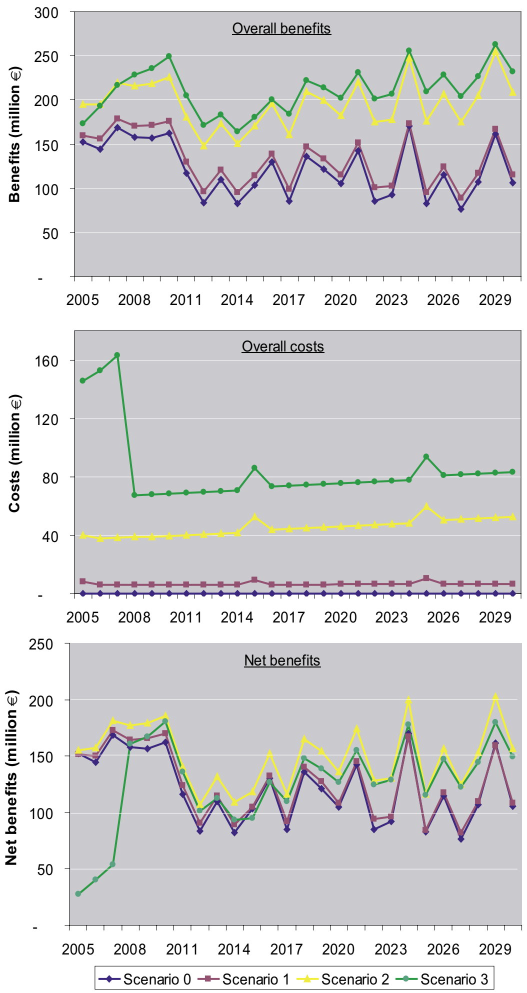


Fig. 13.12. Overall costs and benefits of the four scenarios over time (2005-2030).

Net present value

The next step in analysing the benefits and costs of the four scenarios is to sum up the annual benefits and costs over time. Economists aggregate values over time by converting the annual costs and benefits into present values (PV) by discounting. Discounting is the practice of placing lower values on future benefits and costs as compared to present benefits and costs, reflecting peoples' preferences for the present rather than the future. The discount rate applied in this study is 5%. To demonstrate the impact of this rate, a sensitivity analysis for a range of discount rates is also performed. The calculation of the present value costs and benefits is explained in more detail in Appendix X.

Table 13.8 shows the PV of the *overall* net-benefits of the four scenarios aggregated over the full period (column 2) and as annual values (column 3), respectively. These values represent the total net economic value of each scenario. Both columns show that scenario 2 generates the highest net-benefits while scenario 3 generate the least. This implies that the addition of the Fomi dam has a negative impact on the overall economy.

To analyse the exact individual economic impact of the three combinations of dams, the difference of the dam scenarios with scenario 0 (no dams) is considered. These additional net-benefits of the three dam scenarios are calculated by subtracting the overall net-benefits of scenarios 0 from the net-benefits of scenario 1, 2 and 3. Columns four and five of Table 13.8 show the marginal PV of the aggregated and annual net-benefits of the three dam scenarios, respectively. By looking at the difference between scenario 2 and 3, the additional net-benefit of the Fomi dam to the present situation (Markala and Sélingué) can be determined. By building the Fomi dam, society at large will lose more than €500 million (i.e. €121 + €380 million), which implies an annual loss of €35 million (i.e. €8.5 + €26.4 million). The Sélingué dam generates additional net-benefits of €68.5 until 2030. The Markala dam is the most economically feasible dam of the three by generating aggregated net-benefits of €312 million (i.e. €380 - €69 million), which is equal to almost €22 million per year (i.e. €26.4 - €4.8 million).

Sectoral distribution

The additional net-benefits of the scenarios are comprised of changes in various sectors in the economy. The sectors have been described individually in the previous Section. The configuration of the different sectoral benefits is shown in Fig. 13.13. The negative values represent the accumulative financial costs of

Table 13.8. The net present value (NPV) of the net-benefits of the four dam scenarios calculated by subtracting the overall costs from the overall benefits (net benefits) and comparing the changes of scenarios 1, 2 and 3 relative to scenario 0 (marginal) which resembles the absence of dams.

	Overall		Marginal	
Scenario	PV of net-benefits (*in million €*)	PV of annualised net-benefits (*in million € per year*)	PV of net-benefits (*in million €*)	PV of annualised net-benefits (*in million € per year*)
Scenario 0	1,903	132	-	-
Scenario 1	1,971	137	68.5	4.8
Scenario 2	2,283	159	380.2	26.4
Scenario 3	1,781	124	-121.8	-8.5

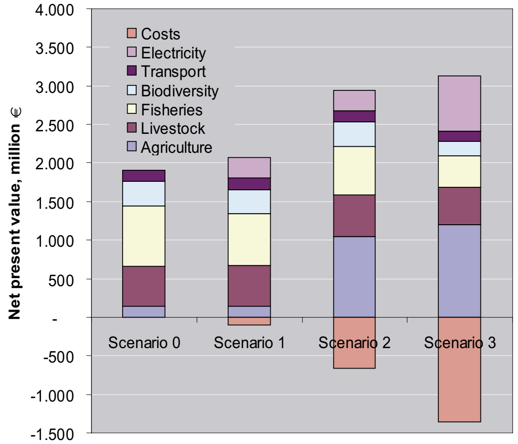


Fig. 13.13. Allocation of the NPV of the related costs and benefits of the four scenarios (26 years, discount rate 5%).

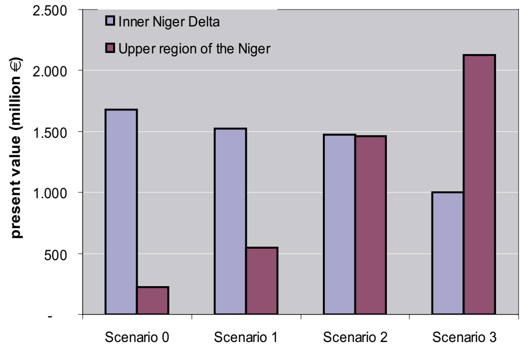


Fig. 13.14. Spatial distribution of the overall benefits divided between the Inner Niger Delta and the Upper Niger region, which includes Mali and Guinea.

each scenario. The costs clearly increase more than proportionally with the addition of the Fomi dam. Although these additional costs are partly compensated for by additional electricity and agricultural benefits, the loss in fisheries, livestock and biodiversity are also substantial. The impact of the Office du Niger and Sélingué are much less pronounced. Fig. 13.13 also shows that a society without dams (scenario 0) mainly generates income through fisheries and livestock. No electricity is produced and agriculture remains rather limited.

Spatial distribution

An important dimension of the study is the spatial distribution of the benefits under the different scenarios. Besides changes in the absolute level of welfare, dams are likely to cause transfers of benefits from one region to the other. Fig. 13.14 shows the allocation of the overall benefits between the Inner Niger Delta and the Upper Niger region. The Upper Niger region includes all those cercle in Mali and Guinea in which dams generate economic activities such as irrigated agriculture and hydropower. In Mali these cercle are Segou, Macina, Niono and Yanfolila. The pattern in Fig. 13.14 clearly shows that with each additional dam, benefits are transferred from the Inner Niger Delta to the Upper Niger region. This transfer is especially large in scenario 3. This implies that the construction of the Fomi dam will substantially benefit Guinea at the expense of the economy in Mali.

Fig. 13.15 shows a more detailed spatial allocation of the overall benefits of the four scenarios across the various cercle. In a situation without dams, Mopti and Ténenkou are the economic centres of the Niger dependent districts. In the present situation, in which both Markala and Sélingué are in full operation, Ségou dominates the river-related economy. Due to the reduced water discharge in the Niger river caused by the Fomi dam, Ségou economic benefits decline, while the Guinean economy increases substantially.

Another way of looking at spatial distribution is to consider the benefits per person in each cercle. Fig. 13.16 shows the different levels of the per

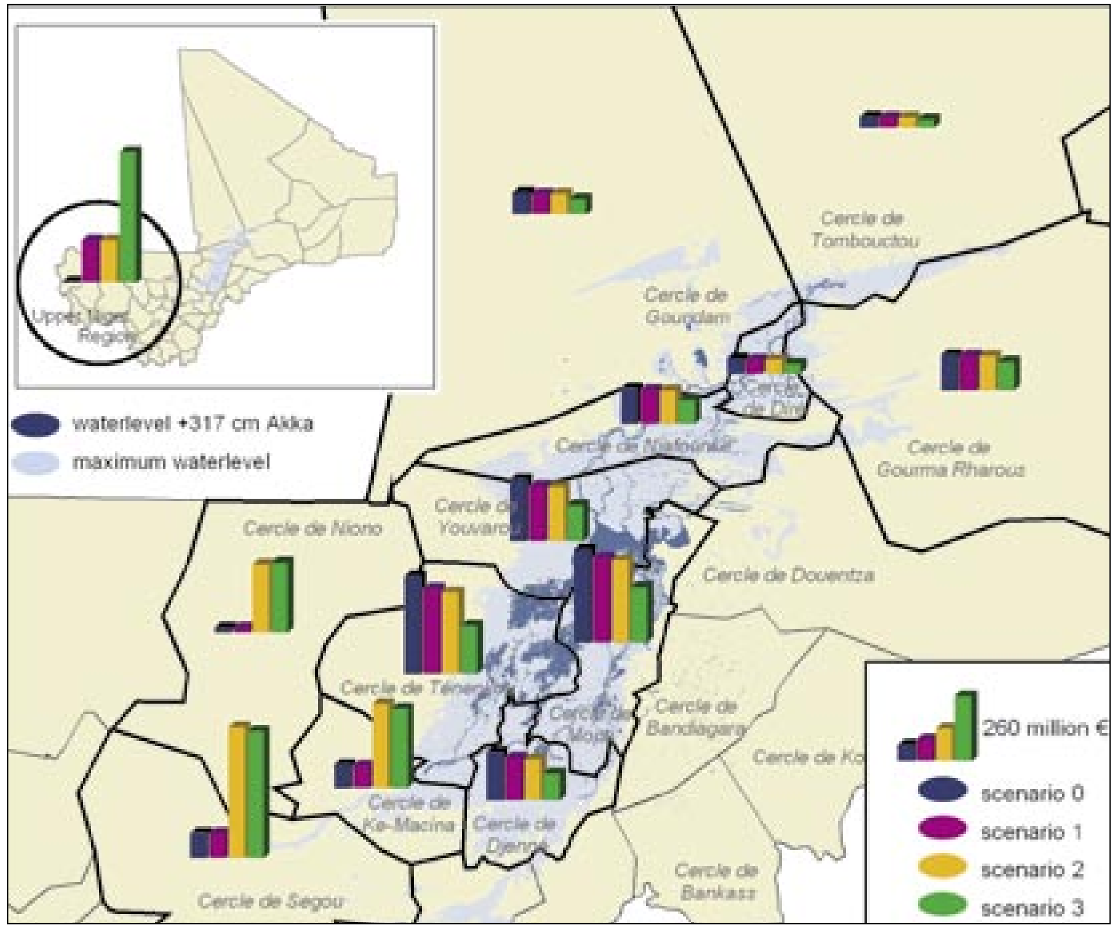


Fig. 13.15. Spatial distribution of the overall benefits across the different cercle for the four scenarios in million € (26 years, discount rate 5%).

capita benefits derived from the Niger river for the four scenarios. Several remarks should be made that explain the outcome presented. First, the current trends in population change have been exogenously extrapolated for the period 2005 to 2030. In reality, these trends are likely to depend on the scenario because more economically successful regions usually attract immigrants from the less prosperous regions. Second, the levels shown in Fig. 13.16 are below the average income levels generally known from the Inner Niger. On the one hand, this may imply that the available statistical data applied in this study underreport the real income generated in the considered economic sectors. On the other hand, it should be realised that the results refer to the river related sectors only. A number of other important economic activities such as road transport, retail and commerce have not been included in the estimates presented in this study. Finally, note that the per capita benefit for the other Upper Niger region in scenario 3 cannot be calculated because the Guinean population benefiting from the Fomi dam is unknown.

Despite these possible methodological caveats, several important lessons can be drawn from the data shown in Fig. 13.16. Clearly, those cercle that are located in the Inner Niger Delta exhibit a significant decline in per capita incomes with an increase of the number of dams. The economic benefits of the Upper Niger cercle obviously show an opposite relationship with the number of dams. Only the establishment of the Fomi dam has a negative impact on the per capita income. For the average Mali citizen, the Markala and Sélingué dam somewhat improved the level of welfare. The average river-related benefit increases with each dam from €44 (scenario 0), to €48 (scenario 1) and €68 (scenario 2). The Fomi dam is expected to reduce the Niger associated welfare of the involved Malinese population from €68 to €52 per capita.

Finally, the spatial distribution can also be presented specifically for the different economic sectors that are active in the cercle. The current allocation of benefits (scenario 2) is presented in Fig. 13.17. In this situation, the region "other Upper Niger" represents the cercle Yanfolila only. The configuration of benefits varies significantly between the different cercle. Gourma depends mostly on livestock benefits while Téenenkou and Mopti are typical fishery disc-tricts. Ségou, Macina and Niono benefit mostly from revenues derived from irrigated agriculture while Yanfolila benefits predominantly from power generation and some fishery income from the reservoir.

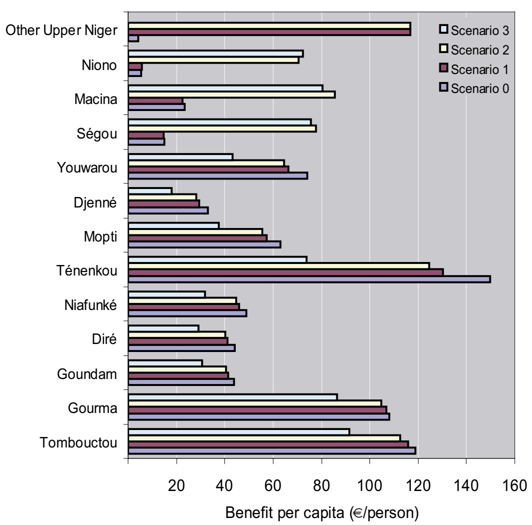


Fig. 13.16. Spatial distribution of the overall per capita benefits generated from the Niger river across the different cercle for the four scenarios in €/person (26 years, discount rate 5%).

Sensitivity analysis

A large number of assumptions have been made to be able to generate the results. This is necessary, given the constraints of data and the time available for this research. These assumptions need not be problematic as long as the results are relatively robust vis-à-vis changes in the assumed parameter values. In this stage, the sensitivity of the outcome is tested for two of the most crucial assumptions: the discount rate, climatic conditions and the valuation of biodiversity.

The standard discount rate used for the economic analysis of the management of the Niger River is 5%. Fig. 13.18 shows the results of this sensitivity analysis for a range of 0 to 15%. Two observations can be made from the graph. First, at a discount rate of zero percent, which implies no discounting occurs,

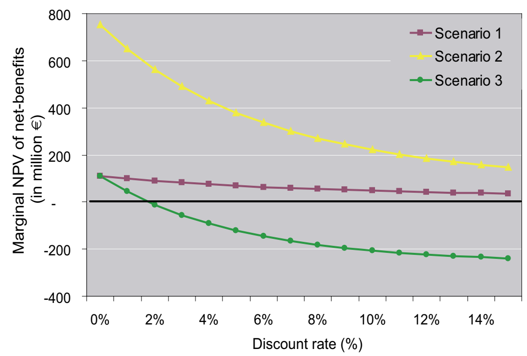


Fig. 13.18. Sensitivity analysis of the impact of the discount rate on the NPV of the net-benefits (in million €).

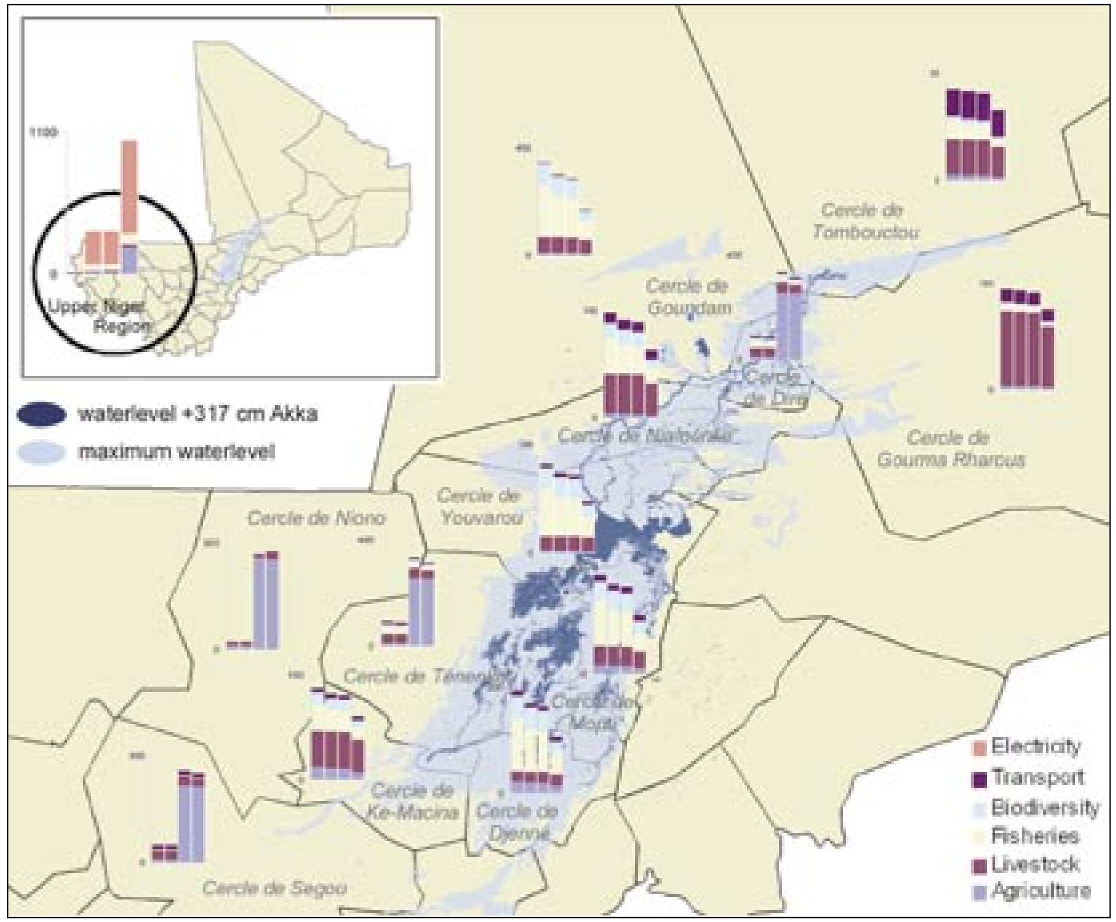


Fig. 13.17. Spatial distribution of the benefits across the different sectors for each cercle for the four scenarios in million € (26 years, discount rate 5%); bars from left to right: scenario 0, 1, 2, 3.

all dam combinations generate a positive NPV of the net-benefits. Second, the curves do not intersect. This means that the ranking of the three scenarios remains the same regardless of the discount rate applied. Therefore, the results are robust as far as the discount rate is concerned.

The second crucial assumption in the study concerns the climatic conditions in the Upper Niger region. On the basis of the previous 75 years it was estimated that rainfall declines by 3.5 mm each year. Due to the overall trend of global warming, this rate of decline may well accelerate over the coming decades. To test the impact of an increased trend of climate change, the reduction in rainfall is subsequently increased by 25%, 50%, 100%, and 150% for the different scenarios. The results of this sensitivity analysis are shown in Fig. 13.19, separately for the Inner Niger Delta and the Upper Niger region. Both regions suffer from increased drought conditions, be it to a different degree. For all three scenarios, the Inner Niger

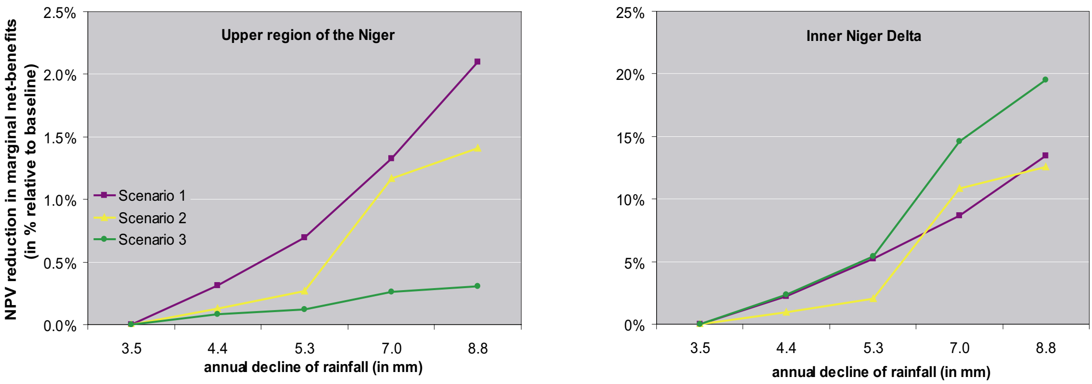


Fig. 13.19. Sensitivity analysis of the impact of more extreme climate conditions on the NPV of the net-benefits (in million €).

Delta is much more vulnerable to drought than the Upper Niger, especially in case of the presence of the Fomi Dam.

The final assumption that is tested is the impact of the biodiversity value on the final outcome. At present, the biodiversity value is mainly an expression of preferences by European citizens. In other words, more biodiversity in the Delta leads to higher welfare in Europe. Only a limited share of this benefit is actually transferred to the communities in the Inner Niger Delta. Because the biodiversity value is a real value measured in Europe and because it is expected that this European biodiversity value is increasingly being used in Mali to protect birds and other types of nature, the estimated value is actually incorporated in the cost benefits analysis in this study. It may be argued, however, that the extent to which the measured biodiversity value will ever benefit the Delta itself is significantly smaller. Therefore we test the sensitivity of the final outcome by assuming that only 10% of the expressed biodiversity value will actually benefit the Malian economy.

The results are shown in Fig. 13.20. The additional net-benefits of the dams have slightly improved as a result of the decline in the biodiversity value. The economic feasibility of the Sélingué and the Markala dam remain intact. The feasibility of the Fomi Dam is somewhat improved so that the losses in the Inner Niger Delta are at least compensated for by the gains in the Upper Niger region. Nevertheless, the addition of the dams still leads to a decline in the additional net-benefits. This sensitivity test shows how biodiversity considerations in the Inner Delta by itself do not fully change economic decisions, yet by making it part of the equation, biodiversity can play a crucial role.

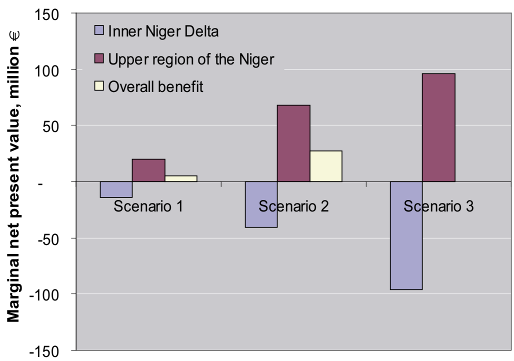


Fig. 13.20. Sensitivity analysis of the impact of the decimation of the biodiversity value on the NPV of the net-benefits(in million €).