Scenarios of water demand management Impacts at regional level. Case study report: The Boutonne River Basin (France)

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1 Introduction

While Europe is by and large considered as having adequate water resources, water scarcity and droughts are increasingly becoming common place. On 18 July 2007, the Commission published a Communication addressing the challenge of **water scarcity and droughts** in the European Union. When drafting the communication several outstanding issues related to water pricing and land-use planning emerging from the Impact Assessment where recognised. In particular:

- Conditions of effectiveness of water pricing in limiting water uses. This refers specifically to the integration of social considerations and sectors where water pricing will have the most significant effects

- Potential of improvement of land use planning in water scarce areas, identifying the room for action where high development of tourism or irrigated crops is dominating.

The objective of this study is address these gaps and to explore and analyse the strategies of actions foreseeable in a set of representative European water scarce river basins in order to progress from a situation of structural water imbalance to a situation of sustainable water balance. Five case studies have been identified:

- The Boutonne river basin in the Poitou Charentes Region (France);

- The Guadalquivir river basin in the Andalucia Region (Spain);

- The South East River Basin of the United-Kingdom (UK);

- The Tisza Danube interstice and more particularly its Hungarian part;

- The entire Cyprus Island.

The studies focus on water demand management and specify the extent to which, in the light of socioeconomic and environmental impacts, measures of water demand management can bring back a sustainable situation in terms of water management in the river basins considered. The results aim to support the follow up to the *Communication on water scarcity and droughts* and the next steps that will follow from the adoption of the river basin management plans and programmes of measures planned required under the Water Framework Directive (WFD) by the end of 2009.

This report presents first the context of the Boutonne river basin, a river basin with severe water scarcity situation in the South-West of France. It then summarises the main methodological steps followed for investigating the socio-economic and environmental impacts of different water demand management scenarios in terms of land use changes and changes in water pricing policy. Finally, it presents the main results of the assessments, focusing in particular on expected impact on the agriculture sector, the main water user in the Boutonne river basin.

2 Methodology and resources mobilised

The evaluation of impacts of different water saving scenarios has been carried out for the different water uses (consumers and non-consumers of water resources) of the Boutonne river basinn including the environment.

As agriculture is by far the largest water abstractor, a more detailed approach was developed for this sector. An (optimisation) economic model was developed, building on existing models for the agriculture sector available for neighbouring agricultural regions. Prior to the economic model development, farming systems of the area were investigated in some details to build a farm typology for the Boutonne river basin. Indeed, this typology and the understanding of the main factors that influence farm production strategy is seen as a compulsory preliminary step to the development of the economic model and to adapting existing models to the Boutonne catchment area. More details on the method used to develop the farm typology are given in Annexe 1, while annexes 2 & 3 present the economic model developed and results of its calibration using data from different sources.

To link agriculture water abstractions to river flows, and thus to investigate the impact of changes in agricultural water abstractions on river hydrology and ecology, a hydrological model was used. This model is made of two modules: (1) the first module calculates the natural flow without human activities, estimated using the rainfalls and the evapo-transpiration as main input; (2) the second module calculates the river flow with human activities, translating abstracted volumes into “river flows” and subtracting them from the natural flow. A scheme explaining the relations between the parameters of the hydrological model are given in Annexe 4. The output of this model was used as an input for the economic model or vice-versa (the output of the economic models being used as input to the hydrological model) depending on the scenarios investigated. The model helped then to transform changes in agricultural water abstraction into changes in river flows.

The impacts of the changes in water abstraction and river flows for users other than agriculture were assessed through interviews and existing data/reports. A three days field trip was carried out to meet the main actors of the Boutonne river basin. The main issues of the sector, the evolution observed during the past 30 years and the evolution of their activity under proposed scenarios were discussed. Other stakeholders were contacted by phone. The list of the stakeholders who were contacted and interviewed for this study is summarised in Annexe 5.

3 Characterisation of the case study area

3.1 Main characteristics of the Boutonne river basin

The geographical situation of the river basin

The Boutonne river basin belongs to the larger Adour-Garonne district, located in the western part of France (see Figure 1). The Boutonne river is 94 km long with a total catchments area of 1 320 km^2. From a hydrological point of view, the basin is a karstic system characterized by close interconnection between surface water and underground water systems, groundwater aquifers with rapid dynamics (for example, the Malm aquifer) recharging the river and vice versa depending on seasons. Taking into account the tributary rivers, the basin has a river network of around 800 km length. All rivers of the basin are tightly linked to superficial water tables. Limited abstraction is made in the captive aquifers located in the North of the river basin.

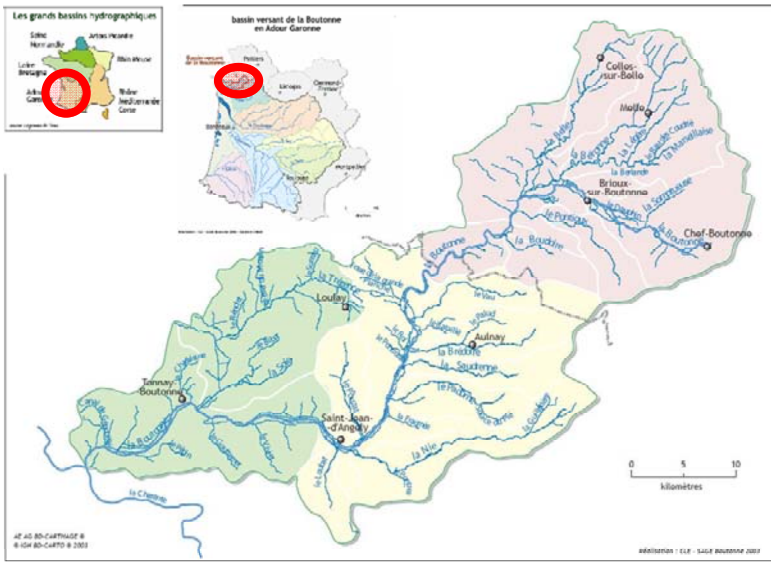


Figure 1 : Location of the Boutonne River Basin
Source: SYMBO and Agences de l'eau

A critical situation for water resources

Globally, the quantitative situation of water resources in the Boutonne river basin is very critical. The main river, the Boutonne, suffers from important flow disruptions during the summer period. The situation is even worse for some of its tributaries. The basin is naturally sensitive and the summer periods are known to be dry. However, according to scientific studies, but also to the local inhabitants from the area[1], the situation of the basin has deteriorated since the early 1980s. Human activities are mentioned as the main driver of this deterioration.

[1] See resident testimonies in SYMBO (2007)

The main water users of the Boutonne river basin

Different categories of users are linked to the Boutonne river and its affluents. Some of them are abstracting water but others perform non-consumptive water use activities with no impact on the quantitative status of the river.

Agriculture is very present in this rural basin. Land use in the valley of the Boutonne River is shared between meadows, poplar trees and intensive maize cultivation. There are also numerous permanent and temporary wetlands in the downstream part of the basin. Moving away from the valleys, the landscape is dominated by open fields occupied by winter crops (wheat, barley and rape) and spring-summer crops (peas, sunflower and maize). In some areas characterised with heavy soils, meadows can represent up to 25-30% of the cultivable area. Today, around 15 Million m^3 (Mm^3) of water are licensed[2] for agriculture water use for the summer period[3] (more details on agriculture water use are provided in Section 3.2.1.1 below).

The poplar trees demand is not considered within the total water abstraction of the agriculture sector. Roughly[4], the annual demand for poplar cultivation is estimated at around 3.6 Mm^3, out of which 80% or 2.9 Mm^3 is abstracted during the summer period.

There are around 76 000 inhabitants in the Boutonne river basin. The most important city, Saint Jean d'Angély, has a population of 8 500 inhabitants only, stressing the rural character of the river basin. The population density is rather low (40 inhabitants per km^2 versus a national average of 123 inhabitants per km^2) with limited seasonal and touristic population. The basin is characterised by family tourism, i.e. people who want to enjoy the area, the natural landscape and its associated activities (fishing, kayaking, hiking, etc) with their family members. To supply water to inhabitants, water is abstracted from the basin and imported also from neighbouring river basins. Overall, 2 Mm^3 are abstracted from the river basin every year, of which around 1 Mm^3 during the summer period only.

Several non-consumptive users are also related to the Boutonne River: fishermen, kayakers, shellfish growers. The link between the river flow and these leisure activities are explained below. Last but not least is the natural environment of the Boutonne River. Its current situation and recent trends are also analysed below in some details.

The sub-regions of the basin

The river basin is host to different sub-regions and shared between administrative regions. First, the basin is located on 2 administrative divisions (the French “départements”): Charente-Maritime and Deux-Sèvres (see the grey dotted line on Figure 1). A differentiation will often be made between these two sub-parts of the basin, in particular in terms of access to data. Indeed, most of the institutions, associations, water companies, etc. are organised and available at the “department” scale. Another level of disaggregation, linked to hydrological considerations is also used. Three sub-basins can be considered[5]: the upstream Boutonne (pink), the middle Boutonne (yellow) and the downstream Boutonne (green). To simplify the link between the two levels, the

[2] It is important to stress the difference between licensed and abstracted water. Indeed, the difference can significant according to the year.

[3] It is also important to make the difference between summer time demand (May to end of September) and annual demand.

[4] The water demand of poplar trees is difficult to assess as it depends on several factors. Moreover, the exact surface of poplar trees is not known. An average consumption of 2400 m3/ha can be taken and a surface of 1500 ha of poplar trees.

[5] Between brackets: the colour code of Figure 1

assumption is made that the middle and the downstream Boutonne are located in the Charente-Maritime part of the river basin while the upstream Boutonne is located in the Deux-Sèvres part of the river basin.

A schematic view of the Boutonne basin

The figure below summarises the main features of the Boutonne river basin in terms of water flows, water transfers and water uses taking place within the river basin. It emphasizes the role of agriculture as the main water abstractor, justifying in particular the importance given to this water use in the analysis of impacts developed in the context of this study.

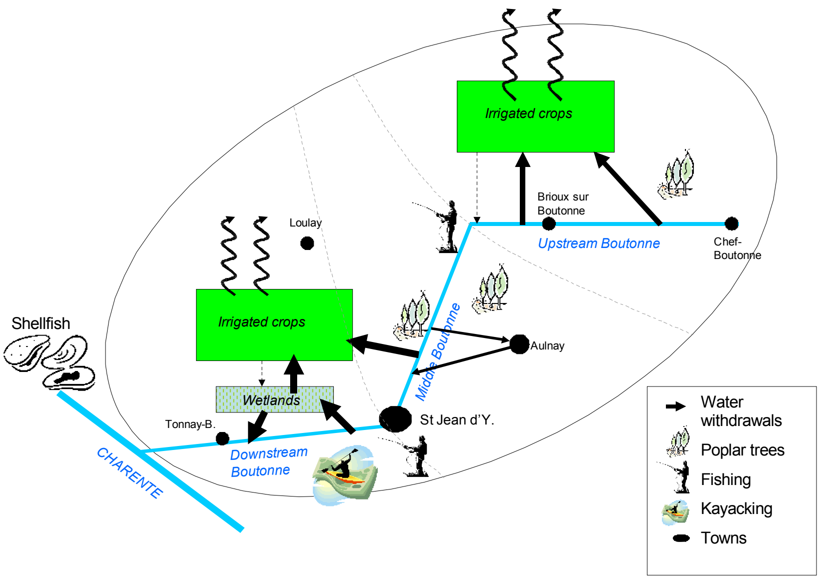


Figure 2 : Schematic representation of the Boutonne river basin

3.2 Water resources and aquatic ecosystems

Abstracted volumes are often difficult to estimate. For agriculture, for example, volumes abstracted depend largely on the year's climatic conditions. Licensed volumes are usually different from volumes consumed, and some estimates available in databases only take summer volumes into account.

The reference volumes used in most studies and analyses in France are the driest flows (monthly average) recorded for a 5 year period, called also the five-year dry flow. The ecological flows and other references are estimated on this basis.

Approximately 22.5 Mm^3 of water are abstracted during a five-year dry year, of which 19 Mm^3 are abstracted during the summer period. Agriculture represents 14.7 Mm^3 thus a significant share of total water abstractions.

A study, accepted as reference for the Boutonne river basin, has shown that 2.8 Mm^3 of water only could be abstracted during the summer period to reach ecological flows. A simple calculation shows that, during a five-year dry year, more than 80% of total water withdrawals represent over-abstractions. The minimum river flow objective (MRFO) was assessed at 0.8 m^3/s. This threshold is reached almost every year. In the reference dry year 2003, river flows were below this threshold for 105 days. In 2005, the river flow was below this limit during 173 days (see figure below). Another threshold, the critical river flow (CRF)[6], was fixed at 0.4 m^3/s. This threshold was reached 35 times in 2003 and 106 times in 2005.

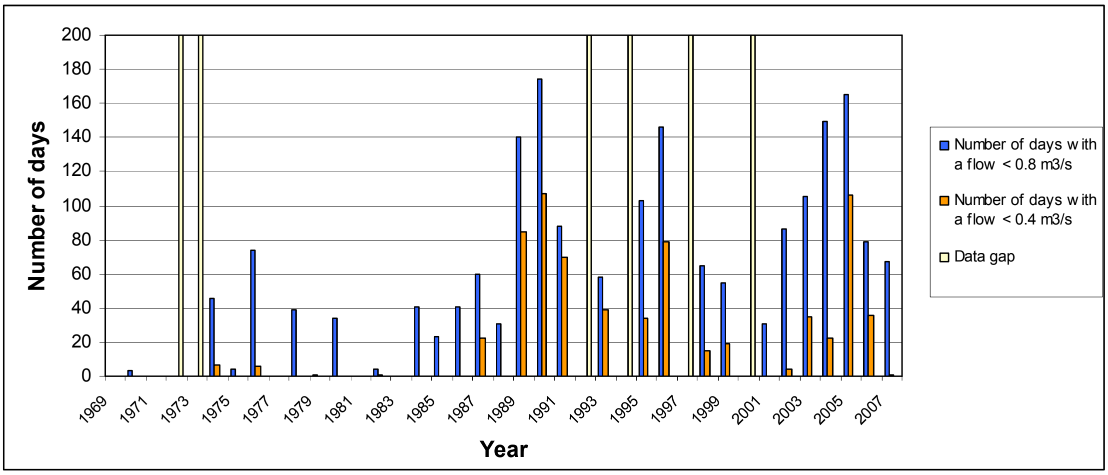


Figure 3 : Number of days with river flows below (ecological) objective flows (0.8 m^3/s) and critical flows (0.4 m^3/s) (1969 to 2006).

Factors other than direct water abstractions by water users are also responsible for water scarcity and summer low flows. One of them is the presence of mills (especially in the upstream part of the Boutonne), leading to an increase spreading of the river network. While this intensive spreading positively reduces flood risks, it also amplifies the water scarcity situation and the importance of flow disruption by increasing evaporation and water recharge.

[6] By definition, the Minimum River Flow Objective is the flow that insures the coexistence of all users and a good functioning of aquatic ecosystems. The Critical River Flow is the threshold below which potable water supply and aquatic species survival are threaten (Definition from Adour Garonne Water Agency website: http://www.eau-adour-garonne.fr)

Another factor amplifying water scarcity in the basin originates from the recent change in the management of wetlands. Overall, 9 wetlands covering an area of 3 471 ha are located in the downstream Boutonne river basin,. Before the 1980s, marshlands were used by agriculture for livestock pasture and meadow cultivation. Wetlands were fully playing their water regulation role, storing water during the winter and releasing it slowly during the entire summer period. Today, all wetlands are drained and intensively cultivated with maize. The trend in wetland use has played against the balance of the aquatic ecosystem and their management has amplified the summer water deficit.

Significant changes occurred in the aquatic ecosystems since the rapid development of irrigation in the early 1980s. Thus, ecological habitats have been damaged provoking important reductions in aquatic species. The upstream and middle Boutonne were well-known for the presence of wild trout. Today, because of the quasi-absence of flow during the summer period, the trout cannot achieve its biological cycle and it has practically disappeared from the Boutonne River. Although farm trouts are re-introduced in the rivers, the downstream limit[7] for the trout has moved back towards the sea.

In the downstream Boutonne, known to have calmer and warmer waters, the situation is less critical. Even if the flow is low or nil during the summer period, water is kept between five locks present in this reach of the river. Fishes such as pikes are particularly present in the downstream Boutonne.

Since the 1970s, the fish populations have seen a severe decline. Although water quality degradation and hydro-morphological changes are cited as causes of this decline, the main factor explaining this trend is increasing water scarcity during the summer period. Natural habitats have been modified and new species introduced, most of them invasive or unwanted. In the downstream part, Ludwigia (an invasive plant) has developed significantly. The presence of Coypu is leading to river bank maintenance problems. Invasive crawfish species (e.g. Louisiana crawfish) are also colonising the basin, competing and evicting the endemic white crawfish.

Other ecological degradations are linked to the drying of wetlands. In order to enter their fields with farm machinery, farmers are drying up downstream wetlands as early as possible at the start of the spring season. Birds, plants and entire habitats are therefore regularly damaged.

3.3 Main Water Users

As mentioned previously, different water uses are taking place in the Boutonne river basin and its tributaries. They can be classified into two categories: (1) consumptive uses such as agriculture, poplar trees, drinking water companies and industry and (2) non consumptive uses such as recreational users (fishing, kayacking, bathing, etc.) or shellfish farming. This section describes these uses, current trends in these uses and their relation to water in the river basin.

3.3.1 Consumptive use

Overall, agriculture consumes more than 70% of total yearly volumes and almost 80% of the summer volumes. The second water use is poplar trees. The domestic sector comes third with

[7] Two categories of fishes of interest for fishermen are often considered. Category 1 includes the fishes living in cold and white waters (e.g. Trouts) whereas category 2 includes the fishes living in warmer and calm waters (e.g. Pike, roach, carp). A virtual limit between the two types of waters can be defined (trout limit).

only 5% of total summer water abstractions. The following figures illustrate the share of each consumptive use in total water abstractions (for 2003).

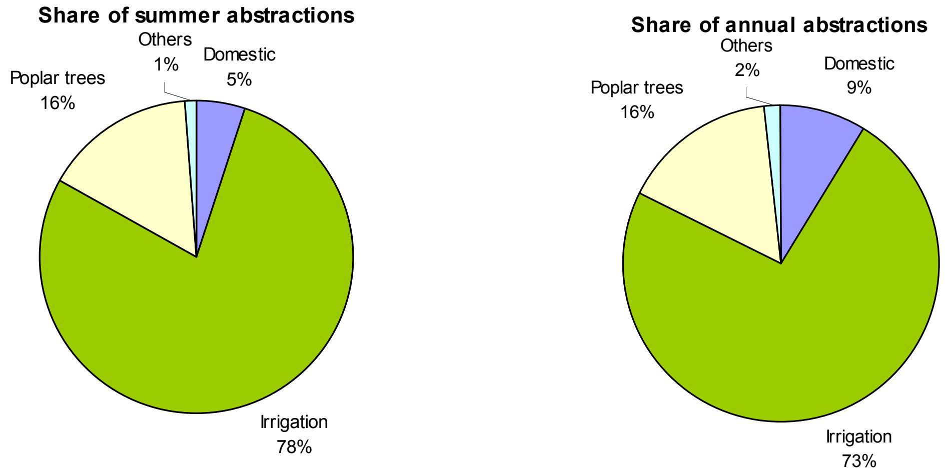


Figure 4 : Share of summer and annual abstractions per user during a reference dry year (Annual abstractions: 22.5 Mm^3, Summer abstractions: 18.9 Mm^3)
Source: SYMBO, 2007

3.3.1.1 Agricultural demand/supply

The characteristics of agricultural water demand in the Boutonne river basin is presented along the following lines. First, an overview of farming systems is presented. Recent trends in abstracted volumes, irrigated areas and irrigation technology are then presented. The spatial heterogeneity in farming systems is then illustrated with a series of maps for soil depth (linked to water storage capacity), number of wells and average depth of the wells. Finally, the results of the investigation for identifying farm types and farm production strategies are provided, this step providing also the basis to the development of economic models.

Overview of the Boutonne farming system

The Boutonne river basin is composed of 105 municipalities in which 408 farms are operating according to the 2000 Agricultural Census. The agricultural area represents 45 008 hectares of which 13 722 (or 30%) are irrigated. Cereals are dominating the cropping pattern while fodder crops represent 12%. The cropping pattern is equally shared between summer crops (38%) and winter crops (43%). Two crops dominate: maize in the summer and wheat in the winter. Irrigation plays a major role since 70% of summer crops are irrigated. Some irrigators have also livestock, the total herd for the river basin accounting for 4 400 milk cows, 1 900 meat cows and 3 000 goats.

Evolution of volumes abstracted by the agriculture sector

Agriculture is by far the largest water consumer, abstracting 73% of the annual volumes of a five-year dry year. Data about the evolution of volumes abstracted by the agriculture sector was available but unfortunately not for the same time periods for the two départements. The figure below illustrates trends in annual volumes consumed at the département and river basin levels. Recorded volumes are plain lines with estimated (averages) being illustrated by dots.

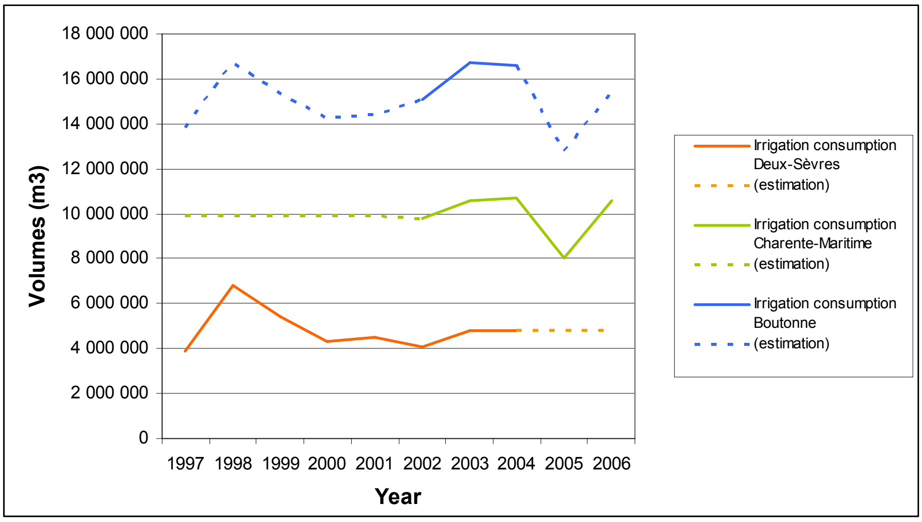


Figure 5 : Trends in annual volumes consumed by agriculture (1997-2006)
Source: DDAF 17, DDAF 79 and ASL Boutonne, found in SYMBO (2007)

Irrigated areas

The irrigated area of the Boutonne river basin has been multiplied by 4 between 1980 and 2000. Since, it is rather stable. In 2005, irrigation represented 13 000 hectares, i.e. 30% of the agricultural area. This however hides large differences within the river basin. Irrigated areas decreased by 32% in the upstream part of the catchment while they still increased by 10% in its downstream part between 2000 and 2005. This can be explained by 2 factors. Firstly, upstream farms are more cattle-oriented (subject to structural financial difficulties) whereas downstream, farms are mainly cereals oriented. Secondly, natural conditions to access alternative water resources (groundwater) are less favourable in the upstream portion of the river basin.

Irrigation technologies

In the 1970s, the most used technology was solid set sprinklers. Progressively, this high labour consuming technique disappeared. Today, farmers irrigate using travelling rain guns or pivots when topographic conditions and field size are favourable. In 2005, in the upstream Charente River basin (neighbouring basin), the different technologies represented 65%, 23% and 12% of the irrigated area for travelling rain gun, pivots and solid set sprinkler, respectively. No specific study was found for the Boutonne basin. Building on expert's knowledge, it is assumed that travelling rain gun represents around 80% of irrigated areas while pivot irrigation accounts for around 15% of irrigated areas in the Boutonne river basin. Solid set sprinklers are marginally used to irrigate plots with a less favourable topography and field corners that can not be reached by pivots.

Types of soils

Considerations about soil types are necessary as they are tightly linked to irrigation water needs. The Boutonne river basin is characterized by 4 types of soil depth:

- In the upstream part of the basin, soils useful reserves are around 105 millimetres per meter (figure 6).This area is also characterized by the smaller density of withdrawal point (figure 7) and deep boreholes (figure 8).

- Irrigation is the most important in the middle part of the river basin where soil are superficial and their useful reserves around 60 millimetres per meter.

- Downstream, on each side of the river, there is a large area where soils are deep (150 mm/m) and where irrigation is not needed.

- The rest of the downstream area is characterize by rather superficial soils where the useful soil water reserve is on average 75 mm/m. Irrigation is less developed than in the middle basin but more than in the upstream part.

Because of the marginal difference between the downstream and middle river basin soil depth, only 2 classes of soil are considered (105 mm/m in the upstream part and 60 mm/m elsewhere). The following figures illustrate the soils depth, the number of withdrawal points per municipality and the average well depth per municipality. The colour code is made in way that the indicator considered is red when it has the highest value for each map. Full size maps are given in Annexe 6.

Figure 6 : Deep soils classification

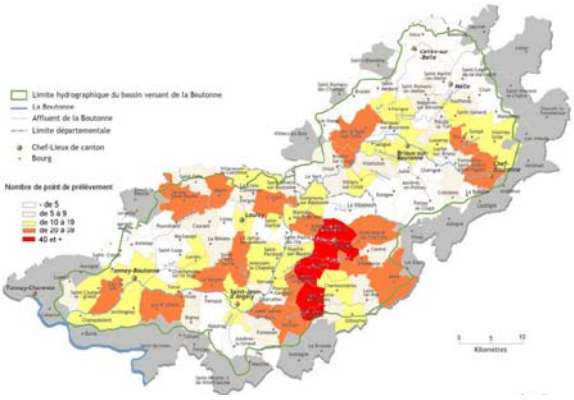


Figure 7 : Number of withdrawal per municipality

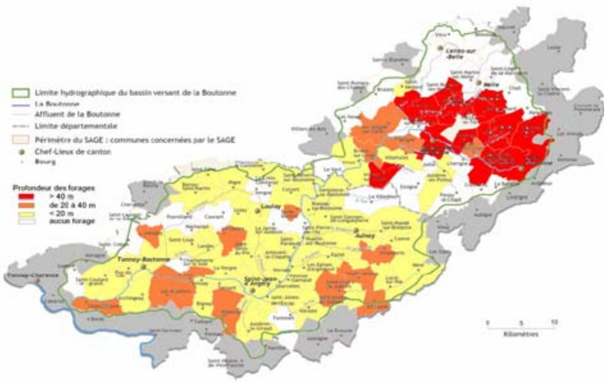


Figure 8 : Average borehole depth per municipality

Farming systems

The diversity of farming systems within the area can be captured by four different farm types (see Table 1) that can be further grouped into three groups.

- Cereal farms are the largest group, characterized by (1) an average farm area equal to 134 hectares among which 45 are irrigated and by (2) a low labour availability. Frequently, these farms have few hectares with fodder that are mainly permanent grass. Such areas are used by meat cows characterized with a low productivity.

- The mixed type combining cereals and milk cows is composed of 66 farms. The average farm area is 128 ha, the irrigated area 29 ha and the labour force is rather important: 2.4 units of labour per hectare that explains the importance of milk cows. Fodder is mainly composed of cropped fodder (maize). Permanent grass is rather limited. Mixed farms with milk goats can also be attached to this group as they have similar farm characteristics.

- The last group combines cereals with meat cows. This type only account for 10 farms. The average farm area is 117 ha with only 17 irrigated for 1.8 units of labour. This group is characterized by a high proportion of fodder area based on permanent grassland. The fodder area is used for meat cow breeding with high productivity objectives. Irrigation is partly used to improve permanent grassland production.

Table 1: Main farm types in the Boutonne river basin

Farm characteristics	Type 1 cereals	2 Cereals & milk cows	3 Cereals & meat cows	4 Cereals & goats
Number of farms	239	66	10	14
Farm area (ha)	134	128	117	149
Irrigated area (ha)	45	29	17	19
Annual labour units	1.7	2.4	1.8	2.8
Number of animals	4	51	52	179
Total fodder area (hectare)	5	43	57	41
Of which permanent grassland (hectare)	3	9	38	13

The two first types represent 93% of the farms and have 97% of the irrigated area. The following table (Table 2) illustrates the share of the irrigated area according to farm types and the different hydrological basins defined above. Areas are given in hectare.

Table 2 : Irrigated are per farm type and per hydrological basin (in ha)

Farm types	Downstream Boutonne	Middle Boutonne	Downstream + middle Boutonne	Upstream Boutonne	Total
Type 1 Cereals	1 512	5 550	7 062	3 749	10 811
Type 2 Cereals & milk cows	471	673	1144	796	1 941
Type 3 Cereals & meat cows	11	42	53	112	164
Type 4 Cereals & goats	208	20	228	20	249
Total	2 202	6 285	8 487	4 678	13 165

Considering that soil types in the middle and downstream parts are almost similar (60 and 75 mm/m of useful reserve), these two hydrographical regions can be grouped. In such conditions, farm types 3 and 4 still represent less than 3% of the irrigated area in the two remaining hydrographical region considered. In conclusion, it is possible to represent most farming systems and irrigation water use in the Boutonne catchment with 2 farming systems only: Type 1 specialised in cereals and Type 2 mixing cereals and milk production. Economic models will then be developed for these two types that represent around 93% of total irrigated areas of the basin.

3.3.1.2 Public water demand/ supply

Public water supply is not a significant water user, as explained in the introduction to this section. Only 9% of annual water volumes and 5% of summer water volumes is abstracted by the sector. Tourism water demand is evaluated to be less than 1% of domestic water demand (around 6 000 m^3 per year). The water demand of this sector will then be considered within the domestic water demand.

Domestic water demand represents around 3.9 Mm^3 per year. Three main water companies are in charge of drinking water supply. “Syndicat des Eaux 17” is in charge of water supply in the Charente Maritime part of the basin (downstream and middle sub-basins), although it should be noted that it is supplying water to a much larger area (most of the Charente Maritime department). According to water companies’ records, the Boutonne part of their sector of activity has an average annual deficit of 70%. Indeed, 0.7 Mm^3 of water is abstracted in the basin whereas 1.6 Mm^3 of water is imported from neighbouring basins. For the Deux-Sèvres part of the basin (upstream portion of the Boutonne basin), around 1.4 Mm^3 of water is abstracted by “Syndicat 4B”. A third company, SAUR, manages drinking water in Saint Jean d'Angély, the main town of the basin. The company does not abstract water in the basin but it buys 0.2 Mm^3 of water to the “Syndicat des eaux 17”. In total, around 2 Mm^3 of water per year are abstracted for drinking water in the basin.

More water was abstracted by “Syndicat des eaux 17” 20 years ago. To respond to deteriorating water quality and to the limited capacity of wells, only a couple of wells are still used today. The following figure illustrates trends in abstractions of drinking water companies for the period 1984-2006. Because of data gaps, estimations are made for some years (see lines in dots).

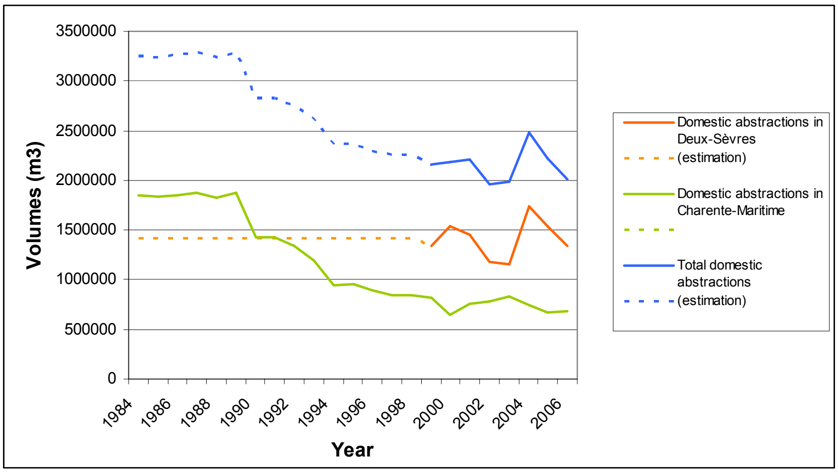


Figure 9 : Evolution of the annual volumes abstracted by drinking water companies between 1984 and 2006.

Public water supply companies are aware of water shortages in the Boutonne river basin. To reduce water supply risk, they have developed different strategies: import of water for “Syndicat des eaux 17”, possibility to use agriculture wells pumping in the captive aquifer for “Syndicat 4B”.

3.3.1.3 Poplar trees

The growing of poplar trees is a secondary income (although not negligible) for farmers and poplar growers. However, industries producing light wood for crates from poplar trees are highly relying on local poplar production, stressing the local economic importance of this production. The area under poplar trees is estimated at around 1 500 ha for the basin. With a water demand similar to maize (around 2 000 m^3/ha/year), the total water demand of the sector is significant: 3.6 Mm^3 per year of which 3 Mm^3 concentrated during the summer period. Poplar trees can adapt their root system to regular changes in the level of the water table. Therefore, except for specific fields, the sector is not suffering from low water table levels during summer. However, poplar trees are very sensitive to sudden variations in the water table level.

3.3.1.4 Industry

Industrial activity is limited to the Rhodia factory that has significant water abstraction. Located in the Northern part of the basin, it produces chemicals. The plant pumps 0.8 Mm^3 of water per year of which 80% is discharged back into the river. Its “real consumption” is then lower than 0.2 Mm^3 per year.

Rhodia also faces water quality constraints. Indeed, according to regulation, the factory wastewater disposal flow must be diluted by a factor of 3. During very dry years, it occurred that this limit value was not complied with. However, the plant's activity was not interrupted.

3.3.2 Non consumptive use

3.2.2.1 Shellfish farmers

The Boutonne River is a tributary river of the Charente river, which is the main source of fresh water supplying the Marennes-Oléron coastal basin. The production of oysters in this basin accounts for 1/3 of the total French production. Overall, more than 1 250 holdings are producing shellfishes in the region, providing jobs to 30 000 people (of which 10 000 are directly linked to oyster production and 20 000 indirectly). The total sales of the sector amount to 200 M€ per year.

The relation between fresh water and the shellfish development cycle is extremely complex. Research studies are still being carried out to better understand this relation. Fresh water is needed at different levels of the shellfish development (spats collection, providing of mineral salts for plankton development which is the nutriment of the shellfishes). However, too large fresh water flows during specific periods would also have a negative impact on the taste of the oysters.

Today, the sector is globally suffering from the low flow of fresh water entering the estuary during summer. According to oyster farmers, the largest damages caused to the oysters are coming from the intensive drying of the estuary's wetlands. These wetlands play a very important role in the regulation of fresh water, acting as a sponge that would be filled in the winter and that would release water progressively during the dry summer period. Today, human activities (agriculture abstraction or building houses on the coast) are accelerating the drying out these areas.

3.2.2.2 Recreative users

Fishermen

The Boutonne River and its tributaries were very popular in the past for fishing. The upstream and middle parts of the basin are classified in “fishing category 1” (Trout River) and the downstream part is classified in “fishing category 2” (calm river fish species).

No precise counting was carried out to calculate the number of fishermen fishing in the Boutonne river basin. Around 26 000 annual fishing permits are sold in the Charente Maritime départment. In addition, tourist fishing permits are sold (daily or weekly permits), fishermen from other departments can pay a right to fish in the Boutonne basin's rivers and finally, fishermen are also present in the upstream part of the basin. Overall, a number of 50 000 fishing days per year is estimated for the Boutonne river basin.

Fishermen satisfaction is clearly suffering from the decline in fish populations. The number of fishing permits is decreasing every year. In 1998, more than 30 000 annual permits were sold in the Charente Maritime départment, a figure 15% higher than today’s figure.

Kayaking

There is one kayak club present in the basin that offers services to 50 annual members (equivalent to 2 000 kayak days/year), to school children (around 2 000 kayak days/year) and to tourists (1 400 kayak days in 2007). Tourists practicing kayaking during the summer are the most sensitive group to ecosystem quality. The activity generated by the club linked to this category amounts to approximately 20 000€/year[8].

During the driest years, lengths of river reaches of the Boutonne suitable for kayaking are reduced and become of poor quality (e.g. bad smell because of stagnant water). This can impact on the reputation of the basin and thus negatively impact on the number of visitors to the river basin.

Tourism

Tourism in the basin is limited to family tourism. Most tourists are attracted by the global quality of the basin natural environment and landscape, including hiking and water related activities (fishing, kayaking, and bathing). The number of nights spent by tourists in the Boutonne river basin is evaluated at around 40 000 nights per year[9].

3.4 Today’s Water Pricing Policy in the Case study

Agriculture is the main water user. As changes in water abstraction will only be investigated for this sector, water pricing for the agricultural sector only is presented in this section.

[8] The rates applied by the club for tourists are 7€/h and 23€/day. To estimate the turnover provided by the tourist category, it was estimated that half of the kayaking days paid were for one hour and half for one day.
[9] Data about the number of tourist days in the basin are not available directly. The tourism sector considers other subdivision. Calculations, based on river basin Boutonne features, were made to estimate that number.

To respond to water scarcity, institutions in charge of water resource management decided in 2003 to implement a Volumetric based Management (VM). This water management system exists in several other basins in France (groundwater management in the Beauce plain, surface water management in the Neste and Charente resupplied river systems). The main characteristics of VM consist of (i) allotting a water quota for each farming operation, (ii) establishing a calendar for the distribution of this water quota during periods of low water availability, (iii) developing rules for restrictions based on the state of the resource, and (iv) setting up a system for monitoring irrigators' practices.

A past study carried out at Charente river basin scale (including the Boutonne river basin) revealed the importance of individual pumping systems. Overall, 79% of farmers practising irrigation have individual water abstraction systems, 13% belong to collective irrigation systems and 8% have both systems. The part of individual pumping system is likely to be higher in the Boutonne river basin where 3 collective schemes only are identified.

Water pricing objectives are different in collective and individual systems. In collective systems, water pricing helps sharing the costs (investment, operation and maintenance) between irrigators and can provide incentives for better water allocation and use. Its main objective is to balance the annual budget of the irrigation system. In individual pumping systems, there is no water price as it is a self-service. Both systems, however, pay the water agency abstraction tax levied proportionally to the abstracted volume. In the Charente river basin, this tax is around 0.004 €/m^3. This is why the water pricing scenario investigated in the present study will consist of assessing the impact of changes in the water abstraction tax levels.

At the Charente river basin scale, the average cost of irrigation is 0.115€/m^3. This cost is distributed among capital cost (52%), maintenance cost (10%) and operation cost (38%). An assessment of the financing system of the equipments reveals that 95% of this cost is taken care of by farmers with 5% of the costs being supported by the financing of different institutions (water agency, local authorities…), the high share of water costs being born by farmers being typical for individual pumping systems that receive limited subsidies. These results hide the heterogeneity of the basin as the share of costs supported by farmers in individual systems is generally higher than 100% (because of the abstraction tax) while it reaches around 60% in collective systems.

The economic modelling implemented in this study[10] does not allow taking into account farms fixed costs[11]. Capital costs of irrigation will then be exclude as well as 60% of maintenance costs (part of the costs not generated by the use of the system). Irrigation costs will then be assumed to be equal to 0.05€/m^3 plus the agency water abstraction tax. However, to take into account the fact that upstream farmers have higher abstraction costs (because of their deeper borehole depth), an additional cost (25% of total operational costs) is added to average irrigation costs for farmers from the upstream area. Abstraction costs of 0.061 €/m^3 and 0.05 €/m^3 are then estimated for the upstream reach and for the downstream + middle reaches, respectively.

3.5 Existing Water Saving Measures

In line with the elements provided above, this section only concentrates on water saving measures for the agriculture sector. For the past twenty years or so, several technical support programmes for irrigation have been implemented to optimize farmers' use of available water resources. These measures were often initiated by institutions representing the agricultural

[10] See Annexe 2 and chapter 4.

[11] Fixed costs, or investment costs, are not taken into account in the economic model which uses Gross Margins and not Net Margins.

sector itself (Chamber of Agriculture, Charente Irrigators Group…) in partnership with government services, local authorities or the Adour-Garonne water agency (providing financial support to water saving measures).

Three categories of actions have been identified: (i) actions for improving farm and field irrigation, aimed at helping farmers to define the adequate quantity of irrigation water for each crop and time period of the year, (ii) actions involving equipment for optimizing supply and use of water and (iii) incentives measures from the Common Agricultural Policy (CAP) agri-environmental programme (*CAD* in France).

- ***Several advisory actions for monitoring and piloting irrigation have been implemented***; the most important one being the development of an irrigation warning system. During the maize irrigation season, a weekly bulletin is sent free of charge to all irrigators. This bulletin provides data on local climatology, potential evapo-transpiration, start & stop orders for irrigation and irrigation quantities to be provided. The information presented comes from around thirty fields representing the diversity of soil conditions and climatic situations in the basins. This bulletin also informs farmers on the condition of water resources and restrictions that have been (or might be) taken.

- ***Actions for modernising irrigation equipment*** are diverse. Farmers can take advantage of financial aids for purchasing improved irrigation equipment. This involves electronic regulation, slow-return spouts, automated supply systems and “jet-disturbers”. The second action involves equipment diagnostics (hose reels and swivels) to improve the distribution of water to fields and reduce over-irrigation. It has been shown that the expected water saving does not compensate for the costs born by farmers for such diagnoses. These first two actions are the more important ones implemented in the river basin since equipment is relatively old and hose reels are used heavily even though they are not as accurate for supply. The last action is aimed at providing financial, administrative and technical support to farmers wishing to create substitution reservoirs, with priority given to reservoirs developed in the context of farmers’ collective actions.

- ***Agri-environmental measures*** consist in establishing a contract between farmers and local authorities. Farmers receive financial compensations for each hectare they decide to turn from irrigated to rainfed crops. The duration of the contract for this financial compensation is 5 years. The financial support is around 400€ per hectare per year.

Other supporting actions surveyed are not limited to the Charente region. They are more like service delivery and involve technical support for irrigation provided either by the technical services department of the chamber of agriculture or by equipment suppliers.

3.6 Current water management and future developments

To move towards a better management of water resources, several management plans have been developed or are in the process of being developed. In particular: a River Basin Management Plan (RBMP) for the Boutonne river basin is in its final stage of development; a Low Flow Management Plan (a *Plan de Gestion des Etiages*, or PGE) for the Charente river has been validated in 2004 and other environmental programs have been set up.

The main issues defined by the RBMP are the following:

- To improve the summer flows in the Boutonne and its tributary rivers;

- To keep a good water quality within the captive aquifers;
- To focus on a pollution reduction policy for agriculture, domestic and industry;
- To protect and restore the aquatic ecosystems;
- To monitor flows during normal, low flows and flood situations;
- To reduce flood risks.

Regarding low flows, two thresholds have been set: an objective flow at 0.8 m^3/s and a critical flow at 0.4 m^3/s. The flows of the Boutonne are recorded at the Moulin de Châtres station, located close to the limit between the two départements. Local authorities are aware of current water deficit and of its amplitude. Plans are to move towards a 80% reduction of summer abstractions by 2015. To help addressing water scarcity problems, several projects are also being studied for enhancing the storage capacity in the basin. In total, 42 storage reservoirs are planned for a total capacity of 9.8 Mm^3. More details on these proposed infrastructures are provided in Chapter 4.3.

4 Investigating water saving scenarios for the Boutonne river basin

The present chapter investigates different water saving scenarios and their socio-economic and environmental implications. It first recalls the base case scenario and proposed environmental objectives or targets for the Boutonne river basin prior to investigating scenarios aimed at restoring ecological flows in the Boutonne River.

4.1 Base case

The base case considered for the project is the continuation of the present situation. Indeed, drastic changes in the stakeholders' habits, behaviour and strategies are not expected for the coming years. The water scarce situation of the Boutonne is not very recent and abstractions of the different users seem to be stabilized. The base case is then characterized by the following elements taken from the description above:

- 11.9 Mm^3 of over-abstraction during the summer period of a dry year;
- 80% of the summer withdrawals abstracted by agriculture;
- A summer irrigated land dominated by maize production;
- An advanced implementation of technological improvements to save water;
- A rapid degradation of the situation since the 1980s, linked to the intensive development of irrigated agriculture;
- Important damages to the natural environment (loss of some aquatic species and development of unwanted invasive species);
- Recreational activities, in particular fishing and kayaking, threatened by low river flows;
- A link between general low flows of the region's rivers and the degradation of the shellfish production conditions;
- An adaptation of some users to the water scarce situation (drinking water companies and producers of poplar trees in particular).

4.2 Specifying environmental objectives/targets

As mentioned in previous sections, calculations have already been made to assess the amount of surface water available for abstractions during a five-year dry year in order to reach the ecological flow. This volume is 2.8 Mm^3. This represents a reduction of the agricultural summer abstractions of surface water by 80%.

It should be stressed that groundwater is being abstracted in limited amounts in small parts of the river basin. Thus, the focus of the study is limited to surface water as the predominant source of water in the Boutonne river basin.

4.3 Base case and technological improvements

Technological improvements are already largely implemented in the basin (see section 3.4). No further obvious technological improvements could be identified.

4.4 Base case and alternative water supply

4.4.1 Alternative water sources to be considered

As regards to the structural water deficit, authorities decided to reduce licensed amounts of water given to each farm. As compared to the 2003 situation, the objective is to reduce progressively the volumes of water licensed to farmers by 80%.

Faced by the important socio-economic consequences such political decisions would have, farmers organizations are promoting the building of storage capacity as an adequate alternative to reductions in water abstraction. The reservoirs are supposed to be filled during the winter period for water to be used during the summer period. This alternative water supply is globally thought to be relevant, but, given the greats amount of water at stake, some stakeholders (Environmental NGO) are questioning its impact on winter water scarcity. At present, the different projects are still being discussed, especially in terms of the level of public subsidies that would be made available to co-finance such investments. The question of equity, as only farmers with irrigation would benefit from the project, is also questioned.

Two specific projects, one in each department, are under discussion and can be considered in this section. In the Deux-Sèvres département (upstream sub basin), 11 reservoirs are proposed for a total capacity of 2.5 Mm^3. Six of them would allow the drinking water company “Syndicat 4B” to recover boreholes pumping in good quality captive aquifers. In the Charente-Maritime département (dowstream and middle sub basins), a larger increase in storage capacity is proposed. It concerns 26 reservoirs for a total storage capacity of 6.3 Mm^3.

However, because of geographic constraints, all farmers would not directly benefit from these infrastructures. Three categories of farmer were identified:

- Farmers who can be directly connected to one or several reservoirs and who will substitute all their withdrawals with reservoir resources;

- Farmers who cannot be connected to a reservoir but that will benefit from the volumes still authorized for the first farmers;

- Farmers who refuse to contribute to the financing of reservoirs and who will face drastic restrictions of their authorized volumes.

The water pricing system and resource sharing between the 2 first categories is interesting. Both categories would become members of water user associations (ASA) managing all available volumes of water. Thus, volumes not consumed by the first category of farmers in the summer could potentially be reallocated to the second class of farmer.

4.4.2 Total costs of the alternative water sources

The reservoirs that are planned are of small capacity, 0.2 Mm^3 on average. Investment costs are therefore expected to be high. An investment cost of 25.7 M€ is estimated for the Charente-

Maritime project for a capacity of 6.3 Mm^3. This represent an investment cost of 4.1 €/m^3. Taking a life-time of 75 years, the actualised annualised investment costs amounts to 0.17 €/m^3.

This volume could seem insufficient to compensate for the reduction of abstracted volumes. Indeed, for the Charente Maritime part of the basin, withdrawals have to decrease from 11.4 to 2.3 Mm^3 which represents a drop of 9.1 Mm^3. However, for farmers, having 70% of secured water is often preferred than having 100% of unsecured water. For the Charente Maritime part of the river basin, the ratio of secured water is slightly above 70%.

No data about investment costs was found for the Deux Sèvres projects. Using the same unitary cost as for the Charente Maritime project, total investment costs for the entire river basin would amount to 10.2 M€. As a result of these projects, abstracted volumes of water would decrease by 2.9 Mm^3 (from 3.3 to 0.4 Mm^3) with 86% of this decrease being replaced by secured water.

The total investment cost to build reservoirs for a capacity of 8.8 Mm^3 is then estimated at 35.9 M€. This volume does not cover the abstraction reductions of 11.9 Mm^3. Nevertheless, irrigated farming activity would not be impacted. Indeed, farmers prefer 8.8 Mm^3 of secured water as compared to 11.9 Mm^3 of unsecured water.

Information on the maintenance costs where not found, but it can be assumed that this is not a major cost factor

4.4.3 Affordability of the measures

The affordability of the proposed reservoirs is a key issue. Theoretically, public subsidies could represent up to 70% of total project costs. As these reservoirs projects are only benefiting farmers (except for the 6 reservoirs that will allow public water supply to access good quality water), obtaining these financial resources would however be difficult, explaining why projects have not been launched yet.

4.5 Scenarios – Water demand management

The characterization of the case study area has shown that the water deficit in the Boutonne basin is extremely high. The agriculture sector is by far the largest water abstractor (73% of annual abstraction and 78% of summer abstraction during the reference year). Water demand management measures will then be applied to this sector.

To reach good quantitative ecological status during the summer period, an 80% reduction in surface water abstraction as compared to the reference dry year has to be achieved. Indeed, during a five-year dry year, 14.7 Mm^3 are abstracted whereas only 2.8 Mm^3 are available. Two types of scenarios are considered within the study:

(a) The application of a quota on water abstraction (*Scenario 1 – Improvements in land use planning/Quota).* The impacts linked to 80% reduction of the summer abstraction will be investigated. In theory, this scenario would bring river flows to ecological flows. To allow a comparison between case studies, the impacts of a "-50%" abstraction is also described for agriculture, the most sensitive sector to a quota on water abstractions.

(b) Changes in water pricing/economic instruments (*Scenario 2 – Pricing*). The impact of different water prices will be evaluated. The level of water prices that would lead to the ecological flow and to a 50% reduction in water abstractions will also be investigated.

As for the “quota” scenarios, water pricing will be applied to the agriculture sector only. The impacts on other water users will be the same if the ecological flow is reach through the implementation of a quota or through changes in water pricing. Therefore, the evaluation of impacts for other users is provided in the first section only (i.e. section 4.5.1 “Land use and restrictions/quotas”).

4.5.1 Scenario 1 - Land use planning and restriction/quotas

4.5.1.1 Description of the scenario in the context of the case study

An 80% reduction in agriculture summer abstraction is necessary to achieve the good ecological flow in the Boutonne. The impacts of this scenario on the different uses are analyzed in the following section.

For agriculture only, the consequences of a 50% reduction in agriculture summer abstractions will be also be investigated.

4.5.1.2 Impact on the environment

Impacts on the river flow

The hydrological model was built in a way that “natural flows” and influences of agriculture abstractions could be calculated separately. The addition of both gives the observed flow. Thus, it was possible to simulate the effect of different scenarios on river flow. Figure 10 illustrates the river flow simulated by the model in different situations for a reference “dry year”. River flows are recorded in a station located at the border between the two departments (Moulin de Châtres). Therefore, only the upstream abstractions are considered in this figure.

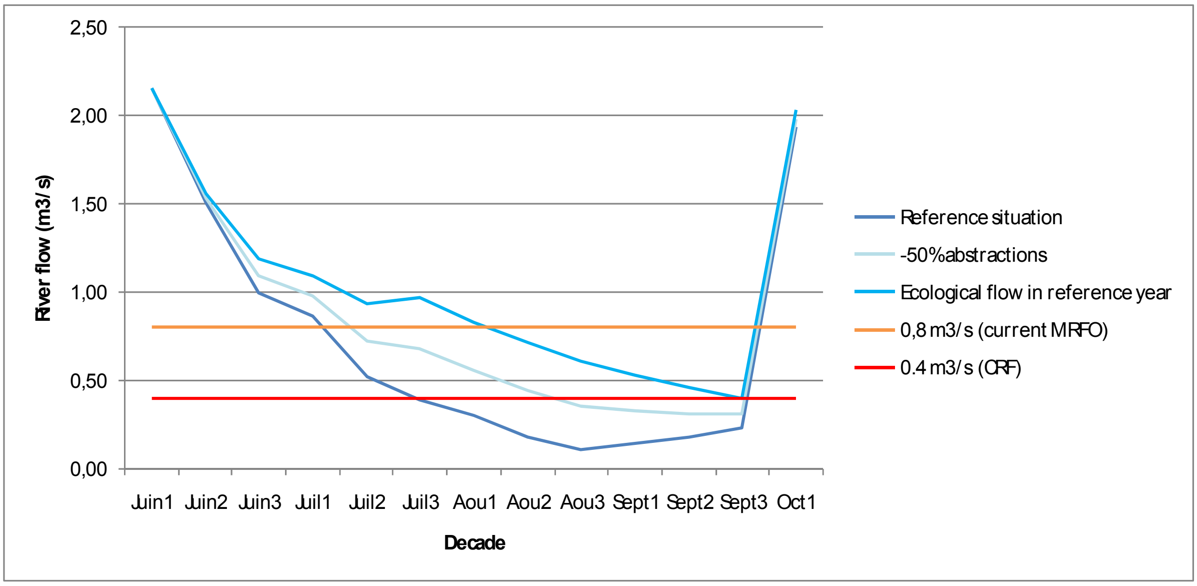


Figure 10: Simulation of the river Boutonne flows (averages per decade) during summer of a “dry year” according to different scenarios

The figure represents the two thresholds: Minimum River Flow Objective (MRFO) and Crisis River Flow (CRF). One can see that, in the reference situation, the MRFO is reached from the second decade of July and the CRF from the third decade of July. With a -50% reduction of total abstraction, the first threshold is reached almost at the same period whereas the CRF is reached at the end of August. The ecological flow reaches the MRFO too but much later (middle of August). The CRF is not reached. This figure illustrates the significant changes in terms of river flows that a reduction in the summer abstractions could provide.

Impacts on aquatic species

As seen in Chapter 3, the environment has suffered from significant damages since the beginning of intensive agricultural abstractions. If a precise assessment of the improvement cannot be achieved, experts think that most of the changes are not irreversible. Reaching the ecological status, which actually means for the Boutonne reaching a situation close to the situation before the 1980s, would lead to habitats being rebuild. Most of the species which are today suffering from water shortages would develop again. Some invasive species such as ludwigia (an invasive plant) would probably significantly reduce. The "trout/calm water fishes" limit would move towards its original location. However, some invasive species such as the Louisiana crawfish are expected to stay in the river.

From these different ecological improvements, the coming back of the wild trout is considered. Studies carried out on the Lignon river[12] have estimated the non marketable benefits of different ecological improvements that include the wild trout coming back to rivers. Different values are given to such improvement depending on different types of citizens/inhabitants. The situation of the Lignon basin is relatively close to the Boutonne. Both are rural river basins and the water body considered is a river. The values found in the report can then be transferred to the Boutonne in a relatively robust way. The study on the Lignon river basin being from 2001, the monetary values were updated[13].

Table 3 presents the updated monetary values (upper and lower bound) for each type of person. Then, the assumptions to calculate the population of each type and the corresponding value for the Boutonne are given.

Table 3 : Monetary values given to the wild trout coming back for different types of inhabitants

Type of user	Value given to the coming back of the wild trout in the Lignon (updated values, €/person)		Assumption to calculate the number of person of this category	Boutonne population in each category	Value of the improvement in the Boutonne (€)	
	lower bound	upper bound			lower bound	upper bound
Fisherman fishing on the site	7,77	22,2	Nb of persons or 17% of the départment fishermen	2 000	15 540	44 400
Fisherman from the department not fishing on the site	3,89	3,89	Nb of persons or 85% of the départment fishermen	24 000	93 240	93 240
Inhabitant used to stroll on the site	6,66	12,21	Nb of inhabitant or 24% of the RB population	19 000	126 540	231 990
Inhabitant not "direct" user of the site	5,55	5,55	Nb of inhabitant or 75% of the RB population	57 000	316 350	316 350

According to these figures, 550 000 to 685 000 €/year could be used as proxy to the value of the ecological improvement in the Boutonne River that would result from the trout coming back in its traditional ecosystem. Additional improvements in ecology (other fauna and flora) are also expected to occur but these could not be estimated nor monetised.

It is important, however, to keep in mind that factors other than over-abstraction are also responsible for the environmental degradations observed in the Boutonne river basin. Among

12 Data found in Test sur la confirmation des MEFM, Affinement de la méthodologie et études de cas pour les masses d'eau impactées par l'hydroélectricité dans le bassin Adour-Garonne

13 1€ in 2007 = 1.11€ in 2001 (INSEE : http://www.insee.fr/fr/themes/indicateur.asp?id=29&type=1&page=achatfranc.htm)

them are water quality deterioration and hydro-morphological changes. The complete recovering of the ecosystems would then imply that these aspects are also improved.

4.5.1.3 Economic and land-use impact of a change in water abstraction for the agriculture sector[14]

Quotas (licensed volumes variation) are an effective instrument even for low variations. The relation between licensed volumes reduction and real consumption is, especially in the case of Boutonne river basin, not linear. Indeed, a reduction by 50% of authorized volumes will induce consumption equal to 55% of this quota (67% in the -80% scenario) whereas the consumption equals 47% of the authorised volumes in the base case scenario. This is mainly due to changes induced in summer variability of water availability. Today, farmer's average consumption is lower than the authorized volumes because of they face water restriction leading to changes in their irrigated area to be able to supply crop water requirement 3 or 4 years out of 5. If water consumption is lower at the basin level because the implementation of a quota, restrictions will be less frequent and for the same level of risk taken, farmers will not reduce their irrigated area in the same proportion. Thus, because of this phenomenon, when 2.8 Mm^3 is allowed to be pumped (-80% scenario), the model shows that summer water consumption is only 1.9 Mm^3 for an average year.

The economic models developed for farm types of the Boutonne river basin were used to estimate the expected impact on farm income resulting from different quota levels. It is estimated that an 80% reduction in water abstraction would lead to a loss of gross margin for the agriculture sector of 2.68 M€ per year which represent a drop of 7.8% as compared to the base case. However this situation hides disparities within the river basin and between farm types: indeed, farm types specialised in cereals will see their gross margin more affected than farms specialised in milk production, the expected reduction in farm income being -8.8% and -5.1%, respectively.

With a 50% reduction in water abstraction, this loss would reach 2.06 M€ per year which is less than proportional to the quota reduction. As compared to the base case, this is a drop of 5.9%. The same disparities between farm types would be observed.

Note that both scenarios induce an increase in spring irrigation. Indeed, the main effect of the quota scenarios on the cropping pattern is a shift from summer irrigation to spring irrigation (as shows by Table 5). This could affect spring hydrology but also summer hydrology because of groundwater abstraction. At the same time, and as illustrated in this table, farmers are expected to change their irrigation practices on maize, changing both the total area irrigated under this crop and the water allocated per hectare (reduction in the area supplied with 100% of Crop Water Requirements or CWR)

[14] NOTA: The economic model and the simulations being still under development, expected results only are presented in this section. These conclusions are inspired by previous studies carried out in neighbouring river basins (Charente, Beauce and Neste system). Results linked to quotas and water pricing are both presented in this chapter.

Table 4: Summer and spring irrigated surface for the different levels of water quotas

Irrigated area (in ha)	Base Case	-50% Scenario	-80% Scenario
Summer Out of which :	9 461	2 484	1 332
Maize100% CWR*	828	-	-
Maize 85% CWR	1 247	-	-
Maize 75% CWR	1 777	-	826
Maize 65% CWR	5 609	-	337
Maize 50% CWR	-	4 541	170
Spring	2 145	9 497	10 648
Total	11 606	11 981	11 981

* CWR stands for Crop Water Requirements. Thus, "Maize 75% CWR" stands for maize crop irrigated at 75% of its crop water requirements.

Another set of scenarios was tested: -50% and -80% of total abstractions (instead of reduction in summer abstractions only). In that case, the total water allowance is consumed during the summer period. And the expected drop in farm income would be more important: -7% for the -50% scenario and -11% for the -80% scenario at the scale of the basin. For an 80% reduction in total abstraction, the summer ecological target would however not be reached as 4 Mm^3 would still be abstracted by the agriculture sector.

More details on the results of the different quota scenarios are provided in Annexe 7 of the present report.

4.5.1.4 Impacts on other uses

Drinking water supply companies and households

Water supply companies have adapted their strategy to the current situation and have now (or will soon) reach a high level of water supply security. Additional water in the Boutonne would therefore not change the strategy of these companies. Indeed, the networks would have to be resized which is probably, according to experts speeches, not profitable.

Poplar tree production

As specified in Chapter 3, poplar trees are sensitive to variations in the water table level. A reduction in abstraction would then lead to a rise in the water table level and would then damage trees that are already in place.

Because of the 1999's storm, 80% of the 1 574 ha of poplar trees is planted with young trees (5-6 years old). No precise data was found about the number of trees that would effectively be damaged by a significant water table rise. It is thought that taking an assumption of about half of the surface of trees being affected by this change in water table would be reasonable as a first assumpation. Thus, 40% to 60% of trees would need to be replaced (equivalent to between 630 and 944 ha) by new trees that will adapt their root system to the new (higher) water table level. The gross margin of poplar trees is around 6 000 €/ha for a 20 year old tree. If trees are replaced when they are 6 years old, the owners suffer a one-time loss of 1 800 €/ha. At the scale of the basin, this represents a lump cost of between 1.1 and 1.7 M€. This number does not take into account the economic losses the industry using poplar trees might face, the assumption being made that these losses are negligible as the industry would turn to other areas to compensate for the reduction in production from the Boutonne river basin.

The impact of the scenario would be negative for the current generation of trees. No negative impact is expected for future generations of poplar trees – as new trees would adapt to new groundwater levels.

Industry

As explained above, the Rhodia factory faces a dilution constraint when river flows of the Légère River, a tributary to the Boutonne River, are too low. A regulation has been put in place to limit polluted discharges during low river flows. In practice, however, the company has never stoped its activity when dilution limits are reached.

An estimation of the loss that could occur if the plant would have to stop its activity can be made. The assumption is made that for the critical period, i.e. the period when the dilution limits are met, estimated at around 1 month every 5 years (around 1.6% of production time).

The total turnover of the plant being estimated at between 30 and 60 M€ per year[15], the cost that would be avoided by increasing river flows is estimated at between 0.5 M€ and 1 M€ per year. One has to keep in mind the important uncertainty on (1) the turnover of the plant and (2) the certainty of enforcement of the actual regulation limiting polluted discharges to the river.

Shellfish farmers

The situation of the shellfish sector as regard to fresh water was presented in Chapter 3. It is estimated that, with current water abstraction levels during a dry summer, the oyster weight could decrease by 25% leading to a shift from size category 2 or 3 to 4 (ASCA, 2006). The selling price of the Category 4 oysters is lower by 10 to 25%. At the scale of the sector, the reduction represents a loss ranging from 20 to 50 M€ per year. This figure shows the importance of the shellfish issue. However, the direct link between 1 cubic meter of water saved in the Boutonne river basin and the economic gain of the shellfish sector is extremely hard to assess. Indeed, the Boutonne contribution in fresh water as compared to the other rivers is not well known and the direct relation between fresh water and oyster development is still subject to research. According to flow records from 2003 to 2005, the average Boutonne flow makes around 5% of the Charente flow which itself brings around 95% of the fresh water to the coastal basin. The Boutonne fresh water contribution would then be around 1/20. The economic weight of the shellfish that could be linked to the Boutonne is therefore between 1 and 2.5 M€. It is important also to note that there are indirect economic benefits that result from activities linked to the production of oysters. These however have not been estimated.

Recreational users

The improvement of the fish populations in the Boutonne (in particular the return of the wild trout) is expected to lead to increases in the sale of fishing permits. The precise increase of sales could however not be estimated by the fishing federation but is thought to be significant. For a first rough estimation, it is assumed that 500 to 1000 more annual permits would be sold in the department because of ecological improvement in the river Boutonne. At a unitary price of 61€ per permit, this increase represents between 30 000 € and 60 000€ per year. Temporary

15 The contact person could not give an accurate value as the accounts of the company are only available at the group level (70 plants, sales = 5 billion euros/year). The plant has an activity smaller than the average according to him leading to the range given in the text.

permits would also increase as well as the sales of fishing equipment. However, no specific numbers could be provided because of large uncertainty in making such estimates.

Reaching the ecological status would result in much higher flows, especially in the middle Boutonne where there is almost no water during summer. The tourist kayaking activity is currently suffering from the water scarce situation, as explained in Chapter 3. Provided that the kayak club is able to offer more kayaking days, it is assumed that the tourist kayaking activity would increase. As for fishing, no precise estimation of this increase can be made at the scale of the present study. For a first estimation, an increase between 20% and 40% is considered[16]. At an average day rate of 15€, an additional turnover of 4 500€ to 9 000€ would result from the improvement in river water flows.

The improvement of the environment quality would certainly have a positive and significant effect on tourism. Indeed, a recent reduction in the campings' economic activities has been recorded – although the link to water status degradation remains uncertain. No prospective study for this sector could be found. But it is known that the type of tourism in the river basin is of family type, meaning that environment status and nature related activities (of which water related activities) play an important role in tourists' choice to spend vacation in the region. As a rough estimate, it is assumed that reaching good ecological status would increase tourist nights by 10 to 30%, or 4 000 to 12 000 nights. With average expenses of 50€/person/day (including accommodation, meals and paid activities), this increase represent a turnover of 0.2 to 0.6 M€ for the basin.

For the uses other than agriculture, the benefits linked to a -50% scenario are extremely difficult to assess as a -50% abstraction would lead to an intermediary situation between today's situation and a good ecological status that can be referred to as a situation close to the ante 1980s situation. With current knowledge, it is unclear which share of the -80% benefits would be obtained from a -50% reduction in water abstraction.

4.5.2 Scenario 2 - Water pricing

4.5.2.1 Detailed description of the scenario in the context of the case study

Different water pricing scenarios can be tested. One objective of this section is to find the level of pricing that leads to the good ecological status (80% reduction in summer water abstractions) and a 50% reduction in total water abstraction.

4.5.2.2 Impact on the quantitative status of water resources and the environment

For the environment, the impact of water pricing changes will be the same as for the quota scenario. With changes in water pricing leading to an 80% reduction in water abstraction, river flows will reach again their balance and ecological flow.

4.5.2.3 Impacts on the users

As mentioned in the introduction to section 4.5, the impacts on water users other than agriculture are expected to be the same as in the case of the quota scenario. The impacts for agriculture only are expected to be different because of the financial transfer that water pricing imposes out of the agricultural sector. Thus, these impacts only are presented in this section.

[16] This estimation is based on the assumption that the kayak club is not completely restructured which means that number of kayaks and monitors stays relatively stable. In case that the kayak club extends, the sales could be higher

Both instruments (changes in quota or water pricing) lead to a reduction in water consumption for the agriculture sector. However, the impact on farmers' revenue is different. Quotas variation affects proportionally farmers' revenue and water consumption. For water pricing, the situation is different: first increases in water pricing affect farmers' revenue without any water consumption change. It is only after a certain level that water pricing starts to affect water consumption of less productive crops.

When water pricing changes, the behaviour of the two types of farms that represent the majority of farms of the river basin is different: a 50% and an 80% reduction in the summer water abstractions is not reach at the same level of water price for each farm type. The water demand and profit curves, which were estimated using the economic models developed for each farm type, are presented in the following figures (see Figures 11 to 13). Note that the curves provided in figures 11 and 12 are for an average farm of each type and not aggregated for the entire farm population of the river basin for each type.

The water consumption of the farms specialised in cereal production do not significantly decrease before the water tax has reached 0.3 €/m^3 (figure 11). Until that point, the effect of the tax is only leading to reduction in farm income (proportional to the tax level increase). Above 0.3 €/m^3, spring water abstractions are stopped and summer abstractions decreased. A 50% reduction in water abstractions is reached at 0.45 €/m^3 and an 80% reduction at 0.525 €/m^3. The same trends can be observed for the milk type. A 50% reduction is obtained at the price of 0.35 €/m^3 and an 80% reduction at 0.40 €/m^3.

To obtain a -80% reduction at the scale of the basin, water pricing level has to be settled at 0.525 €/m^3, which generates a drop in the total farm gross margin of 20.1% or 6.89 M€. Cereal farms are more affected with a 23.6% drop whereas milk farms record a drop of 11.0%.

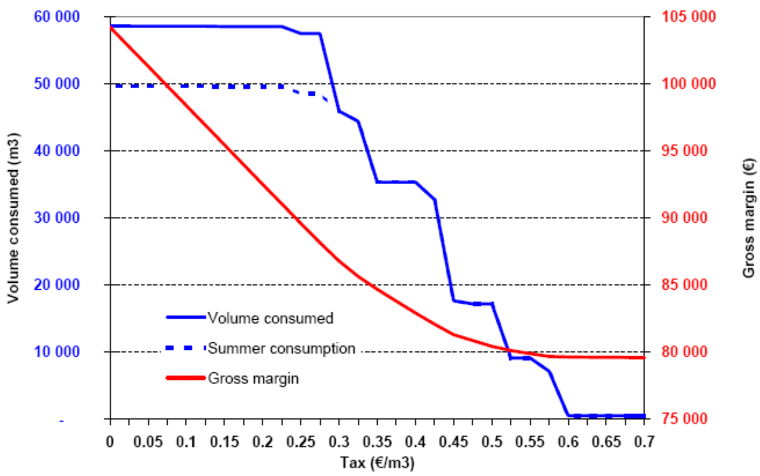


Figure 11: Water demand and gross margin curves of an average cereal type farm

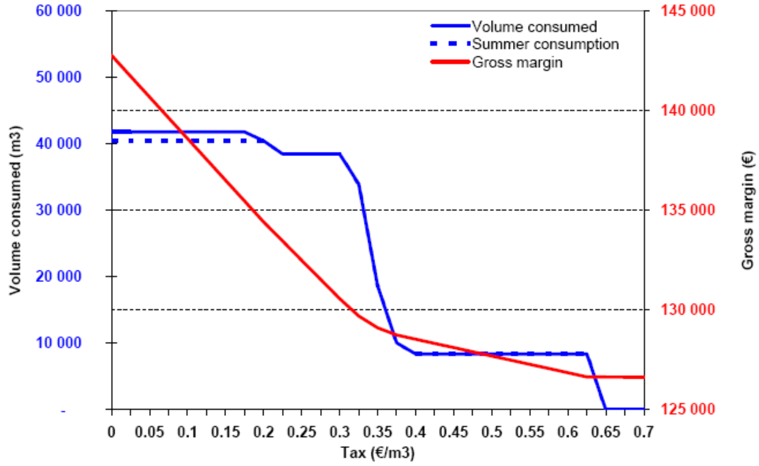


Figure 12: Water demand and gross margin curves of an average milk type farm

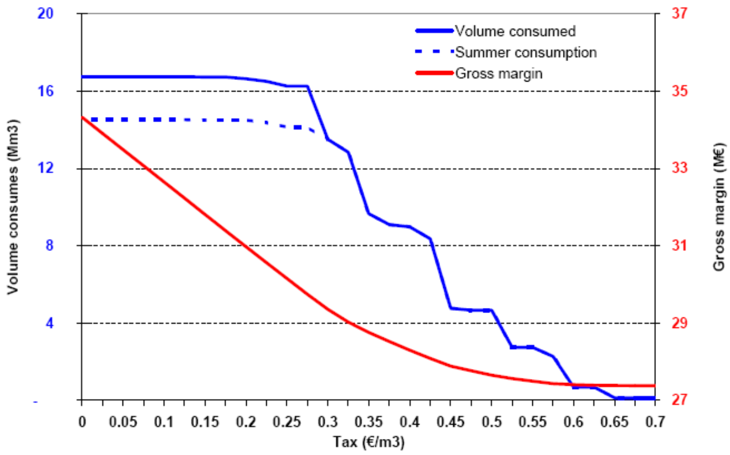


Figure 13: Water demand and gross margin curve at the basin level

Details about the results of the different water pricing scenarios are provided in Annexe 8. It is interesting to note that increases in water prices up to levels equivalent to a -50% or -80% summer quota significantly influence rainfed cropped area, something that did not take place with the quotas. Indeed, too high water prices do not make irrigation profitable as compared to rainfed agriculture, rainfed agriculture providing however a buffer limiting the reduction in farm income resulting from water price increases.

4.5.3 Potential mitigation measures to limit the negative social impacts of the scenarios on agriculture sector

A illustrated above, a reduction in water abstraction is expected to have a negative impact on agriculture gross margin and farm income. To compensate for this expected loss of income, different mitigation measures, acting at different levels, could be considered. Some measures can act on water demand management; others on implementing a subsidies program, etc. This section reviews different mitigation measures.

Water demand management

To be able to keep the same level of irrigated activity with a global reduction of the abstraction, technological improvements could be considered. As shown in Chapter 3, the irrigation technology of the basin is already almost at its most maximum level. Low improvement in terms of water saved can be expected from modernising the remaining farms that do still not have the most modern farm irrigation technologies. It is the same for the potential of water management awareness. As explained in Chapter 3, several advisory actions for monitoring and piloting irrigation have already been implemented in the river basin.

Proposing subsidies to compensate for income losses

A specific subsidy programme could be designed to financially support farmers. In the case of a 80% reduction of summer abstraction, the model predicts a global drop in the farm gross margin of 4% which represent 2.68 million Euros. In that scenario, the reservoirs would not need to be built anymore, representing a total saving of 25 M€, representing 1.05 M€ per year[17] when actualised and annualised. Moreover, in that scenario, the irrigated corn surface is reduced by 8090 ha; replaced by irrigated spring crops (mostly wheat). The corresponding CAP subsidy for irrigated corn is saved. The amount of money saved is 0.27 M€[18]. Thus, 1.32 M€ of public subsidies would be saved from the reduction in abstraction or from imposing higher water prices. This money could be used to support farmers and address half of their gross margin loss. The decision maker could also use that money to subsidy some types of farmers only that would deliver additional environmental benefits.
Another source of subsidy to help farmers that deliver additional environmental benefits could come from the Rural Development Plan which allow budgets to help environmentally friendly practices.

4.5.4 Performing the sensitivity analysis

A sensitivity analysis on different crop prices was performed, to account for the uncertainty in today's and future prices of agricultural products in the world market. It is assumed that the prices of cereals, oleaginous and proteaginous products only vary and that variations in proteaginous and oleaginous product prices is equal to 50% of cereal water price changes. The sensitivity analysis is performed for a 25% increase and a 25% decrease in cereal prices.

Results highlight a reduction in the economic impact of the 80% reduction scenario in case of cereal decrease by 25% (see table 5). The gross margin losses at the basin level would be 1.18 M€ instead of 2.68 M€ with the initial price structure. For a +25% cereal price scenario, the gross margin losses would be 4.22 M€. Cereal type farms are always more affected than milk types.
The table also shows that the relative loss is more important when the cereal price increases. Nonetheless, farmers would earn higher incomes when cereal prices are higher.

[17] This high value comes from the important length of the reservoirs life time (75 years)
[18] The value taken for maize subsidy is 117€/ha and for wheat is 84 €/ha. The difference equals to 33€.

Table 5: Impact of a cereal price variation on the agricultural gross margin of the basin

Cereal price scenarios	Gross margin			
	Reference situtation (M€)	80% reduction in summer water abstractions ((M€)	Absolute difference ((M€)	Relative difference (%)
Reference price	34,27	31,59	-2,68	-7,82%
Cereal price +25%	45,34	41,12	-4,22	-9,30%
Cereal price -25%	23,77	22,59	-1,18	-4,98%

A second analysis consists in presenting results per annual unit of labour. In the reference scenario the gross margin per unit of labour is 7% less in farm types specialised in milk production than in farm types specialised in cereal production that would see the gross margin per unit of labour decrease by only 3% after the implementation of an 80% reduction scenario.

Implementing a quota scenario reduces economic inequities; inequities that are in reality higher than the situation presented since fixed costs are not included in the analysis. Indeed farms specialised in milk production have higher fixed costs than farm types specialised in cereal production as they must get equipments and infrastructure both for cereals and for their breeding/milk activity.

5 Summary of assessment results

Table 6 summarizes the impacts on each water use of an 80% reduction of summer abstractions by agriculture that helps restoring the good quantitative ecological status of the Boutonne River. As the land use planning and pricing scenarios are applied to agriculture sector only, it is only for this sector that differences between the two scenarios are investigated. Indeed, there is no implication for other water uses whether the -80% reduction in abstraction is obtained via the establishment of a quota or a change in agricultural water pricing.

For agriculture, the financial impact of the different scenarios is significantly different depending on the scenario as illustrated in Table 6.

Table 6 : Expected changes in farm gross margin for different scenarios (results of economic model simulation)

[redacted]

There are two reasons why water pricing affects farm income differently than the quota. First, water pricing implies in itself a financial flow outside of the agricultural sector proportional to the quantity of water used. Second, water pricing has a larger negative impact as it affects water use during the entire year (including spring water consumption), while the quota was specified for the summer period where water scarcity needs to be addressed. A quota applied to both the summer and the spring water abstractions was also simulated. The results show a drop in the profit still limited as compared to reduction in farm income resulting from increases in water pricing.

Changes in water pricing have a more significant negative impact on agricultural gross margins. The budget obtained from tax receipts (around 1.30 M€[19]) could be used to mitigate these negative impacts on agriculture income. The drop in total farm gross margins at the river basin level would then be 16.3% instead of 20.1% if tax receipts are not cycled back to the agriculture sector.

The quantification of the impacts for other users has been assessed for scenarios where the ecological flow is reach (equivalent to an 80% reduction of summer abstractions). In practice, it helped stakeholders and economic sector representatives interviewed to have a clear (and shared) reference: indeed, the -80% reduction is considered as equivalent to the situation before the 1980s. It is assumed that with a 50% reduction of total water withdrawals, positive[20] effects will also be recorded. However, it was not possible to quantify the marginal impacts this would have and the share of expected benefits estimated for the -80% scenario that could be allocated to the -50% scenario.

Overall, the largest monetary impact of the scenarios is for the agriculture sector. According to the economic model, the losses of this sector would amount to 2.68 M€ in the case of an 80% reduction of summer abstractions. A variation in the cereal price has a great impact on that loss as shown in the sensitivity analysis (Section 4.5.4). The poplar trees sector also has monetary losses estimated between 1.1 and 1.7 M€. All other uses would benefit from higher river flows. The highest benefits are for shellfish farmers (between 1 and 2.5 M€ per year + additional benefits from connected economic actors that have not been estimated). Put together, the benefits would range from 2.3 M€ to 4.8 M€. A summary of the impacts for each water use is given in Table 7.

When a quota on summer abstractions is applied to reach the required summer river flows equivalent to ecological flows, total costs range from 2.2 M€ to 5.4 M€. Despite the uncertainties highlighted in the previous sections when making the estimations, one can see that costs and benefits are more or less balanced.

The use of water pricing to achieve an 80% reduction leads to total costs between 4.1 M€ and 12.5 M€. In that case, total costs would be much higher than total benefits.

In conclusion, a quota on summer abstraction would be seen, from a farm income's point of view, as a more suited tool than water pricing to reach the ecological equilibrium of the Boutonne river basin. One should keep in mind that the model predicted that in the case of a quota on summer abstractions, spring abstractions would increase significantly. Thus, this scenario could have indirect important effects on the spring hydrology of the catchment and on connected uses. Possible negative impacts that would result from increases in spring water abstractions have not been estimated in the context of this study.

[19] To reach a 80% reduction in water withdrawals, the level of the tax has to be 0.525 €/m^3. The annual water consumption is 2.27 Mm3.
[20] Except for poplar trees who bear negative impacts

User		Description of the impact	Monetary evaluation			
			Indicator	Lower bound	Upper bound	Monetary impact not taken into account
Agriculture	Quota scenario	A quota that allow a 80% reduction of summer water abstraction leads to an important shift from summer irrigated crops (corn) to spring irrigated crops (mainly wheat). Cereal farms are more affected (reduction in gross margin of 4,5%) than Breeding farms (gross margin drop by 2,5%). The advantage of this scenarios, as compared to water pricing, is equity. Indeed, the water rights of each farmer would be reduced in the same way, wether it a large or a small farm, a breeder or a crop grower.	Gross margin	-1.2 M€[a]	-4.2 M€[a]	Negative impact on the downstream industries
	Water pricing scenario	To reach a 80% reduction in the abstractions in the Boutonne river basin, the water tax has to be settled at a high level (0,575€/m3). The model shows that farmers would rather continue abstracting the same amounts of water and bear a loss of profit for low water price than changing their production choices. For high water prices, the models shows that the Milk farm type reduces irrigation for lower levels of water pricing than the Cereal farm type.	Gross margin	-3.0 M€[b]	-10.8 M€[b]	Negative impact on the downstream industries
Drinking water companies		The 3 companies have adapted their strategies to the current situation of scarce water. Reaching the good ecological status is not expected to have an impact on this sector. Two main issues explain that : (i) pumping more water in the river basin would imply to resize the current network which is probably not profitable and (ii) water quality issues are also very important in the basin	-	0	0	
Poplar trees sector		The 1574 ha of poplar trees currently present on the basin have adapted their root system to the current water table level. A too sudden raise of the water table level could damage the trees. It is estimated that between 630 and 950 ha of 6 year old trees could be affected. The assumption is made that the trees' owners would replace the trees and then bear a unitary loss around 1800€/ha.	Gross margin	-1.1 M€	-1.7 M€	Negative impact on the downstream industries
Industry (Rhodia)		Rhodia industry could benefit from more water in the Légère river, a tributary river of the Boutonne. Indeed, the dilution factor of the plant disposal flow should not be below 3. No measure was taken when it occurred in the past. The avoided cost of an activity break if the existing regulation was applied could however be made. An assumption was made that the plant's disposal flow has an insufficient dilution factor during 1 month every five years.	Turnover	0.5 M€	1 M€	
Shellfish farming sector		The situation of shellfish farming, which is currently suffering from the low flows of fresh water entering the coastal basin, could be improved by higher flows coming from the Boutonne river. The Boutonne is only a limited contributory in terms of fresh water (estimated around 1/20[th]) but it is thought that every additional cubic meter of water brought to the Marennes Oléron basin would be beneficial for the oysters during a dry summer. The shellfishes size decrease (and therefore selling price drop) recorded during the last dry years (up to 25%) would then be partially removed.	Turnover	1 M€	2.5 M€	Additional benefits from positive impacts on economic activities linked to the shellfish sector
Fishing activity		Fishing activity is directly linked to the ecological status of the rivers. The intensity of the summer drought has lead to the disappearing of fish species of interest (e.g. wild trout) and the development of unwanted and invasive species. It is thought that reaching the ecological flow would bring back an equilibrium where species such as the wild trout would develop again. It is estimated that between 500 and 1000 additional annual permits would be sold.	Permits sales	30 000 €	60 000 €	Positive impact on the daily and weekly permits Positive impact for the river reputation
Kayak activity		Larger parts of the river would be available and suited for kayaking activities if a more important flow was present in the Boutonne during summer time. The tourist kayaking activity is expected to show the highest increase, probably between +20% and +40%.	Turnover	4 500€	9 000€	Positive impact on the annual and school kayacking days Positive impact for the river reputation
Tourism sector		The tourists who are are staying in the region are mainly seeking for good quality natural environment. The improvement of the river status would certainly improve the attractiveness of the river basin as more water related activities will be possible (fishing, kayaking, hiking, ...). Overall, an increase between 10 and 30% is expected.	Turnover	0.2 M€	0.6 M€	
Environment		The environment would clearly take advantage of a scenario where the ecological flow is reached. Higher flows would benefit for the come back of some species (e.g. Wild trout) and the reduction of invasive species which have developed because of the stagnant waters (e.g. Ludwigia).	Value of the wild trout come back	0.55 M€	0.68 M€	Positive impact for many other species
a	: The range of monetary losses for agriculture in case of a quota scenario comes from the sensitivity analysis on cereal water prices (see text)					
b	: The range of monetary losses for agriculture in case of a water pricing scenario comes from the relative variation found for quota scenario in the sensitivity analysis on cereal water prices					

Table 7 : Summary of the impacts of reducing water abstraction for agriculture with quotas and water pricing

6 Feasibility of the scenarios and conclusions

To achieve the good quantitative status for the basin, an 80% reduction in summer agricultural abstraction is needed. The impacts resulting from the implementation of a quota or increases in water pricing to achieve this goal were estimated. In the case of the quota, it was shown that benefits and costs were globally balanced.

Today's discussions in the Boutonne at political level are actually considering an 80% reduction of summer abstraction. The reduction in licensed volumes has already started since 2006. No obvious changes in the cropping pattern were recorded so far, probably because the reduction is still low (the final target of -80% is planned for 2015) and also because the three last year were not especially dry. Although a reduction by -80% appears as significant, the fact that these quotas are already discussed in the Boutonne river basin stresses the political feasibility of such drastic water saving scenarios.

As a mitigation option, the measure which seems to be preferred by agriculture is the building of reservoirs. Projects have been launched to replace more than 70% of the water that has to be left to the river. These reservoirs would allow the farmers to keep the same farming activity as today. Financial resources saved from building reservoirs could however be used to support changes in farm cropping pattern to account for reduction in water abstractions.

7 Key findings

The Boutonne river basin is suffering today from important water shortages in particular during the summer period. To restore the ecological balance of the river, a 80% reduction in summer agricultural abstractions would be necessary.

The impacts on farming systems and farm income of two economic tools, a quota on water abstraction and increases in water pricing to reach similar reduction in water abstraction, were estimated. Overall, imposing a quota on summer abstractions would lead to lower farm income reduction as an increase in water pricing resulting in an equivalent decrease in water abstraction.

The reduction in farm income from imposing a 80% reduction in summer agricultural abstractions was estimated at around -8%, a figure in line with financial resources that would be saved from NOT building reservoirs in the Boutonne catchment, an alternative solution to water saving for restoring ecological river flows. This limited reduction in farm income is explained by changes in irrigation practices on maize (watering at quantities lower than crop water requirements) and by the buffer capacity provided by rainfed farming that farmers combine with irrigated crops on their farms.

Total costs of reducing water abstraction were compared to estimated total benefits. Overall, total costs are similar to total benefits for the -80% quota scenario justifying its relevance from an economic perspective.

The economic costs and benefits presented in this study are first estimates. Many assumptions were made to calculate monetary values. The values should therefore not be taken for themselves but more as order of magnitude of costs and benefits. Further work would be required to refine the economic farm models (including a more detailed analysis of the spatial distribution of farm types, expected reduction in water abstraction and economic impact distribution) and to estimate the expected benefits for economic operators indirectly benefiting from enhanced shellfish production.

8 References

ASCA, Etude sur l'irrigation et son évolution en Poitou-Charentes, 2006

SYMBO, Rapport environnemental du SAGE Boutonne, 2005

SYMBO, Les assèchements de cours d'eau sur le bassin versant de la Boutonne, 2007

9 Annexes

9.1 Annex 1 - Typology of farms in the Boutonne river basin

- ***Objective of the typology***

Irrigators are too numerous to consider individual farm modelling. The typology allows to group relative homogenous farms in terms of production and equipments. The main farm types are selected and represented in the economic models that are short and medium terms models where fixed factors do not change.

- ***Data used***

Data used comes from the 2000 agricultural census. Based on responses, the statistical services calculate several indicators; among which:

  - the technico-economics orientation of the farms (OTEX),
  - the standard gross margin (MBS),
  - the total annual amount of work (UTATOT).

To take into account farms evolution since 2000, a 2005 structural survey is used.
In the agricultural context of Boutonne river basin, the typology is based on 3 criteria: (i) the 17 production systems (OTEX), (ii) the economic farm size and (iii) the presence or not of herbivorous. Two main steps are followed:

<u>First step</u>

The 2000 census allow identifying irrigating farms in distinguishing among them the professional and non professional ones that is an indicator of the economic size. Professional ones have a minimum of 8 economic standard unit (ESU) and provide work for at least ¾ of a full annual time. Results are presented in table 1 and 2. Technical orientations are grouped as follow:

  - Large-scale farming where at least 2 third of the standard gross margin comes from OTEX 13 (cereals, oleaginous and proteaginous), and OTEX 14 (general crops).
  - Multiple cropping and breeding where between one third and 2 third of the standard gross margin comes from breeding activities. It concerns OTEX 60 (multiple farming) and OTEX 14 (large scale farming and herbivorous).
  - Herbivorous farms where more than 2 third of the standard gross margin comes from herbivorous breeding. It concerns OTEX 41 and 43 (milk cows), OTEX 42 and 71 (meat cows) and OTEX 44 (ovine and goats).
  - Intensive mass-animal breeding where more than a third od the standard gross margin comes mass-animal breeding: OTEX 50 and 72.
  - Farms where at least one third of the standard gross margin comes from special crops: vine crops (OTEX 37 and 38) and other farms (OTEX 28, 29, 39 and 82).

Non professional farms that practice irrigation are only 24 out of the 408 and represent 1.4% of the agricultural area and 1.5% of the irrigated area. This is mainly small cereals farms (see table 8). Irrigating farms are nearly all professional ones that belong to 4 main OTEX groups heterogeneous in terms of size.
Among professional farms, the most important group is “large scale farming'' that represents two third of the farms, 70% of the agricultural area and 75 of the irrigated area. The second group is the multiple cropping and breeding one. It represents 26% of farms and agricultural area and 21% of the irrigated area.
The third group is herbivorous with milk cows that only represents 3.6% of the irrigated area.
A fourth group composed by horticulture and market-gardening represents less than 0.5% of the irrigated area.

Table 8 : Classification of farms according to the agricultural area, the irrigated area, their OTEX and their economic size

OTEX Groups	Non professional farms			Professional farms		
	Nb of farms	Agricultural area (ha)	Irrigated area (ha)	Nb of farms	Agricultural area (ha)	Irrigated area (ha)
OTEX 13 14	19	606	202	254	31141	10131
OTEX 60 81	C	C	C	100	11342	2827
OTEX 41 43	C	C	C	19	1612	492
OTEX 28 29 39 82	3	1	1	10	251	55
Total	24	608	204	384	44400	13518

SCEES RA 20000 (C = statistical secret)

Table 9 illustrated the breeding activities associated to cereal crops within professional irrigating farms. Almost all breeding activities (milk cows, meat cows and milk goats) are within large scale farming and multiple crops and breeding groups. Cows milk breeding and goat milk breeding is more numerous (70%) within multiple crops and breeding group (OTEX 60 and 80). This is a mixed system cereals / milk.
Half the meat cows breedings are within large scale farming systems (OTEX 13 and 14) and less than a quarter of these farms have an herbivorous breeding.

Table 9 : Boutonne herbivorous breeding according to their OTEX within professional farms that practice irrigation (source: SCEES RA 2000)

.OTEX groups	Nb Farm	NB farm with milk cows	Nb of milk cows	NB farm with meat cows	Nb of meat cows	NB farm with goats	NB of goats
OTEX 13 14	254	11	243	42	941	3	332
OTEX 60 81	100	68	2961	27	853	13	2438
OTEX 41 43	19	19	1172	4	49	0	0
OTEX 28 29 39 82	10	0	0	0	0	0	0
Total	384	99	4396	74	1851	17	3070

Second step
The second step is based on a special query to the agricultural statistical department to better characterize Boutonne professional farms in terms of land use, herbivorous breeding and labour forces (see table 10).

Table 10 shows that Group 2 - cereal farms is the most important. It concerns 204 farms having a 1.7 average annual unity of labour force (ULF), irrigating an average of 40 hectares and where the irrigated area always represents less than half the agricultural area. Two other groups less important are attached to group 2.

- Group 5 - Cereals farms with a small meat cow breeding (36 farms) and having permanent grass land they valorise with their breeding.
- Group 3 (11 farms) characterized by the same cropping pattern and importance but owning a 22 milk cow breeding. This group tends to disappear since the average number of cow reduced by 30% between 2000 and 2005. The reduction in the number of cow is more important than in the 2 other specialized groups (6 and 10) respectively -16% and -9%. The reduction seems to be inversely proportional to the initial number of animal.

Three farm groups combine cereals and herbivorous with a number of animal more important.

- 63 farms are in Group 6, cereals and meat cows. These farms have an average agricultural area of 118 ha, a 44 cows breeding using less than a third of the agricultural area and have more than 2 units of labour force.
- Group 7, cereals and milk goats is only composed by 13 farms. This is large size farms (130 ha) with a 188 goat flock. For 38% of these farms, also owning 35 milk cows, goats are a mean to develop milk production in a context where milk cow quota are blocked. Milk production (cow and goat) used less than a third of the agricultural area as well as in the group ''cereals and milk cows''. These farms used more labour than cereals farms, 3 units of laver in average.
- Group 8, cereals and meat cows, is also a small group. The average size of the 12 farms is about 100 hectares with 1.8 unit of labour force, just like cereals farms of the same size. The average number of adult cow is 40. The breeding used 44% of the agricultural area and permanent grass land represents two third of the fodder area. This group has the higher proportion of irrigated temporary grass land (25% against 12% in other groups). The irrigated area is lower than in other groups (17%).

Group 10 is composed by 19 farms specialized in milk cows. The average size is 85 ha for 2.3 units of labour. They own 62 milk cows that used 34% of the agricultural area. Some of them also own a small meat cow breeding. Fodder system is mainly based on fodder crop and cereals since maize represents 43% of the fodder area, temporary grass land represents 37% and permanent grass land 20%. These farms have a land use similar to cereals farms and they irrigate 30% of the agricultural area.

Table 10 : Results of a specific query to the agricultural statistics department

Farm type	Query	Farms (nb)	Labour force (unit/ha)	Agricultural area (ha)	Irrigated area (ha)	Fodder crops (ha)	Animals (nb per farm)
1	**[**OTEX 13 (cereals, oleaginous, proteaginous) **or** OTEX 14 (general crops)**]** **and** Milk cow = 0 **and** meat cow = 0 **and** goat = 0 **and** irrigated area $\geq$ 50% of the agricultural area	0	0	0	0	0	0
2	**[**OTEX 13 (cereals, oleaginous, proteaginous) **or** OTEX 14 (general crops)**]** **and** Milk cow = 0 **and** meat cow = 0 **and** goat = 0 **and** irrigated area < 50% of the agricultural area	204	1,7	120	40	1	0
3	**[**OTEX 13 (cereals, oleaginous, proteaginous) **or** OTEX 14 (general crops)**]** **and** Milk cow > 0 **and** goat = 0	11	2,3	148	41	18	22 vl
4	**[**OTEX 13 (cereals, oleaginous, proteaginous) **or** OTEX 14 (general crops)**]** **and** goat > 0	3	3,0	169	32	27	111 ch
5	**[**OTEX 13 (cereals, oleaginous, proteaginous) **or** OTEX 14 (general crops)**]** **and** Milk cow = 0 **and** meat cow > 0 **and** goat = 0	36	1,8	126	40	24	24 va
6	**[**OTEX 60 (multiple crops) **or** OTEX 81 (large scale farming and herbivorous)] **and** milk cow > 0 **and** goat = 0	63	2,4	118	32	33	44 vl

7	**[**OTEX 60 (multiple crops) **or** OTEX 81 (large scale farming and herbivorous)] **and** goat > 0	13	3,0	130	24	41	188 ch
8	**[**OTEX 60 (multiple crops) **or** OTEX 81 (large scale farming and herbivorous)] **and** meat cow >0 **and** milk cow = 0 **and** goat = 0	12	1,8	101	17	44	40 va
9	**[**OTEX 60 (multiple crops) **or** OTEX 81 (large scale farming and herbivorous)] **and** meat cow =0 **and** milk cow = 0 **and** goat = 0	12	3,1	83	27	1	0
10	**[**OTEX 41 (milk cow) **or** OTEX 43 (meat cow and milk cow)**]**	19	2,3	85	26	48	62 vl
11	Other OTEX (28 or 29 or 37 or 38 or 39 or 42 or 44 or 50 or 71 or 72 or 82)	11	2,8	28	6	0	0
	Total	384					

- ***Updating 2000 census data with 2005 structural survey***

This updating allows taking into account the evolution between 2000 and 2005 in terms of population, agricultural area, irrigated area, breeding… Two steps are followed.

Step 1: assessing evolution coefficients

For a given variable (number of farm, agricultural area), ''c'' coefficient is equal to the ratio between the value of the considered variable in 2005 and it value in 2000 (X2005/X2000). These coefficients are calculated for farm groups and respect the 2005 structural survey sampling (geographical, OTEX and economic size). The 2005 structural survey is an opinion pool query for which results for marginal crops are imprecise and that only provide the total irrigated area per farm and not per crop. Coefficients are calculated for the 2 departments (Charente-Maritime and Deux-Sèvres), for professional farms and for the 3 main OTEX groups presented before. Results are presented in table 7 for 11 variables:

Table 11 : Evolution coefficient of selected variables from 2000 to 2005 per department and per type of farms (only professional farms).

variables	Charente Maritime			Deux-Sèvres		
	OTEX 13 or 14	OTEX 60 or 81	OTEX 41 or 43	OTEX 13 or 14	OTEX 60 or 81	OTEX 41 or 43
Number of farm	0.95	0.83	0.73	0.96	0.83	0.84
Agricultural area	1.05	0.96	0.87	1.04	0.91	1.06
Irrigated area	1.16	0.84	1.11	0.76	0.51	0.91
Unit of labor per farm	0.92	0.83	0.83	0.88	0.79	0.99
Summer crop	1.15	1.02	1.03	1.14	1.02	1.17
Winter crop	0.91	0.79	0.69	0.86	0.67	0.87
Number of milk cow	0.73	0.76	0.89	0.62	0.95	1.00
Number of meat cow	0.92	1.13	0.36	0.67	0.75	1.00
Number of goat	0.94	0.81	0.00	0.56	0.98	
Fodder area	1.09	1.04	0.97	0.81	0.92	1.00
Grass land	0.96	1.09	0.66	0.93	0.95	1.07

Source: SCEES RA 2000

Step 2: implementing coefficients to the main variables

Applying such coefficients in the Boutonne river basin supposes that Boutonne farms evolved in the same way as the totality of farms of the department they depend between 2000 and 2005.

Coefficients calculated for Deux-Sèvres department are applied to Boutonne's upstream farms and those calculated for Charente Maritime are applied to the remaining Boutonne's farms (middle and downstream farms). Some coefficients are used to update several variables. The total irrigated area coefficient allows updating the area of each irrigated crop. This is also the case for the summer crop, winter crop and grass land coefficients.

Table 12 : List of evolution coefficients for the updating of the 2000 data with 2005 variables.

Variables of 2000 census	Coefficient C
Number of irrigating farms	C_farm
Agricultural area	C_agricultural area
Irrigated area Irrigated maize Fodder maize irrigated Wheat and other irrigated cereals Sun flower irrigated Proteaginous irrigated Temporary grass land irrigated	C_irrigated area C_labour
Total unit of labour per farm	C_UTATOT
Maize grain and seeds sorgho grain Sun flower Soja Proteaginous	C_summer crop
Wheat Barley Rape	C_winter crop
Milk cow	C_cow milk
Meat cow	C_cow meat
Goat	C_goat
Fodder maize Total fodder	C_fodder
Grass land	C_STH

9.2 Annex 2 - The economic model for farms

As shown in the Typology Annexe, almost all the farms practising irrigation are present into two types (93% of the farms, 97% of the irrigated area). As for climatic and soil conditions, two regions can be considered. Rainfalls are less important and temperatures higher in the upstream river basin than in the rest of the basin. In such conditions, despite the soil differences, crop water requirement are rather similar. The most important difference comes from the rain heterogeneity (inter-annual and intra-annual) among the basin.
Therefore, a model will be built for 4 types of farms.

Economic models are developed to represent farmer's behaviour face to several types of water demand management scenarios: a water price increase and a quota.

The unique objective linear programming method integrating farmers risk aversion is used.
In such models, farmer's objective is to maximize their gross margin. Fixed cost are then not included in these models. The method used to take into account risks and risk aversion is the generalized MOTAD model which allows transforming dispersion into linear functions.
In the present work, two types of risk are considered: climatic risks and resource risks.
Climatic risk is taken into account through the dispersion of crop water requirement over 20 years (1988 to 2007). Resource risk is only considered in summer, i.e. when both crop water requirement and irrigated area is the most important. A special development presented in the following paragraph allows reducing summer variability of water resource proportionally to the reduction of the authorized volume, i.e. proportionally to the quota variation. It is then assume that a 80% reduction of the 2003 authorized volume would nullify the variation of water availability in summer.

Considering that, for each irrigated crop, we know the average crop water requirement and its annual dispersion; we assume that the available summer water resource of a given year (Ve) corresponds to the administrative authorized volume (Va) minus spring consumptions (Vp). In order not to take into account spring variation in crop water requirement (double account) we consider that $V_e = V_a - \overline{V_p}$ d However, summer administrative restrictions are considered as follow:

1. When water requirement of crop "i" in year "j" is lower than the average crop water requirement of the same crop ($a_{i,j} \leq \overline{a_i}$) then the volume consumed in year "j" is equal to the authorized volume minus the average crop water requirement during spring period ($V_{j,e} = V_a - \overline{V_p}$)
2. When $a_{i,j} > \overline{a_i}$ then $V_{j,e} = (1 - k_j)(V_a - \overline{V_p})$ where "k" is a coefficient of reduction of the summer water resource that can really be used

3. "k" is determined in such a manner that in year 2005 (highest summer water deficit), the summer available water resource is reduced by 30% (k_{2005} = 0.3). Thus $k_j^0 = k_{2005}\left(\frac{a_i - \overline{a}}{a_{2005} - \overline{a}}\right)$ and $\overline{k} = \frac{1}{T}\sum_{j=1}^{T} k_j$. K is determined using maize crop water requirement only.

Annual "k" coefficients are calculated both upstream and downstream. As an example, the following table gives the different k value downstream.

Year	Crop water requirement $a_{i,j}$	Crop water requirement dispersion	k
1988	1790	-310	-
1989	2780	680	0,19
1990	2570	470	0,13
1991	2980	880	0,25
1992	910	-1190	-
1993	1600	-500	-
1994	2170	70	0,02
1995	3030	930	0,27
1996	1860	-240	-
1997	1710	-390	-
1998	3160	1060	0,3
1999	2000	-100	-
2000	1870	-230	-
2001	1950	-150	-
2002	1460	-640	-
2003	2310	210	0,06
2004	1160	-940	-
2005	3150	1050	**0,3**
2006	3030	930	0,27
2007	510	-1590	-
Average	2100	0	0,09

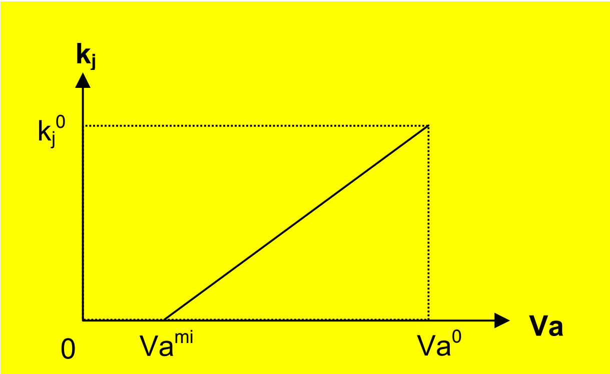
The average dispersion for summer water availability $EMVe$ is then calculated as follow:

$$EMVe_j = Ve_j - \overline{Ve} = Ve_j - \frac{1}{T}\sum_{j=1}^{T} Ve_j = Va\left(\overline{k_j} - k_j\right) - \overline{V_p}\left(\overline{k_j} - k_j\right)$$

To take into account summer restrictions (administrative) a linear relation between k_j and Va is considered. This means that a reduction of licensed volumes will reduce summer water resource risk. Thus, $k_j = \frac{k_j^0}{Va^0 - Va^{\min}}\left(Va - Va^{\min}\right)$ where Va^0 is the administrative reference volume of the reference scenario and Va^{min} the licensed volume determined in such a manner that the impact of that volume withdrawal do not hamper reaching water bodies' good ecological status.

For the present study, "k" is always equal to zero in case of implementation of the 80% reduction in summer water consumption compared to the reference scenario.

Not taking into account "k" in the models would induce a 15% higher consumption in summer and nearly no crops would be irrigated in summer which does not reflect reality.


k_j
k_j^0
0
Va^{mi}
Va^0
Va

9.3 Annex 3: Results of the modelled reference scenario

The results of the economic models built for each type, upstream and downstream, are presented in the following table. These results define the reference scenario. They allow checking the validity of the models since the current situation should be represented.

	Cereals		Cereals and milk cow	
	Up stream (Useful reserve = 105 mm/m)	Downstream (Useful reserve = 60 mm/m)	Up stream (Useful reserve = 105 mm/m)	Downstream (Useful reserve = 60 mm/m)
Gross margin	100 383	104 935	143 266	142 218
Total consumption	50 942	60 584	41 645	41 736
Summer	44 101	51 094	37 854	41 736
Spring	6 841	9 490	3 791	0
Total irrigated are	31.4	44.6	21.5	28.6
Summer	24.0	36.0	18.0	28.6
Maize100	*1.1*	-	*18.0*	-
Maize 85	*22.9*	-	-	*6.4*
Maize 75	-	*9.3*	-	-
Maize 65	-	*26.7*	-	*22.2*
Maize 50	-	-	-	-
Sunflower irrigated	-	-	-	-
Spring	7.4	8.6	3.4	-
Weat irrigated	7.4	8.6	3.4	-
Proteaginous irrigated	-	-	-	-
Dry area	91.9	82.0	46.5	42.1
Weat	43.3	37.7	28.9	28.7
Bareley	23.6	21.5	0.8	-
Sunflower	24.8	22.7	13.8	10.4
Sorgho	0.1	0.1	3.0	3.0
Colza	-	-	-	-
Grassland, fodder and fallow	10.2	7.5	60.9	57.1

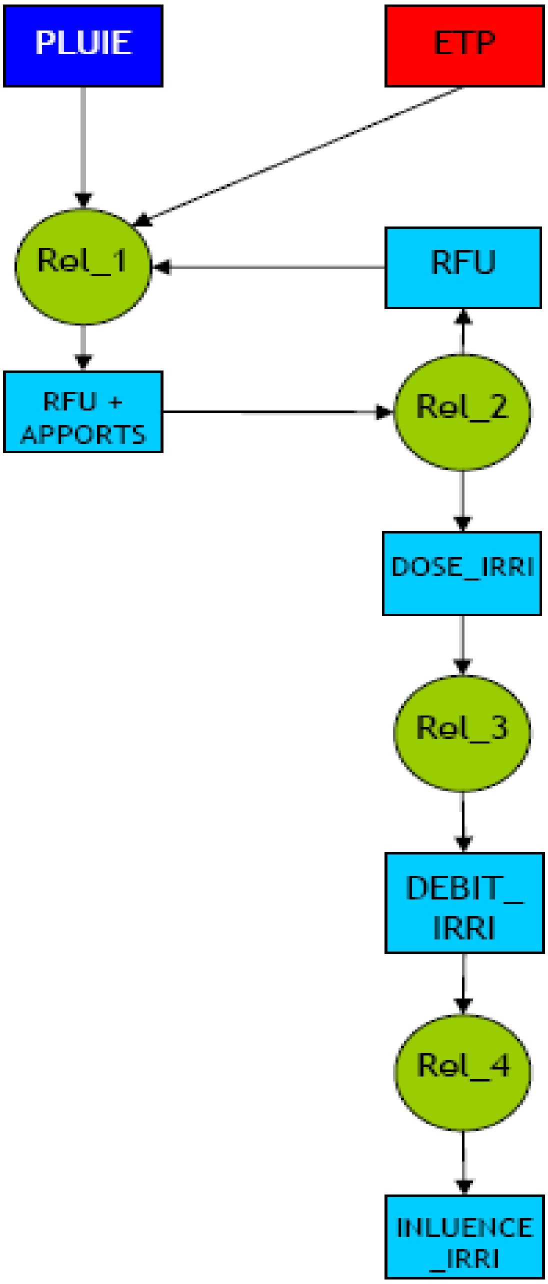
9.4 Annex 4 - List of persons interviewed during the study

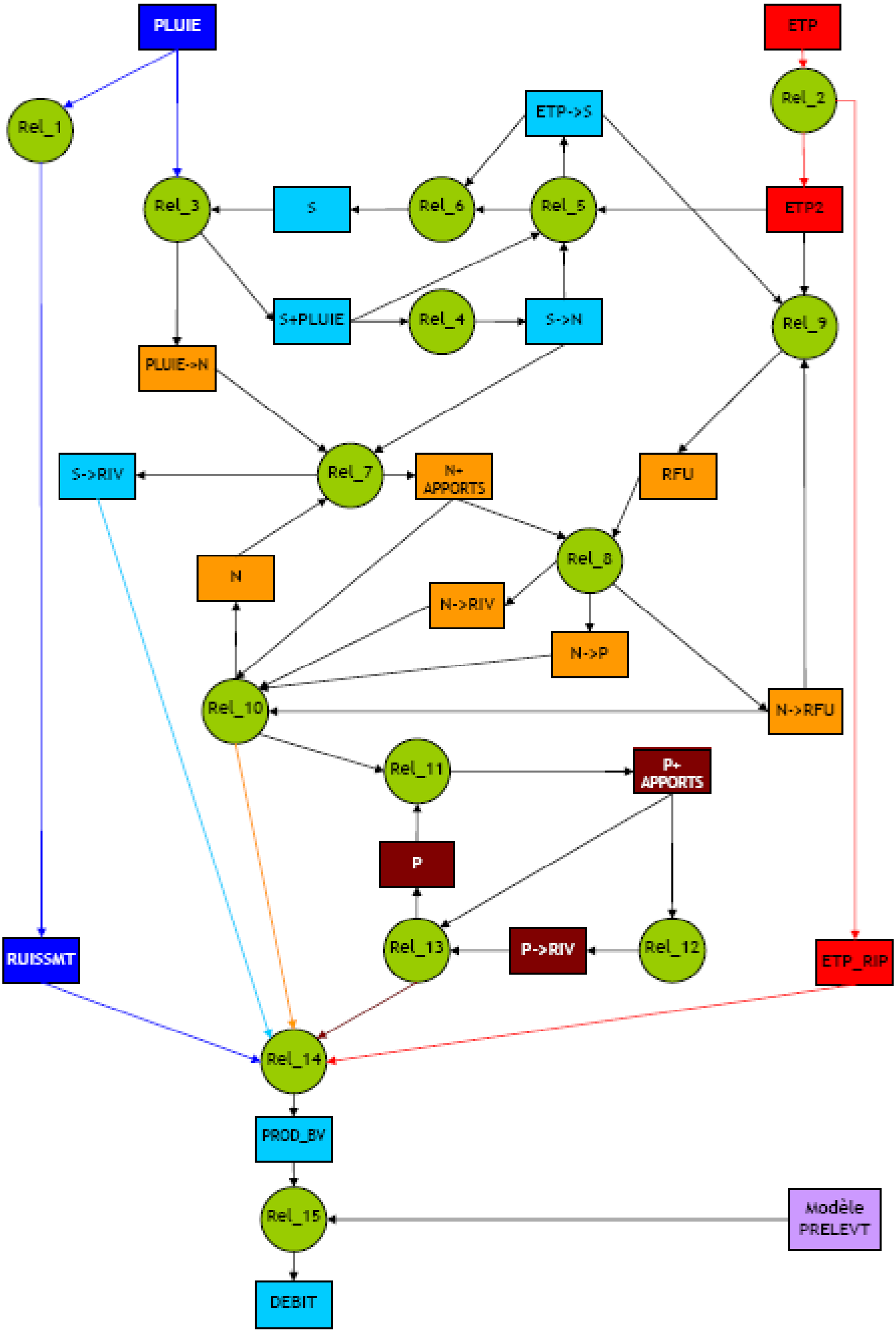
Name	Organisation	Function
BROUSSEY M.	Syndicat Mixte de la Boutonne	River Bassin Management Plan coordinator
VOIX P.	Syndicat Mixte du Bassin de la Boutonne en Deux-Sèvres	Upstream Boutonne river technician
STAUDT F.	Syndicat Intercommunal de la Boutonne Amont en Charente Maritime	Middle Boutonne river technician
FOUTENY S.	Conseil Général de Charente Maritime	Downstream Boutonne river technician
MOIZANT J-Y.	Association Syndicale Autorisée Boutonne	Irrigators association president
AMBERT J-M.	Association Syndicale Marais Ternant Voissay	Irrigators association president
BARRE D.	Association de Protection, d'Information et d'Etude de l'Eau et de son Environnement	Environmental NGO former president
LAVAUR S.	Fédération de Charente Maritime pour la pêche	Fishing federation employee
LEPINE J.	Syndicat des eaux de Charente Maritime	Drinking water company employee
ROUSSET A.	Association pour le Développement du Peuplier de Charente Maritime	Poplar trees association employee
DELESCLUSE C.	Section Régionnale Conchylicole de Poitou Charente	Shellfhish organisation employee
VIAUD G.	-	Shellfish farmer
AURIOL O.	Etablissement Public Territorial de Bassin	Water management organisation employee
PERTHUISOT J.	Direction Départementale de l'Agriculture et la Forêt	Head of the “water police”
CHARLES P.	Association des Irrigants de Deux-Sèvres	Irrigators association president
PAUTRET S.	Chambre d'Agriculture des Deux-Sèvres	Working at the irrigation management section
LOUSSOUARN G.	Comité Régional du Tourisme de Poitou-Charente	Tourism organisation employee
CADOURET M.	SAUR Périgny	Drinking water company employee
DEBORDE M.	Syndicat 4B	Drinking water company former employee
PERRONA P.	Usine Rhodia de Melle	Engineer in charge of environment security
FLATREAU X.	Club de canoë-kayak de Saint Jean d'Angély	Kayak club employee

9.5 Annex 5 - The hydrological model

A hydrological model was developed by a company named EAUCEA. This model was used within the study to calibrate the model and to translate water abstractions reduction into river flows increases.

The following figures illustrate the hydrological model mechanism. The first figure is the "agricultural part" which is linked to the "natural" part at its last step.




PLUIE
ETP
Rel_1
ETP->S
Rel_2
Rel_3
S
Rel_6
Rel_5
ETP2
S+PLUIE
Rel_4
S->N
Rel_9
PLUIE->N
S->RIV
Rel_7
N+ APPORTS
RFU
N
Rel_8
N->RIV
N->P
Rel_10
N->RFU
Rel_11
P+ APPORTS
P
RUISSMT
Rel_13
P->RIV
Rel_12
ETP_RIP
Rel_14
PROD_BV
Rel_15
Modèle PRELEVT
DEBIT

9.6 *Annex 6 - Geographical heterogeneities of the different indicator linked to the water resource*

Figure – Depth soils classification

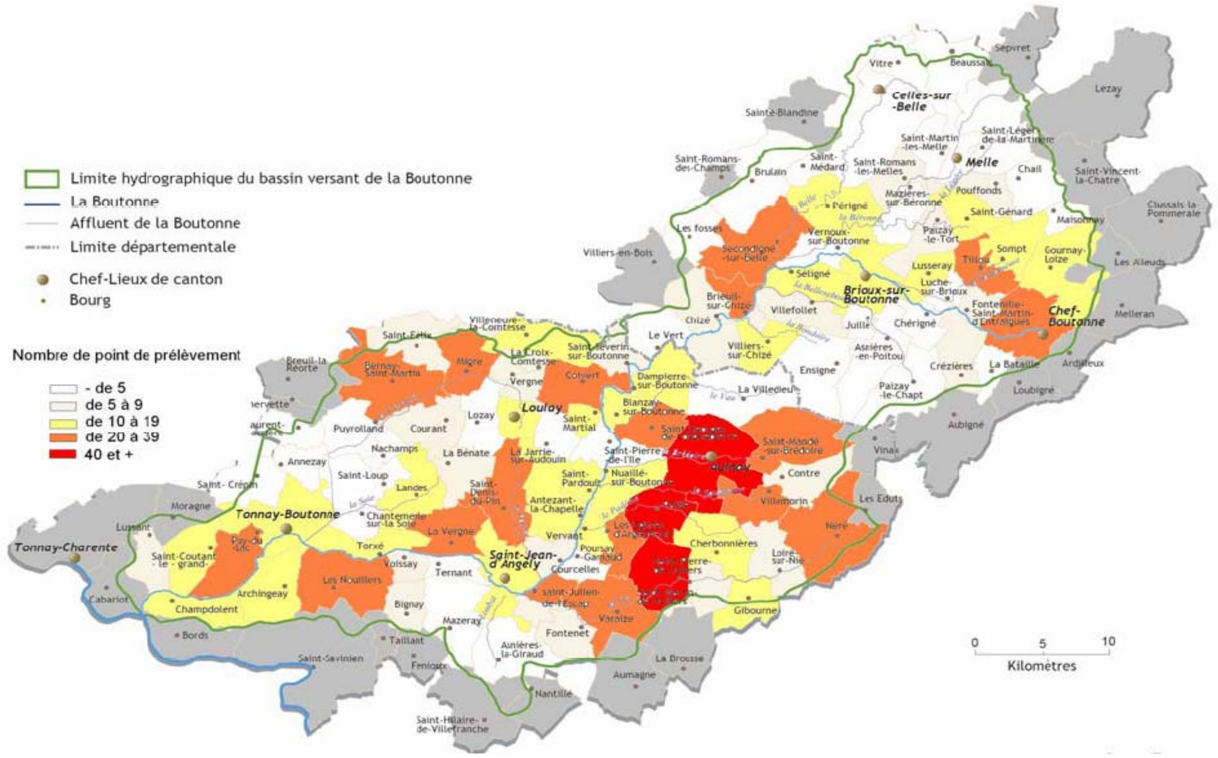


Figure - Number of withdrawal points per municipality

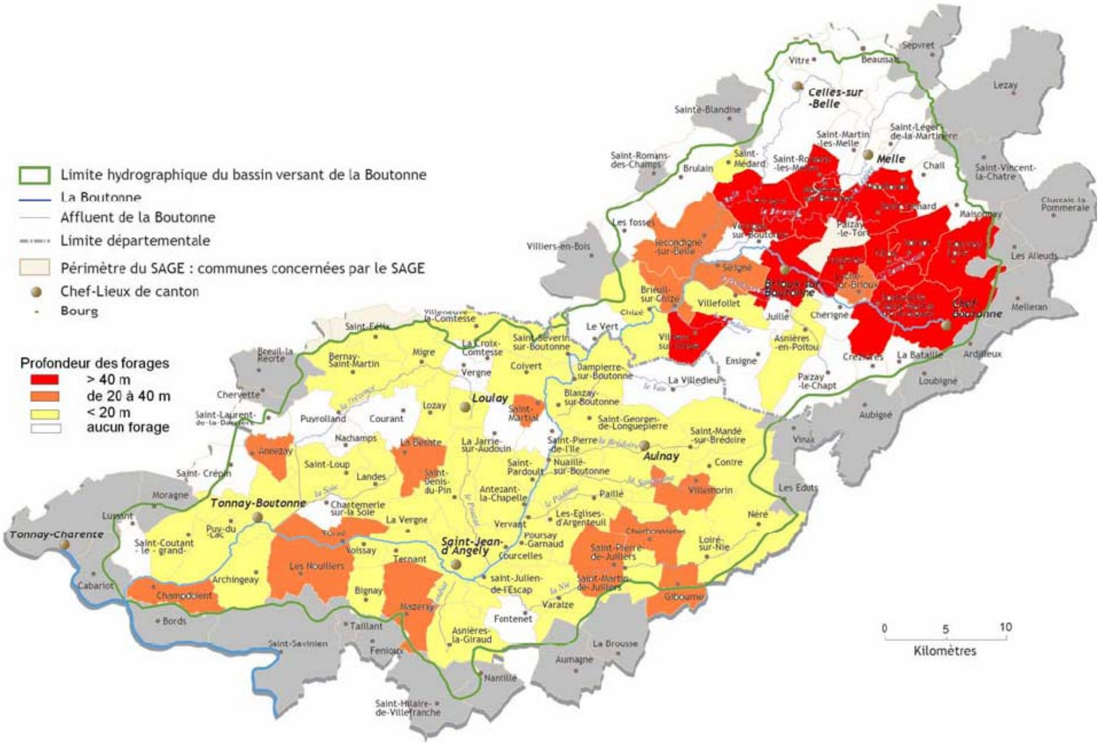


Figure - Average borehole depth per municipality

9.7 Annex 7 - Results of the economic model for quota scenarios

		REFERENCE			QUOTA -80% summer abstractions			QUOTA -80% total abstractions			QUOTA -50% summer abstractions			QUOTA -50% total abstractions		
		DS	US	Total	DS	US	Total	DS	US	Total	DS	US	Total	DS	US	Total
cereale type	Gross Margin	104 935	100 383	2,5E+07	95 725	91 226	2,3E+07	87 325	87 879	2,1E+07	97 707	93 191	2,3E+07	96 316	94 325	2,3E+07
	AV total	110 000	90 000	2,5E+07	110 000	90 000	2,5E+07	22 000	18 000	5,1E+06	110 000	90 000	2,5E+07	55 000	45 000	1,3E+07
	AV summer	110 000	90 000	2,5E+07	10 219	8 820	2,4E+06	22 000	18 000	5,1E+06	25 547	22 050	5,9E+06	55 000	45 000	1,3E+07
	CV total	60 584	50 942	1,4E+07	51 270	31 065	1,1E+07	14 657	12 338	3,4E+06	53 937	33 135	1,2E+07	34 337	28 940	7,9E+06
	CV summer	51 094	44 101	1,2E+07	6 808	6 046	1,6E+06	14 657	12 338	3,4E+06	13 974	12 191	3,3E+06	34 337	28 940	7,9E+06
	CV spring	9 490	6 841	2,1E+06	44 462	25 020	9,7E+06	-	-	0,0E+00	39 963	20 944	8,6E+06	-	-	-
	IS total	44,6	31,4	10 025	44,6	31,4	10 025	14,0	11,5	3 218	44,6	31,4	10 025	32,7	24,0	7 398
	IS summe	36,0	24,0	8 028	4,3	4,3	1 034	14,0	11,5	3 218	8,4	8,7	2 024	32,7	24,0	7 398
	IS spring	8,6	7,4	1 997	40,3	27,1	8 991	-	-	-	36,2	22,7	8 001	-	-	-
milk type	Gross Margin	142 209	143 266	9,4E+06	135 516	134 824	8,9E+06	131 794	134 198	8,8E+06	137 919	136 956	9,1E+06	136 576	139 242	9,1E+06
	AV total	83 000	83 000	5,5E+06	83 000	83 000	5,5E+06	16 600	16 600	1,1E+06	83 000	83 000	5,5E+06	41 500	41 500	2,7E+06
	AV summer	83 000	83 000	5,5E+06	8 342	7 571	5,3E+05	16 600	16 600	1,1E+06	20 854	18 927	1,3E+06	41 500	41 500	2,7E+06
	CV total	41 708	41 645	2,8E+06	37 602	24 624	2,2E+06	10 476	10 476	6,9E+05	41 538	25 588	2,4E+06	24 262	24 948	1,6E+06
	CV summer	41 708	37 854	2,7E+06	5 623	4 879	3,5E+05	10 476	10 476	6,9E+05	11 515	9 922	7,2E+05	24 262	24 948	1,6E+06
	CV spring	-	3 791	8,7E+04	31 980	19 745	1,8E+06	-	-	0,0E+00	30 023	15 666	1,7E+06	-	-	-
	IS total	28,6	21,5	1 723	34,0	21,5	1 956	7,7	7,7	507	34,0	21,5	1 956	17,8	18,0	1 179
	IS summe	28,6	18,0	1 644	5,0	3,6	299	7,7	7,7	507	6,8	7,3	460	17,8	18,0	1 179
	IS spring	-	3,4	79	29,0	17,9	1 657	-	-	-	27,2	14,2	1 496	-	-	-
Total	Gross Margin	2,6E+07	8,1E+06	3,4E+07	2,4E+07	7,5E+06	3,2E+07	2,2E+07	7,3E+06	3,0E+07	2,5E+07	7,6E+06	3,2E+07	2,4E+07	7,7E+06	3,2E+07
	AV total	2,5E+07	6,2E+06	3,1E+07	2,5E+07	6,2E+06	3,1E+07	4,9E+06	1,2E+06	6,2E+06	2,5E+07	6,2E+06	3,1E+07	1,2E+07	3,1E+06	1,5E+07
	AV summer	2,5E+07	6,2E+06	3,1E+07	2,3E+06	6,0E+05	2,9E+06	4,9E+06	1,2E+06	6,2E+06	5,8E+06	1,5E+06	7,3E+06	1,2E+07	3,1E+06	1,5E+07
	CV total	1,3E+07	3,4E+06	1,7E+07	1,1E+07	2,1E+06	1,3E+07	3,2E+06	8,3E+05	4,1E+06	1,2E+07	2,2E+06	1,4E+07	7,6E+06	2,0E+06	9,6E+06
	CV summer	1,2E+07	3,0E+06	1,5E+07	1,5E+06	4,0E+05	1,9E+06	3,2E+06	8,3E+05	4,1E+06	3,2E+06	8,1E+05	4,0E+06	7,6E+06	2,0E+06	9,6E+06
	CV / AV sum	47%	48%	**47%**	67%	67%	**67%**	66%	67%	66%	55%	54%	**55%**	62%	63%	62%
	% summer	86%	88%	87%	14%	20%	14%	100%	100%	100%	26%	37%	28%	100%	100%	100%
	IS	9 748	2 001	11 748	9 980	2 001	11 981	2 996	729	3 725	9 980	2 001	11 981	7 010	1 567	8 577
Gross margin	Cereals	0%	0%	0%	-9%	-9%	-8,8%	-17%	-12%	-16%	-7%	-7%	-6,9%	-8%	-6%	-8%
	Milk	0%	0%	0%	-5%	-6%	-5,1%	-7%	-6%	-7%	-3%	-4%	-3,5%	-4%	-3%	-4%
	Total	0%	0%	0%	-8%	-8%	-8%	-15%	-10%	-13%	-6%	-6%	-6%	-7%	-5%	-7%
Volumes	Cereals	0%	0%	0%	-15%	-39%	-19%	-76%	-76%	-76%	-11%	-35%	-15%	-43%	-43%	-43%
	Milk	0%	0%	0%	-10%	-41%	-21%	-75%	-75%	-75%	0%	-39%	-14%	-42%	-40%	-41%
	Total	0%	0%	0%	-15%	-40%	-20%	-76%	-76%	-76%	-10%	-36%	-15%	-43%	-42%	-43%

Gross margins are in Euros, volumes of water in m^3 and cropped areas in hectares. Note that the values in the columns that are not named “Total” are values for an average farm of each type and not aggregated values for the type.

Legend:

AV : Authorized volumes
CV: Consumed volumes
IS: Irrigated surface
DS: Downstream part of the basin
US: Upstream part of the basin

9.8 Annex 8- Results of the economic model for water pricing scenarios

	Tax level (€/m3)	0,7	0,6	0,575	0,55	0,525	0,5	0,45	0,4	0,35	0,3	0,2	0,1	0
	Gross margin	125 833	126 051	126 257	126 464	126 670	126 876	127 289	127 702	128 264	129 864	134 052	138 240	142 427
	CV total	-	8 254	8 254	8 254	8 254	8 254	8 254	8 254	18 033	41 876	41 876	41 876	41 876
Milk farms -	CV summer	-	8 254	8 254	8 254	8 254	8 254	8 254	8 254	18 033	41 876	41 876	41 876	41 876
Downstream	CV spring	-	-	-	-	-	-	-	-	-	-	0	0	-
	IS total	-	8	8	8	8	8	8	8	13	29	29	29	29
	IS summer	-	8	8	8	8	8	8	8	13	29	29	29	29
43,3	IS spring	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gross margin	128 134	128 362	128 578	128 794	129 010	129 226	129 658	130 090	130 691	131 889	135 106	139 268	143 433
	CV total	-	8 639	8 639	8 639	8 639	8 639	8 639	8 639	19 772	32 176	37 854	41 645	41 645
Milk farms -	CV summer	-	8 639	8 639	8 639	8 639	8 639	8 639	8 639	19 772	32 176	37 854	37 854	37 854
Upstream	CV spring	-	-	-	-	-	-	-	-	-	-	-	3 791	3 791
	IS total	-	8	8	8	8	8	8	8	14	18	18	21	21
	IS summer	-	8	8	8	8	8	8	8	14	18	18	18	18
23,3	IS spring	-	-	-	-	-	-	-	-	-	-	-	3	3
	Gross margin	79 234	79 284	79 334	79 555	79 775	80 098	81 043	82 883	84 773	87 035	93 060	99 119	105 177
	CV total	502	502	8 818	8 818	8 818	18 900	18 900	37 800	37 800	49 140	60 584	60 584	60 584
Cereal farms -	CV summer	502	502	8 818	8 818	8 818	18 900	18 900	37 800	37 800	49 140	51 094	51 094	51 094
Downstream	CV spring	-	-	-	-	-	-	-	-	-	-	9 490	9 490	9 490
	IS total	0	0	8	8	8	18	18	36	36	36	45	45	45
	IS summer	0	0	8	8	8	18	18	36	36	36	36	36	36
190	IS spring	-	-	-	-	-	-	-	-	-	-	9	9	9
	Gross margin	81 025	81 095	81 113	81 290	81 554	81 817	82 385	83 106	84 393	85 870	90 418	95 492	100 587
	CV total	706	706	706	10 542	10 542	10 542	12 867	25 734	25 734	33 454	50 589	50 942	50 942
Cereal farms -	CV summer	706	706	706	10 542	10 542	10 542	12 867	25 734	25 734	33 454	43 748	44 101	44 101
Upstream	CV spring	-	-	-	-	-	-	-	-	-	-	6 841	6 841	6 841
	IS total	1	1	1	10	10	10	12	24	24	24	31	31	31
	IS summer	1	1	1	10	10	10	12	24	24	24	24	24	24
48	IS spring	-	-	-	-	-	-	-	-	-	-	7	7	7
	Gross margin (M€)	27,38	27,41	27,43	27,49	27,56	27,65	27,89	28,30	28,76	29,35	30,97	32,65	34,32
	CV total (Mm3)	0,13	0,69	2,27	2,74	2,74	4,66	4,77	8,98	9,66	13,51	16,63	16,74	16,74
TOTAL	CV summer (Mm3)	0,13	0,69	2,27	2,74	2,74	4,66	4,77	8,98	9,66	13,51	14,50	14,52	14,52
	IS total	123	655	2 159	2 600	2 600	4 424	4 528	8 524	8 902	9 650	11 639	11 719	11 719
	IS summer	123	655	2 159	2 600	2 600	4 424	4 528	8 524	8 902	9 650	9 650	9 650	9 650
	IS spring	-	-	-	-	-	-	-	-	-	-	1 988	2 068	2 068
	Gross margin	126 638	126 859	127 069	127 279	127 489	127 698	128 118	128 537	129 113	130 573	134 421	138 599	142 779
Milk	CV total	-	8 389	8 389	8 389	8 389	8 389	8 389	8 389	18 641	38 483	40 469	41 795	41 795
	CV summer	-	8 389	8 389	8 389	8 389	8 389	8 389	8 389	18 641	38 483	40 469	40 469	40 469
	Gross margin	79 595	79 650	79 693	79 905	80 134	80 445	81 314	82 928	84 696	86 800	92 527	98 387	104 251
Cereal	CV total	544	544	7 182	9 166	9 166	17 214	17 683	35 367	35 367	45 976	58 568	58 639	58 639
	CV summer	544	544	7 182	9 166	9 166	17 214	17 683	35 367	35 367	45 976	49 612	49 684	49 684

Except when specified, gross margins are given in Euros, volumes of water in m^3 and cropped areas in hectares. The legend is the same as in Annex 6.