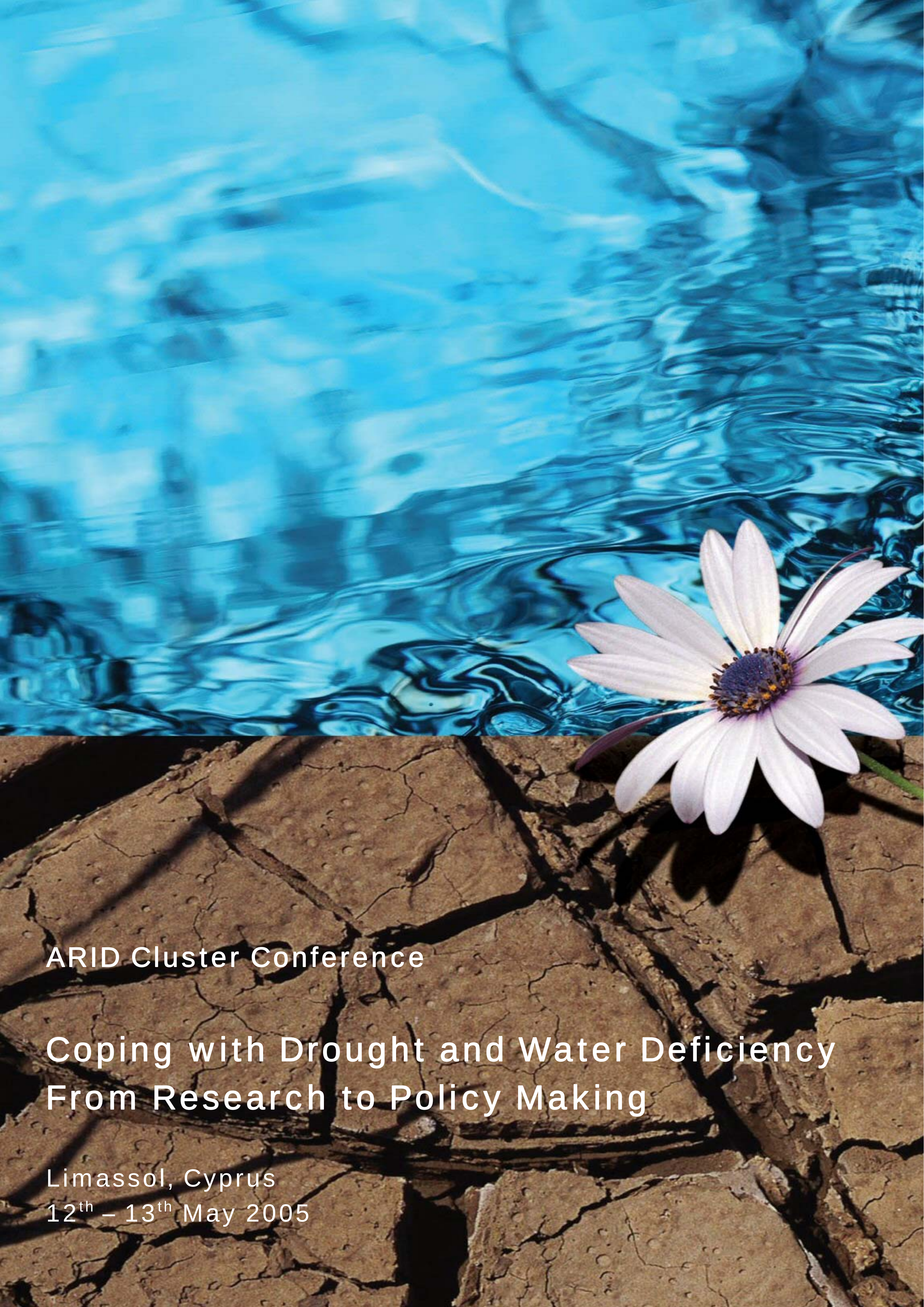
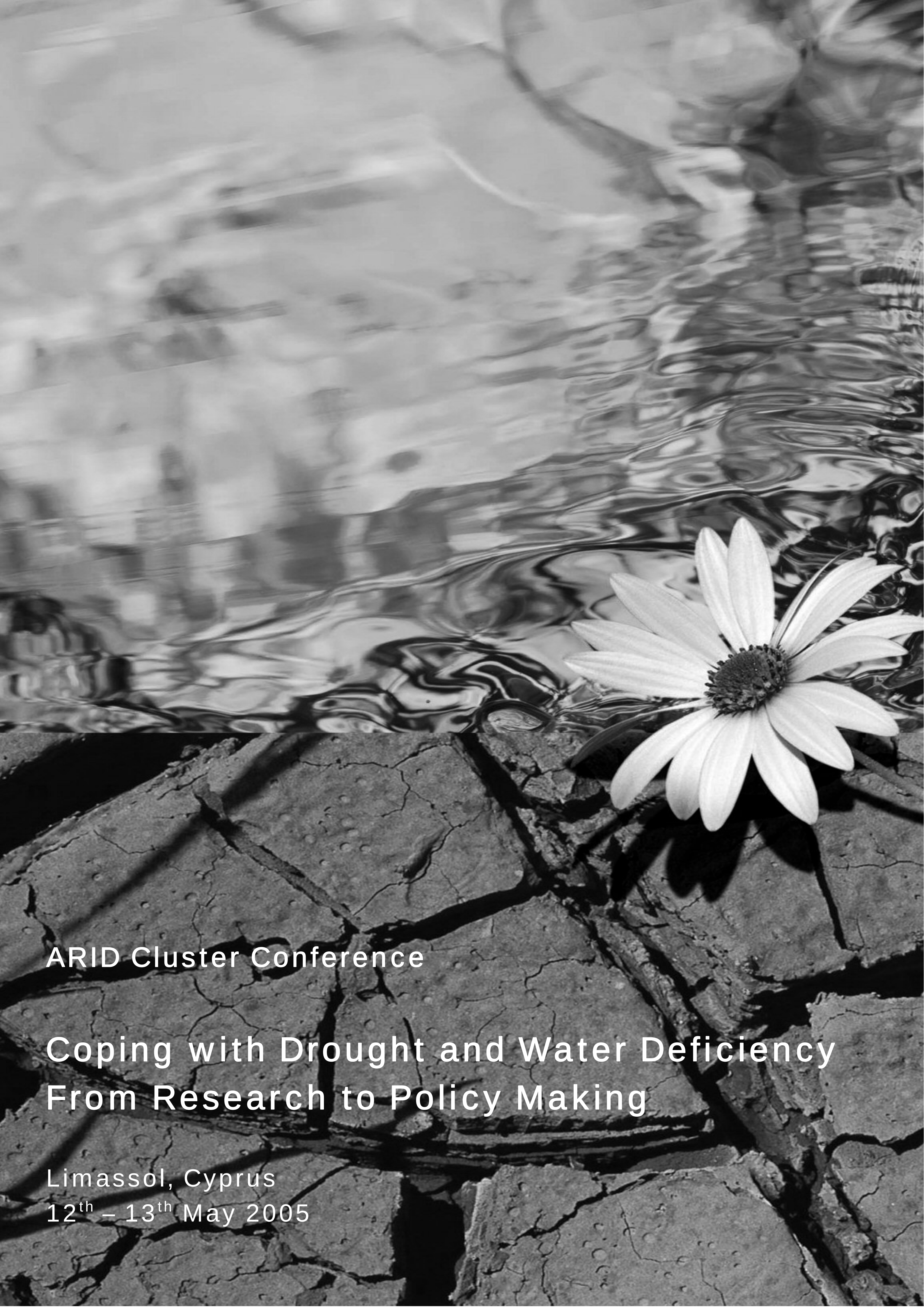


ARID Cluster Conference

Coping with Drought and Water Deficiency From Research to Policy Making

Limassol, Cyprus
12th – 13th May 2005



ARID Cluster Conference

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THE ARID CLUSTER

The "ARID Cluster: Strengthening complementarity and exploitation of results of related RTD projects dealing with water resources uses and management in arid and semi-arid regions" is an Accompanying Measure, supported by the European Commission under the 5th Framework Programme, and contributing to the implementation of the Key Action *Sustainable Management and Quality of Water* within the *Energy, Environment and Sustainable Development (EESD)* Specific Programme. The ARID Cluster project aims to consolidate the work of three funded EU projects with a view at ensuring that through collaboration, information sharing and dissemination a consistent set of recommendations and user friendly tools and methodologies for water management in arid and semi arid areas are developed. The three research projects comprising the ARID Cluster are: AQUADAPT, MEDIS, and WaterStrategyMan, aiming to contribute to the following objectives:

- Sustainable management and quality of water,
- Regulation of stocks and technologies for arid and semi-arid regions and generally water deficient regions.
- Improving knowledge on water resources use and management.

The ARID Cluster projects conduct and disseminate research on Integrated Water Resources Management and Strategies for environments which are under water stress. The overall aim of the research undertaken within the projects is to assist in the implementation of the Water Framework Directive, in terms of equitable and efficient resource allocation, adaptive management approaches, and larger consideration of adapting to changing socio-cultural conditions. Research also offers a comparative analysis between case studies in order to reveal important differences between policy recommendations and current water management practices.

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THE CONFERENCE

The ARID Cluster Conference "Coping with Drought and Water Deficiency: From Research to Policy Making" was jointly organised by the ARID Cluster, the Common Implementation Strategy, the European Commission and DG Environment, the Cypriot Government and AEOLIKI Ltd, in Cyprus on May 12th and 13th 2005. Under the broad title of Water Management in Deficient Regions, the Conference themes included:

- Policy and Governance,
- Management and decision-making tools,
- Eco-adaptation,
- Economic issues,
- Implemented measures
- Experience-based future recommendations.

This was the fourth major event in a series of escalating magnitude and importance. The first seminal event was organised in Paris in October 2003, within the framework of the EC DG Research Project "Developing Strategies for Regulating and Managing Water Resources and Demand in Water Deficient Regions" (WaterStrategyMan), which incorporated both a Public Workshop on "Comprehensive Water Management Strategies for Water Stressed Regions", and an ARID Cluster Meeting. The decision was taken that subsequently to the success of the Public Workshop, further Workshops and Conferences would be undertaken by the Cluster, in order to address the water scarcity issue and promote the presentation and dissemination of the Cluster results. Furthermore, the planned events would contribute to developing the interaction between the three individual Projects and promoting the sharing of results and methodologies within the Cluster and with the general public.

The three events planned subsequent to the Paris Workshop were aimed at presenting the research outcomes of the three Projects towards the development of integrated water resources management strategies to the public in a series of successive steps. The initial step, presented in La Palma of the Canary Islands in February 2004, involved the identification and analysis of traditional and new instruments that are or can be used for the management of water resources in Arid Regions.

This was followed by a new initiative; following the 2003 drought, the Common Implementation Strategy Water Directors decided to examine the type of action necessary in this field at the European level. The Sicily Joint Workshop "Drought and water deficiency: from research to policy making" was jointly organized by the European Commission (DG Research and DG Environment) and France in October 2004, and was supported by the ARID Cluster. In the wake of the success of this initiative, it was decided that the final event, the Cyprus Conference, would continue this effort, integrating the efforts so far undertaken in developing a policy-oriented, reality-based framework for managing drought and aridity.

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CLOSING SESSION

Coping with Drought – The Experiences of Cyprus

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ABSTRACT

The objective of this presentation is to illustrate in a simplified manner how Cyprus manages water scarcity resulting from supply – demand imbalances as well as the measures taken during drought conditions. A brief overview of the water balance and use of water in Cyprus will provide the necessary background for presenting the Cyprus experience.

1. INTRODUCTION

Water scarcity is very real in Cyprus. Like other Mediterranean countries, Cyprus has a semi-arid climate and limited water resources which depend almost entirely on rainfall.

Rainfall is highly variable with considerable regional variations and often two or three or sometimes up to six consecutive dry years are observed. Statistical analysis of rainfall in Cyprus reveals a stepped drop in the early 70's, which persists. Furthermore Cyprus has numerous small but of great importance catchments, none of which provide perennial flow.

The limited availability of the water resources coupled with increased water demands are the principal causes of the water scarcity problem. Presently, water demand for various uses exceeds the amount of water available, while in recent years, the problem has been exacerbated due to the observed prolonged periods of reduced precipitation.

2. WATER BALANCE

The mean annual precipitation over the first 70 years of the last century amounts to approximately 500 millimetres, whereas during the last thirty years (1971-2000) it has dropped to 460 millimetres. The quantity of water, which corresponds to the total surface of the Government controlled area, is 2.670 million cubic metres (MCM), but only 14% or 370 MCM is available for development since the remaining 86% returns to the atmosphere through evapotranspiration. The mean annual quantity of 370 MCM of water is distributed between surface and groundwater in the ratio 1,75:1 respectively.

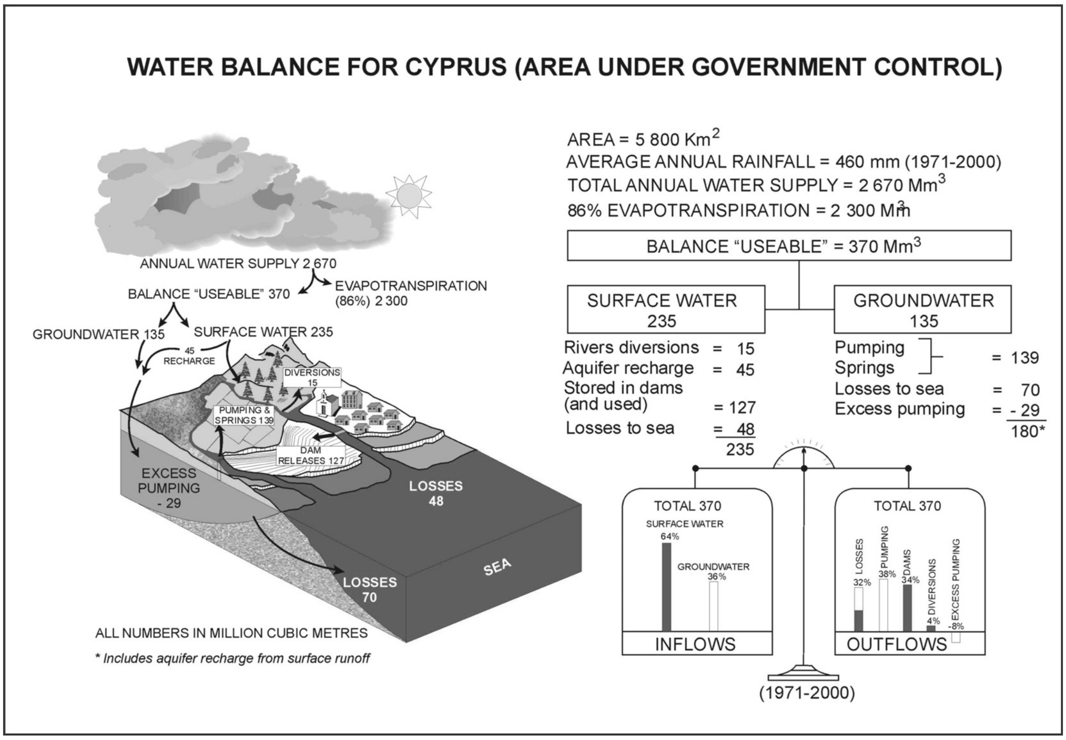

Figure 1: Water balance

3. WATER USE

Domestic use and irrigation are the two main water-consuming sectors in Cyprus. Irrigated agriculture accounts for about 69% of total water demand and the domestic sector which includes the tourist and industrial sector for 25%. The remaining 6% is used for industrial (1%) and environmental purposes (5%). The tourist demand accounts for about 5% of total.

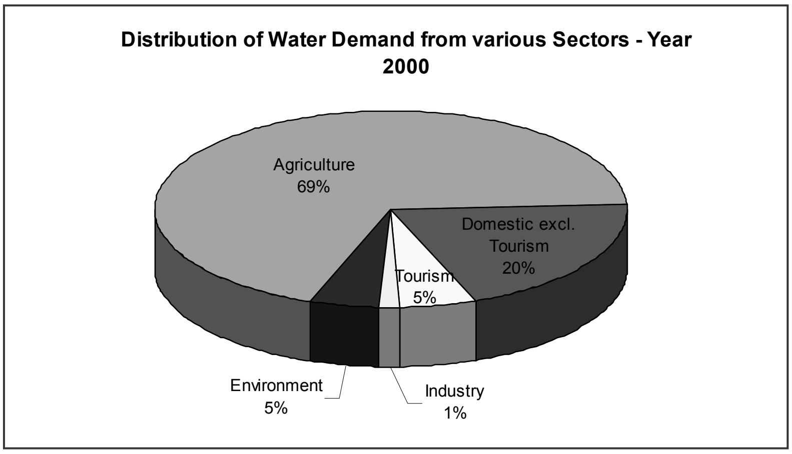

Figure 2: Water demand by sector (Source: WDD - FAO, 2002)

4. LONG TERM WATER SCARCITY MANAGEMENT IN CYPRUS

The Republic of Cyprus, recognizing the need for the effective and efficient utilization of its limited water resources, embarked during the late sixties on the implementation of a Water Master Plan with the objective to satisfy, in a sustainable way, the different users of water and to safeguard human and other life.

Several measures were used to increase availability of water and decrease water demand. On the supply side the dams' capacity was increased from 6 MCM in 1960 to 307,5 MCM today. Boreholes were drilled for domestic and irrigation purposes and water treatment plants and recharge works were constructed. On the demand side the installation of improved on farm irrigation systems was encouraged, the construction of modern efficient conveyance and distribution systems with minor losses was promoted and water charges were imposed both for domestic water supply and for irrigation water. Leakage detection methods are applied on water distribution systems for reducing water losses and real time tele-monitoring and tele-control are now used on the most important projects to optimize the operation and maintenance.

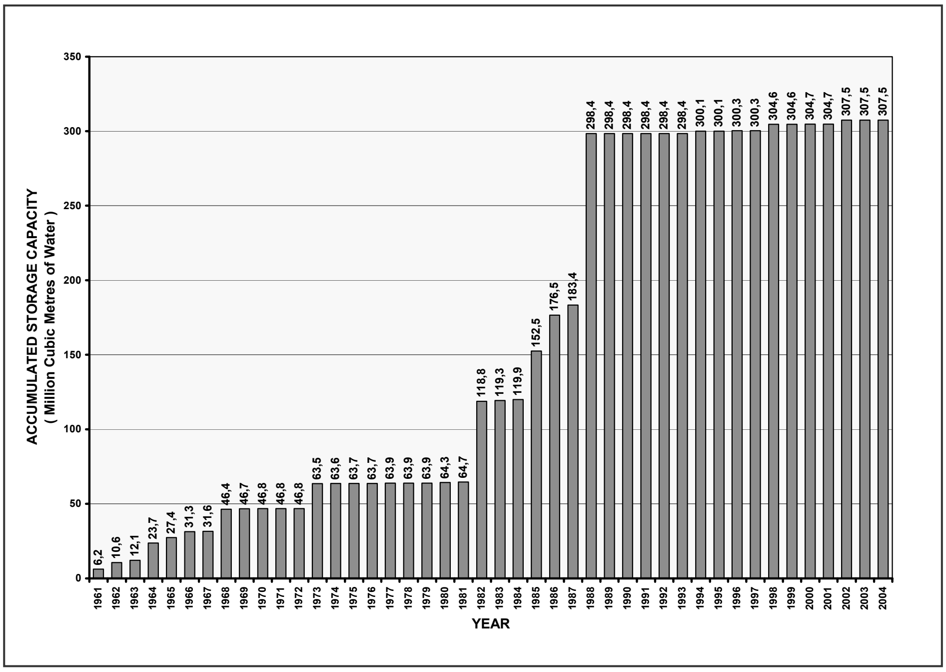

Figure 3: Dam construction 1961 - 2004

Still, after substantially completing the implementation of the Master Plan the available water was not enough to satisfy the water demand for domestic and irrigation needs. An analysis of the situation indicated that water shortage was due to a great extent to the climatic change, which caused a reduction of approximately 20% in the precipitation and resulted in a 40% reduction in surface runoff. In addition more frequent occurrence of extreme drought events is experienced. Furthermore there was also a rapid increase in the number of tourist arrivals in Cyprus, which placed additional seasonal demands for water.

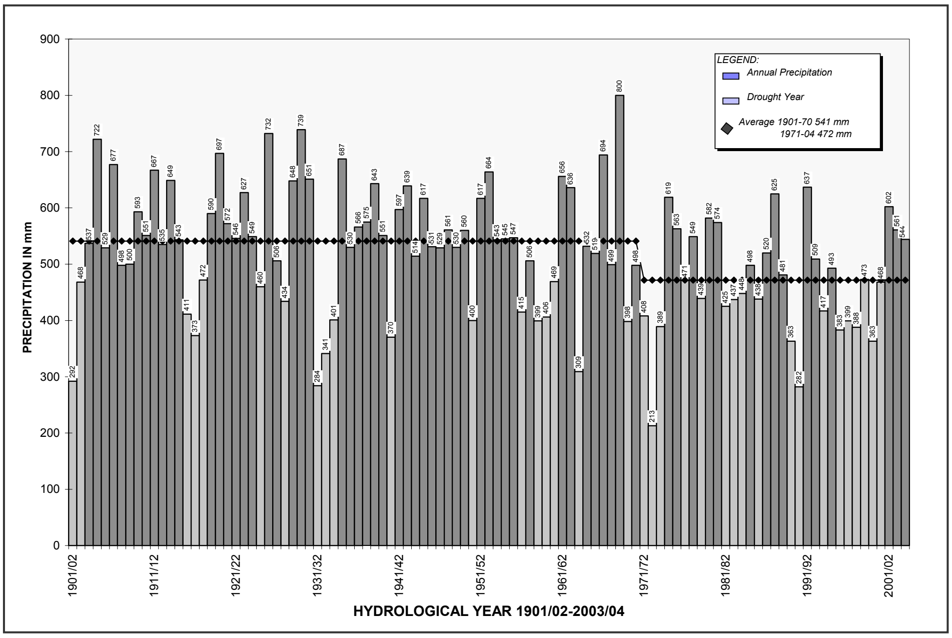

Figure 4: Cyprus annual precipitation and average 1901/1970 – 1971/2004, (Area under government control)

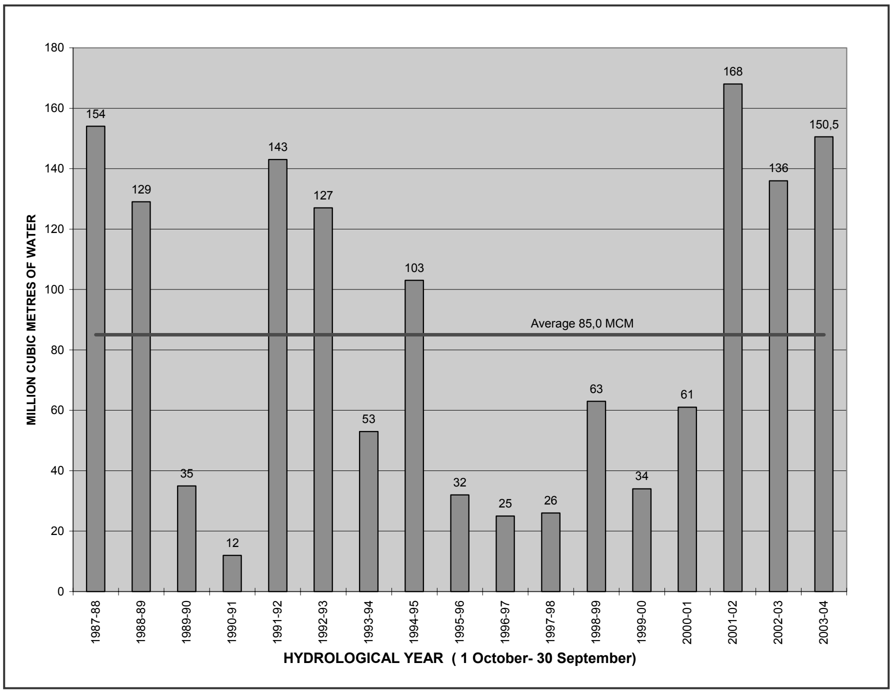

Figure 5: Inflow of water to the dams 1987 - 2004

The construction of surface water reservoirs was meant to provide a certain amount of resilience to the water resources system during low rainfall years by creating multi-year storage. However, several consecutive years of rainfall, which are significantly below normal, can lead to drought conditions.

The groundwater resources of the island have been the most obvious and easily accessible sources of water for many years and as a result, they have been heavily over pumped especially during periods of drought. This has led to seawater intrusion of many coastal aquifers and deterioration of both quality and quantity of groundwater.

The above conditions forced the Government of Cyprus to revise its general water policy for promoting effective water governance and providing water security so that every person has access to safe water. The revised policy objective is to increase the water security by making the supply of water for domestic needs independent from the climatic behavior, to increase the reliability of supply of water and to reduce water demand. To achieve this, Cyprus had to turn to non-conventional water resources such as seawater desalination for securing drinking water supply and to recycling of treated municipal effluents for irrigation and groundwater recharge purposes. Reuse schemes using treated domestic effluents are now in operation and many more are under study or construction. This will increase the supply of water for irrigation and groundwater recharge.

The introduction of desalination has enabled the Government to lift the water restrictions for domestic water supply and since January 2001 the supply of drinking water to towns and villages is continuous and without any restrictions.

Furthermore the Government decided to revise the existing legal and institutional framework in order to create an enabling environment for promoting effective water governance allowing all stakeholders to work together for effective water management. In this context, efforts are now focusing on establishing a new Directorate for Integrated Water Management, which is proposed to manage the island's water resources within the framework of the national water policy in a holistic way.

At the same time water demand management has always been an integral part of the Government policy on water. The current Government policy also provides for such demand management measures as the restructuring of agricultural cultivations and the promotion of cultivations which require less water, the promotion of water saving measures, the creation of awareness among the public for the proper use of water, the establishment of subsidies for saving good quality domestic water, the metering of water services and use of rising block-tariffs for domestic water supply, the application of a quota system for the allocation of government irrigation water in combination with penalty charges for over consumption, etc.

5. MEASURES IN PERIODS OF DROUGHT

Most recently, low rainfall in the years from 1996 to 2000 has produced drought conditions in Cyprus creating an even bigger gap between supply and demand.

It has been estimated that the available supplies of water during the period 1996 - 2000 from all the sources at the areas covered by the Government Water Works was on average 87,5 MCM. The demand for water in the years from 1996 to 2000 was calculated to be on average 136 MCM, of which 56 MCM was for the towns and villages and 80 MCM for irrigation.

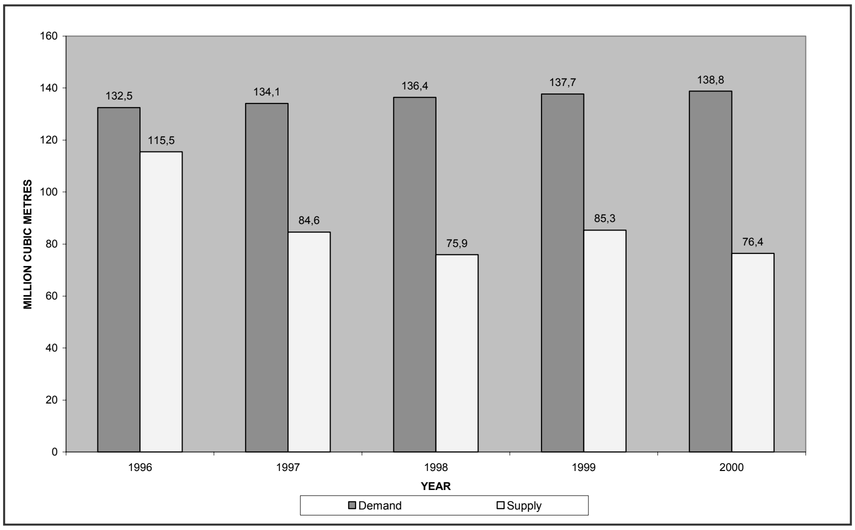

Figure 6: Government Water Works – Water demand and supply balance 1996 - 2000

The drought has caused a variety of socio-economic problems for Cyprus and various measures were implemented to face the situation. These were as follows:

- Water supply restrictions
- Demand management measures
- Supply enhancement measures

Furthermore a Drought Committee was set up with mandate to examine and assess the measures proposed by the Water Development Department in consultation with other public or private bodies and to monitor and coordinate without bureaucratic procedures the implementation of the measures finally approved by the Council of Ministers.

5.1 Water supply restrictions

Water rationing measures were introduced such that water was supplied to households for as little as two or three days per week and this for only a few hours each time. Irrigation water to seasonal crops was almost completely restricted and water allocated to permanent crops was reduced to the absolute minimum needed for survival.

Furthermore the greenhouses were receiving water only for one plantation period instead of two periods that is the usual practice, while animal husbandry and industry suffered a reduction in the supply of about 28%.

In general, the water supply restrictions amounted to over 20% for domestic uses and 30-70% for irrigation purposes.

It is true that in the selection of these restrictions there was no unanimity in the discussions with the different socio-economic partners. The most severe objections or reservations were raised by:

The agricultural organisations who demanded that the farmers be compensated by the Government for the lost income due to the unavailability or shortage of water, The hotel owners who demanded that the tourist industry be given either a zero or a very small reduction in the supply of water. The same line of action was supported by the mayors of the coastal tourist towns, and

The environmental organisations who argued that reducing the quantity and timing of supply of water may not be an effective measure especially when compared to the hardships and dangers these measures inherently have.

5.2 Demand management measures

The measures adopted were addressed to the two main uses of water, the domestic sector and the irrigation sector.

5.2.1 Domestic sector

- Establishment of subsidies for saving good quality domestic water. For example, a subsidy was granted for the drilling of private boreholes within the Water Boards and Municipalities areas which are served by the Government Water Works and for the connection of private boreholes to toilet tanks. Subsidies were also granted for the installation of grey water recycling systems in houses, schools, etc.
- Distribution of sealed plastic water bags, free of charge, for use in the toilet flush tanks as displacers, thus reducing the volume of flush.
- Reduction of the "unaccounted for water" in the distribution systems of the Water Boards, Municipalities and Villages.
- Amendment and strict implementation of the Law 1/91 which prohibits the use of a hosepipe for the washing of cars and pavements (increase of fine from approximately €26 to €52).
- Education and Awareness Campaign of the need to conserve water.

5.2.2 Irrigation sector

- Subsidy for the installation of a system to collect rain water from the roofs of the greenhouses; subsidies were also envisaged for the use of improved irrigation systems.
- Application of a quota system for the allocation of government irrigation water in combination with penalty charges for over consumption.
- No supply of water to new irrigation areas.
- Educating farmers for better use of water and for adopting new low water demand crops.

5.3 Supply enhancement measures

The immediate measures for enhancing water supply were:

- Expansion of the existing desalination plant (at Dhekelia) from 25.000 m^3/day to 40.000 m^3/day.

- Acceleration of the process for a new desalination plant (west of Larnaca) with a capacity of 52.000 m^3/day.

  The main aim of the desalination plants policy was to eliminate the dependency of the towns and tourist areas on the unpredictability of climate and rainfall and thus ensure that water is provided on a continuous basis to households.

  The environmental organisations, however, were against this measure because of its high cost and because of environmental concerns.

- Use of recycled water for irrigation.

  The farmers were apprehensive in using recycled water for irrigation as this was the first time recycled water was used commercially at such a large scale. Water scarcity, however, has faded out the reluctance of the farmers in using the recycled water.

- Emergency measures to increase temporarily the supply of water for drinking purposes to both urban and rural areas. (This was achieved through sinking of wells, requisition of private boreholes or through transfers of water using pipes or trucks).

5.4 Efficiency of measures

The restrictions in the supply of water were, in general, accepted by the public. Nearly everybody realised the necessity of imposing such restrictions because of the existing large gap between the supply and the demand. During the application of the restriction measures the consumption in every economic sector decreased. The results were deemed as satisfactory.

The demand management measures announced by the Government were readily accepted by the water consumers as evidenced by the large number of applications filed, especially for those measures bearing subsidies by the Government. The largest numbers of applications were filed in Nicosia, which faced the most acute water shortage.

The third and last bundle of actions in combating the prevailing drought i.e., the increase in the supply of water via the erection of a new desalination plant and the use of recycled water had found approval by the majority of the people.

In conclusion, the emergency plan for combating the prevailing drought was quite successful. The objectives of the plan were met in full. The "water consciousness" of the public towards this scarce resource was high and vivid making the introduction of the measures rather easy.

6. CONCLUSIONS

The key conclusions are as follows:

- In Cyprus, water is a commodity faced with depletion. Droughts are a very usual phenomenon and often two or three consecutive dry years are observed.
- In view of the possible future increases in drought frequency not only in the Mediterranean region but across Europe as well, as a consequence of climate change, Cyprus vulnerability to drought may increase.

- Water availability is affected by changes in climate. Cyprus has experienced approximately 20% reduction in precipitation, which resulted in a 40% reduction in surface runoff.
- The use of storage reservoirs helps overcome the uneven distribution of natural water resources over time and reduces vulnerability to short term droughts. Nevertheless, when several dry winters cluster together, severe drought conditions may develop. Such infrastructure measures, however, can have negative environmental effects and are nowadays considered with extreme caution.
- In certain semi-arid areas, wastewater reuse and seawater desalination may constitute vital alternative sources of supply. Wastewater reuse is best applied during drought conditions.
- The recent drought has increased public awareness of the fragility of the water resources and has demonstrated clearly the economic, social and environmental consequences of a drought.
- A suitable response to a drought largely depends on adequate management of the water resource system.
- The adopted measures have significantly increased capabilities to withstand the impact of drought episodes.
- Demand management measures such as the use of economic instruments, leakage control, public education programmes, water reuse etc. offer the potential for ensuring that limited water resources are used in a sustainable way.

Our vision on water is to provide sustainably to the people of Cyprus sufficient, safe, clean, healthy and reliable water for domestic and irrigation needs and for the environment. The Water Framework Directive, which was put into force in December 2000, sets out the basis for achieving this vision and despite the challenges that lie ahead, Cyprus is totally committed to the efficient and effective implementation of its principles and provisions to help secure the water resources for today and for future generations.

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Implementation of Articles 5 & 6 of The EU WFD 2000/60/EC
The Perspective From a Semi-Arid Mediterranean Island

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ABSTRACT

Cyprus, as every other member of the European Union has to satisfy all the requirements set by the EU on water quality, such as those specified in the Water Framework Directive (WFD) (2000/60/EC). In this paper, the implementation of Articles 5 & 6 in Cyprus is presented. A general overview of the implementation of the Directive in Cyprus is given at the beginning and then, an account is given on how Articles 5 & 6 are implemented in a small Mediterranean island like Cyprus. Finally, in the concluding remarks an account is given on the problems faced by small semi-arid Mediterranean islands on implementing the WFD.

Key Words: Cyprus, Articles 5 & 6, EU Water Framework Directive (2000/60/EC)

1. INTRODUCTION

This paper is based on the reports which and have been prepared by the Consortium consisting of WL | Delft Hydraulics, ENVECO S.A. and D. Argyropoulos & associates. Due to the lack of available human resources with the necessary expertise within the Cyprus government sector, this project was given to the above consortium of international experts. The reports cover the identification of water bodies, the analysis of pressures and impacts, the economic analysis and the establishment of the register of protected areas. They are based on information that was made available through various institutes and experts on Cyprus. The Water Development Department (WDD) of the Ministry of Agriculture, Natural Resources & Environment was the contracting authority of the project.

2. THE WATER FRAMEWORK DIRECTIVE 2000/60/EC AND CYPRUS

One of the obligations that Cyprus undertakes by joining the European Union is to stop further deterioration of the quality and quantity of all the water systems and their constant improvement up to the final goal, which is good condition of all waters in terms of quality and quantity. The implementation of this directive is obligatory to all member states and aims at the viability of the water resources. Delay or unjustifiable failure on achieving this objective involves serious penalties. All Member States are obliged to protect, restore and upgrade all their water systems. The citizens of the European Union, with this directive seek to ensure so much their own survival, prosperity and quality of life but also, that of the future generations. The water framework directive covers the following:

- It protects all waters: rivers, lakes, coastal and underground waters.
- It places the very ambitious target that all waters will achieve "good ecological status" by 2015.
- It develops a management plan on river basin level.

- In the case of international regions of river basins, it requires cross-border collaboration between countries and all the involved parts.
- It ensures active participation of all institutions, in the activities of water management.
- It ensures reduction and control of all pollution sources.
- It requires development policies on pricing of water and ensures that the “polluter pays”.
- It counterbalances the interests of environment with the interests of what depends from it.
- It ensures reduction and control of pollution from all sources.
- For each river basin district, there are defined actions, which need to be finalised within certain timeframe.
- For Surface waters the directive specifies that "good condition" is considered "good ecological" and "good chemical status".
- For Underground waters the directive specifies that "good condition" is considered "good quantitative" and the "good chemical status”.

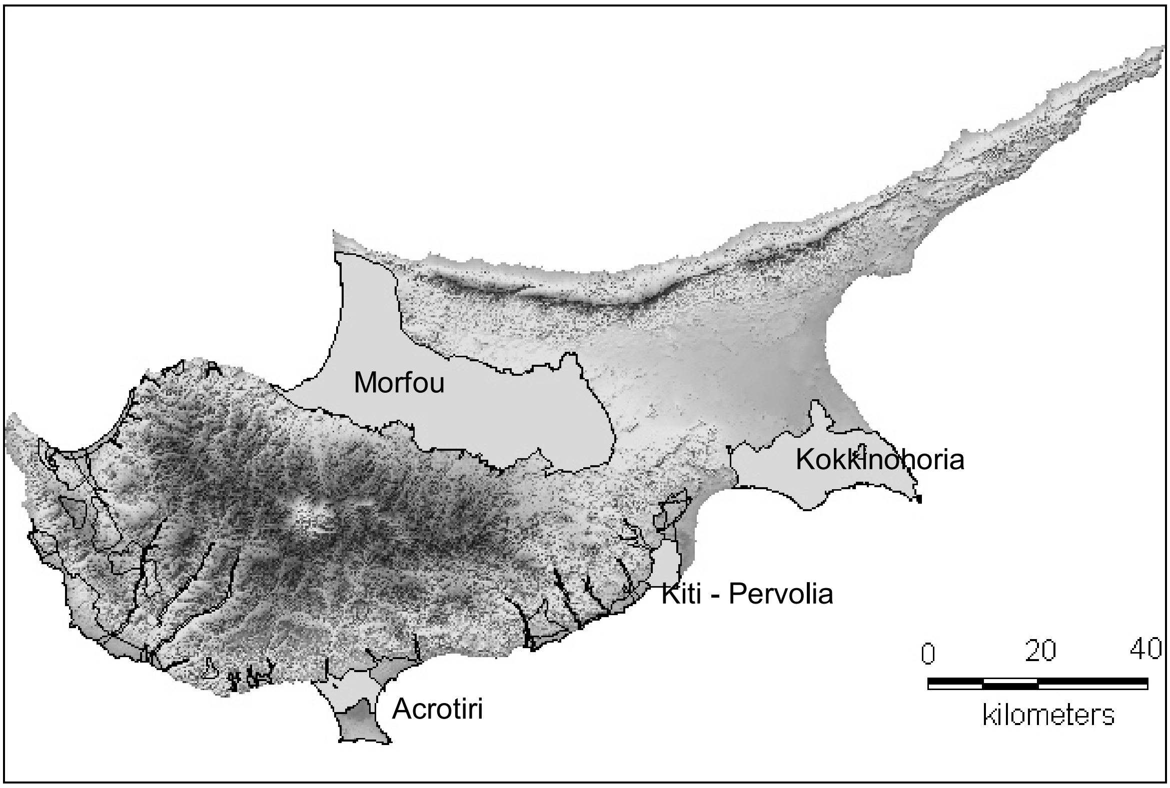

Figure 1: Cyprus shaded relief map depicting the four most important aquifers**.**

The key activities of the WFD, their importance as they are related to different phases of the implementation process determined by the deadlines as they have been laid down in the WFD, can be accessed from the web

(http://forum.europa.eu.int/Public/irc/env/wfd/home).

2.1 Application of the directive in Cyprus.

High importance was given at the initial stages of the implementation plans of the Directive, which are considered critical and decisive. The Cyprus legislation was harmonised with the requirements of the Directive by enacting a new bill. The bill was passed by the parliament on February 2004. For determining the river basin districts, it was decided that the entire island of Cyprus constitutes one river basin district. The competent authority is the Minister of Agriculture, Natural Resources and Environment. The "Responsible Authorities" for the implementation and reporting to the EU about the Directive are the Water Development Department and the Environment Service.

The reported competent authority has responsibility over the entire River Basin District. It has to be noted, however, that according to the provisions of Article 1 of Protocol No. 10 on Cyprus, attached to the Treaty of Accession to the EU, the application of the acquis is suspended in those areas of the Republic of Cyprus in which the Government of the Republic of Cyprus does not exercise effective control.

3. IMPLEMENTATION OF ARTICLE 5 IN CYPRUS

3.1 Characterization and typology

The reports on Articles 5 and 6 of the Directive have been prepared since December 2004. These reports cover topics such as the analysis of the characteristics, review of pressures and impacts, economic analysis and creating a register of protected areas.

A rather detailed characterization and analysis of both surface water and groundwater bodies in Cyprus has been carried out and reported. Based on the obtained results, both the Monitoring and River Basin Management Plans will be prepared in the next stage of the implementation of the WFD. The characterization and analysis has been carried out pursuant to the provisions of Article 5 and 6 of the Water Framework Directive, contains:

- An analysis of the river basin district's characteristics.
- Identification of pressures and a review of the impact of human activities on the status of surface waters and groundwater.
- An economic analysis of water use.
- A register of international and national protected areas.

The aim of the characterization and analysis is:

- Identification of surface and groundwater bodies at risk of failing to meet the WFD's objectives that they should achieve at least good status by the year 2015 at the latest with the environmental measures proposed or taken.
- Identification of the need for further characterization, including environmental monitoring, as a basis for planning the programme of measures.
- Establishment of the economic background for planning the programme of measures.

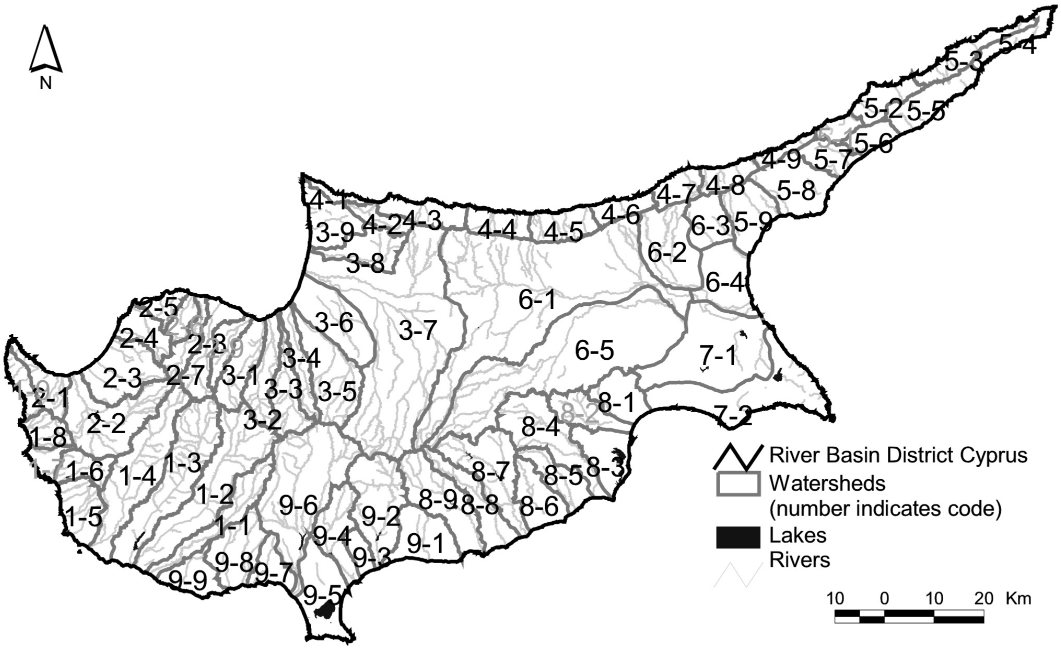

Figure 2: The river basin district of Cyprus with its watersheds and rivers. (Numbers present watershed number).

To the extent permitted by scientific considerations and time, the present characterization and analysis has differentiated surface waters (including coastal) and groundwaters according to types. These types are in turn subdivided into discrete water bodies. Each water body has thereafter been assessed to determine whether it has been subjected to such great physical modification that it has to be characterized as 'heavily modified'. Also reference conditions have been searched and described to define the status without disturbance by human activities.

As described in the information supplied to the Commission in 2004 under WFD Article 3, Cyprus has been identified as one River Basin District. Hydrographically, the island of Cyprus is subdivided into 9 hydrological regions made up of 70 watersheds (see Figures 1 and 2). There are no rivers with perennial flow over their entire length. The whole island is considered as one River Basin District, made up of all the watersheds.

As a result of the Eastern Mediterranean climate with long hot summers and a low mean annual precipitation, there are no rivers with perennial flow along their entire length. Most rivers flow 3 to 4 months in a year and are dry during the rest of the year. For the ecology in Mediterranean areas like Cyprus the extreme hydrologic conditions in the discharge regime, e.g. continuous or non-continuous flow, is the most important characteristic. For descriptors like geology and altitude there is no evidence that these factors influence the ecology in Cyprus in such a way that it will result in a different type. Based on the available information, the descriptors 'catchment size', 'precipitation' and 'flow continuity' were used for the typology of the river water bodies, resulting in four river types from which three river types occur in Cyprus. All surface water bodies have been categorised into: Natural, artificial and heavily modified. These are shown in Figure 3.

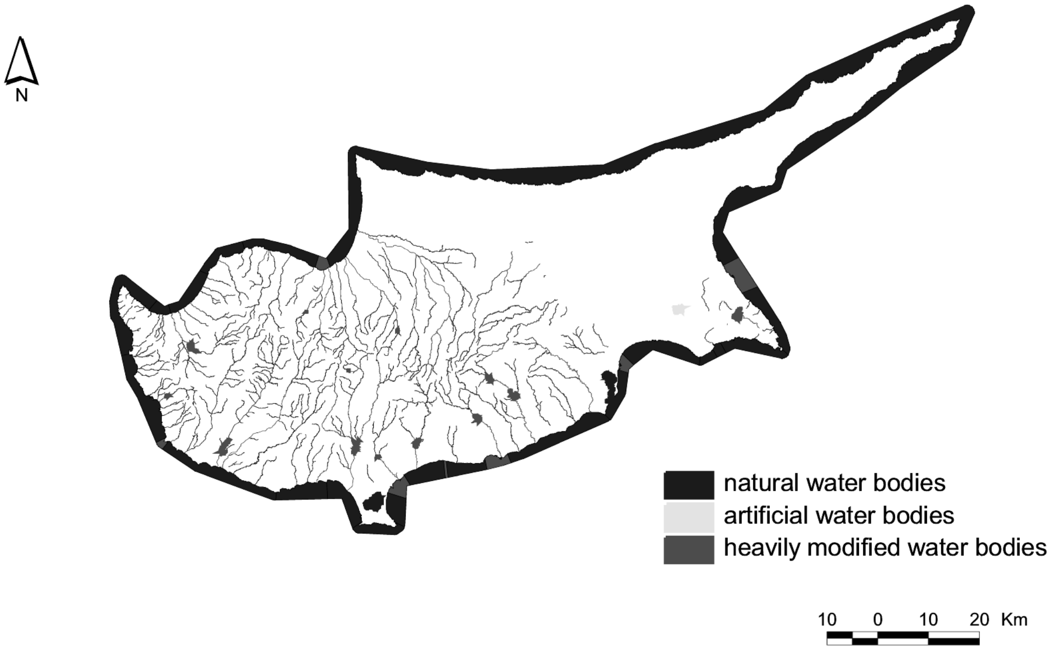

Figure 3: Natural, artificial and heavily modified water bodies**.**

There are only 5 natural lakes in Cyprus all of which are brackish or salt. The other lakes are created by human as a result of damming of a river or the creation of storage basins. The salt content, water depth, connection to a river and the size appeared to be important characteristics for ecology in lakes of Cyprus and consequently the lake types.

The most biologically relevant factors for the typology of the coastal waters of Cyprus are the mean substrate composition, wave exposure and depth. The tidal range is considered irrelevant, and all Cyprus coastal waters fall within a single class of for the salinity, i.e. euhaline. Twelve types were initially identified by this classification scheme, from which three occur in Cyprus coastal waters. From the selected water bodies there are 13 water bodies heavily modified, 1 is artificial and 5 are natural. For coastal waters in total 7 water bodies have been identified as heavily modified (see Figure 3).

All major Cyprus groundwater bodies identified and characterised (see Figures 1 and 4). Ten groundwater bodies have a connection with the sea. One groundwater body is completely located in an area that is not under government control, and partly this applies for three other groundwater bodies. Most groundwater bodies are phreatic with parts that are semi-confined or confined. Almost all the groundwater bodies of Cyprus have been characterised as being at risk, due to the particularities of the island geography and due to the strong pressures that they receive (15 of the 19 groundwater bodies). These have therefore been further assessed for a full characterization (see Figure 4). The fast urbanization in several places in Cyprus during the last 30 years and the direct sewage disposal in the aquifers gradually deteriorated groundwater quality. Nitrate pollution problems appear in aquifers developed in inhabited areas because of direct sewage disposal in absorption pits. Also, intensive agriculture and excessive use of fertilizers resulted to nitrate contamination of the groundwater bodies.

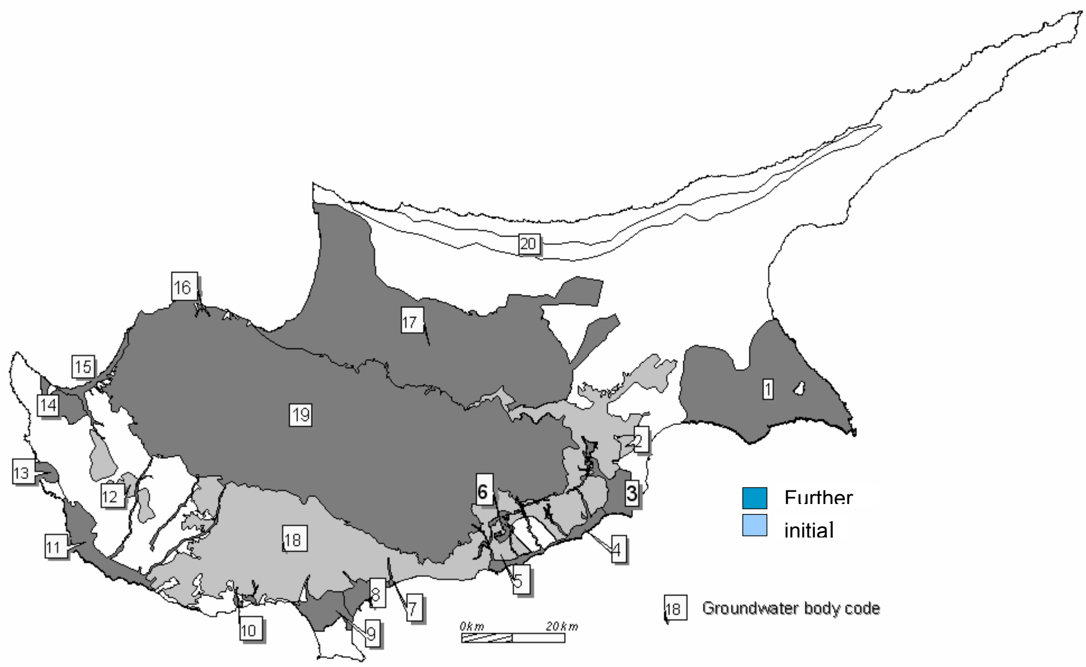

Figure 4: Groundwater bodies of Cyprus and their characterization status**.**

3.2 Reference conditions

Cyprus has no natural freshwater lakes, and rivers are in most cases are non-continues. This significantly hampers the specification of reference conditions that can be used in practice. The creation of the freshwater reservoirs through the construction of dams in the majority of rivers and storage basins comprised a remediation measure for the collection of winter flows for use later in the non-rainy hot period. According to the WFD the conservation objective of these lake-reservoirs should be derived from a natural lake with equal conditions. Reference conditions have been specified based on available information such as the LIFE project. The current reference conditions might therefore be further refined as soon as more data becomes available after and during the monitoring. The reference conditions for coastal waters were easier due to the availability of additional information from other Mediterranean sites with similar conditions.

3.3 Pressures and impacts

The analysis of pressures related to agricultural activities, either in the form of cultivation of land or livestock breeding, shows that the areas with increased loads of nitrogen and phosphorous are located in the eastern part of Cyprus. The cultivated land in this part of the country corresponds to about 70% of the total cultivated land, whilst the central and western part of the country consists mainly of forest, accounting for 73% of the total forest area and therefore, the central and western parts are characterised by significant lower nutrient loads. Regarding breeding of pigs, activities are more intensive in 8 villages where 70% of the pig population is located. On the basis of both nutrient load and monitoring data analyses the list of water bodies assessed to be at risk of failing the objectives of the WFD due to increased nutrient load are identified. It is noted that the water bodies (surface and coastal) which have been designated as sensitive according to the 91/271/EEC Directive are also included to the list of the water bodies at risk.

In this analysis, it has been difficult to make the link between specific point source and diffuse source pressures and a water body at risk. The ‘at risk’ assessment has been made by a combination of ambient monitoring data and analysis of pressures (pollution sources). Therefore, there is no clear estimate of the percentage (number) of water bodies at risk specifically as a *result of point source or diffuse pollution.* The same holds to some extent for water abstractions, and significant water flow and morphological regulations.

A significant point source of pollution to groundwater is from solid wastes. The current practice with respect to solid wastes involves mostly uncontrolled or in some cases semi-controlled dumping of municipal solid wastes in more than 80 dumping sites spread over the country. Another possible point source is from various mines. There are 1 active mine and 9 abandoned mines in Cyprus, which, primarily affect surface water, but may contribute to contamination of groundwater. Five major landfills serve the main regions of the country. The yearly load of solids disposed in these five landfills corresponds to 80% of the total solid waste load. For these five major landfills, 33% of the solid waste is estimated to be organic waste. The potential discharge of toxic substances due to the, in most cases, lack of adequate control of the disposal operations cannot be excluded. In terms of future projections, it should be stressed that according to the Strategic plan for the management of solid wastes in Cyprus, a progressive closure of these dump sites will be followed by the construction of organised sanitary landfills that will serve the needs of the inhabitants of Cyprus. Therefore, pollution from solid wastes is expected that in the future, will be significantly reduced.

Another form of pressure is groundwater abstractions. The present level of groundwater abstraction for Cyprus is estimated to be 130 million m^3/year, of which, 10 million m^3/year are made available by artificial recharge. The average yield of abstractions for domestic water supply during the period 1991-2000 is estimated to be on the order of 25 million m^3/year, for irrigation around 102 million m^3/year and for industrial use around 2.5-3.0 million m^3/year. During the last years, the abstractions for domestic water supply decreased to a level of 18 to 20 million m^3/year. The total sustainable yield from all groundwater bodies is estimated to be in the order of 80 million m^3/year. During the last decade, almost all the groundwater bodies, except the river bedded coastal water bodies are being overexploited. Of the 19 groundwater bodies in Cyprus, 18 have significant abstractions and therefore are considered to be ‘over-pumped’.

3.4 Water bodies at risk

A water body is classified as being at risk for one or more of the following reasons:

- Nutrient loads and eutrophication.
- Oxygen demand and microbial pollution.
- Toxic substances.
- Other (influence of mines and major landfills).

The methodology used to categorise water bodies is based on an analysis of both relevant loads (pressures) as well as ambient monitoring data. The classification of water bodies at risk in terms of nutrients and eutrophication includes the analysis of pressures from agricultural activities such as land cultivation and livestock breeding, which create pressures of increased loads of nitrogen and phosphorus.

The judgment with respect to risk of failing the objectives was based on a comparison of these estimated concentrations to the interim criteria outlined in the methodology. Whenever the hydrological characteristics of the water bodies were not sufficient comparison was made with known cases and expert judgment was applied. Water bodies (surface & coastal), which have been designated as sensitive, are also included in the list of water bodies at risk.

The water bodies have been classified in three groups: “no risk”, “maybe at risk” and “at risk”. The last two groups are based on the amount and quality of data we had in hand.

The classification of water bodies at risk in terms of oxygen demand and microbial pollutants considered primarily the (point source) pressures from urbanised areas with high populations and breeding of livestock at farms that are located close to surface water bodies. Furthermore, the location of sanitary landfills and specifically the organic matter that finds its way to leachate, as well as the industrial activity from the industries that produce and dispose conventional pollutants, were considered. Due to the expected degradation (typically exponential) during transport towards the recipient, the criterion of vicinity was used (e.g. water bodies near pig farms, landfills or urban communities).

The classification of water bodies at risk in terms of toxic substances includes the analysis of pressures primarily from industrial activities, and also industrial waste waters, uncontrolled dumping sites (landfills) mines and storm water discharges. Specifically, consideration was given to water bodies in the vicinity of industries potentially producing dangerous and toxic substances. Given that no data was available there was no possibility for quantitative assessments and a conservative evaluation was adopted on the basis of qualitative data.

Almost from all the groundwater bodies of Cyprus (15 of the 19 GWB’s), due to the particularities of the island geography and due to the strong pressures that they receive, have been characterised as being at risk, and have therefore been identified as needing further assessed for a full characterization. The main risks of degradation are at the recharge areas of the aquifers. This recharge may be natural, like in places where rivers cross phreatic aquifers or artificial; e.g. at places of artificial recharge of coastal or riverbed aquifers with high permeability. The overpumping of the coastal aquifers, and the subsequent fall of the groundwater level below critical level, lead to seawater intrusion. Figure 5 presents a contour map of water levels of the Kokkinochoria aquifer (see Figure 1) for December 2004. The areas with the shades of red colour are the parts of the aquifer where the water level is below mean sea level. The darker the red colour, the lower the water level is with respect to the mean sea level. In some areas, the water level reaches up to 40 meters below mean sea level. With blue colour are presented the regions with levels above the mean sea level. Around the Paralimni town one can see water level up to 99 meters above mean sea level. This is misleading because the thickness of the water-bearing stratum is very thin there and also, being a small lens, is not connected with the rest of the aquifer. The blue line depicts the region that has been influenced by seawater intrusion.

A total of five groundwater bodies are at risk due to excessive nitrate concentrations, primarily due to urbanisation and agricultural activities.

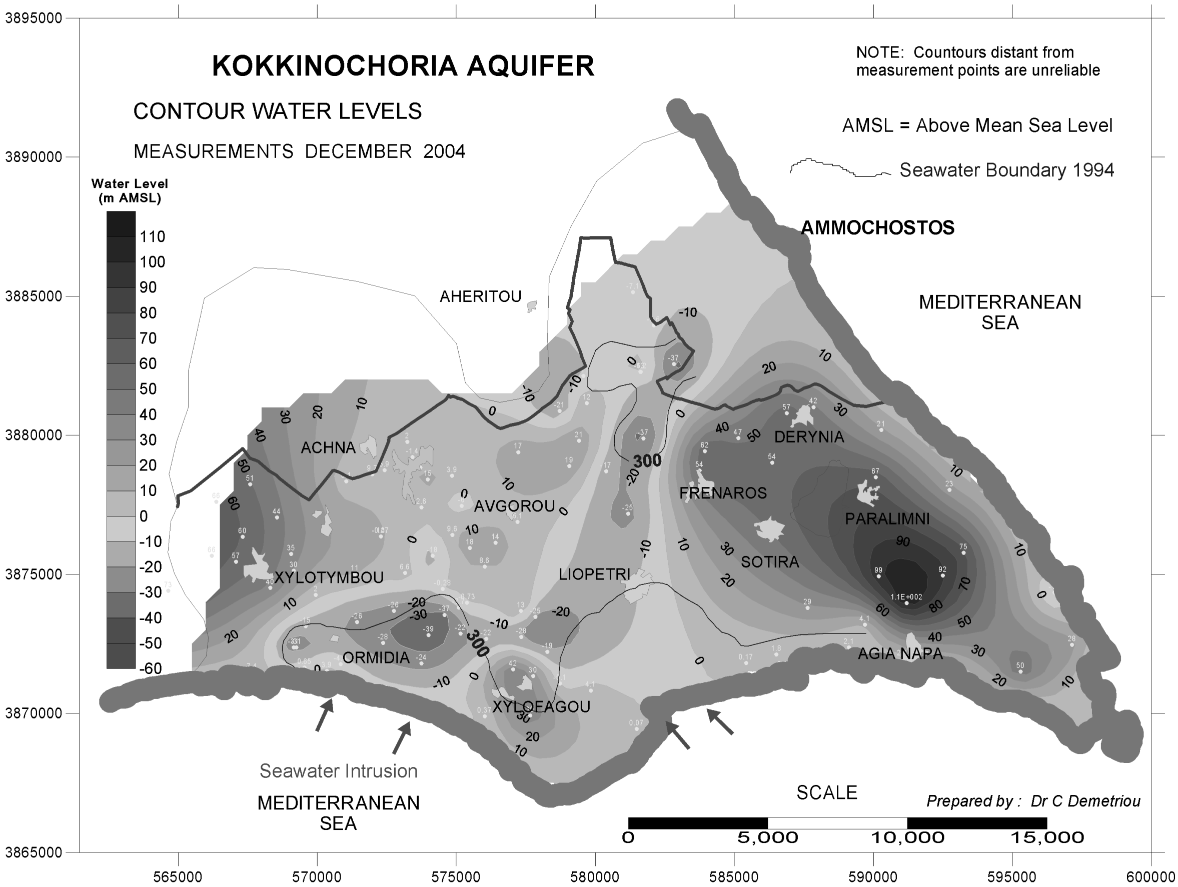

Figure 5: Groundwater contours at the Kokkinochoria aquifer on December 2004.

3.5 Economic analysis

The cost recovery of water services is analysed for different users, by considering storage and main transportation, distribution, sewage collection, wastewater treatment, and the environmental and resource cost. The water services analysed are:

- Freshwater provision to domestic uses (households, industry and tourism) and irrigation through the Government Water Works, administered by the Water Development Department of the Ministry of Agriculture, Natural Resources and the Environment of Cyprus.
- Urban waste water collection and treatment by the Sewerage Boards.
- Recycled water supply to irrigation through the Government Water Works.

Regarding the economic characterisation of water uses, the analysis is carried out for the different types of users. The most important economic sector in Cyprus is currently the tertiary sector, both in terms of output (76.4 % of the GDP in 2004), and employment (72.1% in 2004). However, demand for domestic use currently constitutes only 25% of the total. Agriculture presents a decreasing economic importance, both in terms of economic output and employment (3.9 % of the GDP, 7% of the total employment in 2004).

Agriculture, and especially irrigation, remains one of the major water consuming sectors in Cyprus, accounting for 69% of the total water demand. During the same period, total domestic demand, for supplying both households and tourism, and including conveyance and distribution losses, was estimated at 25% of the total water (i.e. 67.5 million m^3). Landscape irrigation demand accounts for 14 million m^3/yr, i.e. 5% of the total amount. Finally, industry used the lowest volume of water that did not exceed 3.5 million m^3 (1% of the total). One of the most significant water management issues that were identified concerns the allocation of water resources between the two major water uses under drought conditions, with social conflicts arising due to the prioritisation of domestic water use.

The most significant water management issues that arise, also assessed in the economic analysis of water uses, concern the regulation of groundwater abstractions and promotion of artificial recharge, the allocation of resources between domestic use and agriculture, and the excessive application of fertilizers and pesticides. One of the major gaps of the current assessment concerned the societal importance of agriculture. Although economic output from agricultural activities is low, the current assessment did not investigate other social and environmental factors that add value to both agriculture and to irrigation water use. Agriculture, especially in semi-arid regions like Cyprus, is particularly important for landscape preservation, and prevention of desertification.

In general, after the pricing reform effected by the Government of the Republic of Cyprus, recovery of costs for freshwater provision has improved considerably. This is especially true when considering the fact that financial costs reported in the current assessment also include costs of old investments (some irrigation water works considered have been constructed before 1975), while the costs associated with flood protection and aquifer recharge have also been included and allocated to both uses, since it was impossible to differentiate at this stage. It should be noted that according to recent water resources re-assessments and due to the reduction of precipitation, most of the constructed dams are oversized by approximately 35%.

Instruments analysed in the cost-effectiveness analysis concerned legislative instruments, economic and fiscal instruments, codes of good practice, sets of measures to promote adapted agricultural production, abstraction monitoring and charges, upgrade of existing sewage treatment plants, desalination, artificial recharge, and educational projects targeting mostly the agricultural sector. The purpose of the analysis was to create an appropriate background for the future establishment of a programme of measures for the river basin district of Cyprus, taking into consideration the initial characterisation of the district, through the identification of pressures and impacts and the economic analysis of the water uses performed. According to those analyses and the measures already implemented and foreseen by the Government of the Republic of Cyprus, additional potential measures were suggested, aiming to address the specific needs of the region. A pre-assessment of potential effects and costs was performed.

4. IMPLEMENTATION OF ARTICLE 6 IN CYPRUS

4.1 Register of protected areas

According to Article 6 of the Water Framework Directive (WFD) ‘Member States shall ensure the establishment of a register or registers of all areas lying within each river basin district which have been designated as requiring special protection under specific Community legislation for the protection of their surface water and groundwater or for the conservation of habitats and species directly depending on water’.

The water bodies that are designated in Cyprus for the abstraction of drinking water are either surface water resources from dams-reservoirs or bodies of groundwater. There are 5 surface water bodies and 10 groundwater bodies that are used for drinking water purposes in Cyprus. The former are reservoirs created by river damming and are initially characterised as Heavily Modified Water Bodies.

Almost the whole of Cyprus coastal waters is used for bathing and recreational activities. All of the coastal areas sampled were found to be in conformity with the Directive 76/160/EEC for Bathing Waters and have an excellent quality as bathing waters.

With respect to the Nitrate Vulnerable Zones (Directive 91/676/EEC) and the Urban Waste water Sensitive areas (Directive 91/271/EEC), high nitrates concentrations are observed. High concentrations result from excessive application of nitrogen fertilisers in irrigated agriculture, particularly in the potato growing areas and in the coastal and valley areas where vegetables and fruits are intensively grown. Isolated areas of high nitrates have also been identified in the fractured igneous aquifers of the Troodos mountains.

Two areas are designated as urban wastewater sensitive areas under the Directive 91/271/EEC: a coastal area in southeast Cyprus and an area above the city of Lemesos.

Finally an overview was prepared of areas designated for the protection of habitats or species where the maintenance or improvement of the status of water is an important factor in their protection, including relevant Natura 2000 sites designated under Directive 92/43/EC and Directive 79/409/EEC.

5. CONCLUDING REMARKS

Many problems are encountered on the implementation of Articles 5 & 6 of the Directive. These are as follows.

- The lack of an integrated rationally organised national network for data collection.
- Much of the information collected over the years is still in paper form.
- The lack of water quality data, especially chemical analysis information other than ionic.
- The difficulty on co-ordination between the responsible authorities and all the involved institutions.
- The lack on specialised expertise and suitable human potential.
- The mentality of users of water.
- The high cost of implementation.
- Difficulties associated with the extended periods of low rainfalls observed in Cyprus in the last decades.
- Difficulties arising from the fact that the Directive is more focused on the big river basins of Europe.

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Governance structure and environmental taxes as a policy instrument: The French experience

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ABSTRACT

Improving water governance at river basin level implies to empower stakeholders with the common use of money that they will have themselves contributed to fund. This helps support new mediation techniques which are needed to improve participation and bottom-up processes of water allocation. The experience of the French *Agences de l'eau* is recalled here, since it shows how economic incentives have been used in practice first to support investments to reduce pollution discharges and improve summer flows, and later to develop more integrated policies on various territorial scales, borne by institutions in charge of mediating interests and values for a better sustainability. It is argued that a mutualist and regional approach to the polluter pays principle is superior to the classical vision of environmental economists favouring individual (sector-b y-sector) legal or economic control by a government regulator.

1. INTRODUCTION

In the WaterStrategyMan project, the different scenarios introducing some flexibility in water resources allocation under conditions of scarcity are confronted through a rough economic model which Office International de l'Eau and myself designed. The model is rough o.k., but it follows the spirit of full cost recovery: it includes proxies for environmental costs and users costs on top of full direct costs (including depreciation of investments). These proxies have been chosen, because environmental economic theory is difficult to implement. Indeed, we are still unsatisfied by the available tools to express demands, like hedonic pricing and contingent valuation. Interestingly enough, proxies are derived from the experience of the French *Agences de l'Eau* (Barraqué, 1995, 2000). It is a well known case where a "water parliament", set up at hydrographic district level, is empowered to levy two sorts of environmental taxes, one on water abstraction and another one on pollution discharge, and then to use the available money to provide grants and low interest loans to environment-friendly projects which have been considered on a 5-year basis by the same parliament. We have considered that these two types of levies could be considered as proxies for environmental and users costs. More interestingly, together the *Comité de Bassin* and the *Agences de l'Eau* offer a case of reduction of transaction costs within an overall trend to move towards integrated water management at appropriate level. So the French experience can help support a "Coasean" interpretation of full cost recovery: while many economists would prefer to confront each sector to its full costs, water policy analysts start from evidence that this will never be the case for agriculture, in particular in Mediterranean Europe where irrigation schemes have been heavily subsidised by governments. The idea is then that territorialized bargaining between various users may lead closer to full cost recovery at regional level, rather than sector by sector, with of course transfers from some types of users to other types; which implies to follow a policy-minded logic rather than pure economic rationality. This is even supported by economists like R. Coase (1960) or S. Ciriacy Wantrup (1985). Indeed, the case of the French *Agences* is illustrative of this.

2. GENESIS AND DEVELOPMENT OF THE AGENCES DE L' EAU

When they were created, in a 1966 Decree of the 1964 law, the polluter pays principle (PPP) was yet an unknown or unpopularised economic principle. The model that French water administrators were trying to set up was a combination of British, American, Dutch and German experiences of integrated river management[1]. What was the situation? Urbanisation and industrialisation were fast growing since the Second World War, and both the quality and the low flows of rivers were becoming insufficient. There was a clear need to build sewage works for cities and non-connected industrial premises, and also to build multipurpose reservoirs upstream (in particular due to the cooling needs of the nuclear power plants). Yet central government wanted to pull out of the systematic subsidisation of investment projects which it had developed within the 'democratic planning' approach adopted in the aftermath of the Second World War. Through a think tank called the DATAR[2], the government initiated a decentralisation at regional level (many European countries were experiencing this regionalisation at the time). While for many policies administrative regions were empowered, for water it was decided that the new policy should be run on a hydrographic district basis, with France split in 6 groups of river-basins. What was adopted was basically a mutualist system with cost recovery principles, i.e. a system close to the Dutch *Waterschappen* or the Ruhr *Genossenschaften*, where representatives of the users[3] get together and vote both a 5-year action program (corresponding to the periods of the National Planning scheme) and the levies they will have to pay to support the implementation of this program no more than 50% though). The difference with the above mentioned institutions is that the *Agences* do not do any implementation themselves : at the time, government and local water actors did not want to set up institutions which would be redundant and would compete with traditional authorities in charge of building upstream reservoirs, sewers or treatment plants. Even today, after a renewed debate during the preparation of the 1992 law, the *Agences* do not manage any investment directly; they just fund those who are willing to make investments to improve the environment. The cost recovery principle is then supplemented with some degree of hypothecation : the *Agences* and the basin boards are increasingly unwilling to fund projects which are not good for the environment, like for instance upstream reservoirs supposedly built to protect constructions in flood plains, which is not necessarily efficient, and in many cases is more expensive than to remove the constructions from the flood plain; it is also the case with many irrigation projects, which dramatically increase the risks of drying up rivers in the summer, while being usually

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[1] In fact, to be precise, at the time, water policies were not so much 'integrated' than 'multi-purpose': the idea was to mutualise investments which could postpone or alleviate conflicts over water resources allocation. Indeed, the Ruhr Genossenschaften are a good example, since they invested in dams and sewage treatment processes in such a way as to specialise the 3 rivers of the Ruhrgebiet, one for quality water, one for process water, and one as an open sewer. Recently, there has been a significant change with the new policy of *renaturierung* giving more space to the natural environment and less to the previous specialisation.

[2] Délégation à l'Aménagement du Territoire et à l'Action Régionale

[3] Typically the Basin Commission is composed of around 100 people. Initially they could be split in 3 parts, elected representatives of various territorial levels; representatives of industry, electricity company and chambers of agriculture; Government representatives. Over the years, however, Government representation was reduced, and this made more room for fishermens' NGOs consumers, ecologists, etc.

uneconomical. But since the enforcement of water regulations and permits is not in the hands of the *Agences* either, they can only persuade water users to increase the level of their efforts, through the investments they subsidise. This has resulted in funding de-pollution or summer flow increases rather than stopping discharges or water demands. It was obviously very efficient in the early phases of water environmental policy, when everybody agreed on the first investments needed; but it might end up less and less efficient when point source pollution is controlled, and when more sophisticated integrated policy is needed.

The PPP was popularised at the beginning of the 1970's, in particular by Michel Potier and Jean-Philippe Barde at the OECD, when the *Agences de l'eau* began to operate their first program, which had taken 5 years to set up: not only was there a need for a preliminary assessment of programs and funds needed, but water users were initially opposed to the levies. The PPP was then eventually used as a sort of moral argument to force cities and industry to accept to play their part in the basin boards, and therefore to pay their share. The PPP was also used later to help convince water users that the levies' rates should be increased. In turn, the *Agences* appeared as one of the early implementation cases of the PPP, which was later a source of misunderstanding.

Anyway, this new water policy based on economic incentives managed to supersede the various initial oppositions: the French association of Mayors had initially refused that communes would have to pay as initial abstractors and final polluters (managers of sewer outlets), arguing that their populations were in fact responsible; but a compromise was found, with the inclusion of the levies in the domestic water and sewerage bills[4]. Industrial premises non connected to public sewers, which represent an important proportion in a low density country like France, also objected the charges, but they accepted to pay if the total amount of taxes would not be higher than the total of cities. This was a highly efficient political decision, in absence of the needed information to refine the taxation mechanism.

In the 1970's, the *Agences* have grown in importance, because they had to make up for the declining government subsidies to water policy. And this also altered the original principles: initially the Agences were supposed to fund public works ‘in the common interest’, i.e. not in the private or in the collective interest: for instance they could fund the sewage works (common interest of the basin) but not the sewers (collective interest of the concerned city). But they soon realised that cities would end up building sewage works where no appropriate sewer would be connected! Indeed, sewers represent around 80% of the total cost, and traditional subsidies by central government were being phased out. Through the support of mayors, the *Comités de Bassin* obtained the possibility to raise more funds for the *Agences* through a "collection multiplier" and also an "urban density multiplier" (applying proportionally to the size of cities), so as to be able to fund sewage collection projects. All this happened in a subtle bargaining process between local authorities, the Environment department, and the rest of central government, in particular with the Treasury, which would have liked to limit the rise of the *Agences*, as representing the most important tax revenue escaping its own services.

In the 1980's, the socialist government took power. New political personnel was distrustful of a system which they tended to associate with the private water companies,

[4] The result is that French domestic water users pay the water levies in their bills, but their local authorities get refunded the bonus proportional to the performance of the sewage works. Some observers think that this should be changed. Many argue that consumer NGO’s should be given more seats in the Basin councils.

which they had hoped to nationalise, but in vain[5]. Water prices and the rates of the levies had been capped to fight inflation by former government of V. Giscard d'Estaing, and the new government maintained the capping; in 1982, with the law on prevention of natural catastrophes, they chose insurance companies rather than the *Agences* to manage the superfund generated by a compelled 9% increase on all premiums, etc. All this resulted in an increasingly awkward situation, and in a crisis of the *Agences*, which were stuck to their initial target of point-source pollution control while issues were indeed evolving. At the end of the 1980's the discussions at the European level on the new proposed Directives, and the need to push again catchment planning, led to prepare a new framework law, and thus to discuss the new role the *Agences* should play. But the reader of the 1992 law does not find a word on this issue, which indicates a stalemate situation. Opponents to the *Agences* had indeed threatened to mobilise the official opinion of the Constitutional court, that the *Agences* levies were taxes, and so their budgets should be yearly reviewed by the Parliament. Supporters of the *Agences* had long been accustomed not to formally confront to their opponents, and rather to win battles in the day to day bargaining and through the support of the water users in the basin councils. That is to say, they were, and they still are, accustomed to play "a minor tune". This is fundamentally linked to the weak status of subsidiarity in a centralised political system (Barraqué, 1997). Water policy actors globally have a positive opinion of the *Agences*, but they are tempted to use them as scapegoats for the problems resulting from what they have not let them handle[6]!

Fortunately, the 1992 law maintained the role of the *Agences*, and decided to double and even treble the levies they perceived from water users, so as to make up for the delays of the 1980's, and further to be able to implement the two new and costly Directives adopted in 1991, on Urban Waste Water Treatment and on Nitrates from Agriculture. However, while it was clear that diffuse pollution from agriculture was becoming a serious issue, for political reasons, it was impossible to create a levy on nitrates and pesticides. The government decided to launch the PMPOA[7], and take money from the *Agences* to control the pollution of the bigger animal husbandry (e.g. over 500 pigs); the latter were supposed to pay levies, but only 5 years later (i.e. on residual pollution only). The program was in fact a fiasco, because no institution was set up to control that the aids from the *Agences* be correctly spent, and indeed there was massive fraud. Ironically, it was at that time that a large coalition developed the argument that the *Agences* were inefficient… which eventually was echoed in a book by a colleague working on government by green taxes (Andersen, 1994).

3. THE PRESENT CRISIS AND THE DIFFICULTY TO MOVE TOWARDS INTEGRATED WATER MANAGEMENT

Yet, the achievements of the *Agences* are impressive: in 40 years, the number of French public sewage treatment plants moved from around 300 to almost 17000, including around 3500 waste stabilisation ponds. They also support the development of public services for the operation & maintenance of septic tanks (around 5 million in France, a

[5] One must always recall that even communist mayors prefer to deal with a private giant group than with Electricité de France, the State company.

[6] For a more detailed account of the French debate on the *Agences de l'eau*, see my chapter in Andersen Mikael Skou, and Rolf Ulrich Strenger (2000)

[7] Programme de Maîtrise des Pollutions d'Origine Agricole

rate similar to all low density European countries). They have also increased the safety of water supply in scarcity periods, mostly via interconnection of services. Conversely, the fact that upstream reservoirs had to be paid in the end by water users led to stop several projects which were officially designed to fight floods or protect biodiversity, but were secretly aiming at providing cheap water to securise irrigation schemes. Even if the learning process has been partial, it did take place. In southern France for instance, the government obliges EDF, the electricity company, to release water from their upstream reservoirs to provide the minimum flow in case of late summer droughts. EDF of course accepts but asks for payment of its opportunity cost of not being able to generate peak load electricity in autumn. Contracts then allow the *Agences* to pay half of this opportunity cost, on behalf of biodiversity needs, while General (county) councils pay the other half on behalf of farmers. We are trying to document this case as a WaterStrategyMan case. Other upstream reservoirs planned on the Seine and on the upstream Loire were also abandoned, a reduction of vulnerabilities to floods and droughts, combined with wetlands protection, being at last found acceptable by stakeholders.

More important is thus the role of the *Agences* in developing stakeholder involvement and bargaining. In the 1980's, a policy of 'river contracts' started from the need to develop a more ecologically friendly riverbed and banks maintenance, but contracts ultimately opened up to many other issues of water allocation, flood control etc. The law of 1992 proposes to build up on this experience to transform the contracts into legal planning documents, the SAGE[8]. Even though this participatory planning process is slow, it illustrates the need to move towards integrated river management, and the impossibility to do it through traditional top-down planning. Increasingly, the *Agences* develop basin contracts, metropolitan area contracts, rural contracts, because it allows to financially aid only one important project rather than several tiny ones. One of the major items funded in the contracts is the qualified person hired to develop a simultaneous knowledge construction and bargaining between users. And in the end, farmers may well obtain financial and technical support to reduce their pollution discharge, with money finally paid by water bills. This makes the situation close to what it is in Germany or in the Netherlands.

However, the crisis of the system continues, because several actors have made up a coalition in favour of a re-centralisation of water policy. For some economists, the *Agences* should be replaced by national regulators, like is the case in England & Wales; for some ecologists, they over protect their members who should be punished (yet police powers are in the hands of central government which does not enforce water policy enough); for leftwing alter-globalists and consumer NGOs, the *Agences* are a 'money-pump' to feed the largely private and monopolistic water industry on useless projects which bring water prices to unbearable highs…

The worst demagogy was reached when a member of Parliament, quickly followed by the press, said that "domestic users pay 85% of water bills vs 14% for industry and 1% for farmers, while drinking water was accountable for only 15% of abstractions"! He was only forgetting that the big tax is not on abstractions, but on pollution discharges, and that cities are still responsible for a lot of damages; besides local councils receive 75% of the total amount of money collected by the *Agences*, while indeed nobody thinks of refunding individual residents when the sewage works are working properly (conversely to the case for non connected industrial premises). It is true that farmers pay one and receive 5, and

[8] Schémas d'Aménagement et de Gestion des Eaux

under controversial programmes. But it is on minor amounts, and besides is this not due to the *Agences*; governments, one after the other, refuse to create a significant pollution levy on nitrates (both chemical and organic) and pesticides … The law in preparation even considers reducing the role of water parliaments, and to let central government gather the levies at national level, and then give the money back to the *Agences*. Indeed, the ministry of the Environment is taking a part of the unspent funds to improve water police, to better fight floods, etc. But this takes place on the back of water consumers, and through a reduction of money availability for the Directives implementation. Which means that either French water bills will dramatically rise, utilities being obliged to borrow more money from other sources, or the programs will be delayed … France has been condemned by the European Court of Justice for having more than 400 urban water treatment plants not complying with the UWWTD, and a general feeling of distrust is developing in the country. Nothing much is done on protecting drinking water resources from diffuse pollution, apart from finding other (deeper) sources or treating the water. Yet in many cases farmers would accept to join schemes where they would reduce their use of nitrates or pesticides with some compensation from drinking water utilities. But we argue that this is possible only if they first accept to pay even a small pollution levy, to become a player in the game of the *Agences*, rather than a free-rider as today. Government is in the end responsible not to give enough degrees of freedom to the Aghences to develop the needed learning process.

This negative account of present situation is made in support for a decentralised and participatory approach to integrated water management, which require first appropriate institutions. The Agences de l'eau are very specific to French situation, but there are several lessons to be learnt from them.

4. THE NEED FOR "COMMON PROPERTY ECONOMICS"

To put what we have explained in another way, the French system of the Agences is efficient because it relies simultaneously on the levies system and on the basin councils. But the model can only be efficient on the long run, because it is based on collective learning. If one takes one or the other of the two instruments, like has been experimented by countries willing to imitate the so called French model, it will not work, for lack of a learning process. A basin council without economic incentives or powers is bound to « talk policy »; an incentive mechanism without a users' board will end up as technocratic, and Treasury people will be tempted to drown the money raised into the general budget. Conversely, having the two together makes that the levy system will hesitate between cost recovery and hypothecation in favour of the environment, depending on the type of learning and consensus reached between members of the community (soft or hard). But the level of levies will never reach the PPP incentive.

There are several reasons to this, as explained by Colin Green, a socio-economist working in Middlesex University in London. In a paper on economic instruments for water pollution control, which he wrote in response to a consultation by the DETR, the British ministry in charge of the Environment (Green, 1998), he argued that the underlying assumptions for applying Pigovian taxes were not met in the case of water: natural monopoly means that we are far away from the assumption of a perfect competitive market. Economic valuation cannot catch all the dimensions of the value of environmental assets (and this is a recurrent problem for contingent valuation methods). Marginal costs and benefits, and the cost of pollution abatement need to be knowable and known so that economic incentives perform better than regulation. However, investments are made in a long term perspective, and they are very heavy, so that marginal costs are not significant and difficult to know with certainty, due to the permanent change of context and innovation : « it has been argued (Green, 1997), that efficiency is a wild goose chase, in that pollution abatement requires long term capital investment; so that, by the time the investment has been made, both the marginal costs and the marginal benefits of pollution abatement have changed » (Green, 1998). In order to correctly levy the Pigovian tax, there is a need for much more accurate information on the state of rivers and on pollution discharges. The requested monitoring system is very costly, and probably more costly than the revenue the information can bring! It is the same at the level of water supply: while it is theoretically efficient and equitable to have separate meters for each home, in fact, the inelasticity of indoor water use, and the cost of metering, makes the extra information provided by individual meters more expensive than sharing one meter between several neighbours[9], even for those who consume the least. And, for social reasons, it is impossible to raise water prices to the point where there would be elasticity. Conversely, since the price is largely determined by the investments, a successful campaign on water sparing by users, will often have a short term negative consequence, i.e. to raise the unit price for the sake of being able to reimburse the loans! Only on the long run will a water sparing strategy pay, which implies to train the consumers to understand the sophistication of the situation in which they are placed.

In other words, the transaction costs are too high for either traditional command and control regulation or economic incentives like pure PPP to succeed. This amounts to say that water is a common property, and that it needs common property institutions, so as to first lower the transaction costs through a learning process. For the same reasons, Green is dubious about privatisation of water rights and considers tradeable permits as bound to fail in the case of water: privatisation of water resources makes their subsequent reallocation difficult, while it was the very goal of the policy. There are not enough traders at stake, conversely to the case of air pollution. In another paper, which is part of our Eurowater previous research, we have analysed the history of water law and institutions in Europe, and we have found that there was something in common to Member States beyond the variety of situations (Correia, 1998). Some of the water at least is considered as a common property, and the traditional State regulation, planning and permit systems, which was « top down », is increasingly supplemented, not by the affirmation of private property rights, but by the development of subsidiary and community-type water institutions, at regional or basin level, for the sake of « bottom-up » decision making processes. The State still has a role to play, but it is more the one of warranting the democratic character of water sharing between water users, than the one of mastering the resource (Burchi, 1991). Big hydraulic works are behind us, and water management is « a natural case for cooperation » (Green, Tunstall, 1998).

5. CONCLUSION

The evolution of French water policy in the last 30 years does fit with the general European evolution towards complex water resource management institutional set up.

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[9] This does indeed correspond to the pragmatic approach to metering in France: all single family homes obviously have a separate meter, since outdoor uses are elastic. In Small and older condominiums, there is usually one meter for the whole building, and water bills are spread in proportion to the surface of flats. In large high rise apartment buildings built after the second World War, there are individual meters, because hot water is metered for each individual flat, and it was not very expensive to install and operate also a separate meter for cold water.

Both at the level of public services provision, and of water rights, the ancient policy structure opposing "public" and "private" is giving way to a more "community-based" approach. The major lessons that can be drawn from the French experience, is first that it is essential to develop subsidiary institutions at appropriate territorial level, where water users not only are represented, but pay levies and bring them together to allocate the funds to environmentally friendly projects. It is clear that it is a long and difficult and conflicting process. But the second step is to use these institutions, or to create appropriate ones, to organise the non-partisan mediation between interests and values at stake. This is one advantage of the French system: the Agences only allocate money, and they have no police powers or direct management involvement. They increasingly support more local institutions trying to develop integrated management, in the spirit of the Water Framework Directive.

Now clearly, in the member countries of WaterStrategyman partnership, all the islands already have water institutions in charge of optimising water allocation; conversely, it seems that areas in the mainland will always be tempted to solve water deficit issues through requesting long-distance transfers, while this solution could be avoided. The issue is whether the water institutions can evolve into mediation and funding appropriation for projects that result from compromises between various water uses, rather than keeping the traditional civil engineering bias, with the race forr always more water for all uses. Even rich Europe discovers that it is unaffordable, and unsustainable. It is our opinion that integrated water management leads to develop better cost recovery policies, yet not on a sector-by-sector basis, but on a regional level basis. In the end, it means that domestic water users and tourists might have to pay farmers to help them change to crops needing less water: but isn't it in the end cheaper than to have to import water or use sophisticated treatment technologies? As long as farmers are not put out of business, and the Mediterranean landscapes can be preserved y their maintained activity, the bargaining solution is worth trying.

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Vulnerability of Mediterranean Islands to Increasing Water Stress and Adaptation Strategies

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ABSTRACT

The supply of water in sufficient quantities and adequate quality presents a significant challenge for the Mediterranean in general and for Mediterranean islands in particular. Already today, available resources are scarce on many of the islands and existing reservoirs are often exploited to depletion. This situation is likely to worsen in the foreseeable future based on projected climate changes and resulting decreasing water availabilities. We consider some of the factors constituting present and future vulnerabilities to water scarcity on five islands that are investigated in the framework of the EU-MEDIS project. Measures aiming at enhancing the adaptive capacity of the water sector will lead to reduced vulnerabilities of the islands to increasing water scarcity. In devising such measures, we propose to consider three dimensions of vulnerability and adaptive capacity enhancement: a physical/environmental dimension, an economic/ regulatory/technical dimension and a social/institutional/ political dimension. We present a number of different adaptation measures relating to each of these dimensions but emphasize that the exact choice of these measures will depend on the specific situation under consideration. This notwithstanding, devising adaptation strategies requires a holistic approach and the active involvement of stakeholders.

Keywords: adaptive capacity, climate change, sensitivity, stakeholders, water availability, water scarcity.

1. INTRODUCTION

Water is an essential and indispensable ingredient for life. It serves a multitude of purposes from life supporting functions over cultural and spiritual roles to production functions in agriculture and industry.

The availability of water in sufficient quantities and adequate quality varies in time and space. While some regions of our world are blessed with a plentiful supply of water, for others, the provision of water represents a constant challenge. It is in these arid regions of our planet that an efficient and thoughtful water management takes on overwhelming importance. While already difficult today, ensuring a satisfactory supply of water in these regions may become even more problematic as a result of climate change foreseen for the next 20 to 50 years. In general, global climate change will lead to an intensification of the water cycle with enhanced frequencies of floods and extreme precipitation events in regions traditionally prone to this threat and with increased water scarcity (the term water scarcity depicts an imbalance between availability of (renewable) water resources and water demand for different uses and also embraces water quality aspects) in already water deficient regions of the world (*Alcamo et al.*, 2000; *Arnell et al.*, 2001; *Gleick*, 2000). This fact is illustrated in Figure 1, which provides a projection of future water availability for Europe (*Lehner et al.*, 2001).

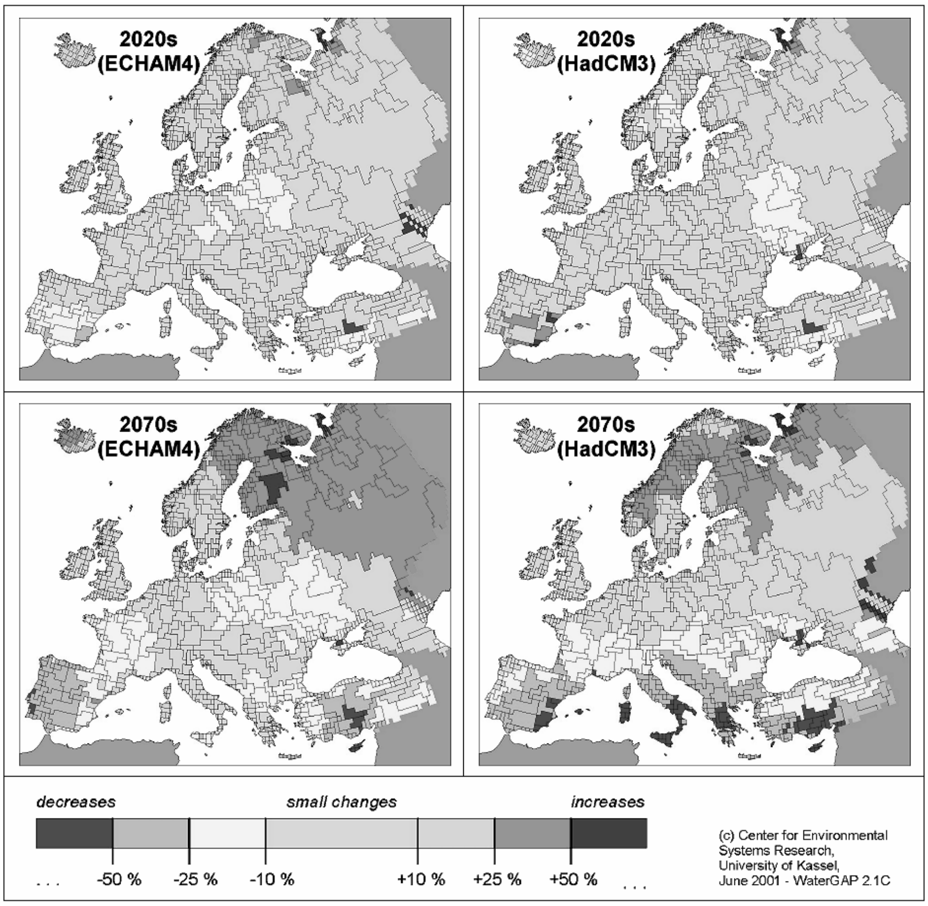

Figure 1: *Change in annual water availability in % (i.e., natural discharge not accounting for consumptive water use) for European river basins based on climate simulations with two global climate models (the ECHAM4 model of the Max Planck Institute for Meteorology, Hamburg, Germany and the HadCM3 of the Hadley Centre, Bracknell, UK) and presented for 2020 and 2070 relative to present discharge values (after Lehner et al., 2001)*

As can be seen, for 2070 significant deficits in water availability are projected for large parts of the Mediterranean, particularly according to results based on the HADCM3 model. The results of the latter model also show that water scarcity is to be expected for most of the Mediterranean islands with decreases in water availability of at least 50%.

Thus, islands are particularly important when considering the future water management and have therefore been chosen as the primary focus of our work in the MEDIS project (*Towards sustainable water use on Mediterranean Islands: addressing conflicting demands and varying hydrological, social and economic conditions*; EVK1-CT-2001-00092; http://www.uni-muenster.de/Umweltforschung/medis/index.html). Islands face a number of challenges that are largely addressed in MEDIS (*Lange and MEDIS consortium*, 2004), including:

- their isolation, which implies that the use of trans-boundary water to compensate for temporal or seasonal water shortage, which is frequently practiced in continental situations is virtually impossible,
- their dependence on the availability, timing and amount of precipitation,
- the extensive exploitation of natural reservoirs on the islands to the point where they can not be consumed as potable water anymore,

- the extraction of water in coastal reservoirs beyond the natural recharge potential, leading to the intrusion of sea water into the aquifer thereby rendering its water useless for human consumption, and
- unresolved conflicts between different users, deficits and inefficiencies in institutional water management and the non-compliance with existing rules and regulations.

In order to address the issue of droughts under current and climatically altered future conditions as well as possible remediation actions, we introduce the concept of vulnerability to water scarcity. Vulnerability is being defined in the context of two other concepts used in assessing climate change impacts (*IPCC*, 2001; *Parry and Carter*, 1998; *Scheraga and Grambsch*, 1998):

- the **sensitivity** of a system describes the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise);
- **adaptation** to climate change refers to adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous (i.e., intrinsic to the system under consideration) and planned adaptation (i.e., adaptation measures initiated through human activities);
- the **vulnerability** represents the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes; the vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its *sensitivity*, and its *adaptive capacity*.

Having clarified these important concepts, we need to define yet another term before proceeding:

- the **adaptability** or the **adaptive capacity**[1] of a system depicts the ability or potential of a system to adjust trough changes in its characteristics or behaviour to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences of climate change; in the context of this paper, we will concentrate on planned adaptability.

Since we do not specifically consider climate change as a major determinant, the definitions given above can be adapted to our discussion by replacing the terms “climate-related stimuli” and “climate change” with “water-scarcity-related stimuli” and “changes in water availability”, respectively.

In the following, we will describe factors that constitute vulnerability to water scarcity of the islands of Majorca, Corsica, Sicily, Crete and Cyprus, i.e., the islands considered in

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[1] here and in the remainder of this paper, we follow the approach taken by the *Intergovernmental Panel on Climate Change* (IPCC) and use the terms ‘adaptability’ and ‘adaptive capacity’ synonymously

MEDIS and will discuss various measures aimed to enhance the adaptive capacity to droughts of these islands, which may reduce their vulnerabilities.

2. VULNERABILITIES TO WATER SCARCITY ON MEDITERRANEAN ISLANDS

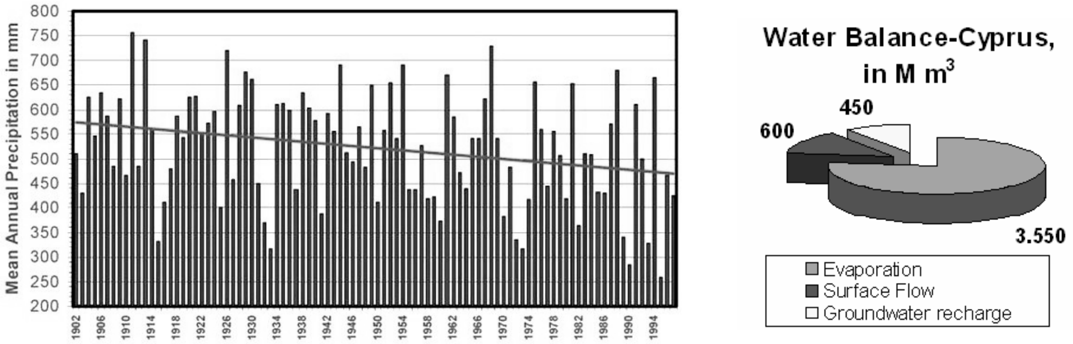
Before considering vulnerabilities, we will briefly provide a few details on the physical conditions and the availability and replenishment of water resources of the five islands under consideration (Table 1).

Table 1: Basic characteristics related to water management on Mediterranean islands

	Parameter	Majorca	Corsica	Sicily	Crete	Cyprus
Regional Context	**Climate type**	Mediterra-nean, tem-perate	Mediterranean	Mediterranean	Mediterranean sub-humid	Mediterranean semi-arid
	Aridity index		0,87	0.388 (semi-arid)	0,48 (semi-arid)	0,3-0,5 (semi-arid)
	Total area	3 640 km^2	8 682 km^2	28 000 km^2	25 706 km^2	9 251 km^2
	Permanent population	609 000	260 196	55 329	5 076 700	793 100
	Annual tourist arrivals	210 000 (max.: 405 000)[6]	2 Mill.		> 4 Mill. (1999)	2,7 Mill.
Water availability	**Mean yearly precipitation**	650 mm/a	900 mm/a	500 - 1 000 mm/a	300-1600 mm/a	500 mm/a (182-759); 477 mm/a [2]
	Total annual water supply	2 400·10^6 m^3	8 000·$10^6 m^3$	14 000 – 28 000·10^6 m^3	7 690·$10^6 m^3$	4 015·$10^6 m^3$
	Annual Evapotranspiration		2 500·$10^6 m^3$		5 380·$10^6 m^3$ (3 550-7 230)	2 918·$10^6 m^3$ (72%)
	Total water resources/availability		1 500·$10^6 m^3$	2 472·$10^6 m^3$	2 310·$10^6 m^3$ (1 520-3 100)	1 097·$10^6 m^3$
Water re-sources:	❖ **Surface water**	12·$10^6 m^3$ (21,2%)	10 500·10^6 m^3	27%	924·$10^6 m^3$ (40%)	250·$10^6 m^3$ (23%)
	❖ **Ground-water**	37,4·$10^6 m^3$ (66,1%)	1 900·$10^6 m^3$	71%	1386·$10^6 m^3$ (60%)	634·$10^6 m^3$ (58%)
	❖ **Storage/ dams/reser-voirs**	7,2·$10^6 m^3$ (12,7%)		2%	23.37·$10^6 m^3$ Infra structure)	183·$10^6 m^3$ (16%)
	❖ **Desalination**				0	30·$10^6 m^3$ (3%)

With regard to the supply of water, it has already been mentioned that there is a singular dependence on precipitation as the sole (natural) (re-) supply mechanism. The current situation, particularly with regard to the eastern Mediterranean can be described by two factors: a decline in precipitation for the last century (*Bolle*, 2003; *Xoplaki*, 2002) and a persistently large evaporation due to high surface temperatures particularly during the summer months (Figure 2).

The precipitation trend as shown in Figure 2, though specifically for Cyprus and the eastern Mediterranean, is in agreement with general trends seen throughout the entire Mediterranean Basin (see, e.g., *Xoplaki et al.*, 2004).



(a) **(b)**

Figure 2: Mean annual precipitation and overall trend for 1902-1997 (a) and relation between evaporation, surface flow and groundwater recharge of precipitated water (b) on Cyprus; Constantinou, pers. comm.

Figure 3 compares current mean monthly precipitations throughout the year and for the winter and summer seasons for the five islands, reflecting significant differences in the provision of water for each island. Strongly influenced by large-scale circulation patterns such as the *North Atlantic Oscillation* (NAO), precipitation for the wet season (i.e., the months October to March) over much of the Mediterranean has steadily decreased by 2.2 mm month^{-1} decade^{-1} during the second half of the 20th century after a general increase since the middle of the 19th century (*Xoplaki et al.*, 2004).

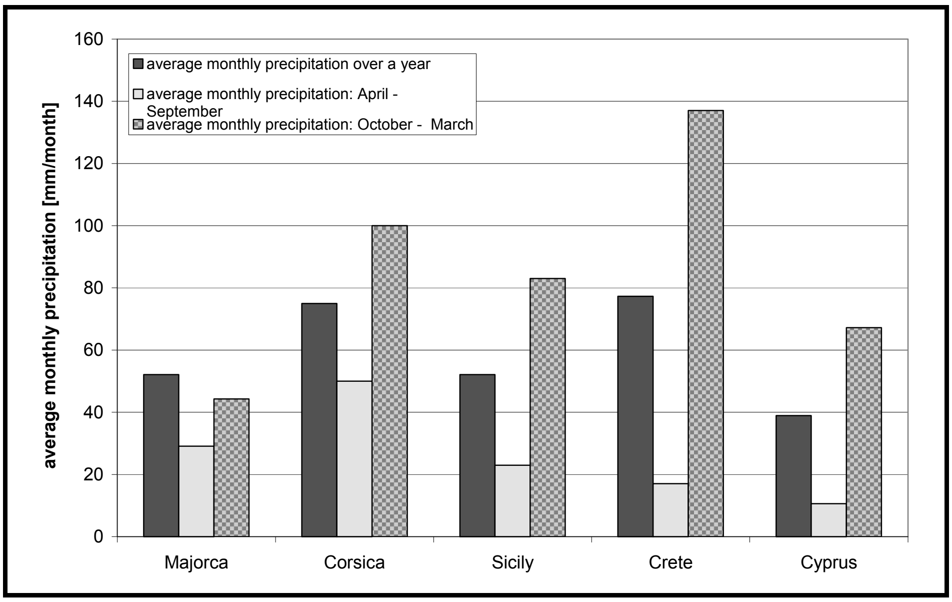


Figure 3: Mean monthly precipitation on a yearly and seasonal base

Because the main water consumers will be adversely affected by a decrease in water availability, the sensitivity of the islands to water scarcity can be regarded very high (mainly due to limitations in the available space for this paper, we refrain from considering sensitivities and vulnerabilities of natural and environmental components of the island systems). Moreover, as a consequence of the above mentioned dependence on rainfall as the major replenishment mechanism for water reservoirs on the islands, falling precipitation rates diminish this replenishment mechanism. This adds to the sensitivity of the islands to water scarcity and may lead to either enhanced exploitation of still existing groundwater resources or the introduction of alternative supply mechanisms. Presently, the latter comprises in most cases the construction and operation of desalination plants, which are, however, a fairly costly alternative to natural precipitation.

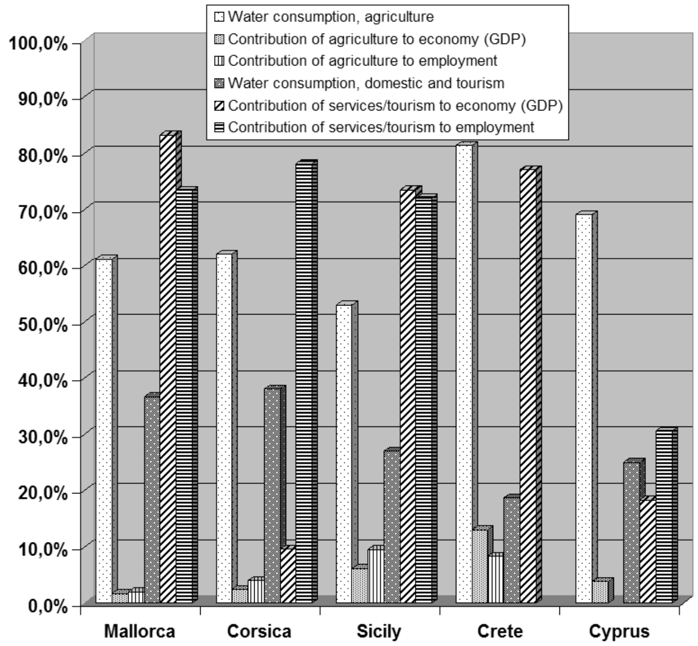


Figure 4: Comparison of water consumption for agriculture and tourism and their contribution to the economy and the employment for the islands under consideration

In order to consider sensitivities to water scarcity in more detail, we present the water consumptions of two major end users (agriculture and tourism and private households; the only other main consumer, industry, requires only a marginal water supply) in relation to their contribution to the economy and the labour market of the five islands under consideration (Figure 4). As can be seen, agriculture is the dominant consumer of water with up to 80% of the total consumption whereas tourism and households comprise relatively moderate consumption rates (up to 37% of the total consumption). This relationship is completely reversed when their contributions to the islands' economies and labour markets are examine. Thus, reduced water availabilities imply:

- moderate impacts on agriculture, since its large proportion on total water consumption will likely lead to a remaining water supply of sufficient magnitude and only minor economic losses for the islands' economies and labour markets,
- more significant impacts for tourism and households because of an already limited consumption and (particularly in the case of tourism) enhanced consequences for the economy and the labour market of each island.

Moreover, the autonomous adaptation of the agricultural industry is likely higher (e.g., through autonomous adaptation of plants to reduced water supply) than that of the tourism industry, which has to satisfy uncompromising demands by the customers. Thus, the vulnerability to water scarcity will be higher for those islands that depend more strongly on tourism as a major contributor to the island's GDP.

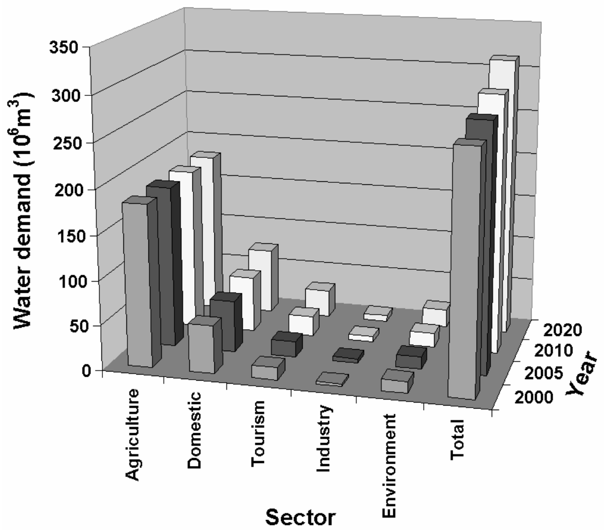


Figure 5: Projected water demand in 106 m3year-1 for various sectors on Cyprus up to the year 2020; Constantinou, pers. comm.

As shown above (Figure 5), projected changes in climate are expected to lead to continued decreases in water availability, thus exacerbating the problem of water supply to the various end users on the islands.

This, in turn, will result in increases in water stress (the term *water stress* describes pressures on water resources quantity and quality, resulting in the inability to meet human and environmental needs and generating conflicts and negative impacts) as a result of envisioned growing demands for water in the foreseeable future (Figure 5).

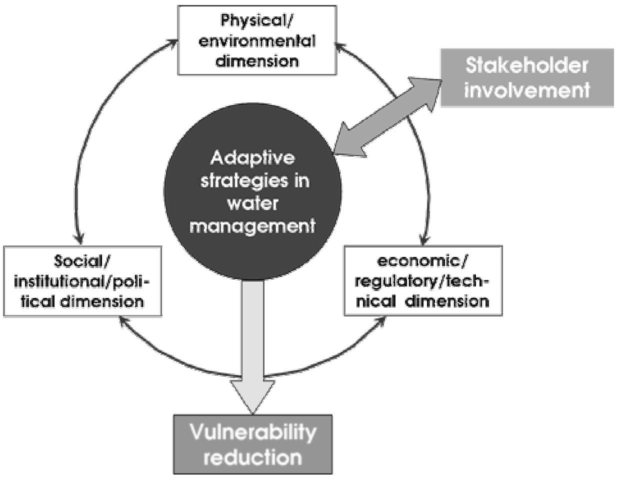


Figure 4: *Schematic depiction of different vulnerability/adaptation dimensions to water scarcity*

Given the consideration on vulnerabilities presented above, the projected increase in water stress is likely to result in continued increase in vulnerabilities to water scarcity, particularly in the tourism sector of the islands.

However, as outlined above, vulnerability not only depends on sensitivity and autonomous adaptation but also on planned adaptation and an enhancement of adaptive capacities. Thus, in the following, we will consider possible planned adaptation measures that may result in reduced vulnerabilities to water scarcity on Mediterranean islands.

3. ADAPTATION MEASURES

Before addressing concrete activities that aim to enhance the adaptive capacity of the water management regime of the islands, we would like to introduce the concept of the different dimensions of vulnerability reduction through adaptive measures. As illustrated in Figure 6, we propose three different dimensions of water management that should be considered: a physical/environmental dimension, an economic/ regulatory/technical dimension and a social/institutional/ political dimension. It is obvious hat this choice of categories is somewhat arbitrary, as would be any other categorization. However, there are mutual relationships between these dimensions. This implies that they will have to be considered holistically, when deriving effective adaptive strategies that will result in overall reductions in vulnerability to water scarcity in a given region.

Moreover, lasting solutions to sustainable water management in the Mediterranean as well as effective adaptation strategies will only be found through recommendations and/or regulations that are based on mutually agreed principles between the stakeholders involved and between stakeholders and decision makers. This requires a stakeholder-based participatory process (cf., Figure 6) that builds on the results of scientific investigations on the one hand and on the consent of major stakeholders on the other (Lange et al., 1999).

In the following, we will briefly present a number of possible adaptation strategies. In so doing, we do not wish to prioritize any of these measures nor do we attempt to provide an exhaustive list of such measures. We have ordered the recommendations according to the three dimensions just introduced.

3.1 Adaptation Strategies: Physical/environmental dimensions

With regard to physical and environmental dimensions of water scarcity, the following recommendations are being proposed:

1) **Reduce water consumption** U

   Under this heading, the most promising strategies embrace:

   a) **Water pricing**, i.e., an increase in consumer prices, possibly differentiated between different user groups; alternatively/additionally **quotas** on water extraction may be imposed, again possibly differentiated between different user groups.

   b) An important option will be to create **incentives** for reduced water consumption, e.g., subsidies for water saving not –as has been often the case- for water consumption.

2) **Change in water allocation**

   a) Sectors accounting for maximum gross-domestic-product generation (GDP) and employment should be supported by the government; however, care should be taken in avoiding possible one-sided economical advantages for specific sectors;

thus, incentives to save water for water-intensive sectors should be introduced in parallel.

3) **Reduce losses**

Given the current water scarcity in many parts of the Mediterranean, it is hard to understand that drinking and irrigation water is being lost in large volumes. While this water is not 'lost' (i.e., it is often fed-back into groundwater aquifers), such losses of valuable potable water should be avoided. More specifically:

a) Loss of water to the sea either as riverine discharge or through sub-sea groundwater discharge (SGD) should at least be reduced (*Burnett et al.*, 2003). However, in devising appropriate measures, care should be taken to avoid adverse impacts on bio-geochemical cycles and on marine ecosystems in near-coastal waters.

b) Reduce losses and contamination of water in distribution networks. On Cyprus, annual losses of drinking water in the distribution network account for $40 \cdot 10^6 m^3$, corresponding to 15% of the total demand and 23% of the total domestic demand on Cyprus. An improvement and renewal of distribution networks, even though an investment of substantial quantity should be pursued where appropriate.

4) **Increase utilization of additional water resources**

While largely neglected for a long time, there is now increasing attention be paid to this possible remedy. In particular, potable or irrigation water can be obtained trough:

a) waste water recycling;

b) utilization of brackish water and

c) rainwater harvesting.

3.2 Adaptation Strategies: Economical/regulatory/technical dimensions

Addressing vulnerability aspects related to economical/institutional dimensions, the following actions are recommended:

1) **Support sectors with high economic potential and small water needs**

This refers somewhat to point 2. a) of the previous section. However, we would like to stress again that such measures will have to be applied with great care, ensuring that one-sided measures that do not account for the overall importance of other, apparently less favourable sectors are being avoided.

2) **Change agricultural practices (quantity, quality of water)**

Under this heading, we make a plea for at least two alternatives to present practices:

a) The first refers to the crops cultivated on each island. Stakeholders should be consulted and informed about possible alternatives to currently practiced cropping patterns, particularly with regard to the water requirement of plants but also related to watering schedules and the amount of irrigation water applied per plant (for a summary on possible alternatives, see *Olesen and Bindi*, 2002).

Furthermore, care should be taken to optimize tillage systems as well as weeding and harvest controls with the aim to minimize irrigation needs.

b) The second recommendation/strategy refers to the application of fertilizers as well as pesticides. Excess amounts of agrochemicals often leach into the soil where they enter the groundwater bodies. This leads to a deterioration of water qualities to the point where the water becomes unsuitable for human consumption. Thus, the application of agrochemicals should also be optimized in order to avoid adverse effects on groundwater quality. In fact, the use of agrochemicals and the aforementioned changes in agricultural techniques should be considered jointly in order to arrive at **best practices** that not only maximize yield but also minimize water use and the possible impact on groundwater quality.

3) **Eliminate/reduce subsidies for water prices**

Subsidies of various kinds have in the past contributed to either excessive water use and/or –in the case of agriculture- to cropping patterns that are economically and environmentally unsustainable. Eliminating subsidies for water prices for any sector is not only desirable with regard to a healthy and just economic development, it is also required with regard to the EU-Water Framework Directive's (EU-WFD) principle objective of achieving full-cost recovery.

4) **Promote cultivation of crops that have a high potential on the domestic and the foreign market (eliminate wasting products and water)**

A particular point in case in this regard, which can however also be observed in one way or another on other islands, is the cultivation of bananas on Cyprus. The species grown, while not characterized by a particularly high specific water demand, nevertheless accounts for the highest total water consumptions of crops grown on Cyprus. However, the banana harvested are not suitable for the European market as they do not adhere to European agricultural norms. Thus, they are difficult to sell on the European market and the capacity of the domestic market is not sufficient to absorb the harvested products. Consequently, large quantities of the harvest has in the past been discarded, resulting not only in the waste of the produce but also in the waste of the water needed to grow it. Farmers need to be informed about possible alternatives and should be encouraged to pursue these, possibly with the help of government agencies or –preferentially- with stakeholder-controlled initiatives (e.g., farmers' marketing organizations).

5) **Provide assistance in capacity building of farmers and for investments in modern irrigation technology**

Providing information and assistance on rational and careful, water consumption as part of the capacity building of stakeholders on the islands is a particularly important strategy to enable enhanced adaptation and to reduce vulnerability to water scarcity. This can take place on various levels and in any sector with sizeable water needs. As mentioned above, the agricultural industry is a particularly pertinent point in case.

6) **Provide economic incentives for rational water use in all sectors**

This measure refers to some of the strategies already mentioned (e.g., point 1 and 4, above). Incentives may be provided through, e.g., specific water tariffs and or relaxation of quotas and limitations in water consumptions to those sectors that strive for a more rational use of potable water.

3.3 Adaptation Strategies: Social /institutional/political dimensions

Reducing vulnerabilities related to social, institutional and political aspects may be pursued through the following actions:

1) **Public awareness campaigns (water use, ownership, conflicts); capacity building**

This recommendation seems to be particularly pertinent given the widespread lack in problem awareness with regard to water availability and use. This measure should be geared specifically to particular stakeholder groups and should enable a more adequate problem awareness as well as an enhanced capacity to deal with water scarcity problems.

2) **Implement a more complete monitoring of water extraction**

As has been observed, the legal and regulatory instruments to enable an adequate water management regime on the islands are often already in existence. However, to utilize such regulations, proper instruments for a comprehensive monitoring need to be established and/or maintained.

3) **Improve enforcement of existing rules and regulations**

Equally important are adequate and consequently executed enforcement mechanisms, which are largely lacking. Equally important are the penalties that are imposed in cases of violation and that need to be followed through consequently and coherently.

4) **Simplify/enhance efficiency of water administration**

Administrative structures that are hard to comprehend and understand are prone to be ineffective. Thus, there should be attempts to simplify and reduce the administrative mechanisms/structures related to water management, in order to improve acceptance by the stakeholders and water consumers.

5) **Transfer of power to regional and local decision makers**

A particularly effective way to increase administrative efficiency is the transfer of power from central (distant) government institutions to local or regional authorities. The so-called TOEBs (*Farmers Irrigation Organizations*) that operate on a local to regional scale on Crete and in Greece are a particularly positive point in case. However, care should be taken to ensure that such institutions do not become an obstacle to harmonized and larger-scale water management regimes such as the EU-WFD. In making this statement, we are well aware that what we are proposing what constitutes a fine balance to be struck between local/regional autonomy and national/international jurisdiction by the political decision makers. However, we are convinced that institutions such as the TOEBs are much better suited to become partners in the EU-WFD than individual users or single municipalities.

6) **Encourage stakeholder-controlled water management structures**

This recommendation follows directly from what has been said above. Again, we are convinced that the encouragement of stakeholder-driven water management practices prepares the islands much better for dealing with water scarcity but also with the implementation of the EU-WFD than individual stakeholders or stakeholder groups.

7) **Ensure/improve adequate factual basis for political decision making**

This is a plea for a more extensive and more adequate alliance between political decision makers and the scientific community. We are convinced that science has to play a major role in devising new strategies for a sustainable water management on Mediterranean islands. However, as has been stressed throughout this paper, we are equally convinced that such strategies need the input from and the consent of all relevant stakeholders on the islands.

When considering these recommendations/strategies, it quickly becomes obvious that they should neither be treated in isolation nor according to just one of the dimensions introduced above. The specific choice of measures to be taken and their implementation will have to be carefully devised based on the specific situation under consideration. In particular, a balance will have to be found between the different levels addressed here, i.e., from the individual to the state government. This again underlines the necessity to seek the active involvement of stakeholders by the decision makers in order to come up with solutions that are feasible and acceptable.

4. CONCLUSIONS

We have shown that water scarcity is already and will continue to be a major problem for Mediterranean islands. Given the main consumers of water it turns out that tourism is probably the most sensitive sector with the least ability to autonomously adapt to droughts. This results in a high vulnerability of this sector to water scarcity and because of the contribution of tourism for the economy and the labour market on the islands, to an equally enhanced vulnerability for the islands' future development as a whole. This conclusion is exacerbated by projections of continued decrease in water availability due to climate change and to growing demands for water by all sectors in the foreseeable future. Carefully planned adaptation measures can reduce vulnerabilities. In devising such measures, we propose to consider three dimensions of vulnerability and adaptive capacity enhancement: a physical/environmental dimension, an economic/ regulatory/technical dimension and a social/institutional/ political dimension. While we provide a number of recommendations for adaptation strategies in each of these categories, we conclude that they should neither be treated in isolation nor according to just one of the dimensions. A careful analysis of the situation at hand will be the basis for the selection of a suite of measures that collectively may lead to reduced vulnerabilities to water scarcity on Mediterranean islands.

ACKNOWLEDGEMENTS

We acknowledge support of MEDIS by the European Commission under contract number EVK1-CT-2001-00092 and would like to thank Dr. Panagiotis Balabanis, the responsible officer at the Commission for his support. We would also like to thank all individuals who have contributed to MEDIS at the partner institutions and particularly those colleagues who have provided data and information for the present publication.

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Putting the WFD into practice: Strategy formulation for IWRM under scarcity conditions

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ABSTRACT

This paper presents a framework for the development and evaluation of strategies for water deficient regions which focuses on the mitigation of water stress and applies the principles of Integrated Water Resources Management and the EU Water Framework Directive. The adopted methodological approach is presented through a tentative application in the island of Paros, of the Cycladic Complex in Greece. The island faces intense supply coverage problems during the summer tourist season, while, like in most Mediterranean coastal regions, groundwater resources are overexploited in order to address the high irrigation and domestic water requirements. The elaboration of two alternative strategies is complemented with the formulation of an alternative model for water resource allocation and management, where there is free competition of the two economic sectors (tourism and agriculture) over scarce water resources and water supplies are developed through private initiatives.

Key Words: Arid regions, Water Stress, Strategic Planning, Cost recovery.

1. INTRODUCTION

Water problems are neither homogenous, nor constant or consistent over time. They often vary significantly even within a single country between regions, from one season to another, and from one year to another (Biswas, 2000). Solutions to water problems depend not only on water availability; two of the most important factors are the processes through which water is managed and the prevailing regional socio-economic and environmental conditions.

In most Mediterranean regions, the presence of continuous sources of water stress is combined with periodic droughts. The decline of water resources and increasing demand for freshwater cause threats to the environment and provoke conflicts between competing uses, even in comparatively water-rich areas (Margat and Valée, 2000). New infrastructure (dams for interseasonal storage, extensive conveyance systems) needs to be built to address the need for adequate supply; this in turn raises the question of adequate funding, institutions and administration that can enable the development and management of such infrastructure. Further compounding the problems, the coastal regions, where population tends to concentrate are an attractive tourist destination. This seasonal peak, which normally coincides with the irrigation season, creates strong competition of users over scarce resources, and should be taken into account in infrastructure planning. The imposed economic burden and low water availability potentially result in low recovery of costs, especially under drought. At the same time, environmental impacts from water usage are significant: wastewater collection and treatment systems are inadequate or even barely developed, while in many regions water resources are overexploited. The development of cost recovery mechanisms and appropriate pricing schemes also needs to address the potentially high resource and environmental costs, and existing cross-subsidies between use sectors and users.

Following from the above considerations and principles, the development of appropriate, integrated water management strategies for arid regions should reconcile multiple goals and objectives: guarantee the provision of water of sufficient quantity and quality for sustaining and developing dominant economic activities while protecting vulnerable ecosystems; ensure the financial sustainability of water services and the appropriate maintenance and renewal of infrastructure while taking into account the affordability of water users. By definition, a strategy is a detailed plan or method that is employed to obtain a goal and a means of translating policy into action. In the present work, strategies are considered to be a set of actions or sequence of responses to existing and emerging conditions, suited/available for the fulfilment of a selected goal.

With this definition, the following paragraphs demonstrate a methodological approach for the development of strategies for water deficient regions, with the goal to alleviate water scarcity. The approach is based on the application of a Decision Support System (WSM DSS), developed in the framework of the EC-funded WaterStrategyMan project ('Developing Strategies for Regulating and Managing Water Resources and Demand in Water Deficient Regions' – Contract no: EVK1-CT-2001-00098). The methodological approach is applied to the Case Study of the island of Paros of the Cycladic Complex in Greece. Paros is a typical case where water shortages occur on a seasonal basis due to the coinciding high tourist influx and irrigation peak season. The elaboration of suitable strategies is thereby followed by the development of an alternative regional development model, based on the free competition of the two dominant economic sectors, agriculture and tourism over scarce resources. In this context, additionally required infrastructure is developed through private initiatives, by the end-users.

2. FORMULATION OF WATER MANAGEMENT STRATEGIES FOR THE ISLAND OF PAROS, GREECE

2.1 The island of Paros

The island of Paros (Figure 1) is one of the most popular tourist destinations in the Cycladic Complex. During the summer months seasonal population is almost three times greater than the permanent residents, while during the winter months local authorities estimate that only 50% of the permanent registered population lives on the island.

The development of tourism and the consequent prosperity of the island began slowly in the early 1960s, after many years of decadence. Since 1950 local inhabitants were mostly farmers and fishermen. Between 1950 and 1965 a large emigration trend was observed that resulted in a great population decrease. In the 1970s this trend was reversed due to tourism that grew rapidly during the 1980s, bringing about changes in the traditional way of living. Unfortunately this development took place without planning and control, leading to the problems that the island is facing today, both economic – offer of accommodation being greater than demand of accommodation – and environmental – great seasonal pressures exerted on water resources. Simultaneously, the agricultural activity that had been abandoned was enhanced to a large extent by this growth, and the resulting demand for local traditional products (e.g. local wines).

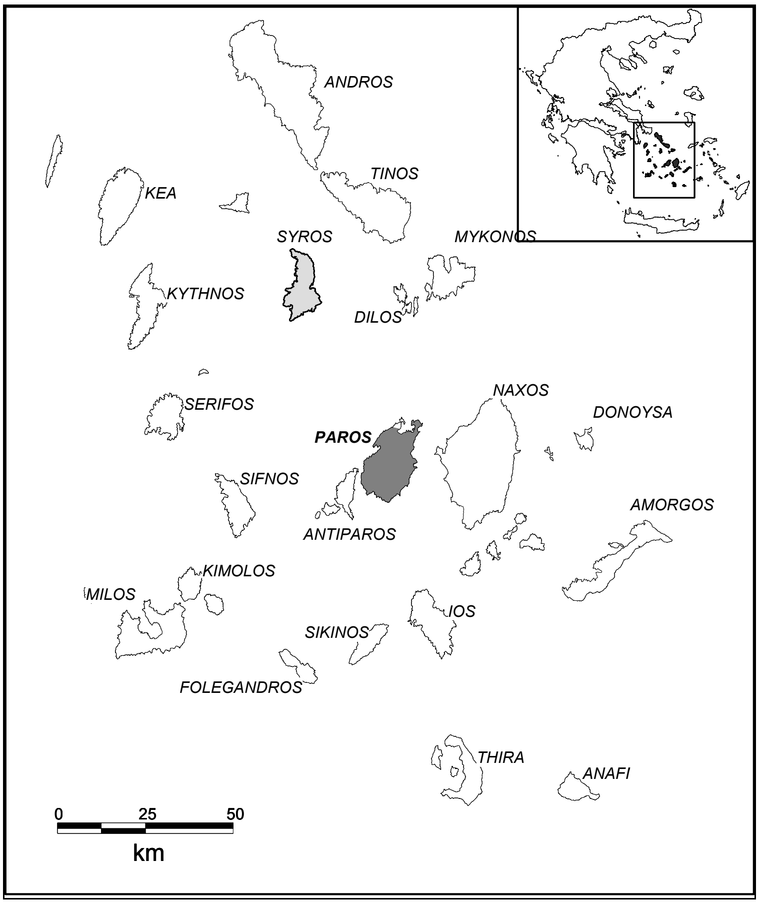


Figure 1: The island of Paros in the Cycladic Complex

Water demand growth in the last decades was mostly addressed through the construction of extensive water drillings to supply the domestic and agricultural sectors. Paros is a typical case where water shortage occurs on a seasonal basis. Tourism and irrigation demand reach their peak during the summer months, creating conflicts between uses and problems with water supply adequacy during peak consumption. The island has the potential to combine multiple activities; both tourism and agriculture can offer a prosperous future for the inhabitants under suitable planning and control. So far however, the existing infrastructure has proven to be inadequate for dealing with these issues. Therefore new water management responses are needed to address the problem and ensure the sustainable management of water resources.

2.2 Strategy formulation

The goal for the formulation of strategies for the island of Paros was to reconcile water supply and demand in order to promote tourism development, while at the same time preserving traditional agricultural activities. The strategies that were formulated aimed at medium to long-term planning, and therefore take into account a 25 year horizon, spanning the period 2005-2030. The targets set for the analysis were to meet (a) at least 80% of the domestic and irrigation needs in the peak summer period, and (b) 100% of the demand during the rest of the year. At the same time, secondary objectives in the overall process was the achievement of (a) economic efficiency, through the maximisation of economic output, (b) environmental sustainability through impact mitigation and reduction of groundwater extractions to sustainable levels, and (c) equity by achieving a more equitable allocation of incurred direct, environmental and resource costs to users.

Appropriate measures and instruments, and their potential limitations were identified through the examination of the current responses to water stress issues and consultation with the local stakeholders. A summary is portrayed in **Figure 2**.

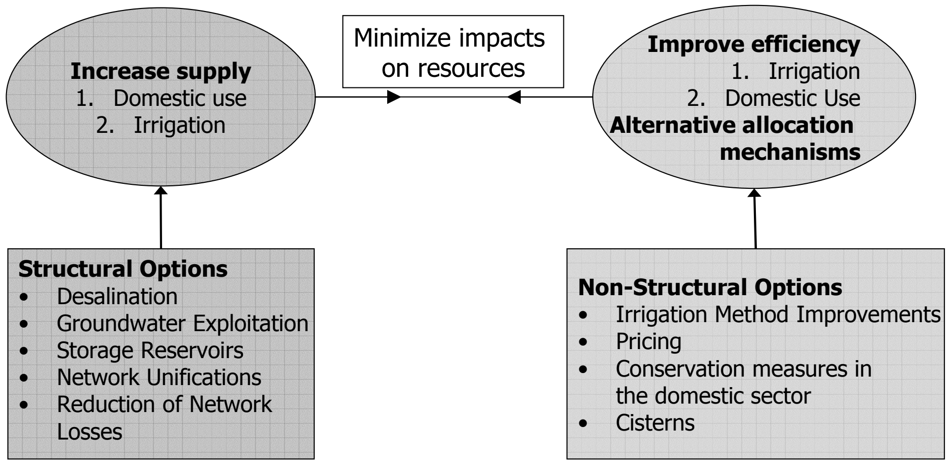


Figure 2: Summary of identified feasible and available options for the island of Paros

Subsequently, the most suitable options were integrated into coherently formulated water management strategies. Two alternative approaches were distinguished, after the water resource planning paths elaborated by Gleick (2003):

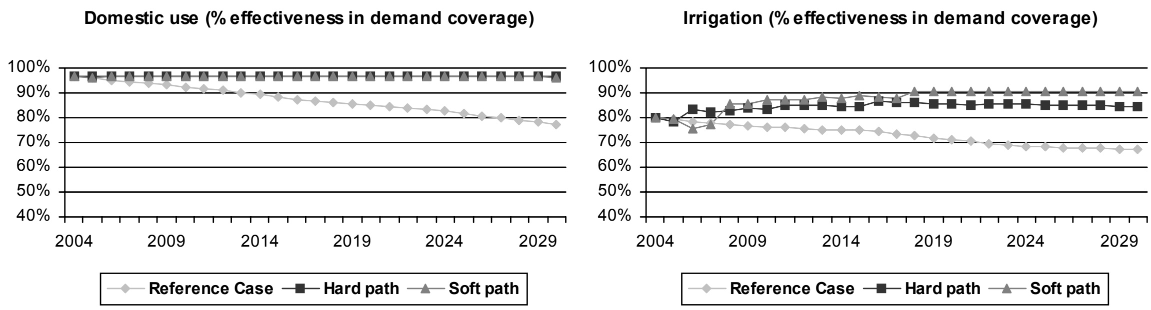
- The **hard-path approach**, mostly oriented towards supply enhancement through the application of structural solutions, and incorporating new technologies such as desalination;
- The **soft-path approach**, integrating demand management options, and small-scale decentralised structural interventions to alleviate major water shortages. Potential demand management responses for the island concern mostly conservation efforts and efficiency improvements, promoted through economic incentives.

A summary of the measures incorporated in the two strategies is presented in Table 1. Measures were subsequently formulated in a suitable timeline, determined through an iterative procedure, and were compared and evaluated against each other and against the reference case on which they were built. The reference case was defined as the foreseen evolution of the water system, including a business-as-usual demand scenario (1.5% growth for permanent and tourist population, stable irrigation demand), and constant, average availability conditions. Planned and already decided interventions were also taken into consideration.

Evaluation results regarding the effectiveness and cost of the two approaches are presented in Figure 3 and Table 2. In terms of effectiveness, both strategies can meet more than 95% of domestic needs; set targets are also met for irrigation water supply. However, in the latter case, the soft-path approach has a slightly better performance, especially after the full introduction of measures that target the agricultural sector, i.e. irrigation method improvements, and measures that limit domestic consumption. Therefore, it becomes evident that agricultural activities can more effectively be sustained through the introduction of measures that improve the efficiency of water usage.

Table 1: Measures incorporated in the two alternative water management strategies

Hard-path approach	Soft-path approach
	Network Unifications
Groundwater Exploitation A total of 4 additional boreholes, yielding 204,000 m^3/yr	**Groundwater Exploitation** 1 additional borehole, yielding 75,000 m^3/yr
Surface water exploitation Interception dam for aquifer enhancement Capacity of 98,000 m^3	**Surface water exploitation** Interception dam for aquifer enhancement Capacity of 98,000 m^3
Reduction of Network Losses From 25 to 20 %	**Reduction of Network Losses** From 25 to 20 %
	Conservation measures in the hotel sector 10% reduction of consumption
	Irrigation Method Improvement Substitution of current methods with drip irrigation
Desalination Additional capacity of: 1300 m^3/d in 2010 2000 m^3/d in 2020 2700 m^3/d in 2030	**Desalination** Additional capacity of 600 m^3/d



(a) (b)

Figure 3: Effectiveness of the proposed strategies in meeting the set targets (a) domestic use (b) irrigation water provision

Estimated costs for the two strategies and the reference case are outlined in Table 2. Direct costs include capital and operational costs for measure implementation, and costs associated with the operation of the water system (e.g. pumping costs for irrigation and domestic supply, network costs, administrative costs etc). Environmental cost is associated with the cost of preventive/mitigation measures and includes two components: one incurred from groundwater over-abstractions, and one dealing with pollution generation from inadequately treated urban return flows.

Table 2: Comparison of strategy costs

	Direct Cost	Resource Cost	Environmental Cost	Groundwater over-abstractions (hm^3-2015)
	(PV, 4%, 2004-2030, million €)			
Reference	27.59	5.07	36.07	0.63
Hard-path	33.99	3.88	35.89	0.58
Soft-path	30.33	0.87	33.84	0.45

The soft-path approach seems to occupy an advantageous position, presenting lower values for direct, environmental and resource costs. The reduction of direct costs is primarily due to the introduction of efficiency improvements, which limit the required desalination capacity (i.e. 600 vs. 2,700 m^3/d). Similar results are obtained for environmental costs, since in most aquifers the abstractions considered "unsustainable" (exceeding the safe yield) are significantly lower.

Therefore, a preliminary conclusion that can be drawn from this analysis is that soft-path approaches can be effective in mitigating water stress, while at the same time incurring lower costs to consumers. This issue is further elaborated in the following section.

2.3 Addressing Cost Recovery Issues

An additional step in the process of defining appropriate strategies is the development of cost recovery scenarios which could ensure the financial sustainability of water services. These scenarios are formulated for each water use sector and service by setting appropriate cost recovery targets to be achieved within a set timeframe, and taking into account the present institutional and administrative framework.

Domestic water supplies in Paros are under the administration and management of a municipal water utility company (DEYAP) since 1999. Increasing block tariffs (IBTs) set by the DEYAP recover operation and maintenance costs for water supply and wastewater collection and treatment, and part of capital costs. Although maintenance and control follow a centralized and better-organised decision-making path than before, there are still remnants of the past administrational structure, when each municipal department used to develop its own water resources. One of these is the differentiation of block tariffs per municipal department. A Local Board for Land Improvement (TOEV) manages irrigation water supplies in the northern part of the island; however most agricultural needs are met through private boreholes and crop irrigation relies solely on groundwater. In this case there is no recovery of any kind of either environmental or resource costs.

On a preliminary basis, cost recovery scenarios were formulated through the definition of flat-rate volumetric prices and charges, to be re-adjusted every five years in order to achieve a set recovery of direct and environmental costs. For this purpose, costs were allocated to each use according to the *'polluter pays'* through the WSM DSS. More specifically, direct and environmental costs associated with supply provision were allocated proportionally to the volume supplied to each use(r) from each supply source, whereas environmental costs from pollution generation according to the loads generated from each use.

For irrigation water, where financial costs are fully covered by the users, environmental cost recovery is effected through charges (penalties) for over-abstraction. It should be noted that the actual implementation of such an instrument would involve the specification of abstraction limits per borehole, and the metering of extracted quantities at the end of the irrigation season. The definition of the maximum charge per 5-year period is based on the consideration that the private welfare surplus (i.e. the difference between benefits and the water costs charged to the consumers) from agricultural activities should be positive. This limited the maximum possible recovery of environmental costs to 50%. On the other hand, tariffs for the Water Utility were formulated to achieve a 100% recovery of direct costs for the entire planning period. The targeted recovery of environmental costs in 2005 was set at 50%, and was gradually increased, reaching 70% in 2030.

The estimation of prices and charges to be eventually applied was based on an iterative process, where demand and allocated volumes were re-estimated according to assumed demand elasticities. Resulting prices and charges are presented in Table 3.

Table 3: Prices and charges estimated for the two strategies, in €/m^3

	2005	2010	2015	2020	2025	2030
Domestic Use						
Hard path	2.19	2.19	2.19	2.27	2.32	2.32
Soft path	2.14	2.14	2.18	2.27	2.32	2.32
Irrigation						
Hard path	0.09	0.12	0.12	0.12	0.13	0.13
Soft path	0.07	0.11	0.11	0.11	0.12	0.12

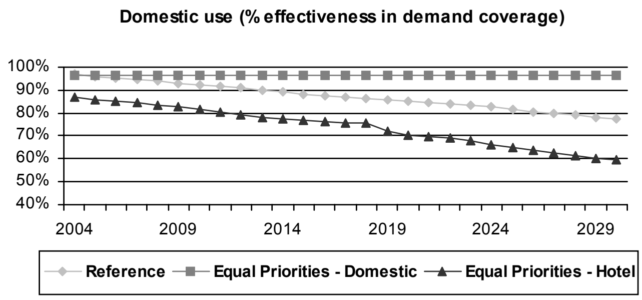
It becomes therefore evident that in principle, and at least up to 2010, the adoption of soft approaches can also result in lower costs charged to consumers. After 2020 both strategies result in similar prices and charges. Although costs for non-structural solutions are lower, due to the reduction of consumption, the volume of water sales is also smaller; therefore higher prices are required in order to attain the same cost recovery targets.

3. AN ALTERNATIVE REGIONAL DEVELOPMENT MODEL

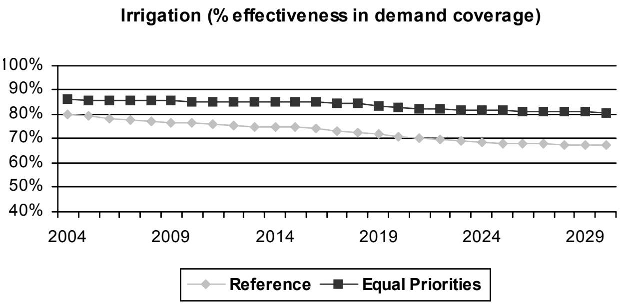
Water resource planning, as presented in the previous paragraphs, was based on the assumption that supply enhancement and demand management are financed through public funds, which are afterwards recovered through the water bill. In addition, strategies were developed taking into account the Greek Law 3199/2003 with regard to priorities for supply provision. Accordingly, the provision of water for domestic purposes, which also includes tertiary sector activities such as tourism, was considered of first priority, to be guaranteed under all circumstances.

This section outlines the development of an alternative model, where users develop supplies required for sustaining economic activities through private initiatives. Water supply for households is of the highest priority, and provided by the public authorities. Free competition over scarce resources is promoted between tourism and agriculture, which both receive water at a lower and equal allocation priority.

The graphs of Figure 4 portray the evolution of effectiveness in demand coverage, assuming that no measures are taken towards supply enhancement. The reference case corresponds to the original priority setting, where no distinction is made between households and the hotel sector. Under the current priority assumptions, the improvement in residential and irrigation demand coverage is evident, while tourism demand is not adequately met. Most importantly however, Figure 4a) portrays that no further action is required to guarantee adequate water supply for households.



(a)



(b)

Figure 4: Effectiveness of the two allocation schemes for the coverage of (a) residential and tourist demand and (b) irrigation demand

The set allocation priorities directly affect total economic output: in present value terms, foregone benefit from tourism reaches 13.11 million €, while benefits accrue from agricultural activities are only equal to 7.54 million €. Similarly, the total social welfare surplus (i.e. the difference between the total value or benefit and the total direct and environmental costs) is also reduced by approximately 8%.

A first response to this income loss could be the enhancement of water supplies by the hotel industry, in order to safeguard tourism revenues. Similar responses, through the installation of small, privately owned desalination units have been considered by hotel and lodging owners in the past in similar popular tourist destinations. For Paros, the required total desalination capacity in order to meet the peak mid-August tourism demand is estimated at 5,700 m^3/d in 2010, and 9,500 m^3/d in 2030. Electricity grid constraints limit maximum installed capacity to 5,000 m^3/d for the period 2005-2020 and 6,000 m^3/d for 2021-2030. The additionally required water supply can originate from surplus of public water supply sources and water purchases from irrigation boreholes. The supply mix for the hotel sector, as estimated through the WSM DSS, is presented in Figure 5.

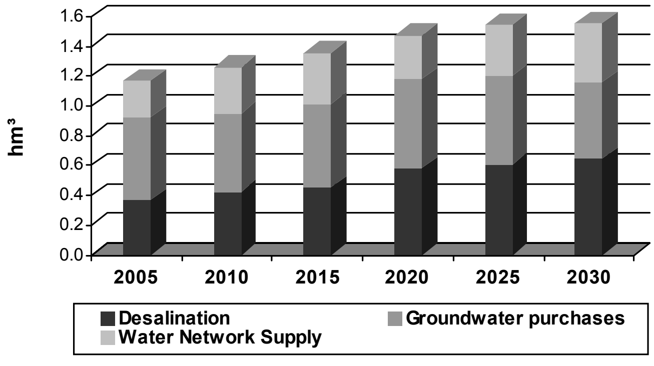
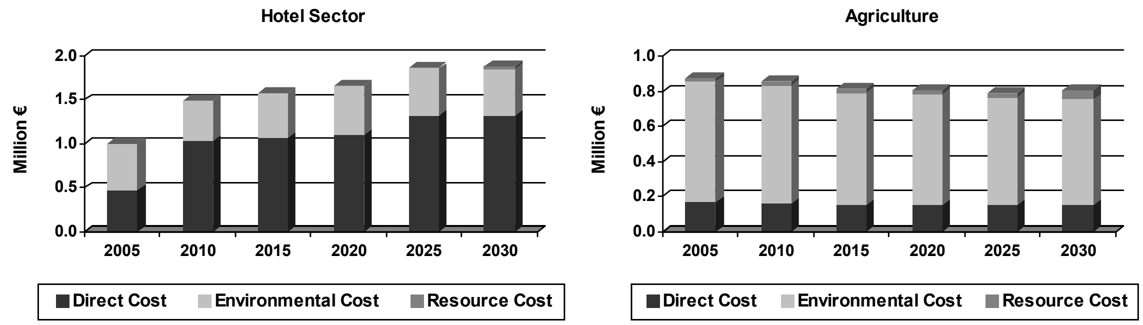


Figure 5: Supply mix for the tourism sector

Figure 6 present the costs allocated to the hotel and agricultural sectors. In the first case, direct costs represent the costs of public water supply provision, the capital and operational costs associated with desalination unit construction and operation, and the cost of groundwater purchases. Prices for the latter are estimated in order to compensate for income loss from agricultural activities, and thus represent a lower limit for this cost.



(a) (b)

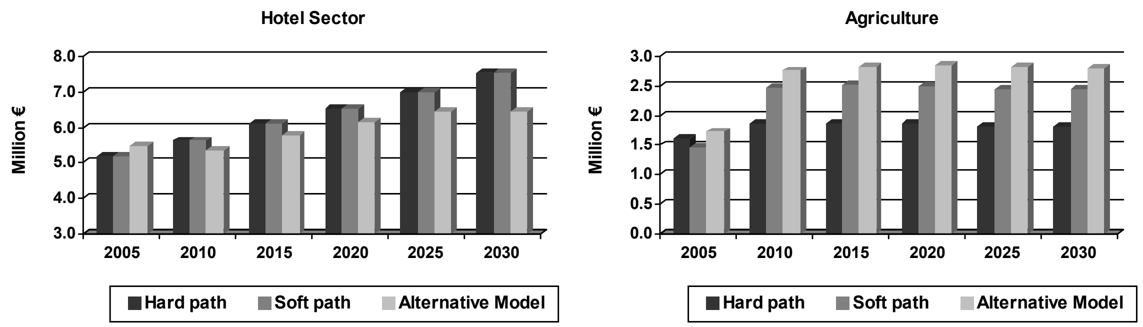
Figure 6: Incurred direct, environmental and resource costs to the hotel and agricultural sectors under the alternative development model

Flat-rate tariffs for supply from the public water system are estimated by assuming the same cost recovery targets. Table 4 presents the resulting unit costs incurred to users for 2015. The most important difference is observed in prices incurred to households, which are even lower than the current weighted average tariff of 1.47 €/m^3. On the other hand, the economic burden imposed on the hotel sector is almost insignificant, with the average unit cost being only 6% higher than the one of the hard-path approach.

Table 4: Costs incurred to consumers under different management plans (2015, €/m^3)

<table>
<tr><th></th><th>Households</th><th>Hotel Sector</th><th>Agriculture</th></tr>
<tr><td>Hard-Path</td><td colspan="2">2.19</td><td>0.12</td></tr>
<tr><td>Soft-Path</td><td colspan="2">2.18</td><td>0.11</td></tr>
<tr><td>Alternative Model</td><td>1.29</td><td>2.32</td><td>0.08</td></tr>
</table>

Finally, Figure 7 presents a comparison of the private welfare surplus for the two economic sectors and for each examined planning scheme.



(a) (b)

Figure 7: Incurred direct, environmental and resource costs to the hotel and agricultural sectors under the alternative development model

In line with the estimated costs, the economic impact of the alternative allocation scheme in the short run does not influence much the total net benefit accrue to users; the difference becomes larger at the end of the simulation period, when the installed desalination capacity is considerably higher and costs incurred to consumers increase.

4. CONCLUDING REMARKS

The development of strategic plans following the principles of Integrated Water Resources Management and the Water Framework Directive should be based on a thorough examination of the institutional and administrative frameworks, and of regional development patterns and users' expectations. In spite of the model used – public or private water supply development, strong regulatory frameworks are necessary in order to ensure the sustainable management of water supplies and the preservation of traditional economic activities, vital to the social structure. This however should not compromise the need for the decentralisation of decision-making, which can help at addressing emerging water management issues locally.

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Drought Policy Interfaces: From Ideal to Real

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ABSTRACT

The present effort emphasizes the need for contingency drought planning instead of the prevailing crisis management approach. Therefore, it tries to delineate an integrated drought management scheme leading towards timely, orderly, proactive and contingency oriented drought responses with the aid of the information technology. In a fast changing era, any present or future oriented drought management efforts should be also able to cope with the larger aims of social and economic dimensions. The proposed approach may, thus, accommodate adaptive policies for resource scarcities, climatic vagaries, changing socio-economic environments and associated long-term ramifications in cases of water shortages. Such a process may enable engineers, managers and decision-makers to identify the onset of a drought, to develop appropriate drought management responses with sensitivity to an expanded horizon and with a richer menu of options as to how human systems can cope and adapt to the far-reaching effects of drought, as well as with a questioning of the assumptions underlying structural and non-structural solutions in drought challenges.

Keywords : drought management, policy, contingency planning.

1. INTRODUCTION

In trying to confront the drought phenomenon, ubiquitous obstacles for any systematic management options surface. Such difficulties emanate from the fact that the concept of this natural hazard remains ambiguous and elusive, since it tries to incorporate physical processes as well as highly complex interactions with the surrounding environment. In addition, catastrophic and widespread drought impacts elicit strong demands for immediate and effective management actions. Nascent sources of difficulties in applying appropriate management responses may be derived from the following causes of confusion: elusive drought definitions; diversified and devastating drought impacts; and absence of systematic response mechanisms. In this regard, the existing tendency among professionals, politicians, managers or even common citizens is to view and consider drought as a natural hazard; a traditional disaster causing emergency mobilization. However, cumulative experience from scientific investigations of the recent decades is indicating that the recurrence of drought is unavoidable, as the phenomenon seems to be an inevitable and permanent part of the world's climate, especially with the recent indications of potentially increasing instability in the environment (greenhouse effect, ozone depletion etc.).

Furthermore, the existing overall conditions in water resources management requires that rather urgent and holistic decisions must be made with regard to such overriding problems as increasing water demands for various users; changes in the physical environment altering the water balance; and the generation of pollutants that may contaminate streams and groundwater. An initial array of issues and concerns that contribute to a such series of problems characterizing, especially water resources use and development under stressed conditions, would include among others: the presence of large numbers of uses and users competing over limited resources; increasing costs of public services and inadequate pricing structures; decay and obsolete facilities, pronounced disparities between cities and rural areas and the attendant problems of social differentiation and inequitable distribution of opportunities; fractionalized governmental units and overlapping jurisdictions; and, haphazard developmental efforts and piecemeal, ad hoc sectoral planning

In this aspect, drought and its ramifications must be recognized and anticipated for all planning and management efforts in water resources.. Nevertheless, a precise, unambiguous definition of drought remains elusive (Vlachos, E.C. and Grigg, N.S., 1993; and Grigg, N.S. 1996; Karavitis, C.A., 1999). One source of confusion in devising an objective definition may be that drought implies a variety of things to various professionals according to the specialized field of study (meteorology, hydrology, water resources, agriculture etc.). A second problem is eliciting because the definition of drought is strongly related to the geographical, hydrological, geological, historical and cultural traits of a given locale. Thus, a broader definition of drought in this effort may be: the state of adverse and wide spread hydrological, environmental, social and economic impacts due to less than generally anticipated water quantities. Such water deficiencies may originate from precipitation decreases, physical and/or operational inefficiencies in water supply and distribution systems, as well as from incompetent water management. Then, drought is not only the lack of precipitation as it is generally believed, but a complex phenomenon requiring a more complete analysis, evaluation and focused responses.

2. DROUGHT POLICY INTERFACES

While the above concerns relate to specific problems in developing drought management policy options, they are at the same time part of the backdrop of a more generalised framework for further expanding new approaches to planning and water resources management that would:

- place emphasis on stronger interdisciplinary approaches integrating a variety of "environments" in any policy related options
- expand the time horizon from a narrow enumeration of immediate impacts, to a long-range forecasting of higher order consequences
- combine the historical experience of the past, the constraints of the present, and the visions of both probable and desirable futures.

All in all, such a framework may become even more complex, if it is seen as part of a series of "strains" that contemporary society and water management are facing and consequently the pertinent policy options should confront. In the literature, a whole litany of such "strains" and "stresses" has been presented, usually in terms of a fast approaching clash between expanding demands and limited water resources. Specifically Vlachos and Braga (2001) present the following areas of "strains" that may be seen as central in any discussion of the physical-social environment interfaces relating to any policy options development: a) ecological strains, part of exhaustion of strategic natural resources and of spillovers of the technical apparatus of society; b) economic strains, resulting from large economic paralysis, global interdependence, and crisis of pricing systems; and c) social and cultural strains, result of a lag between technology and non-material culture, changing values, and the collapse of expectations vis-à-vis limiting the gap between supply and demand in the needed time and space.

In this regard, rapid water consumption growth, coupled with escalating environmental impacts and consequences, contribute to increasing technological and social complexity and interdependence through magnification of effects on the surrounding environment, in terms of intensity, severity and duration; give rise to fundamental questions as to the distribution of effects to various water users; and, require strong efforts to present policy options able to cope in a flexible and responsive manner to both short and long-term problems of drought.

In order to present a special case study, namely the Athenian drought, the annual water consumption in metropolitan Athens was 375.816 x $10^6 m^3$ in 1989, the last year before the drought period (Karavitis, C.A., 1999). During the 1990 drought the consumption dropped to 326.5 x 10^6 m^3/yr and reached a minimum of 246.3 x 10^6 m^3/yr in the 1993 one. Since then it has started to climb to a total consumption of 280.2 x 10^6 m^3/yr in 1995 and to the levels of 1989 at the end of 2004. It has to be noted that all the above quantities are referring to the total water production leaving the treatment plants and thus include losses. Figure 1 illustrates data of water consumption in comparison with the expansion of the Athenian population. Along with that a 1968 water consumption forecast is presented From this figure it may be derived that while the population increase has reached an asymptotic, the water consumption has increased until the drought year of 1990, when, it started to fluctuate below the maximum value of consumption on 1989. Such a fact may, until 1990, be attributed among others, to changing lifestyles one or in decaying water infrastructure and thus increased losses. Drought measures seem to be responsible for the post 1990 water consumption patterns. Finally, it has to be noted the grave failure of the water consumption projections accentuating the volatility, complexification and vulnerability of the overall system.

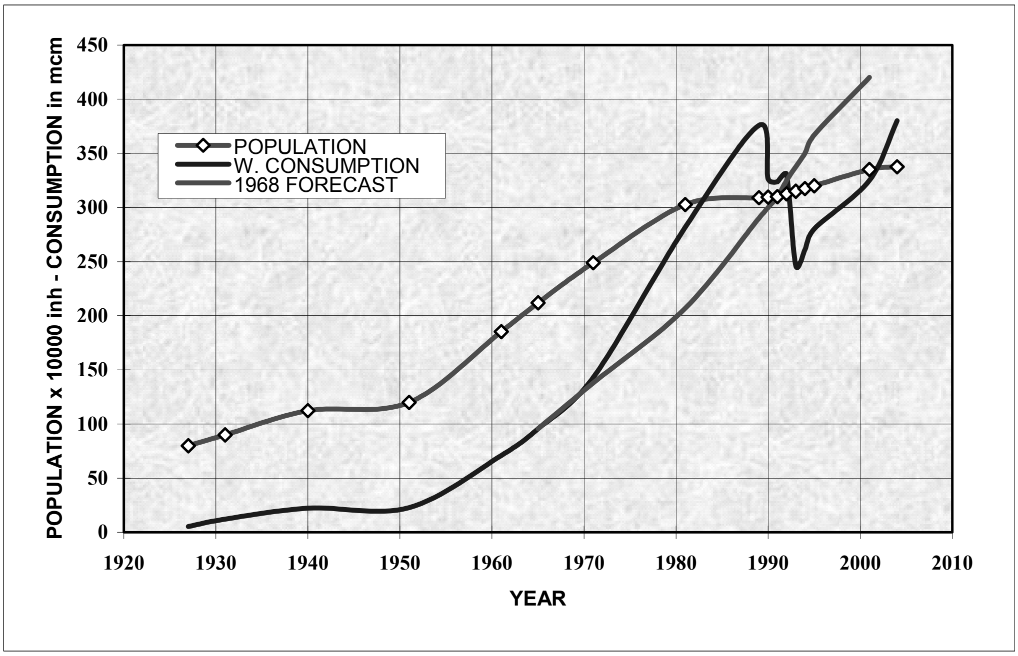

Figure 1: Population, water consumption data and projection in metropolitan Athens.

In this context, based on an array of case studies the premises of an "ideal" drought management scheme may be presented in Table 2 (Karavitis, C.A., 1999; WaterStrategyMan project, 2005).

Table 1: Comparison of an "ideal" to the "real" drought management scheme

Premises of an "Ideal" Scheme	Characteristics of the Real Scheme
Risk oriented/drought forecasting	Absence of contingency planning
Anticipatory and Proactive Drought contingency planning	Reactive and short range crisis management oriented
Delineation of multiple alternatives	Limited range of alternatives limited integration of experts, planners and decision-makers.
Interdisciplinary orientation	Problematic data limited integration of computer information systems
Based on timely, valid and reliable data supported by computer information technologies	Inadequate legal and institutional framework
Existence of appropriate legal, institutional and economic foundations	Haphazard drought organization and mobilization
Efficient drought organization supported by effective water resources planning and management practices	Problematic water resources planning and management practices
Efficient drought decision making process	Centralized decision making process
Timely and effective implementation of responses	Haphazard implementation of responses
Evaluation of the selected and applied actions	Limited evaluation of the applied measures
Risk oriented/drought forecasting	Absence of contingency planning
Anticipatory and Proactive Drought contingency planning	Reactive and short range crisis management oriented
Delineation of multiple alternatives	Limited range of alternatives limited integration of experts, planners and decision-makers.

3. CONTINGENCY PLANNING IN DROUGHT MANAGEMENT

A comprehensive drought responses plan may be centered around existing schemes for drought control measures. Short-term responses should be initiated and terminated according to the drought duration, while long-term ones should be already designed and implemented. All the options and responses of a comprehensive management scheme are presented in Figure 1. Given such considerations, water policy options may be classified in the following parts (Karavitis, C.A., 1999):

supply augmentation options. Such measures should examine all the potential water supply resources for the area. They should be already in place before drought (base and emergency supply). Perhaps with the exception of water purchases, systems supply augmentation should be avoided during the drought as a crisis management action. The existing system designed after long-range planning should be capable of operating under drought conditions according to contingency plans; it should also be well maintained and improved in order to minimize the losses;

demand reduction options. These responses should aim towards the reduction of water consumption according to conservation principles. They may be short- and long-term ones. The long-term measures should be in place according to proactive planning (i.e., legal measures, zoning/land use, landscape changes, etc.). The short-term measures should be initiated during and terminated after the drought (i.e., water restrictions, reduction of uses, pricing, etc.). The implementation and enforcement framework for demand reduction measures should also be in place (economic, legal and institutional). Finally, such measures should be implemented orderly and timely according to contingency plans; and

impact minimization. Such responses should concentrate on anticipatory strategies, relief and recovery measures. The framework for such responses should already be in place (economic, legal and administrative). Spread of drought risk, damage recovery and compensation should be some of the measures considered, according to a water related master plan.

DROUGHT -----	* SUPPLY AUGMENTATION	EXISTING	- Surface/Subsurface Storage - High Flow Skimming - Interbasin Transfer/Import - Cross Purpose Diversion - System Improvement/ Conservation
		NEW	- Water Desalinization - Weather Modification - Groundwater Mining
		MIXED	- Conjunctive Use - Conveyance Grids - Snow and Ice Management - Technological Innovation
	* DEMAND REDUCTION	PROACTIVE	- Legal Measures - Economic Incentives/ Pricing - Zoning/Landuse Policies - Public Involvement/ Education - Prioritizing Demands
		REACTIVE	- Water Saving Programs - Reduction of Non-essential Uses - Recycling/Reuse - Metering
		TECHNOLOGICAL ADJUSTMENTS	- Agricultural Changes - Urban Adjustments - Industrial Modifications
	* IMPACT MINIMIZATION	ANTICIPATORY STRATEGIES	- Forecasting System - Regulation of Consumption - User Discretion - Regional Emergency Action - Conflict Management
		LOSS ABSORPTION	- Insurance - Spread of Risk - Compensation Damages - Disaster Relief - Reserve Funds
		LOSS REDUCTION	- Modify Events - Damage Recovery - Change Water Uses

Figure 2: Drought management options (adapted from Grigg and Vlachos, in Grgg, N.S., 1996; Karavitis, C.A., 1999).

Finally, an important element of holistic drought management strategies is that of post-event measures (figure 2). Based on this procedure, revisions in planning, management and organizational processes and structures may occur. In this essence, changes may also be initiated in the event preparation stage leading to potential improvements of the drought master plan, thus closing the loop in the overall drought management scheme. Figure 2 presents this drought management scheme, based on contingency planning on which holistic drought management responses may be secured.

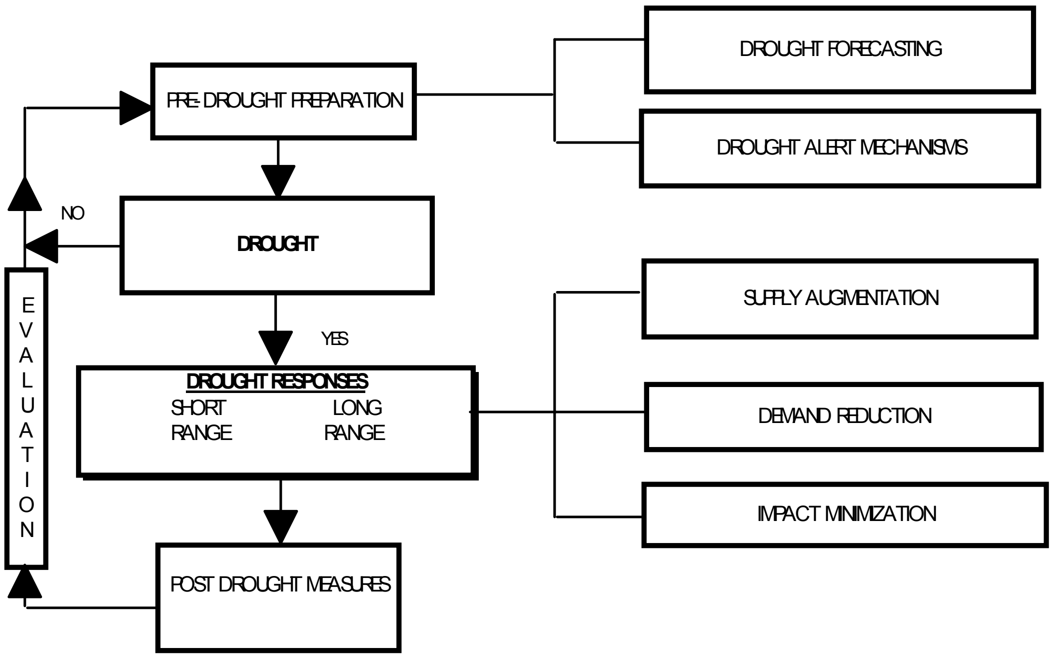

Figure 3: A comprehensive drought management scheme (Karavitis, C.A., 1999)

4. CONCLUSIONS

Finally, in a fast changing era, any present or future oriented drought management scheme should be based in contingency protocols, hence being able to cope with the larger aims of social and economic dimensions. In this context, technological, economic, legal, and social responses in order to face the challenges of a dynamic environment should incorporate both "non-structural" and "structural" mechanisms as components of an integrated policy , linking water resources to growth. Thus, supply augmentation and/or demand reduction projects and measures are both influencing the rate and the extent of change in an interacting environment. In addition to that, water resources development efforts particularly in stressed areas should include sustainability criteria and ecological values. Such, ecological values and the quest for sustainable development require both information and management options confronting the uncertainty and the risk associated with fast changing environments. Furthermore, the Water Framework Directive (WFD, 2000) in the European Union has significant requisites for the protection of quantity and quality of surface and ground water, introduction of water pricing policies, integrated watershed management, and the strengthening of public participation. In this regard, it becomes more than necessary that decision making should move beyond considerations of tradeoffs and traditional methodologies into a more meaningful posture by examining underlying water resources development strategies, and interconnected social goals and visions. As a result alternative drought policy issues emerge (e.g. reservoir storage, conservation, reuse, desalination, transport of water from other areas; conjunctive water use with withdrawals from aquifers, etc). It is believed that in such a decision making approach, the present effort may be of some use in classifying the drought policy options in a more complete and integrated fashion.

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Water Management and Agricultural Practices on Mediterranean Islands

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ABSTRACT

Sustainable water resources management in Mediterranean islands is closely related with water use in agriculture, which uses more than 50 % of available water resources. It is also the least efficient sector in water use, since irrigation efficiency is less than 55 %. The demand for irrigation water is high in all islands even though only a small percentage of agricultural land is irrigated, ranging from 8.8 in Mallorca to 33.4% in Crete. In all islands, water for agriculture comes mainly from groundwater sources, while only in Corsica surface water is the sole source of irrigation water. Among the crops dominating in Mediterranean islands, citrus, fodder and open-field vegetables are the high water demanding crops, while olive is the less water-demanding crop. Modern irrigation systems have been widely used the last few decades in all islands. The growing water demand in Mediterranean islands makes the rational use of irrigation water extremely important for sustainable and environmentally friendly development of agriculture and its multifunctional role. To meet these goals, aspects related to water management and agricultural practices are discussed in this paper, with emphasis on irrigation application, soil and plant management practices, water pricing, reuse of treated wastewater, farmers' participation in water management and capacity building.

Key words: Mediterranean islands; Irrigation; Horticultural crops; Best agricultural practices

1. INTRODUCTION

Water is considered as the most critical resource for sustainable development in most Mediterranean countries. It is essential not only for agriculture, industry and economic growth, but it is also the most important component of the environment, with significant impact on health and nature conservation. The global agriculture now accounts for 70% of water used, while 40 % of the world's food comes from the 18 % of the cropland that is irrigated (Postel, 1999). Irrigated areas increase almost 1 per cent per year (Jensen, 1993) and the irrigation water demand will increase by 13.6 % by 2025 (Rosegrant and Cai, 2002). On the other hand, 8-15 % of fresh water supplies will be diverted from agriculture to meet the increasing demand of domestic use and industry. Furthermore, the efficiency of irrigation worldwide is very low, since only 55 % of the water is used by the crop (Fig. 1). In developed agriculture, losses due to poor nutrition and plant health are greatly reduced to the extent that crop losses relating to water availability continue to exceed those from all other causes (Passioura, 2002). In order to overcome water shortage in agriculture it is essential to increase the water use efficiency and to use marginal waters (reclaimed, saline, drainage) for irrigation

The sustainable use of water is a priority for agriculture in water scarce areas. Imbalances between availability and demand, degradation of surface and groundwater quality, inter-sectorial competition and inter-regional conflicts often occur in these regions.

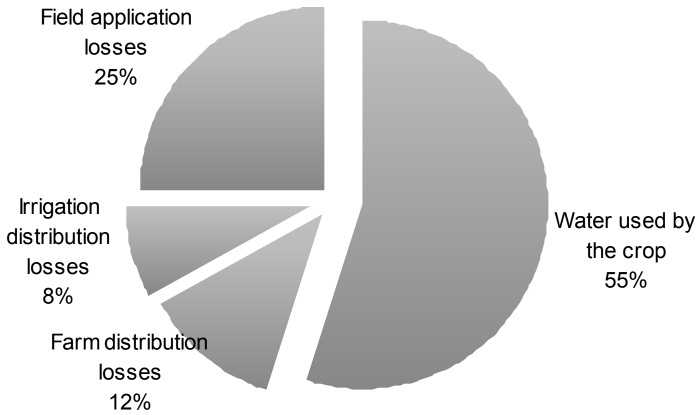

Figure 1. Water losses in agriculture

So, under scarcity conditions considerable effort has been devoted over time to introduce policies aiming to increase water efficiency based on the assertion that more can be achieved with less water through better management. Better management usually refers to improvement of allocative and/or irrigation water efficiency. The former is closely related to adequate pricing, while the latter depends on the type of irrigation technology, environmental conditions and the scheduling of water application. It is well known that crop yield increases with water availability in the root zone, until 'saturation level', above which there is little effect (Hillel, 1997). The yield response curve (Fig. 2) of specific crops depends on various factors, such as weather conditions and soil type as well as the agricultural inputs like fertilizers and pesticides. Therefore it is difficult for a farmer to tell at any given moment whether there is a water deficit or not. Since overabundant water usually does not cause harm, farmers tend to 'play safe' and increase irrigation water amount, especially when associated costs are low.

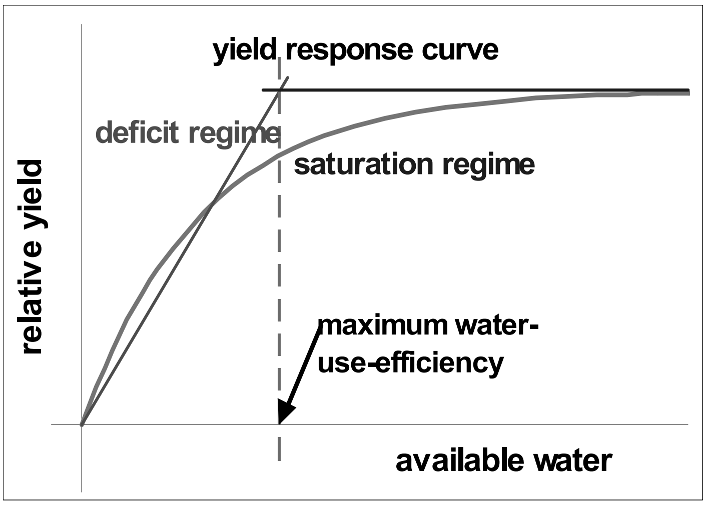

Figure 2: Plant yield response to water

Specialists on water resources in Mediterranean are becoming more and more convinced that growing scarcity and misuse of water in agriculture, which accounts for up to 80 % of the water consumption, are the major threats not only for sustainable agricultural development, but also to the other water use sectors. The situation has worsened during the last decades due to occurrence of occasional droughts, the explosive urban growth and the water quality degradation. In Mediterranean islands, due to technical and financial constrains of transporting water from the mainland, the situation is even worse. In most countries the percentage of agricultural contribution to GDP has been declining over the past decades, reflecting the relative decrease in importance of agriculture, in comparison to other economic sectors. Although contribution of agriculture in the GDP is low, ranging from 13 % in Crete to 1.5 % in Mallorca, agricultural water use is an essential element not only for crop production but also for the environment and tourism industry.

The overall objective of this paper is to describe briefly the existing situation and problems of water management in relation to agricultural practices in Mediterranean islands, as well as to propose irrigation and agricultural practices that should be applied in order to secure the availability of water, improve water efficiency and protect the environment.

2. WATER RESOURCES AND AGRICULTURE

2.1 Water resources and irrigation

The total available water resources in Mediterranean islands participating in MEDIS project are shown in Table 1. Agriculture is by far the main user, consuming more than 50 % of available water resources (Fig. 3), ranging from 55 % in Corsica up to 82 % in Crete. It is also the least efficient sector in water use, since irrigation efficiency is estimated at only 55 %. Agriculture creates pressures on water resources through direct abstraction for agricultural uses such as irrigation and watering of livestock and by potentially polluting activities such as the over-use of fertilizers and pesticides.

Groundwater is the main source of irrigation water in the islands except Corsica, where 79 per cent of the irrigation water comes from surface reservoirs. Treated wastewater, although a valuable irrigation water resource is only scarcely used. Cyprus is the only island where the contribution of treated wastewater for irrigation is 1 %. In Mallorca treated wastewater is used for the irrigation of golf courses, which is not considered as irrigated agriculture. However, the reuse for irrigation of effluent of existing treatment plants may increase the irrigated areas in the islands; for example, in Crete irrigated area could be increased by 5.3 % (Tsagarakis et al., 2001). The high cost of desalinated water limits its use for irrigation.

Table 1. Total water used (Mm3) and origin of the water

	Total water used (Mm^3)	Origin of water (% of the used)			
		Groundwater	Surface water	Recycled water	Desali nated water
Corsica	86	21	79	-	-
Crete	372	93	7	-	-
Cyprus	266	46	38	1	15
Mallorca	246	90	3	7	-
Sicily	1875	78	21	-	1

In Crete the main source of irrigation water is groundwater, with 87 % of the total water used coming from sub-terranean sources. In Cyprus the main source of irrigation water is groundwater

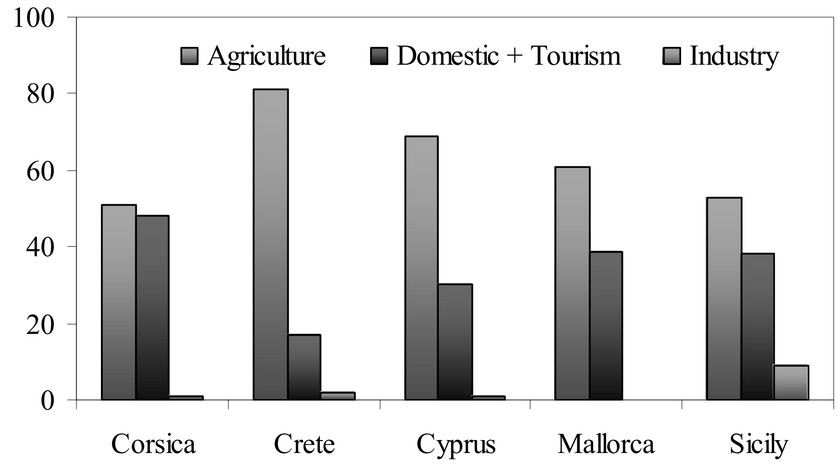

Figure 3: Water allocation among the different sectors in the islands

with 55 % of water used for agriculture coming from groundwater, 44 % from surface water and 1 % from recycled water. In Mallorca 91 % of the irrigation water for agricultural production comes from groundwater sources whilst urban treated wastewater (9%) is used mainly for the irrigation of golf courses and city parks. In Sicily the origin of irrigation water is mostly groundwater (68 %) whereas in Corsica, all the irrigation water comes from surface waters.

2.2 Agriculture and crops

The area used for agriculture varies a lot among the islands, ranging from 16 per cent in Cyprus up to 47 % in Sicily (Fig. 4). In most of the islands there is a slight trend in reducing agricultural land; in Crete agricultural land was reduced by 7 % in the period 1961 - 2001 whereas the reduction in Cyprus was 1 % in the period 1995 - 2000 (MEDIS - Agricultural Report). In Sicily, even though agriculture contributes only by 6 % in GDP, almost half of the island area is used for agriculture. In Mallorca and Crete the percentage of the agricultural land is also high (more than 35 %) whereas in Corsica and Cyprus it is below 20 %.

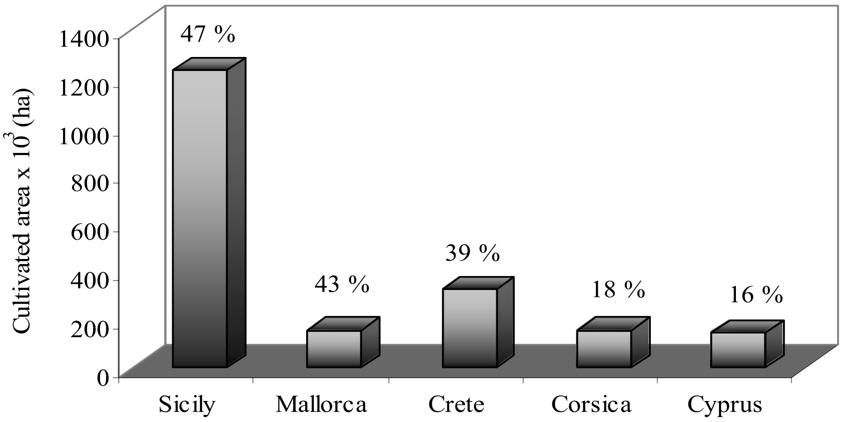

Figure 4: Area used for agriculture in Mediterranean islands

.Although the crops grown in Mediterranean islands are mainly the same due to similar climatic conditions, there are significant differences in the importance of each crop among the islands. Tree crops are the main group of crops in Crete and Cyprus, while row crops dominate in Sicily, Mallorca and Corsica. Tree crops include citrus, olives, fruits with shell (nuts, almonds, etc,), kiwi, cherries and other, while row crops include grain cereals, edible pulse, fodder crop and seeds and industrial plants.

From the tree crops, olives occupy 60 % of the total cultivated area in Crete, while citrus is the dominant tree crop for Sicily and Cyprus occupying 41.65 and 20 % of the total cultivated area respectively. In Cyprus vegetable crops like tomatoes, potatoes, melons and other are very important, covering more than 40 % of the agricultural land. From row crops, grain cereals occupy 38.8 % of the total cultivated area in Mallorca, wheat occupies 40.5 % in Sicily while fodder crops (corn, lucerne) occupy 67 % in Corsica. Grapevines are an important crop in Corsica, covering more than 30 % of the agricultural land, while their cultivation in Sicily and Crete cover 22.8 and 9.6 % respectively.

The demand for irrigation water is high in all islands even though only a small percentage of agricultural land is irrigated (ranging from 8.8% in Mallorca, 14,3% in Corsica, 17,6% in Sicily, 25.0% in Cyprus up to 33.4 % in Crete). Although Mallorca has the lower percentage of irrigated agriculture (8.8 %), the water allocated to agriculture is more than 60% of the total water consumption, indicating that the cultivated crops (mainly row crops) are high water demanding crops.

In Crete 91 % of vegetables, 34 % of row crops, 36.3 % of fruit trees and 45 % of grapevines are irrigated. There has been an increase of more than 30 % in the irrigated area during the last thirty years in the island. From the fruit trees olives occupy the largest percentage (68 %) of the irrigated area.

In Cyprus tree crops and citrus specifically, consume the highest amount of water (32 %) followed by deciduous crops (apples, peaches, cherries, pears, plums, figs, walnuts, pecan nuts and pomegranates) and olives (11 and 5 % respectively). In Mallorca, the largest part of the irrigated area is occupied by fodder crops (51 %) followed by vegetables (19.7 %). Consequently the biggest water consumers are fodder crops, consuming 60.8 % of the total irrigation water, followed by vegetables (17.5 %), potatoes (9.4 per cent) and citrus trees (8.3 %). In Corsica fruit trees (of which 32.5 % are citrus) occupy the largest part of the irrigated land (53 %) while olives represent 22.8 % of the tree crops. In Sicily irrigated land is occupied by vineyards, olive and citrus trees.

Taking into account the crop water requirements, citrus is the high water demanding crop for Cyprus, Crete and Sicily, followed by fodder crops (lucerne, maize) and vegetables (tomatoes, potatoes and other). It is notable that Colocasia, a local open field vegetable of Cyprus, is extremely water demanding crop, while olive is the less water-demanding crop in Mediterranean islands. Crop water requirements must be taken into consideration in scheduling agricultural reforms and water management policies.

2.3 Irrigation systems and scheduling

Modern irrigation systems have been widely used the last few decades (drip, sprinkler, micro-irrigation) in all islands. Localised (drip or mini-sprinklers) irrigation systems are mainly used for tree crops (olives, citrus and deciduous trees), while sprinkler irrigation is dominant for fodder crops and some vegetables (potatoes in Mallorca and Cyprus). For vegetable and greenhouses crops advanced drip irrigation systems are used in all islands, including fertilizer application through the system. Traditional surface irrigation (furrows, basins, flooding), although still used in some cases, are replaced by modern irrigation systems.

Irrigation scheduling is another aspect of utmost importance for the appropriate irrigation of horticultural crops. It consists of a set of procedures which allow, for a given crop, to find out when and how much to irrigate. Irrigation scheduling methods are based on environmental, physiological and soil parameters. The irrigation scheduling methods based on plant physiological indices (leaf water potential, stomata opening, changes in diameter of selected organs, infrared thermometry, refractometry of the sap, etc.), although show important innovations, involve measurements that are complex, time consuming and difficult to integrate and require highly qualified farmers. Furthermore, the cost of such methods is very high and the majority of the farmers in the Mediterranean islands do not use them at all.

For tree crops irrigation scheduling is mainly empirical, although in some cases is based on meteorological parameters (mainly Class A pan evaporation and Reference evapotranspiration ET_o) provided to farmers by local authorities (Crete, Cyprus) or cooperatives. For vegetables, especially in greenhouses, the monitoring of soil moisture (by tensiometers, gypsum blocks or gravimetrically) is the most common method used for irrigation scheduling, since it assures low cost, simple operation and reliable estimation of soil water status.

2.4 Price of irrigation water

The price of irrigation water varies greatly among the islands due to different pricing structure and policies. Furthermore, water prices vary among different areas in the same island or even among catchments. In Crete, the price of water per cubic meter varies greatly between catchment areas and even within the same catchment area, depending mainly on the managing agency. In publicly developed and operated irrigation projects the price of water does not fully cover operation and maintenance (O&M) or capital replacement costs. So, in the large publicly operated irrigation projects the price of water is as low as 0.07-0.08 € per m^3, whereas in community or municipality operated projects it reaches 0.10 – 0.15 euros and in some private projects it reaches 0.23-0.35 euros. The price of irrigation water in Cyprus is on average 0.10 €/m^3, in Mallorca varies between 0.18-2.4 €/m^3, while in Corsica the average price is 0.50 €/m^3.

2.5 Agricultural practices

Agricultural practices, such as soil management, fertilizer application, disease and pest control are related with the sustainable water management in agriculture and protection of the environment. They not only provide the soil moisture and nutrients necessary for plant growth, but they also contribute to control erosion, soil and groundwater degradation.

The agriculture practiced in Mediterranean islands is characterized by the abuse of fertilizers. Farmers very rarely carry out soil and leaf analyses in order to clarify the proper quantity and type of fertilizer needed for each crop and they apply them empirically. This practice increases considerably the cost of agricultural production and is potentially critical for the deterioration of the groundwater quality and the environment. The fertilizers for tree and row crops are mainly applied by spreading on the soil during winter, while fertigation -the application of the fertilizers through the irrigation system- is practiced mainly for vegetable and greenhouse crops.

Agrochemicals (herbicides and pesticides) are also excessively used, endangering the quality of the surface water and negatively affect the environment. Plant-protection products (pesticides) are often used preventively, even when there is not real in the area. Irrational pesticide use pollutes the environment and put the public health at risk (especially when pesticides are used close to the harvest period).

3. RECOMMENDATIONS

In the forthcoming years, if current trends will not change, agriculture will face two main negative impacts related to water: a) The abandonment of cultivation in the mountainous areas, i.e. the areas where the superficial water regime begins, would increase the actual erosion phenomena, and b) The excessive intensification of agricultural production process, which is always concentrated in the areas structurally equipped and in presence of the irrigation, could reduce soil fertility and increase groundwater pollution. Under these conditions, the proposed policies should support agriculture by a) recognizing the multifunctional role of agriculture (economic, social and environmental), b) taking actions for reforestation and initiatives for rural development, c) adopting the "best agricultural practices" (including irrigation) in order to reduce the impact of intensive agriculture and d) promoting the quality and safety of agricultural products, through low-impact, biological and/or traditional techniques which contributes to the protection of the natural resources.

Sustainable water management in agriculture has the basic goal of matching water availability and water needs in quantity and quality, in space and time, at reasonable cost and with acceptable environmental impact. The adoption of sustainable water management in Mediterranean islands is not only a technological problem but involves many other considerations relative to social behaviour of rural communities, the economic constrains, or the legal and institutional framework that may favour the adoption of some measures and not other. The implementation of a sustainable water management program in agriculture for achieving the above mentioned goal requires developments in the following sectors.

3.1 Adoption of best irrigation practices

In most Mediterranean islands irrigation efficiency can be maximized by adoption of the best irrigation practices by farmers or water authorities. Such practices include:

Reduction of water losses. Water leakages in the conveyance, distribution and application networks should be detected via advanced technologies, e.g. telemetry systems, GIS, remote sensing. Old water projects experiencing considerable water losses should be rehabilitated and modernized.

*Improvement of irrigation system efficiency***.** Improvements in surface irrigation methods include land levelling and reduced widths and/or shorten lengths. For the on farm water distribution use gated pipes and lay flat pipes, buried pipes for basin and borders, lined–on farm distribution canals, good construction of on-farm earth canals, easier control of discharges and control of seepage. Improvements in sprinkler irrigation systems include the adoption or correction of sprinkler spacing, the design for pressure variation not exceeding 20 % of the average sprinkler pressure, the use of pressure regulators in sloping fields, the monitoring and adjustment pressure equipment, application of irrigation during no windy periods, adoption of smaller spacing and large sprinkler drops and application rates in windy areas, the adoption of application rates smaller than the infiltration rate of the soil and careful system maintenance. Improvements in localized irrigation systems aiming to reduce the volumes of water applied and increase the water productivity, include the use of a single drip line for a double row crop, the use of micro-sprayers in high infiltration soils, the adjustment of the duration of water application and timing to soil and crop characteristics, the control of pressure and discharge variations, the use of appropriate filters to the water quality and the emitter characteristics used, the adoption of careful maintenance and automation.

Increase water use efficiency. Can be achieved with the obligatory use of localised irrigation systems by the farmers (with or without subsidies), the establishment of a system for advising farmers for irrigation and the proper irrigation scheduling. Irrigation scheduling requires knowledge on a) the crop water requirements and yield response to water, b) the constrains to each irrigation method and irrigation equipment, c) the crop sensitivity to salinity when water of inferior quality is used, d) the limitations relative to water supply system and e) the financial and economic implications of irrigation practice.

Adoption of innovative irrigation techniques. In water scarce regions irrigation approaches not necessarily based on full crop water requirements like regulated deficit irrigation (RDI) or partial root drying (PRD) must be adopted. Fertigation (efficient fertilizer application) and chemigation (easy control of weeds and soil born diseases) should also be promoted. Regulated deficit irrigation (RDI) is an optimizing strategy under which crops are allowed to sustain some degree of water deficit and yield reduction. During regulated deficit irrigation the crop is exposed to certain level of water stress either during a particular period or throughout the growing season. The main objective of RDI is to increase water use efficiency (WUE) of the crop by eliminating irrigations that have little impact on yield, and to improve control of vegetative growth (improve fruit size and quality.) The application of fertilizers through the irrigation system (fertigation) became a common practice in modern irrigated agriculture. Localized irrigation systems, which could be highly efficient for water application, are also suitable for fertigation. Thus, the soluble fertilizers at concentrations required by crops are applied through the irrigation system to the wetted volume of the soil. The potential advantages of fertigation are the precise amount of fertilizer at the root system of the crop, the optimum conditions for the use of fertilizer by the crop, the high fertilization efficiency, the flexibility in timing of fertilizer application in relation to crop demand, the environmental friendly method of fertilization (control of nutrient losses) and the increased yield and improved quality of the products.

3.2 Adoption of best soil and crop management practices

There is a large variety of traditional and modern soil and crop management practices for water conservation (runoff control, improvement of soil infiltration rate, increase of soil water capacity, control of soil water evaporation) and erosion control in agriculture, some of which are also applied for weed control (Pereira *et al*, 2002). Effort should be made in the rational use of chemicals for pest and weed control in order to avoid further pollution of the environment.

3.2.1 Soil management

Soil surface tillage, which concerns shallow tillage practices to produce an increased roughness on the soil surface permitting short time storage in small depressions of the rainfall in excess to infiltration.

Contour tillage, where soil cultivation is made along the land contour and the soil is left with small furrows and ridges that prevent runoff. This technique is also effective to control erosion and may be applied to row crops and small grains provided that field slopes are low.

Bed surface profile, which concerns cultivation of wide beds and is typically used for horticultural row crops.

Conservation tillage, including no-tillage and reduced tillage, where residuals of the previous crop are kept on the soil at planting. Mulches protect the soil from direct impact of raindrops, thus controlling crusting and sealing processes. Conservation tillage helps to maintain high levels of organic matter in the soil thus it is highly effective in improving soil infiltration and controlling erosion.

Mulching with crop residues on soil surface which shades the soil, slows water overland flow, improves infiltration conditions, reduces evaporation losses and also contributes to control of weeds and therefore of non-beneficial water use.

Increasing or maintaining the amount of organic matter in the upper soil layers because organic matter provides for better soil aggregation, reduced crusting or sealing on soil surface and increased water retention capacity of the soil.

Addition of fine material or hydrophilic chemicals to sand/coarse soils. This technique increases the water retention capacity of the soil and controls deep percolation. Thus, water availability in soils with low water holding capacity is increased.

Control of acidity by liming, similarly to gypsum application to soils with high pH. This treatment favours more intensive and deep rooting, better crop development and contributes to improved soil aggregation, thus producing some increase in soil water availability.

Adoption of appropriate weed control techniques to alleviate competition for water and transpiration losses by weeds.

3.2.2 Crop management

Several techniques have been designed to minimize the risks of crop failure and to increase the chances for beneficial crop yield using the available rainfall, such as:

Selection of crop patterns taking into consideration the seasonal rainfall availability and the water productivity of the crops and crop varieties.

Adoption of water stress resistant crop varieties instead of high productive but more sensitive ones

Use of short cycle crops or varieties reduces the overall crop water requirements.

Rational use of fertilizers. Fertilizers (type and amount should be applied according to crop needs (based on leaf and soil analysis). Use of slow-release fertilizers if possible, is desirable. *Reducing the fertilizer rates* when a low yield potential is predicted; this not only reduces costs but also minimizes the effects of salt concentration in the soil.

3.3 Water pricing.

Although Mediterranean islands have to follow the WFD (2000/60) of EU, the most important recommendation we can make at present is that irrigation water tariffs must cover the O&M cost of water use and services. For proper water pricing volumetric water metering and accounting procedures are recommended. Progressive, seasonal and over-consumption water tariffs, as well as temporary drought surcharge rates contribute to water saving and should be promoted. Furthermore, an increasing block tariff charging system, that discourages water use levels exceeding crop's critical water requirements, must me established. It will be the basis for promoting conservation, reducing losses and mobilizing resources. Furthermore, it could affect cropping patterns, income distribution, efficiency of water management, and generation of additional revenue, which could be used to operate and maintain water projects.

3.4 Reuse of marginal waters (reclaimed or brackish) for irrigation.

Reclaimed waters can be used under some restriction for irrigation of tree, row and fodder crops. In addition to water, they provide the soil with nutrients, minimizing the inorganic fertilizer application. Usage of treated sewage is dealt with scepticism by the farmers. They instead prefer to use surface and/or groundwater. Special effort should be given in educating farmers to accept treated sewage. In addition, the tariff for this source of water should be lower than the tariff of the primary sources. This may not be difficult to achieve because the primary and secondary levels of treatment are regarded as sunk costs since they are required by the new WFD. When using low quality water, for example brackish or saline water, an integrated approach for water, crop (salt tolerant varieties), field management (suitable tillage) and irrigation system (adequate leaching, suitable devices) should be considered.

3.5 Wider and more effective participation of farmers in water management.

Participation of farmers in the preparation of the plans, in decision-making, in monitoring the implementation and generally in the operation and management of irrigation schemes has proven very beneficial in improving irrigation efficiency in many parts of the world.

The participation of farmers in the above processes safeguards the acceptability of the plans by the general public, raises support on the part of the body politics and promotes success in possible conflict resolutions.

3.6 Strengthening capacity

The goal of agricultural water demand management in Mediterranean islands cannot be achieved without strengthening the capacity of the irrigation sector to improve the efficiency of institutions in charge of irrigation and to upgrade the scientific and technical knowledge of staff involved. . It includes:

Education and training of professional, technical staff and decision makers and others, including farmers, on a wide range of subjects related to sustainable agricultural water management.

Manpower build up. Institutions to be staffed with qualified manpower (managers, engineers, technicians, social scientists) that should be adequately compensated.

Facilities and procedures. Water authorities at all levels of management should be equipped with technologically advanced devices and programs e.g. computers and software for the application of new techniques such as GIS, remote sensing etc. These advanced techniques facilitate the multi-sectorial information availability and use and help water managers in their decision- making.

Legislative changes to the fragmented and antiquated legislation should be promoted. The changes should be conducive to water directive WFD60/2000.

4. CONCLUDING REMARKS

Agriculture is by far the main water user in Mediterranean islands ranging from 55 % in Corsica up to 82 % in Crete. In all islands water for agriculture comes mainly from groundwater sources, while only in Corsica surface water is the main source of irrigation water. Treated wastewater, although being a valuable irrigation water resource, contributes to irrigation in very low ratio (1 % in Cyprus and 7 % in Mallorca). Although modern irrigation systems are used in most cases, the efficiency of irrigation is still low (55 %).

Socio-economic pressures and climate change impose restrictions to water allocated to agriculture. The adoption of sustainable water management in Mediterranean islands is not only a technological problem but involves many other considerations relative to social behaviour of rural communities, the economic constrains, or the legal and institutional framework that may favour the adoption of some measures and not others. Sustainable water management in agriculture, which has a multi-functional role in Mediterranean islands, can be achieved by adopting improvements in irrigation application, soil and plant practices, water pricing, reuse of treated wastewater, farmers' participation in water management and capacity building.

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Freshwater Management in Flanders, Belgium

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ABSTRACT

The rivers Scheldt and Meuse are the main water bodies of the major basin districts in Flanders, Belgium. Both have international dimensions having their origin in France and flowing into the North-Sea in the Netherlands. Therefore, an important part of the water supply in Flanders depends on upstream water management. The catchments are linked by a network of channels, supplying the Scheldt Estuary with a considerable amount of Meuse water. Links also exist between several subcatchmens of the river Scheldt.

A balanced internal water management implies among other an efficient set of measures (permanent and operational), necessary for interventions during low flows. In order to substantiate the choice of strategy, knowledge of the quantitative aspects of supply (water balance), demand (users and consumers) and potential measures is necessary.

These aspects should be translated into a concrete, practical, acceptable low flow strategy. Therefore a methodology was developed combining quantitative (water balance), economical and social aspects.

Key words: low flow strategy, social acceptance, cost-benefit analysis, Flanders

1. INTRODUCTION

The majority of the Flemish territory (about 80%) lies within the catchments of its two main rivers: the rivers Scheldt and Meuse. They both originate in France and have their mouth in the North Sea in the Netherlands. Within and between the catchments a vast network of canals was excavated to improve navigation and to provide water for industry and irrigation in remote areas. This implies that water is diverted from its natural course, decreasing the amount of water available for downstream users. Nowadays the mitigating measures taken during periods of water shortage are intuitive and based on the expertise of the local water authorities. The exact the impact on all water users is not known. To act with more precision and knowledge about the possible effects of mitigating measures, a universal methodology for low flow strategies was developed [Van Rompaey et al., 2004a & b].

In Flanders, the methodology is actually being applied on two water systems: one in the East, the Albert Canal and the canals of the Campines, and one in the West, the rivers Scheldt and Leie and the canals around Ghent (Figure 1).

The Eastern canal system diverts water from the river Meuse (downstream of Liege) towards the port of Antwerp (Scheldt basin). The river Meuse flows further towards Maastricht (NL) where it also feeds a Dutch canal system. Downstream Maastricht, the river Meuse forms the border between Flanders and the Netherlands over a distance of 46km (this part of the river is called "the Common Meuse"). During periods of low discharges (<100m³/s upstream the diversion at Liege), the distribution of Meuse water is regulated as described in the international treaty between the Flemish Region and the Netherlands [Anonymous, 1995]. This regulation implies restrictions in water availability and caused the creation of a first low flow strategy.

The canals around Ghent are fed by the river Scheldt and its tributary the river Leie. Both rivers are dammed and straightened to improve navigation between Ghent and northern France. To protect the city of Ghent from flooding, two canals were dug, one to divert the major part of the water from the river Leie towards the port of Sea Bruges and one circular canal around Ghent that controls the water flow into the city of Ghent. Both rivers flow into this canal. Furthermore, there is the canal between Ghent and Oostende that finds its origin in the circular canal around Ghent and crosses the diversion canal of the Leie. The canal between Ghent and Terneuzen (NL), connecting the port of Ghent with the Western Scheldt, is the last canal of the system. It is connected to the circular canal around Ghent to guarantee navigation from the Netherlands towards the rivers Leie and Scheldt. Also this canal system is influenced by an international treaty between the Flemish Region and the Netherlands [Anonymous, 1960 and 1985]. It states that a minimum flow of 13m³/s of fresh water averaged over two months should be guaranteed by the (Flemish) authorities to avoid salt intrusion at Terneuzen.

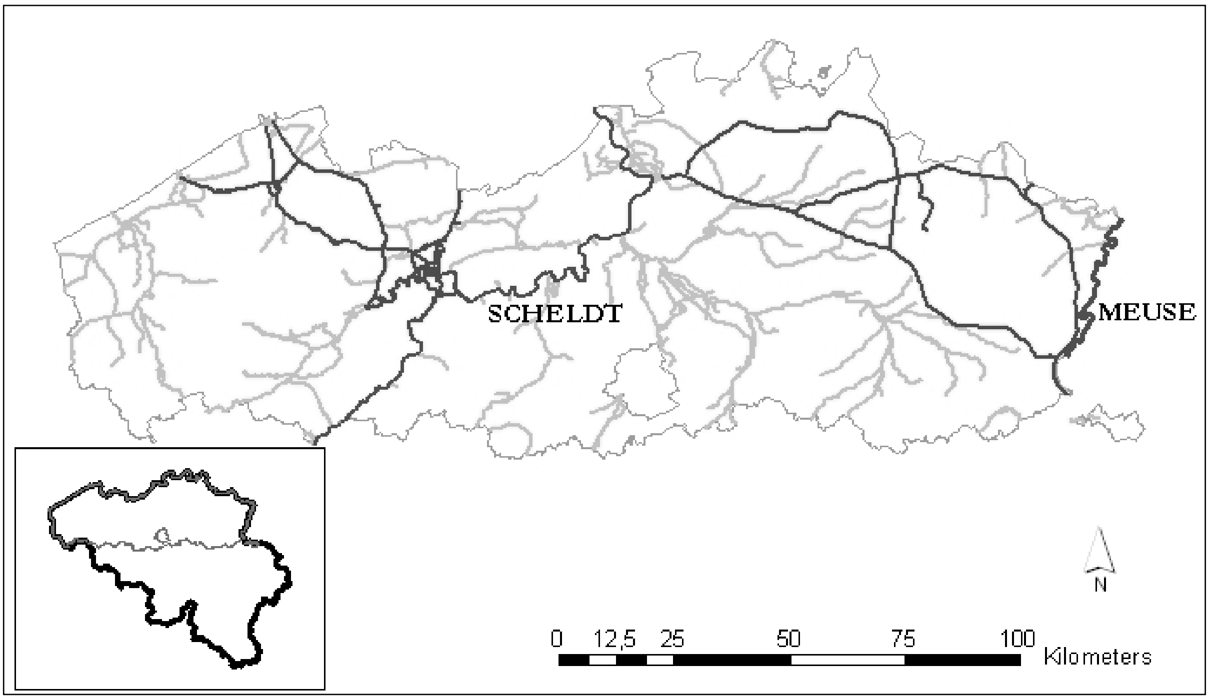

Figure 1 Location of the canal systems in Flanders.

2. THE LOW FLOW METHODOLOGY

The methodology's objective is to create low flow strategies that minimise water shortages during periods of low flow. The aim is to create a minimum of negative effects for the users and maximal acceptance by the users. Applying a methodology satisfying this overall aim leads to an effective (expressed by the gain in discharge (m^3/s) or the rise in water level (m)) and socially accepted (expressed by the number of users for whom negative effects were avoided) low flow strategy (Figure 2). The latter criterion is derived from the results of the problem analysis.

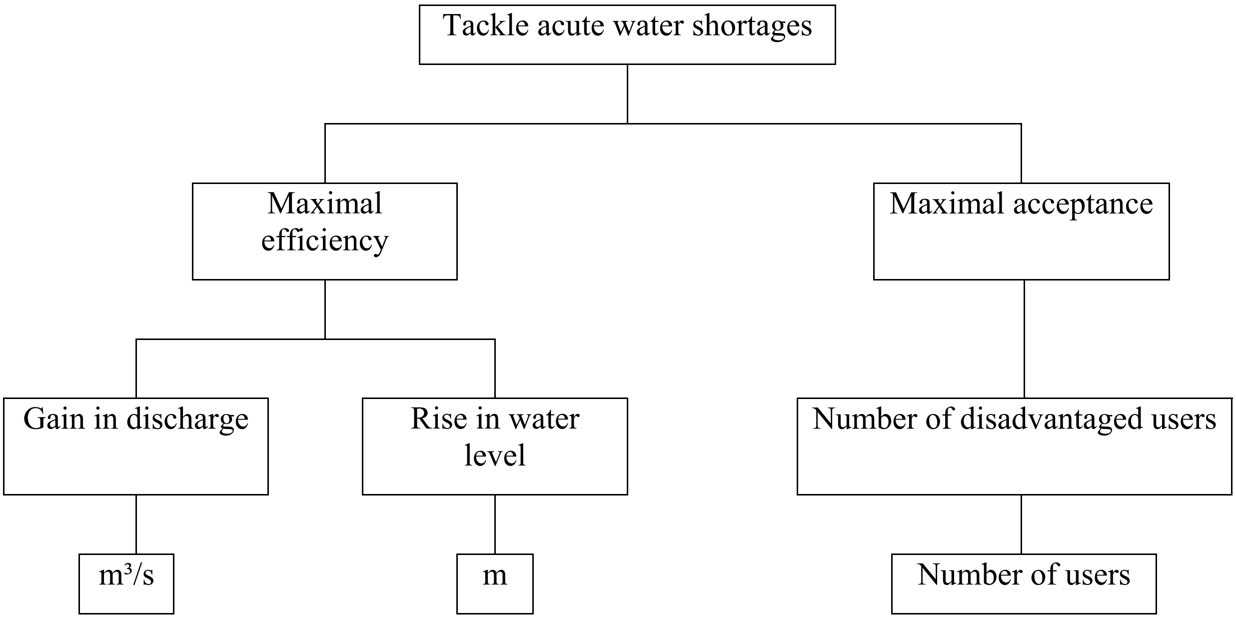

Figure 2: Objective-criteria tree [Resource Analysis at al., 2004a]

The problem analysis is actually the primary step in the methodology: It presents an overview of the problem of acute water shortages. It starts with a preliminary orienting literature research on the water system and –chain of the study area. Besides the enumeration of the involved actors and stakeholders, this survey or inventory will provide insight in all water fluxes of the water system (natural fluxes) and the water chain (anthropogenic fluxes). Moreover possible gaps in the knowledge will become clear [Baetens and Van Eerdenbrugh, 2003]. These gaps can be filled by contacting the stakeholders and actors via bilateral interviews (to become acquainted with their point of view and attitude towards low flow problems) and/or by inquiries (to collect specific, technical information). This way, the water authority can realise a specific strategy adapted to the local needs and strengthens the involvement of the contacted parties. Both, stakeholders and actors, are involved in the water system through their activities and functions. Actors are allowed to decide which measures are to be taken, stakeholders are not, but they experience the consequences. After processing the information it should be clear which parties are involved and what their needs and demands are with regard to the low flow problems.

Based on the inventory and the discussions with the involved parties several sets of potential measures for periods of water shortage can be identified. Each set is related with and has consequences for the user and their functions with regard to the water system, e.g. 1) Grouped navigation through a sluice realises water savings but will increase the waiting time for the ships in front of the locks or 2) no longer maintaining the water level on canals or dammed up rivers will have consequences for navigation and industry relying on cooling water (temperature problems).

To evaluate the selected sets of measures, these will be examined in three ways: a study of the social acceptance of the measures, a water balance analysis and a cost-benefit analysis.

By analysing the social acceptance of the identified measures, the measures should be divided into two groups: those measures with little negative and possible tempering effects and measures with non-tempering effects.

The outcome of the inventory and the social acceptance analysis will be used as input for the water balance analysis. By means of a conceptual river network model it is possible to estimate the effectiveness of the measures to tackle the critical water shortages.

A third way to evaluate the possible measures is a cost-benefit analysis; it compares the advantages and disadvantages of different measures expressed in a general unit (currency). A cost-benefit analysis is executed according to the following steps [Van Rompaey et al., 2004b]: 1) definition of the zero-strategy (the strategy where no exceptional measures are undertaken to maintain water levels and discharges) and of the selected measures, 2) identification of the effects (financial, direct, indirect and external effects) due to the implemented measures, 3) expressing the effects monetarily, 4) actualise the costs and benefits and 5) comparing the costs and benefits. In reality it will be hard to achieve a detailed result as impacts on environment, nature, recreation, agriculture, etc. are at times difficult to estimate. Statistical data, prices and cost structures on these topics are not yet available. Therefore the methodology advises to work conceptually and to concentrate on the principles of the cost-benefit analysis by using the relevant effects of which useful data are available.

Furthermore it's important to also examine the technical feasibility of the measures. The acceptance by the involved parties will after all be highly dependent on how they assess the technical and organisational feasibility.

Applying the phases of the methodology described above (the problem analysis, defining the objectives, the identification and analysis of the selected measures and the analysis of the technical feasibility) only makes sense if the selected measures aren't contradictory to the appropriate legal conditions and any policy decisions. Special attention should be paid to those measures that can possibly interfere with the flood management.

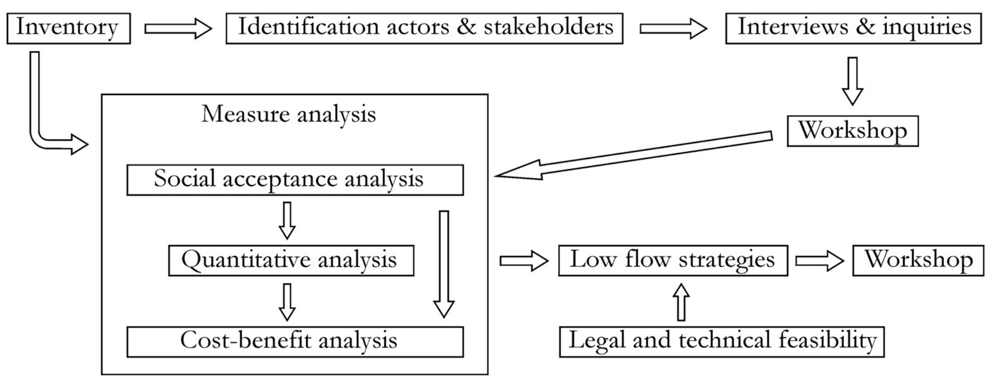

Figure 3: Schematic synthesis of the low-flow methodology.

Implementing this methodology will lead to a set of strategies that will mitigate the impact of water shortage. Passing through the different phases of the methodology it will become clear that efficient communication with the actors and stakeholders is absolutely necessary. Therefore 2 workshops should be organised.

The first should take place after all information gathered during the interviews and inquiries with the users is processed. At that time the users will have the opportunity to change or correct their opinions. Hereby it is assured that the interviews and inquiries are understood by all parties and interpreted correctly. At the same time those stakeholders attending the workshop will be confronted with the problems others are facing.

During the final workshop the users will be confronted with the selected low flow strategies. This workshop will actually show the results of the entire process of the development of the strategies and should lead to the acceptance of the proposed low flow strategies and communication strategy describing how to inform the different parties involved. This workshop is the final part of the process leading to efficient and social accepted low flow strategies.

3. PROVISIONAL RESULTS

Due to the different needs and priorities of the respective water authorities, the methodology will be applied in more detail for the Eastern canal system leading to effective low flow strategies applicable in real circumstances. For the Western canal system, on the other hand, the methodology will be applied on a more general scale since it will be used as a sensitising tool towards the water users.

Although their physical environment is completely different, the inventory of both systems contains the same build-up [Michielsen et al., 2004a, b; Baetens et al., 2004 & 2005]. It is an extended enumeration and discussion of the water system properties (such as hydrology, topography, (hydro-)geology, soil) and the water chain properties (such as structures, groundwater and surface water withdrawals, wastewater, land use, water users – navigation, industry, water supply, agriculture, nature, recreation). Up to now, the Eastern canal system and the Common Meuse and the supplying rivers (Rivers Leie and Scheldt) of the Western canal system have been inventoried completely. By the end of 2005 the inventories of the remaining Western canals should be finished.

The remaining gaps in the knowledge after inventorying the research areas will be the core subjects of the interviews and inquiries with the water users and the authorities. Besides gaining additional (technical) information it's important to awake interest in - and awareness of - the possible water shortage problems. Crucial information like the user's opinion towards potential measures as well as their financial consequences need to be understood in order to make the social acceptance analysis and to estimate their additional cost and/or benefits due to the implementation of the measures.

During the development of the methodology a general actor analysis was made. The actors' regional representatives were contacted and interviewed on a more generic level. The consulted actors included the electricity producers; the different Flemish administrations responsible for surface water, groundwater and nature; the drinking water producers; the Flemish Economical Union; the Agricultural Union; the provinces and polder boards. Out of these sessions an extended series of possible measures to mitigate the impact of acute water shortages were collected. To give feedback, a workshop was organised with these and other actors to obtain more information concerning the impacts these measures have on the different functions that are granted to the water system.

All the information gathered from the inventories and the interviews will lead to a 3-way analysis: a social acceptance analysis, a quantitative analysis and a cost-benefit analysis. The social acceptance- and cost-benefit analyses have not been conducted yet. The interviews with the water users are planned to take place halfway 2005, the cost benefit analysis is planned for spring 2006.

The research of the quantitative aspects of both canal systems is in progress and consists of a modelling phase and a statistical phase.

The objective of the statistical analysis is to create Quantity-Duration-Frequency (QDF) relations and low flow composite hydrograms for several return periods. This happens by applying an extreme-value-analysis according to the methodology developed by Van Rompaey et al. [2004b]. QDF relations describe the average discharge (quantity) as a function of the length of the low flow period (duration) and the return period (frequency). Figure 4 shows an example of such relationships for the river Leie at Menen, Flanders. These relations make it possible to extract a low flow composite hydrogram which expresses the synthetic behaviour of the discharge for a low flow period with a specific return period. The statistical analysis is done on measured time series of the most upstream gauging stations. These composite hydrograms can be used as input data for the numeric water balance model. This way the model can test strategies depending on the severity of the boundary conditions.

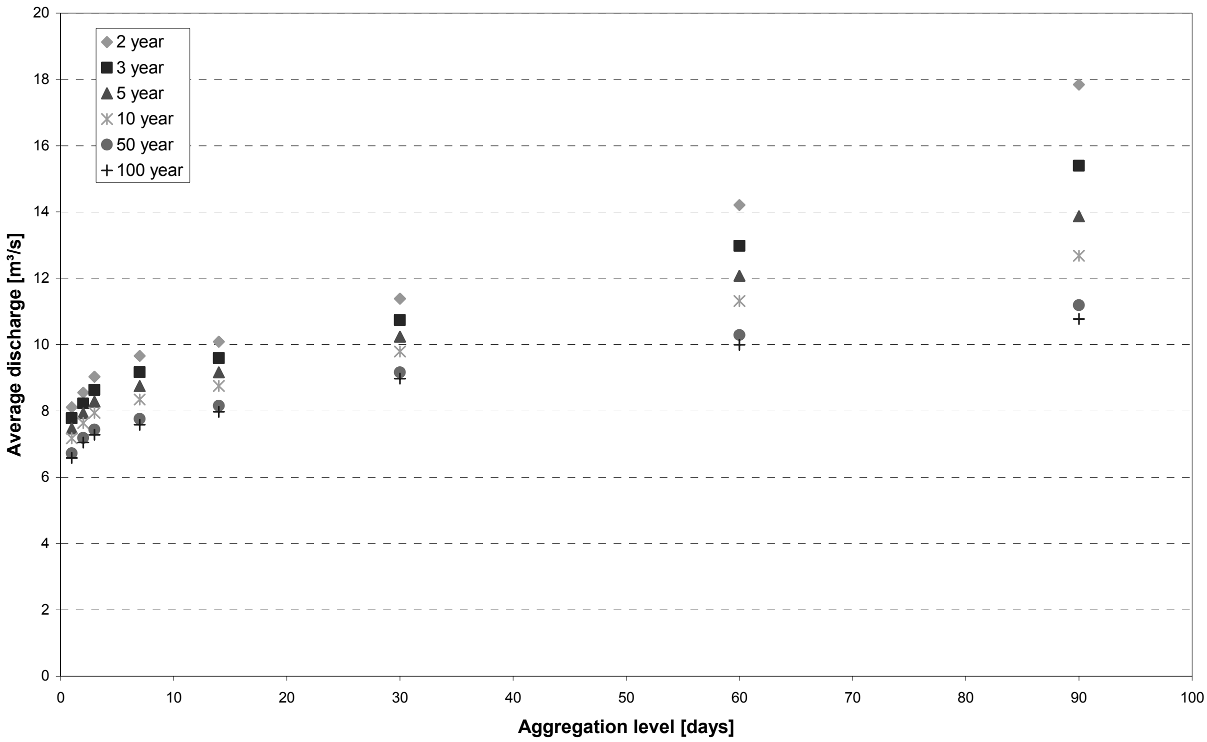

Figure 4 QDF-relations of the discharge minima of the discharge series of the river Leie at Menen.

MikeBasin [DHI, 2004] is used to create a water balance model of the canal systems. It allows to express the canals as a network of branches and nodes (regular nodes, diversion nodes or off take nodes). Water can be supplied to or extracted from the river/canal at a certain location, or it can be extracted at one point and supplied at another point. (Figure 5)

Using the model, some abstractions should be made. Canal systems aren't free flowing rivers, therefore each section is defined as a reservoir with its own reservoir regulation. The canal sections are connected by means of combined users extracting water from the upstream branch and supplying it to the downstream section. This way the water fluxes due to sluice operations (shipping movement and water balance regulation) are modelled. Figure 5 (inset) gives an illustration of a diversion of one canal branch into three downstream branches. To model this, three (yellow) users are inserted to extract water and to deliver it to the downstream branches.

Since water flow in a canal system is dependent on human-driven withdrawals from and supplies to the system, flow is only simulated by calculating the overall water requirement of the system. Therefore an external programme was developed that computes the water requirement of each canal section at each time step. Under normal flow conditions, the programme uses simple water balance equations of the canal sections to compute the overall water requirement of the canal system as a whole. This required amount of water is, in MikeBasin, extracted from the source (in this case the river Meuse). During periods of water shortage, the low flow treaty between Flanders and the Netherlands that describes the distribution of the Meuse water is enabled and low flow strategies must be executed. The effectiveness of the strategies for this canal system can be tested in three ways: 1) do they meet the low flow treaty (reducing the water requirements of the system), 2) are they socially accepted and 3) what are the extra costs that the users meet? To test the potential strategies with the MikeBasin model, the priorities granted to the users should be changed. This makes it possible to save water at the level of each user individually.

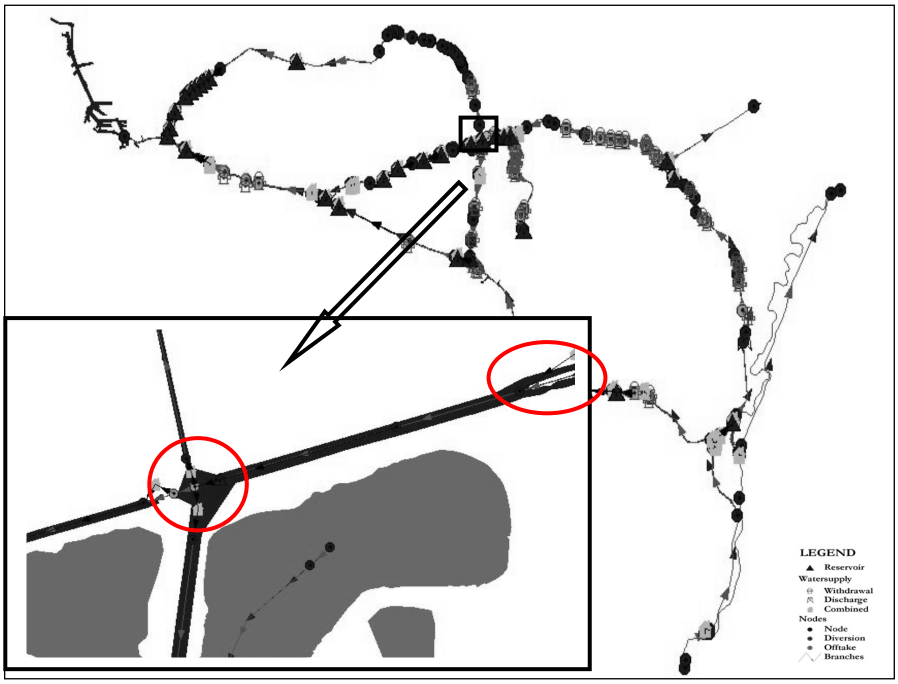

Figure 5: The Eastern canal system as it is constructed in MIKEBASIN with a detailed view of the crossing between two canals (left) and the representation of a lock (right).

In order to obtain realistic strategies the quantitative and economical effects on the navigation should be known as well. A mitigating measure that will harm navigation will be the longer waiting time at the sluices in order to realise grouped navigation, minimising the water use for sluice-filling.

Navigational uses will be determined separately from MikeBasin and implemented in the model as a combined (withdrawal and discharge) user as shown on the right of Figure 5.

The complete set of measurement analyses are expected to be finished in spring 2006 for both canal systems.

4. PROSPECTS

For each major river in Flanders there is a 1D-hydraulic model that is currently used to simulate flood-mitigating and other measures. Besides these models the flood management plans intend, by means of specific software, to predict floods on all the modelled rivers. This infrastructure will be used to forecast low flows as well. This way it is possible to estimate when the discharge or water level in a river or canal will drop below a critical value assuming it won't rain for a certain period. Especially the local authorities will use these forecasts as they can anticipate and try to avoid severe shortages by carrying out the developed strategies. The research to implement low flow forecasts is currently in progress and will be finished by July 2005.

Presently also a literature review is ongoing on the impact of anthropogenic induced climate change on the hydrology of Flanders. The intention is to use the outcome of the review to examine the impact of climate change on the water balance of the two canal systems and the problems occurring under these possible future conditions.

5. CONCLUSIONS

The intuitive, on experience based approach of tackling acute water shortages as it happens nowadays is not sustainable anymore. The impact of these measures on all stakeholders is unknown which can lead to indignation and agitation. To avoid this, a methodology, suitable for all navigable waterways in Flanders, is developed to create strategies that will minimise the impact of water shortages and that will use the available water in the most effective way. Implementing the methodology will lead to a set of measures that is maximally supported by the parties involved and of which the water quantitative and financial effects are known. By allowing the actors and stakeholders to participate during the process of strategy development, a platform is created where they can have an open communication and where they are confronted with each others problems which will make future cooperation much easier.

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Water Management Strategies for Cyprus

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ABSTRACT

Sustainable water resource management has become a critical issue for the development of areas where renewable freshwater resources are highly constrained. A new methodological approach has been developed for the formulation of integrated water management strategies in order to mitigate the water stress problems and was applied to Limassol region of Cyprus. The method endeavors the principles of the Integrated Water Resources Management together with the provisions of the EU Water Framework Directive. The Limassol region was studied extensively with respect to formulating integrated water management strategies in order to meet the growing demand for water exerted by the permanent and seasonal population without affecting detrimentally the traditional agricultural demand while at the same time ensuring the stability of supply and maintaining the groundwater exploitation to sustainable levels achieving the environmental protection of the aquifers of the region. Two different strategies were formulated resulting from a tentative timeframe of water management options combination including hard (structural) and soft (non-structural) measures, with the main goal of mitigating the water shortages identified in the region.

Key words: Limassol, Water Resources, Decision Support System, Sustainable Management, Water Strategies

1. INTRODUCTION

Cyprus is an arid to semi arid island state situated in the northeastern Mediterranean. In the Mediterranean region the water resources are becoming scarce in quantity and quality (Hamdy, etal. 1994). Consequently in the island of Cyprus the renewable freshwater resources are highly constrained. These are characterized by a strong spatial and temporal scarcity caused by the seasonal distribution of precipitation, and the topography.

Although a large number of various water supply investments and interventions have been made, such as surface water dams, groundwater exploitation, inter-basin water transfers, desalination and reuse of tertiary treated effluent, Cyprus is still a long way from reconciling the demand to the availability of water. Competing demand and the dynamic competitive tension between different water user groups (agriculture, urban growth including tourism, industry, animal breeding) and the protection of the environment are challenging the existing water management practices in the island.

A useful tool to satisfy the water needs is the application of the principle of Integrated Water Resources Management which involves the co-ordinated planning and management of land, water, and other environmental resources for their equitable, efficient and sustainable use (Prinz, 1999).

This principle dictates that in water stress conditions :

- the most appropriate water management options;
- a suitable strategy to mitigate water shortages identified in the region; and
- the best planning process to reach the goal,

have to be applied in a tentative timeframe.

In this paper a representative region in the island of Cyprus (Limassol region) was studied extensively with respect to formulating integrated water management strategies in order to alleviate and mitigate the water shortages identified in the region. At the same time, the strategies attempt to ensure stability of supply and maintain the groundwater exploitation to sustainable levels achieving thus environmental protection of the local aquifers.

The management options that were developed and analyzed to combat water stress conditions in Limassol area, resulted from a synthesis of the current responses regarding water management, the responses proposed by the stakeholders and the requirements of the Water Framework Directive that can be implemented in this specific area. Environmental, social and economic constraints were included and considered in the approach.

Two strategies were formulated based on the emerging paradigms (STRATEGY A) including already applied and tested measures (hard measures) and shifting paradigms (STRATEGY B) that include options not currently used or accepted including measures that increase the productivity of water (soft measures).

2. THE LIMASSOL REGION

Cyprus has an intense Mediterranean climate with the typical seasonal rhythm strongly marked with respect to temperature, precipitation and weather in general. Hot dry summers from mid-May to mid-September and rainy, rather changeable, winters from November to mid-Match are separated by short autumn and spring seasons. During the last 30 years a considerable reduction of mean annual rainfall has been experienced in the island (Figure 1).

MEAN ANNUAL RAINFALL FOR CYPRUS
(NON-OCCUPIED AREAS)
1987-2002

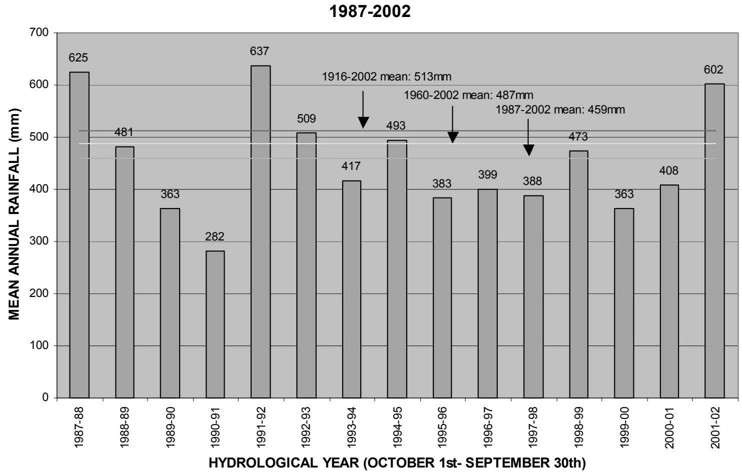


Figure 1. Mean annual rainfall for Cyprus (1987 – 2002)

The objective in the formulation of the scenarios and strategies for the Limassol Region is to meet the growing demand for water exerted by the permanent and seasonal population without affecting detrimentally the traditional agricultural demand which appears to have stabilized. At the same time, the scenarios attempt to ensure stability of supply and maintain the groundwater exploitation to sustainable levels achieving thus environmental protection of the local aquifers.

The Limassol region (Figure 2) is a typical representative study region for the formulation of scenarios and strategies to address the competing and conflicting water uses in the island, since :

- the region is one of the main tourist destinations in Cyprus,
- the agricultural production in the area accounts for more than 25 % of the fruit trees, 6% of the vegetable and 20% of the table grapes production of the country
- the water system of the region is very complicated (Figures 3)

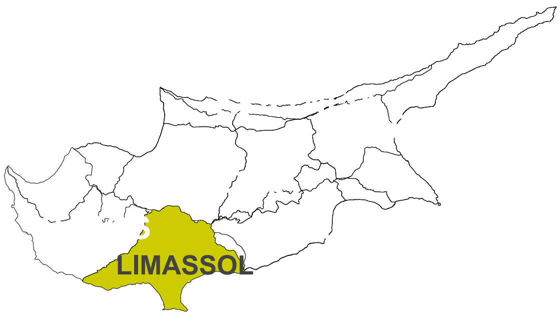


Figure 2:. The selected Limassol region

The domestic consumption of the region accounts for almost 12,8 mi m^3, whilst the domestic water consumption for the tourism (seasonal population) accounts for 3,6 mi m3 in 2000 which is almost 26 % of the island's total seasonal consumption. The domestic consumption is supplied from surface waters after treatment in the Limassol Water Treatment Plant (almost 7,8 mi m^3), and from groundwater -boreholes and springs (almost 8,2 mi m^3). Irrigation water demand in the region accounts for almost 31 mi m^3 from which 24mi m^3 were supplied from the major government irrigation schemes (Figure 3). In addition the annual water demand for animal husbandry in the region accounts for 820.000 m^3 and the industrial demand for 1,5 mi m^3 or 43% of the total industrial demand of the island. Environmental demand in the region accounts for 4 mi m^3 (3 mi m^3 groundwater, 1,5 mi m^3 municipal domestic and 0,5 mi m^3 treated effluent).

The sources of water supply in the region include :

- Surface water stored in the three dams of the region, namely the Kouris Dam (of a total capacity of 115 mi m3), the Polemidhia Dam (of a total capacity of 3,4 mi m^3) and Germasogeia Dam (of a total capacity of 13,5 mi m^3) which is used for domestic and irrigation purposes.
- Certain quantity of the stored surface water resources is treated and used for domestic purposes in the Limassol Water Treatment Plant which has a capacity of 40000 m^3/day with a potential capacity of 80.000 m^3/day. The plant receives raw water from the Kouris Dam and supplies water to the Limassol city, some villages west of Limassol and to the British Bases of Akrotiri.
- Ground water extraction from a number of boreholes to be used for domestic and irrigation purposes.
- Treated effluent from the Limassol Sewage Board Treatment Plant used for agricultural and landscape irrigation.

The irrigated areas in the region fall in two categories : Areas within the Major Government Irrigation Schemes of the region (Akrotiri West and Germasogheia-Polemidhia) and areas outside the Government Irrigation Schemes.

Water from the Kouris Dam (the biggest dam in Cyprus) is transferred to the eastern part of Cyprus (Kokkinochoria region) through the pipeline of the Southern Conveyor Project (Figures 3).

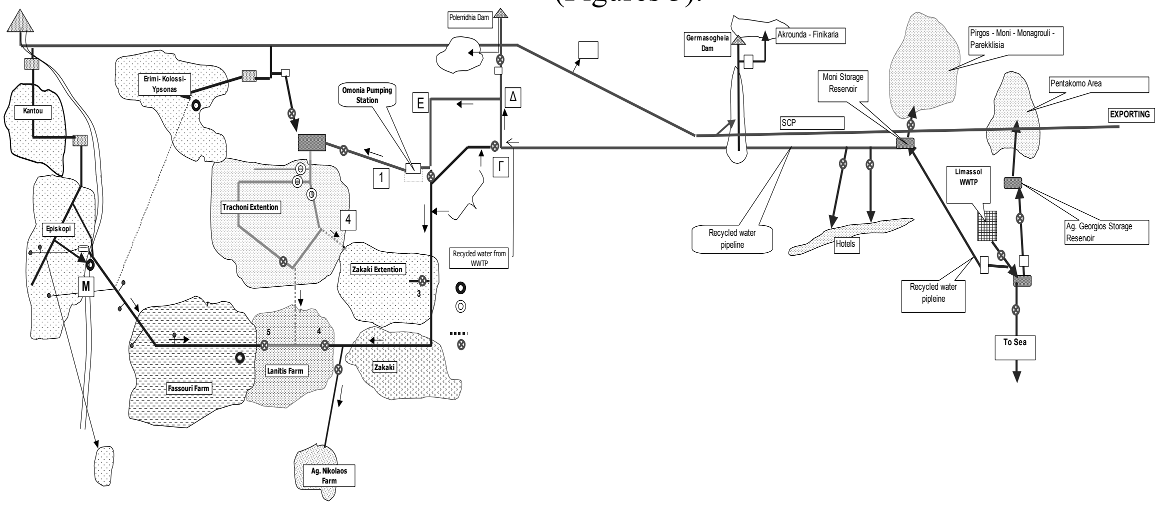


Figure 3a. The irrigation system of the region

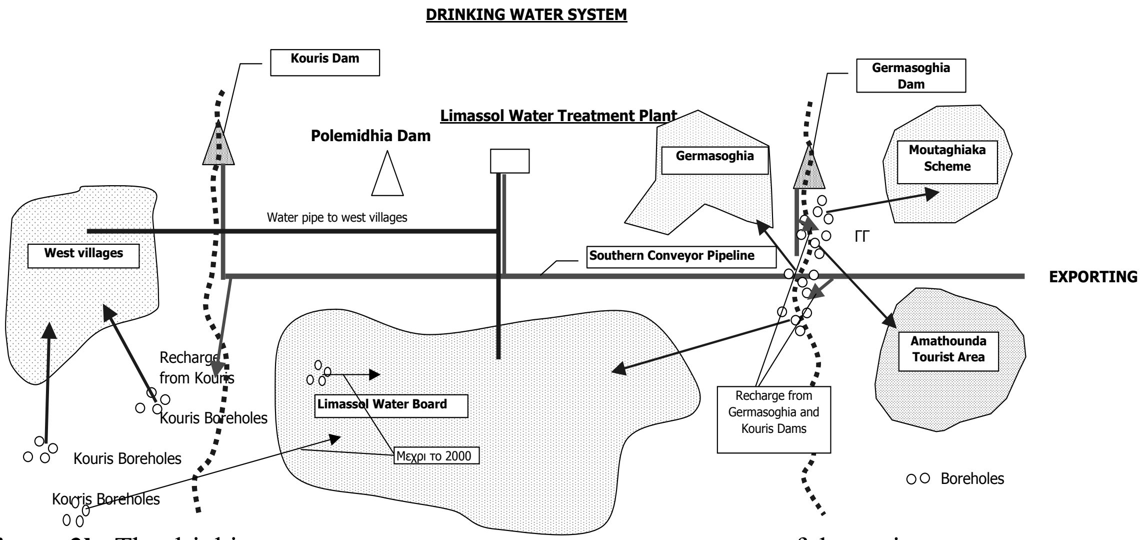


Figure 3b. The drinking water system of the region

The mean annual rainfall in Limassol is 409 mm according to the last 30 years measurements at the meteorological station of Limassol (Figure 4). In the same Figure 4, the mean rainfall throughout the region can be seen. The inflows into the surface storage reservoirs depend on the catchment rainfall and they reflect this.

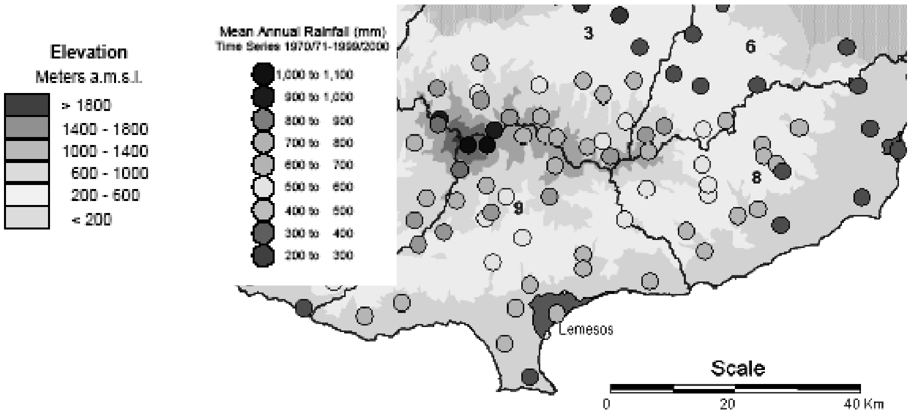


Figure 4. Mean annual rainfall for the Limassol region (1970 – 2000)

The distribution of the precipitation through the year is similar all over the island. In the Limassol region the mean precipitation increases to maximum in December and January. The decrease of the mean precipitation is slower than the increase, it spans over eight months from December – January to a minimum in July – August (Figure 5).

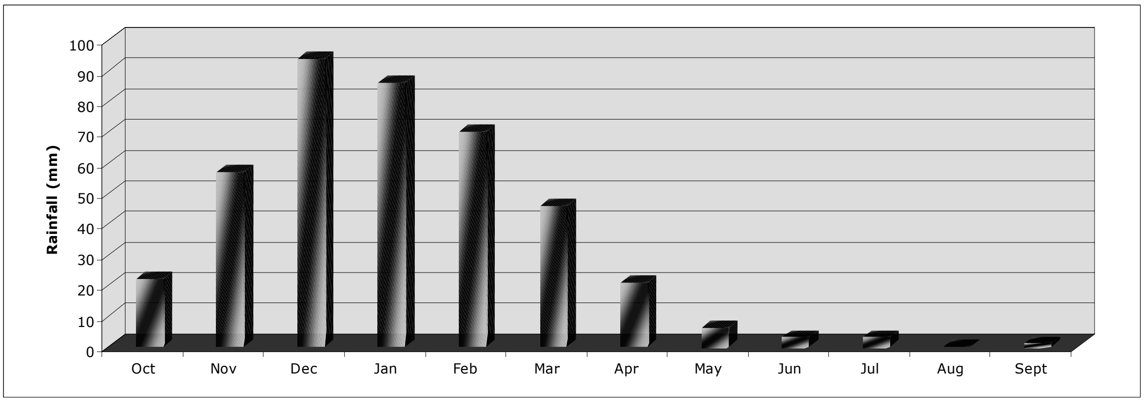


Figure 5: Annual distribution of the rainfall of the Limassol region (1970 – 2000)

3. DEFINITIONS OF TARGETS AND ASSUMPTIONS

Since the water management practices in the region reflect the competing demand and the dynamic competitive tension between agriculture, urban growth including tourism, and the environment, the formulation of the strategies were based upon the following objectives :

- Meet at least 80% of domestic and irrigation needs in the peak summer period
- Meet 100% of domestic and irrigation needs during the rest of the year

The above targets are justified since the perceptions of the stakeholders for a strategy for more efficient use of the region's and the island's water resources and their future reservations dictates among others that the coverage of the domestic demand must be guaranteed as well as the sustainable distribution of the water at a national level, whilst on the other hand the agricultural activities should be maintained for socioeconomic reasons.

The formulated and assessed strategies refer to medium to long-term planning (period 2002 – 2030) and to the worst case scenario with regard to water availability conditions (high frequency of dry years conditions) and water demand (high demand scenario) assuming 0,5% annual increase for domestic population throughout the planning period, 0,5-1% increase for seasonal population, 10% increase for irrigation demand and 2% and 1,5% increase for domestic and seasonal consumption rate respectively.

4. IDENTIFICATION OF AVAILABLE AND FEASIBLE OPTIONS

The management options that were developed and analyzed to combat water stress conditions in Limassol area, resulted from a synthesis of the current responses regarding water management, the responses proposed by the stakeholders and the requirements of the Water Framework Directive that can be implemented in this specific area. Environmental, social and economic constraints were included and considered in the approach.

A summary of the identified options is given in the next Table 1.

Table 1 : Examined water management interventions

Interventions related to Supply Enhancement - STRUCTURAL	
GOALS	**INTERVENTIONS**
Agricultural Demand will be met by surface and recycled water freeing the burden on groundwater Domestic and tourist demand will be met by surface water	**ST1 :** Water reuse **ST2 :** Upgrade Program of the existing Water Treatment Plant – minimization of groundwater abstraction for drinking water **ST3 :** Construction of a WWTP for the western rural areas
Interventions related to Demand Management – NON STRUCTURAL	
GOALS	**INTERVENTIONS**
	SE1 : Conservation measures in the domestic sector **SE 3 :** Loss reductions in the domestic sector
Interventions related to Socio-Economic context – NON STRUCTURAL	
Conciliate water availability with demand Water tariffs should reflect the true water costs allowing an adequate cost recovery	**SE 2 :** Irrigation water pricing **SE 4 :** Domestic water pricing

5. OPTION EVALUATION

The selection of the appropriate options was based on their performance with respect to a number of indicators including coverage of domestic and irrigation demand, direct cost as well as the groundwater exploitation index.

The results of the options performance evaluation process are presented in Table 2 that presents the normalised results of the performance evaluation under a scale ranging from 1 to 5 (worst performance : 1 – best performance : 5). From the matrix it is apparent that the studied options do not perform the same with respect to the three adopted indicators. Soft measures perform better in relation to the relative sustainability index for demand coverage and economic efficiency and economic efficiency, whilst they have a poor performance with regard the environmental sustainability (groundwater abstractions). On the other hand the structural options (water reuse – water treatment plant – waste water treatment plant) perform better in relation to environmental sustainability and effectiveness and poorer in relation to economic efficiency indicators.

Table 2. Normalised performance matrix of the studied interventions (HD+DRY scenario)

Option	**Effectiveness** (Sustainability Index for Demand Coverage)	**Economic Efficiency** (B/C Ratio)	**Environmental Cost** (PV – million €)
Water reuse	***	*	* * *
Water Treatment Plant	*	*	* * * * *
Waste Water Treatment Plant	***	*	* * * * *
Loss Reduction	* * * * *	* *	*
Conservation measures	* * *	* * * * *	*
Irrigation Pricing	* * * * *	*	*
Domestic Pricing	* * *	* * * * *	*

6. STRATEGY FORMULATION

The strategies were formulated from the available feasible options in three steps :

- Choice of measures thorough examination of the strategy goals and of forecasts for the future
- Determination of the timing for the measures application
- Scheduling of a sequence of acceptable/available measures

The next level of action included the evaluation of the selected Strategies using a Decision Support System (WSM DSS, 2005), developed in the framework of the EC-funded WaterStrategyMan project (Developing Strategies for Regulating and Managing Water Resources and Demand in Water Deficient Regions – EVK1-CT-2001-00098). The DSS optimally allocates water from available and user-defined sources to user-defined uses, taking into account user-defined priorities for each use and the selected strategy under different scenarios, and assesses the quality of the available resources. The Decision Support System was used to estimate how much water is needed and to determine what interventions, as well as when and where, are necessary, and their cost. It provided indicators of performance for the selected strategy under every given scenarios, and rank those scenarios.

Thus the overall approach was followed by a thorough examination of the strategy goals and of forecasts for the future developing quantitative and qualitative projections for the supply and for the demand in the various sectors. These were ranked in order of importance, in order to enable efficient allocation of the resources to the highest value use. Another important issue was determined was timing, as issues needed to be addressed in different time frames.

Following the above mentioned steps, two strategies were formulated based on the emerging paradigms (STRATEGY A) including already applied and tested measures (hard measures) and shifting paradigms (STRATEGY B) that will include options not currently used or accepted including measures that increase the productivity of water (soft measures).

Strategy A

Strategy A includes already applied and planned for the future measures which, based on the experience of the various stakeholders, are expected to be effective and efficient for the Limassol water system.

The interventions incorporated in STRATEGY A include :

- The construction of a new Waste Water Treatment Plant to serve the West Rural Areas. The realization of this intervention is scheduled for the year 2007, and includes the following technical aspects
    - A new 4000 m^3/day WWTP will be constructed to treat the effluent of the villages Polemidhia, Ypsonas, Erimi, Episkopi and Kolosi.
    - The tertiary treated effluent will partially cover the needs of the Episkopi and Fassouri farms
- Water Reuse. The realization of this intervention is scheduled for the year 2007, and includes the following technical aspects :
    - Recycled water during the winter months (when the irrigation demand is minimum) will be stored in Polemidhia dam and/or will recharge the Kouris Delta aquifer. Under these circumstances, the Kouris Delta aquifer may not be used for domestic purposes.
    - The pipeline form the WWTP will be connected to the existing network to transfer water to Zakaki Ext., Ag. Nikolaos, Lanitis and Fassouri farms.
    - A new pipeline will connect Ypsonas reservoir with Zakaki farm to transfer fresh water from the Kouris dam to cover the irrigation demand of the farm. The cost of the pipeline is estimated to approximately 250.000 €.
    - A new 5 km pipeline will connect the existing network with the Kouris Delta aquifer. The cost of the new pipeline is estimated to approximately Water Treatment Plant. The realization of this intervention is scheduled for the year 2010, with the following technical aspects:
    - Upgrade of the existing Water Treatment Plant to reach a capacity of 80.000 m3/ day.
    - Minimisation of groundwater abstractions from the Garylis aquifer for domestic uses.

The tentative timeframe of the selected interventions are presented in Figure 6.

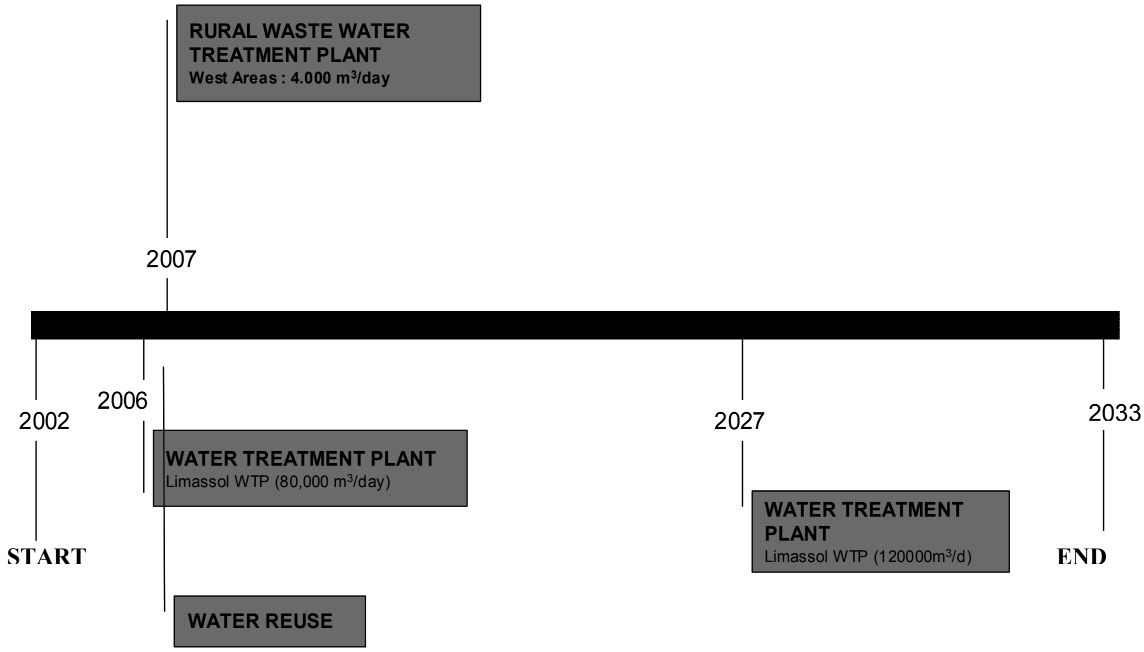


Figure 6:. Tentative timeframe of interventions under Strategy A

<u>Strategy B</u>

The second strategy attempts to reconcile the supply and demand through soft interventions reflecting a shift in the traditional paradigm of water management in Cyprus. The strategy formulated is highly dependent on efficiency improvements dealing with water reuse – conservation measures – domestic and irrigation pricing complementary to the planned structural measures but making them of a smaller size and extending the implementation timeframe

The additional interventions (with respect to that of STRATEGY A) incorporated in STRATEGY B include the following soft options :

- Reduction of distribution network losses (domestic sector). The realization of this intervention is scheduled for the year 2006, with the following technical aspects:
    - Reduction of the losses to 15% (through successive network replacements) for the three biggest settlements in the study area that is the Lemessos Municipality, Lemessos Touristic Part and Germasogeia Municipality.
- Conservation measures for domestic use. The realization of this intervention is scheduled for the year 2010, with the following technical aspects:
    - Reduction in the domestic demand of 10% (excluding the seasonal demand)
- Domestic Pricing. The realization of this intervention is already applied by the WDD since year 2004. The option will also be applied in year 2017, with the following technical aspects:
    - A block structured water tariff was applied in the study with an average cost of 0,77 €/m3.

    - An elasticity of –0,25 was assumed for residential consumption

- Irrigation Pricing. The realization of this intervention is already planned and applied by the WDD since year 2004, with the following technical aspects:
    - This option examines the case of raising the irrigation water prices from 0,12 €/m3 to 0,19 €/m3 within a period of three (3) years according to the tentative timeframe shown in Figure 7.
    - Data for demand elasticities is available for individual agricultural products (Nicolaides, E. 2000) and are given in the following table.

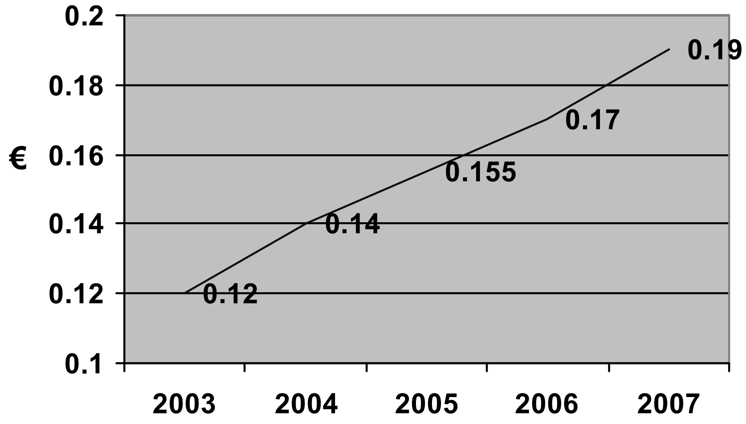


Figure 7: Tentative timeframe of irrigation pricing scheme

The tentative timeframe of the selected interventions are presented in Figure 8.

Table 3 : Agricultural products price elastici**ties**

Product	Price Elasticity
Potatoes (spring)	-0,33
Tomatoes (greenhouse)	-0,70
Cucumbers (greenhouse)	-0,58
Water melons (open)	-0,50
Oranges	-0,02
Grapefruits	-0,02
Lemons	-0,01
Mandarins	-0,02
Grapes	-0,02

Under both strategies domestic and irrigation demand coverage reaches almost 100% on an annual basis, and so achieving the basic objective set for the strategy formulation, which was to meet 100% of domestic and irrigation needs.

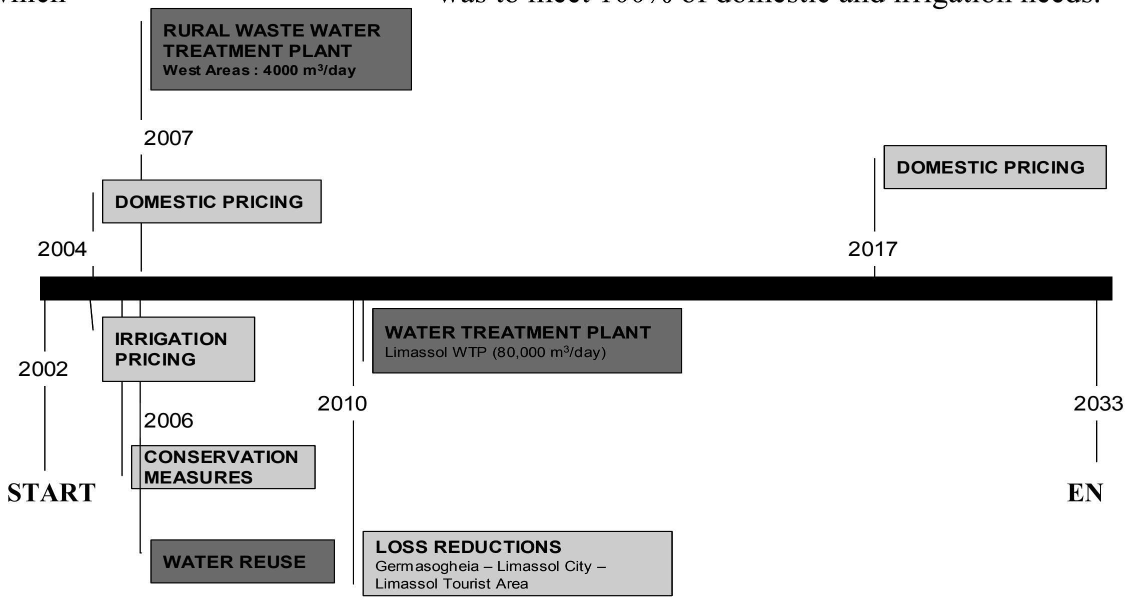
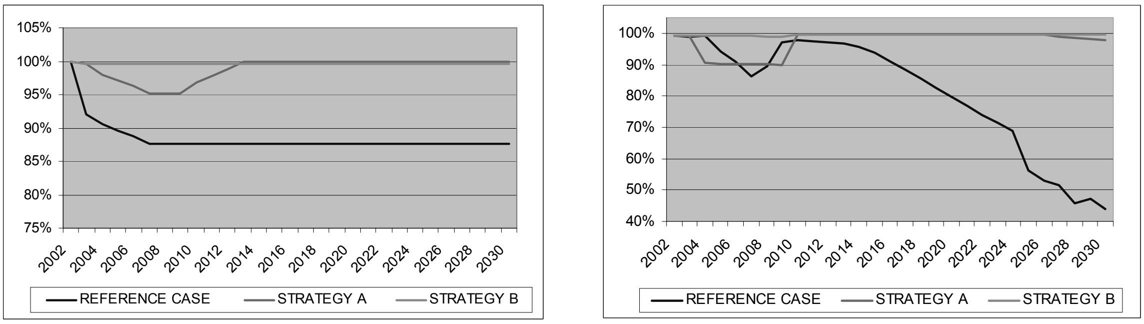


Figure 8. Tentative timeframe of interventions under Strategy B



(a) **(b)**

Figure 9. (a) Irrigation and **(b)** domestic demand coverage (%)

7. STRATEGY EVALUATION

As a next step the developed strategies were evaluated through a series of indices and indicators describing the actual range of the activities applicable to the region reflecting the perception of the locals towards economic development, social and environmental sustainability. Since it is widely acceptable that future economic growth of the area is to rely to tourism, the analysis of options were assessed on the ground of the **coverage of domestic needs.** On the other hand due to the importance of the agricultural sector in the area, the options formulation was also assessed on the basis of the **irrigation demand coverage.** Finally, environmental protection was expressed through the **groundwater exploitation index**, since until recently a large part of the domestic water supply in the area relied upon groundwater from the existing aquifers.

Table 4: Evaluation indicators

Indicator	Satisfactory range of values	Weight
Domestic demand coverage	90-100%	0,50
Irrigation demand coverage	80%	0,25
Groundwater exploitation index	0-80%	0,25

The evaluation scores are presented in the text that follows.

Table 5: Strategy evaluation scores

	Relative Sustainability Index for Demand	Direct Cost (PV – million €)	Environmental Cost (PV – million €)	Total value to users (PV – million €)
Reference case	0	389	342	162
Strategy A	0,741	359	118	10
Strategy B	0,751	350	109	3

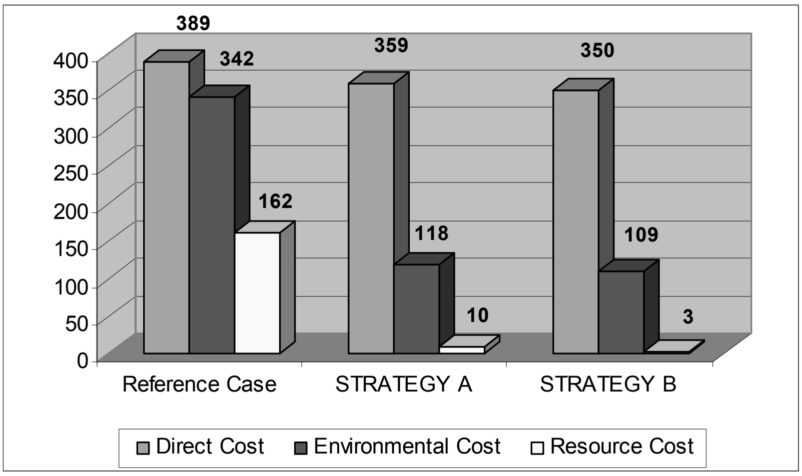
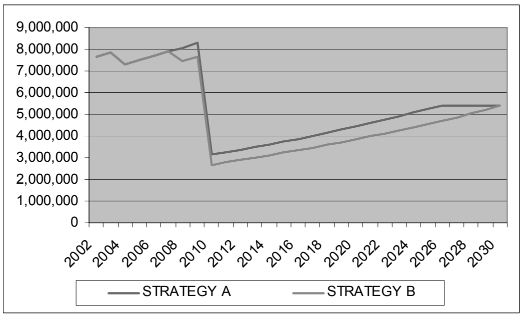
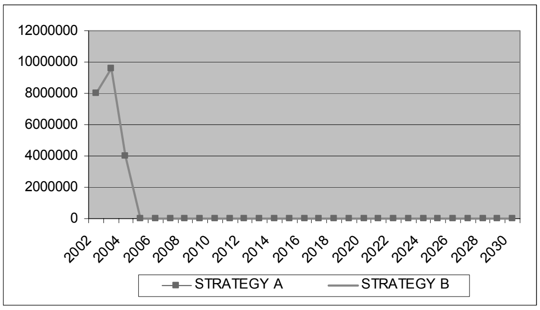


Figure 10:. Present Values in million €





(a) **(b)**

Figure 11: Environmental costs **– (a)** Domestic use (€) **– (b)** Irrigation use (€)

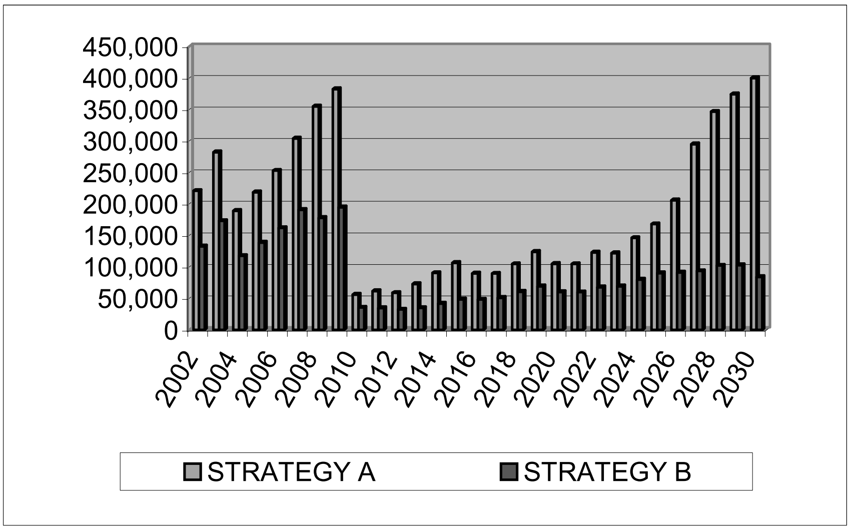


Figure 12: Resource costs (€)

8. DEVELOPMENT OF A COST RECOVERY SCHEME

The Water Framework Directive introduces the fundamental idea that water is a social and at the same time an economic good. This concept imposes the implementation of measures for the recovery of water services costs. Article 9.1 refers to the recovery of the full cost of water services which includes : the supply cost (costs of investments, O&M, labour, admin) – resource cost (loss of profit because of the restriction of available water resources) – environmental cost (cost from the damage on the environment).The Directive recognizes that water pricing constitutes an important instrument for the achievement of the recovery of full cost.

The achieved cost recovery rate referring to the two strategies are presented in Figure 13. For the domestic use the cost recovery rate under STRATEGY B is expected to be slightly greater than 90% whilst for the irrigation use is slightly greater than 80%. Under both applied strategies full cost recovery cannot be achieved.

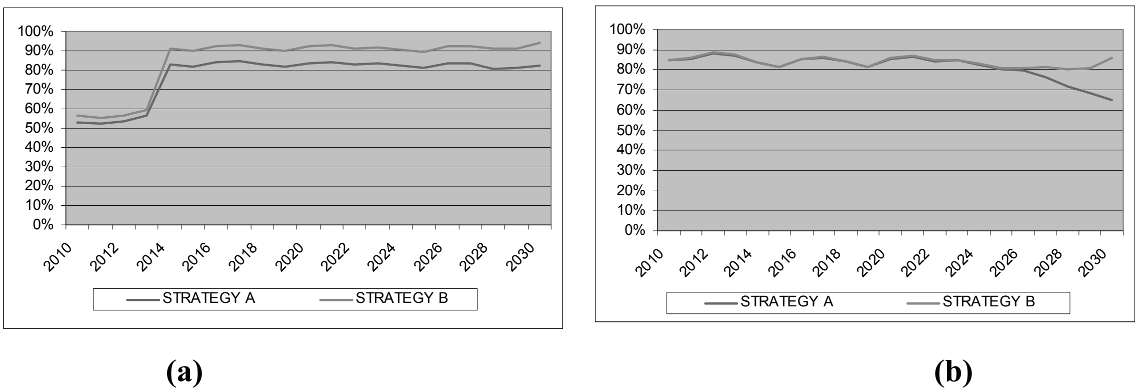


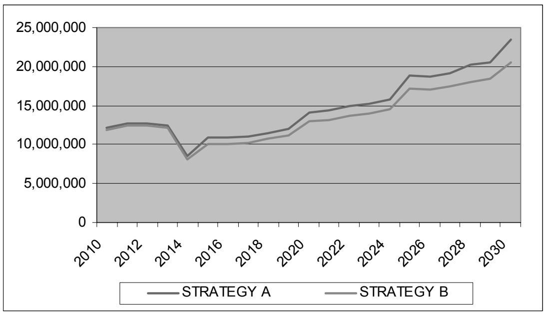
Figure 13: Cost recovery rate for : **(a)** domestic us**e – (b)** irrigation use

In order to examine and analyze the difficulties which could be encountered if the provisions of the WFD would be applied in the Limassol region, a cost recovery pricing scheme was developed for both Strategies for the domestic and irrigation uses.

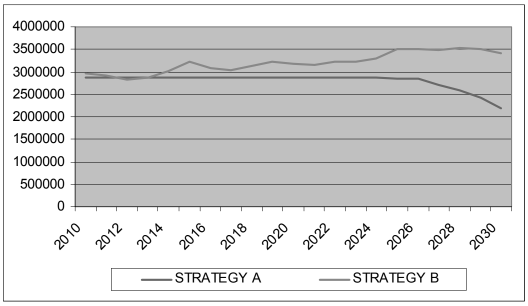
The developed scheme was considered as a flat-rate average volumetric price scheme to be readjusted on a periodic basis. The set targets regarding the rate of cost recovery were:

- Domestic use : after year 2015 the recovery of direct costs should be more than 80% reaching 100% by 2030, with average volumetric prices readjusted every 5 years
- Irrigation use : 100% recovery of direct costs, by 2030, with average volumetric prices readjusted every 5 years

Given the demand elasticity for the domestic and irrigation use in Cyprus (for the domestic use estimated at –0,2 and for the irrigation related to the different crops – seasonal and permanent) the introduction of pricing is expected to affect the demand significantly. Therefore an iterative process was used in order to redefine the extent for the application of options, their costs, the timeframe of implementation, and the prices required for the targeted cost recovery.



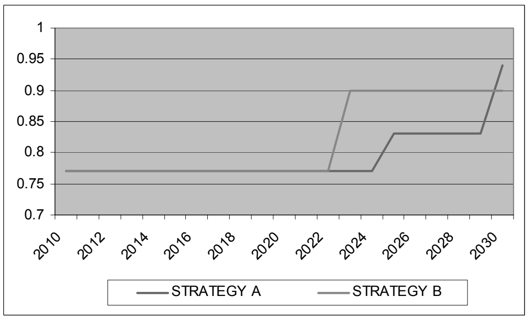
(a)



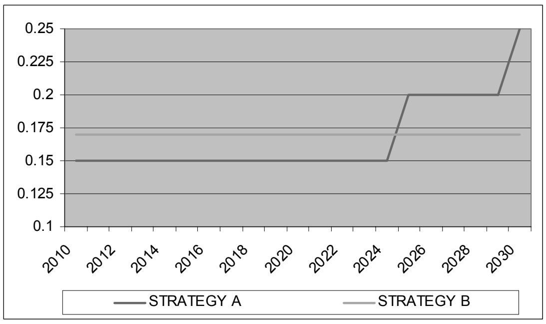
(b)

Figure 14: Total costs to be recovered **– (a)** Domestic use (€) **– (b)** Irrigation use (€)

The applied volumetric prices for domestic and irrigation use are presented in Figure 15.



(a)



(b)

Figure 15. Average volumetric price for :(**a**) domestic use (€/m3) **– (b)** irrigation use (€/m3)

The average volumetric price for domestic use under the cost recovery strategy was determined at 0,95 and 0,9 **€**/m^3 for Strategies A and B respectively, whilst the average volumetric price for irrigation was determined at 0,25 and 0,17 **€**/m^3 for Strategies A and B.

9. RE-EVALUATION OF STRATEGY OPTIONS AND PERFORMANCE

As it was mentioned before, given the elasticity for the domestic and irrigation use in the area, the demand was affected significantly as a result of the introduction of the new pricing policy (Figure 16).

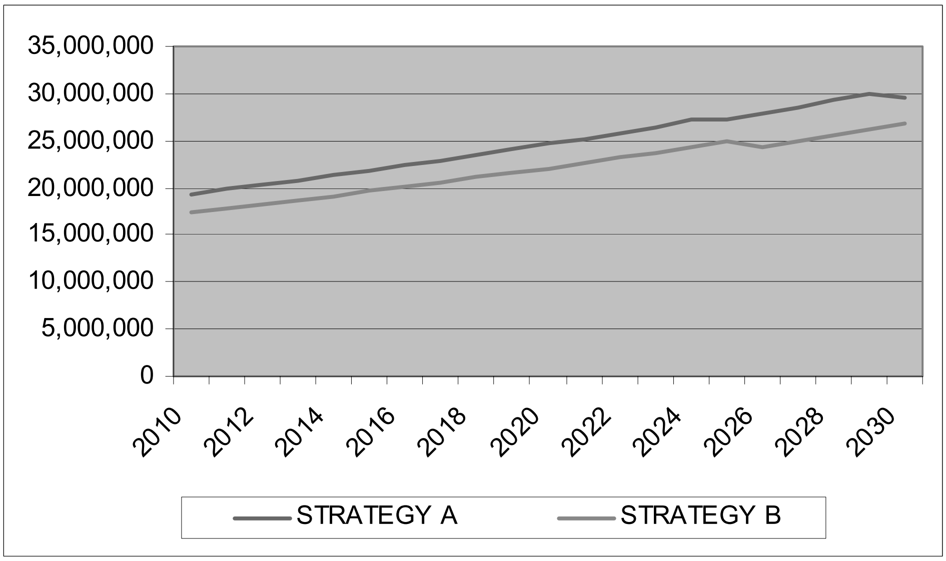


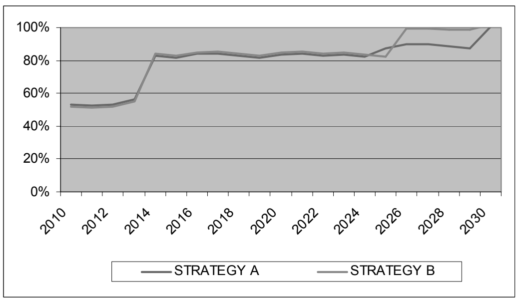
Figure 16: Domestic demand under cost recovery strategy

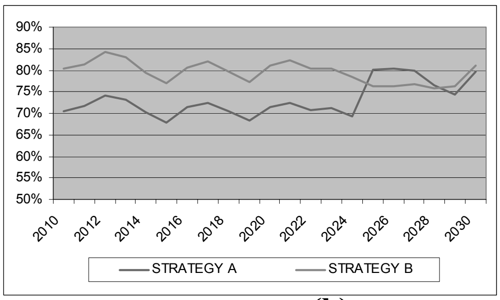
For the same reason, the performance of the two Strategies was affected with the following results (Table 6).

Table 6: Adjusted Strategy evaluation scores under cost recovery strategy

	Relative Sustainability Index for Demand	Direct Cost (PV – million €)	Environmental Cost (PV – million €)	Total value to users (PV – million €)
Reference case	0	389	342	162
Strategy A	0,742 (0,741)	353 (359)	113 (118)	4,1 (10)
Strategy B	0,757 (0,751)	345 (350)	108 (109)	2,9 (3)

The new cost recovery rate of the direct cost for the domestic and irrigation use is given in Figure 17. Under the new circumstances, full cost recovery can be achieved under both strategies by year 2030 for the domestic use, while not more than 80% can be achieved for the irrigation use.





(a) **(b)**

Figure 17. Cost recovery r**ate – (a)** domestic use **– (b)**irrigation use (under cost recovery strategy)

10. CONCLUSIONS

In this paper a representative region (Limassol region in Cyprus) was studied extensively with respect to formulating integrated water management strategies in order to cope with the water shortages identified in the region and at the same time enduring stability of supply and maintaining the groundwater exploitation to sustainable levels achieving so environmental protection of the local aquifers.

Two different strategies were formulated resulting from a tentative timeframe of water management options combinations including already applied and tested measures (Strategy A) and not currently used or accepted including measures that increase the productivity of water (Strategy B).

Both strategies achieve to meet local water needs for domestic and irrigation use since they both succeed 100% demand coverage for both uses.

The analysis of the two economic policies adopted shows that total direct costs can be fully recovered for the domestic use (in line with the requirements of the WFD), and up to 85% for the irrigation use. Strategy B (that included also pricing measures), showed better results than Strategy A (which was based only on structural measures) ; this is an indication that the adoption of soft measures, like pricing measures, can contribute to recover the full cost of the water for the domestic use, in line with the suggestions of the WFD.

In terms of economic performance, strategy B appears to be more effective and more attractive after cost recovery strategy is applied, resulting in smaller average volumetric prices for domestic and irrigation use :

The average volumetric price for domestic use under the cost recovery strategy was determined at 0,95 and 0,9 €/m^3 for Strategies A and B respectively, while the average volumetric price for irrigation under the cost recovery strategy was determined at 0,25 and 0,17 €/m^3 for Strategies A and B respectively.

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Water Conservation and water Protection Plan in Emilia-Romagna

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ABSTRACT

The regional Water Protection Plan adopted from the regional Council in December 2004 is presented. It follows the national regulation and anticipates the WFD and is composed by a General Report, a document about the Evaluation of Environmental and Territorial Sustainability, Regulations and Annexes. A water saving and conservation Programme is an integral part of the Water Protection Plan. The Paper discusses some issues concerning Water Conservation and Water Demand Management and the connection between water and energy savings. Conclusions about water conservation economics and suggestion are given.

1. INTRODUCTION

Truly sustainable water resources management involves managing demand, not just supply. Water currently wasted in poorly constructed or managed irrigation systems, through leakage in urban supply systems, in wasteful industrial practices and so on, could be conserved, and must be to satisfy increasing demand for water. Water efficiency must be addressed at several levels, both through technical means and through improved management practices in Integrated Water Basin Management (IWBM). This Paper try to expose this approach examining the international framework, trying to clear aspects of water conservation (WC) and water demand management (WDM), and describing the **Water Conservation and water protection Plan in Emilia-Romagna. Moreover some points could be useful for the Common implementation strategy and the scarcity group work**.

2. INTERNATIONAL FRAMEWORK

The main references about Water Conservation and Water Demand Management (WDM) are from the United States Environmental Protection Agency (EPA) and the European Environment Agency (EEA). The Safe Drinking Water Act (1996) requires the U.S. Environmental Protection Agency to publish guidelines for use by water utilities in preparing a Water Conservation Plan. At their discretion, States may require water systems to prepare a plan consistent with the guidelines as a condition of qualifying for a loan under the Drinking Water State Revolving Loan Fund. These Water Conservation Plan Guidelines http://www.epa.gov/owm/water-efficiency/webguid.html are addressed to water system planners but use of the Guidelines is not required by federal law or regulation. States decide whether or not to require water systems to file conservation plans consistent with these or any other guidelines. Although voluntary, the Guidelines may help bring conservation into the mainstream of water utility capital facility planning. Strategic use of water conservation can help extend the value and life of infrastructure assets used in both water supply and wastewater treatment, while also extending the beneficial investment of public funds. The relation between water conservation and quality, which appears evident, is stressed with a specific document (Cleaner Water Through Conservation http://www.epa.gov/OW/you/intro.html). Another EPA initiative started in the summer of 2002 investigating ways to enhance the market for water-efficient products as a potential program to respond to the growing demands placed on water supplies and water infrastructure systems. The results of this initial investigation demonstrate many potential environmental, economic, and energy benefits of market enhancement programs for water efficient products. In July, 2003 over 100 such organisations expressed support for a national "water-efficient product labelling program". The tools to increase water efficiency are represented by informing water users of the advantages of water-efficient products, motivating manufacturers to produce more water-efficient products, and encouraging distributors, retailers, and local water utilities to promote these products.

In Europe a first relevant document was the common declaration released in 1997 from the European Environment Agency (EEA) and UNEP about the water stress in Europe http://reports.eea.eu.int/92-9167-025-1/en. A statement included was that "**increasing demand for water is leading to a switch in approach from just increasing its supply, through reservoirs etc, to demand side management**, which focuses on the more efficient use of water by reducing losses, less wasteful use of water, more efficient appliances and water recycling. **In many cases it is cheaper and more effective to improve water use efficiency than it is to increase water supplies**. For example, water efficiency measures reduced the consumption of water in Madrid by 25 per cent between 1992 and 1994. This is the equivalent to a reservoir providing over 100 million m^3 of water per year. The use of 6 litre toilet water flushes in the UK, rather than the usual 9 litres, would save 10 per cent of the UK's household water use, according to a recent estimate."

The EEA (1999) later has undertaken an assessment on the *Sustainable use of water in Europe - Part 2: Demand management*.

The report http://reports.eea.eu.int/Environmental_Issues_No_19/en looks in particular at demand-side management of water across Europe. In the past, efforts to satisfy increasing demand have often been expended principally on increasing the supply (supply-side management to increase availability of water by using reservoirs, transfer schemes, more recently desalination etc..) which were available abundantly and at relatively low cost. However, the relationship between water abstraction and water availability has turned into a major stress factor in the exploitation of water resources in Europe. Therefore, it is logical that the investigation of sustainable water use is concentrating increasingly on the possibilities of influencing water demand in a way which is favourable for the water environment. In recent years, demand management has achieved more prominence, but both approaches are necessary, especially in areas prone to drought. Demand management includes initiatives having the objective of reducing the amount of water used (e.g. the introduction of economic instruments and metering), usually accompanied by information and educational programmes to encourage more rational use.

The report seeks to identify the key aspects and factors of WDM as they relate to the different economic sectors. The use of water across Europe is as varied as the respective countries, because of different climates, cultures, habits, economies and natural conditions. Common to all European countries is the need to satisfy the water demand of households, industry and agriculture. Also common to many countries is a limitation on water resources, both in terms of quantity and quality. Increasing human demand for resources such as water, energy and land for waste disposal can be met either by expanding supply or by managing demand. **Water demand management seeks to ensure that the right balance of demand and supply side options is achieved**. Therefore, it is logical that the investigation of sustainable water use is concentrating increasingly on the possibilities of influencing water demand in a way which is favourable for the water environment. Sustainability must seek to balance the water available at any particular point in time and space with the demand for water for various ‘uses’, and the need for enough water to safeguard human health and the aquatic ecosystem. Underpinning this, the water available must be of sufficient quality to satisfy the different users of water including again safeguarding human and other life.

3. LONG TERM WATER PLANNING: THE ENGLAND ENVIRONMENT AGENCY STRATEGY

A general Planning Strategy is defined by the EA, the statutory body with a duty to secure the proper use of water resources in England and Wales.

The approach of the Agency's new water resources strategy for England and Wales (2001) http://www.environment-agency.gov.uk/subjects/waterres/?lang=_e looks some 25 years ahead and considers the needs of public water supply, agriculture, commerce and industry, as well as the environment. The strategy examines the uncertainties about future water demand and availability **including the potential effects of climate change**. The Agency’s approach to water resources planning is based on four main principles: sustainable development, the “twin-track” approach, robustness to uncertainty and change and the precautionary principle. **The “twin-track” approach takes a balanced view, seeking the efficient use of water while bringing forward timely proposals for resource development where appropriate**. **The approach implies that, as more resource development is required, increasing effort must be applied to the efficient use of water**.

EA tried to cope also with the climate change issue. The Agency assumed an increase in the water demand by household for personal washing and water gardening, about 180 Ml/d by 2025, meanwhile forecasts of industrial demand do not need to be modified. Over the next 25 years, climate change will be one of many challenges facing agriculture. Given that the EA results are preliminary they have not included climate change in the assessment of incremental demand for agriculture. Changes in climate will change flow regimes and therefore the availability of water for abstraction. All of the current UK Climate Impacts Programme (UKCIP) scenarios suggest on average more annual rainfall throughout England and Wales, with less summer rainfall in the South. Higher temperatures mean that potential evaporation rates will probably increase. In his strategy, the EA has assumed that over the years most public water supply systems will retain their existing yields. This is a reasonably conservative assumption, as most systems depend to a great extent on the storage of winter water in either aquifers or reservoirs. The strategy is also particularly strong in terms of promoting prudent use of natural resources. Examples of these actions include bankside storage schemes which make use of available winter flows and water efficiency measures such as increased leakage control, domestic water metering, water audits and water use minimisation in industry. All of the regional solutions place significant emphasis on these water efficiency measures.

4. THE EMILIA-ROMAGNA REGIONAL WATER PROTECTION PLAN

The regional Water Protection Plan www.ermesambiente.it/PianoTutelaAcque adopted by the regional Council in December 2004 following the national regulation and someway anticipating the WFD is composed by a General Report, a document about the Evaluation of Environmental and Territorial Sustainability (VALSAT), Regulations and Annexes. **The water saving and conservation Programme is an integral part of the Water Protection Plan.** The General Report comprises a Knowledge Framework :Significant bodies of water, Summary of relevant pressures and impacts exercised by anthropic activity on water status, list and map of protected areas, classification of significant bodies of water, identification of water bodies intended for specific use, Objectives, summary of adopted programmes, Modelling supporting the setting of action scenarios.

Emilia - Romagna Region, together with Basin Authorities, has established the Plan objectives for each drainage basin with reference to the WFD. “Objectives” have been set, by identifying main critical features, linked to quality protection and use of resources, on the basis of acquired understanding of drainage basin features, the impact exercised by human activity, qualitative features of surface waters (classification) and qualitative - quantitative features of groundwater, as well as the quality status of coastal marine waters. By December 31st, 2016, every significant surface and ground water body must reach the “good” ecological quality status. In order to assure the fulfilment of this objective, each classified surface water body, or a portion of it, must acquire at least the requisites of “sufficient” status by 31st December 2008. For quantitative aspects, priority objectives are: **eliminating water deficit in groundwater**, **and maintaining a minimum vital flow in rivers**.

5. WATER SAVING AND CONSERVATION PROGRAM

In Emilia-Romagna, the total withdrawals in the mid of the 70’ were estimated (in millions of cubic meter, Mcm.):

	Civil Uses	**Industrial Uses**	**Agriculture Uses**	**Total**
Groundwater	350	240	150	740
Surface water.	negligible	290	852	1142
Total	350	530	1002	1882

Studies for the middle of the 80’ gave:

	Civil Uses	**Industrial Uses**	**Agriculture Uses**	**Total**
Groundwater	310	227	193	730
Surface water	170	337	681	1188
Total	480	564	874	1918

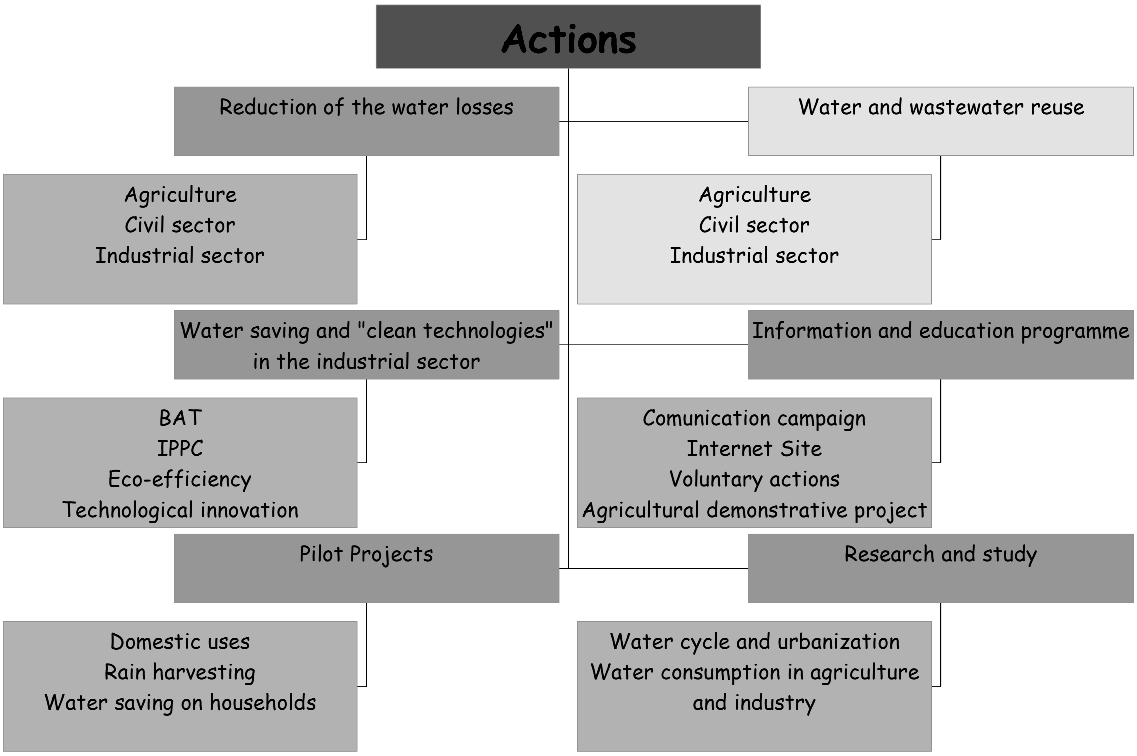
last (2000) data are:

	Civil Uses	**Industrial Uses**	**Agriculture Uses**	**Total**
Groundwater	282	171	222	675
Surface water	205	62	1183	1450
Total	487	233	1405	2125

We observe a modest increase of the total withdrawals, with a strong replacement from the industrial uses to the irrigation uses and, partially, to the civil uses. There is an important decrease in the groundwater withdrawals. Is interesting also to note that the civil withdrawals are stable form the 80’. The increase in surface water withdrawals depends from the regional policies developed to answer the subsidence problems posed by the unsustainable uses of groundwater in the South East part of the region (Bologna, Ravenna and the coastal zone), using a canal (Canale Emiliano Romagnolo, CER), which can take about 60 Cubic m/sec from the Po River for the agricultural uses, the Ridracoli Dam builded at the end of the 80’ for civil uses and a stronger regulation about groundwater withdrawals. Actually the groundwater annual deficit is estimated around 25 Mcm/y, with the worst problems in Bologna and also in Parma. If we look at the surface water the estimated deficit due to the future application of the MF is around 56 Mcm/y. The average regional consumption for domestic uses is 170 l/capita/day (l/c/d). The estimated overall (real and apparent) leakage from the civil networks are 123 Mcm./y, which means about the 26% of the civil withdrawals.

The application of MF is the most demanding task. The needs for realising higher volume of water to the rivers impacts the actual use of resources with particular significance during summer when the water flow is low while the water demand is at the highest level. In most of the cases, it is needed to revise “historical” water withdrawal, that were already present in the last centuries for irrigation and old mills and in the 20ies century for drinking purposes. The level of the conflicts is therefore pretty high.

The regional strategy is based on a twin track approach and, considering the regional situation and the regional water balance, is **firstly based on the development of new regional policies for water conservation and the demand government**, not forgetting the infrastructural development where necessary (for instance the local connnections with the Canale Emiliano Romagnolo and the uses of the water for other uses then only agriculture). The conservation Program, integral part of the regional Water Protection Plan, includes also a need to define a regional Drought contingency Programme. The main Conservation program actions are:



6. WATER SAVING AND ENERGY SAVING

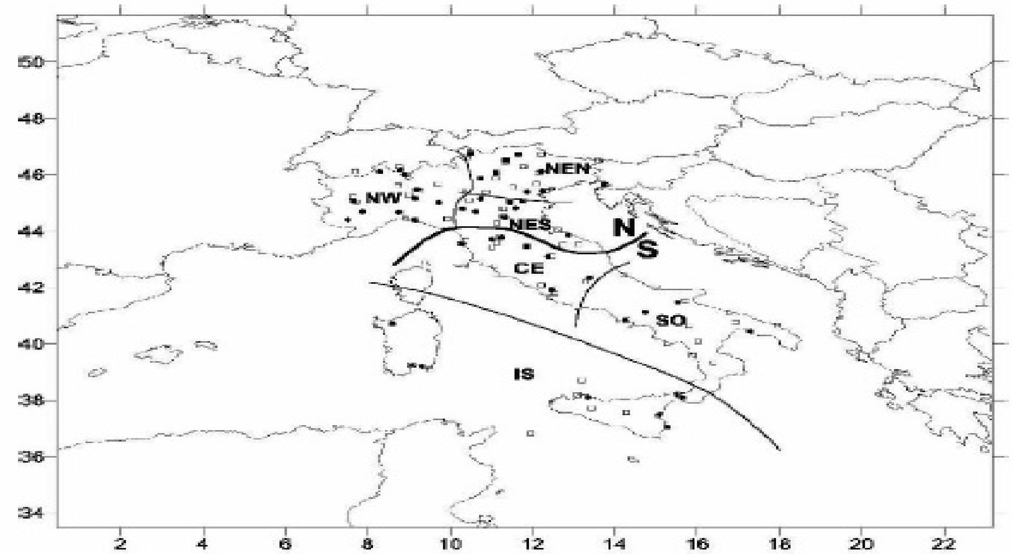
Energy production and use, including in the transport sector, are responsible for the bulk of greenhouse gas emissions. Europe has committed itself in the Kyoto Protocol to reduce these emissions which come from burning fossil fuels, mainly coal, oil and gas. To fight climate change, greenhouse gas emissions should – by 2012 – be reduced by 8 % compared with 1990 levels. However, present trends point to an increase of over 5 %. In its 2000 Green Paper on security of energy supply, the **European Commission set out a strategy to improve energy efficiency and to encourage greater use of new, renewable sources of energy**. Several pieces of EU legislation are designed to foster the uptake of sustainable energy systems, for example electricity production from renewable sources, energy efficiency of buildings and equipment and combined heat and power production. In its Green Paper The Commission reports that the total **final** energy consumption in the EU in 1997 was about 930 Mtoe. A simplified breakdown of this demand shows the importance of buildings in this context: **40.7 %** of total energy demand is used in the residential and tertiary sectors, most of it for building-related energy services. Space heating is by far the largest energy end-use of households in Member States (57%), followed by **water heating (25 %)**. Moreover the final report of the Alliance to Save Energy states "*In the process of improving overall water system efficiency, municipal water authorities should view energy and water consumption as linked inputs, rather than viewing them as separate and unrelated. Energy is necessary for moving water through municipal water systems, making water potable, and removing waste from water. Each liter of water moving through a system represents a significant energy cost. Water losses in the form of leakage, theft, consumer waste, and inefficient delivery all directly affect the amount of energy required to deliver water to the consumer. Wastage of water regularly leads to a waste of energy. Activities undertaken to save water and those to save energy can have a greater impact when they are planned together*".

We are currently estimating prudentially that the planned water savings will bring an energy saving **directly** for the domestic water heating around the 12%, which means the 3% of all the energy needed in the residential sector(in Regione Emilia-Romagna 2,7Mtoe/year), for **81.000 toe**, which is about 1/6 of our Kyoto commitment in the residential sector.

7. CLIMATE CHANGE AND THE WATER PROTECTION PLAN

The regional Plan consider also the climate change. Emilia-Romagna (around 44° latitude) is situated in Northern Italy, in the valley of the River Po, bounded by Apennine Mountains to the South and the Adriatic Sea to the East, in the North East South (NES). The climatic conditions of the region are related to the climatic general conditions of the Po Valley (surrounded by the Alps and the Apennine) and are mostly influenced by the mountains and the sea, this leading to a high spatial variability of the precipitation fields. For our region, but also for the Mediterranean zone, the water uses for irrigation are generally predominant.

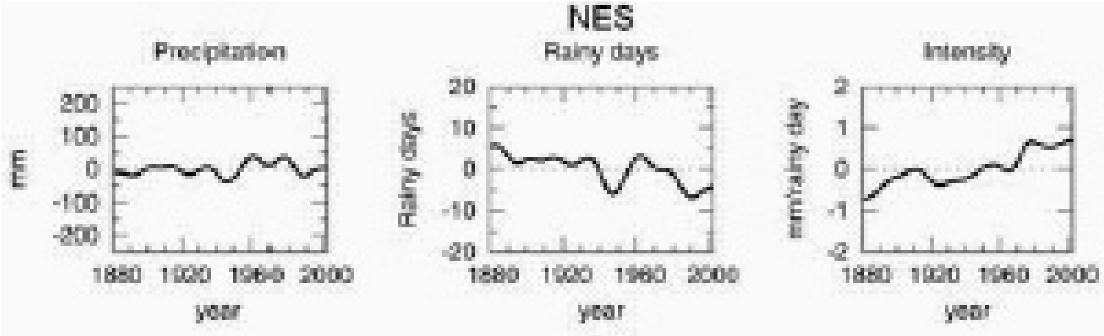
The Third Italian Communication to the UNFCCC confirm the Intergovernmental Panel on Climate Change IPCC Third Assessment Report (TAR). Strong problems for Italy are at South water stress and desertification meanwhile at North could be a stronger "run-off" and the consequent floods, soil erosion etc. The Communication is based on a Paper (Brunetti *et al.*, 2004a) which summarises activities within a broad-based research program for the reconstruction of the evolution of Italian climate in the twentieth century. The series included in the database are coming from 46 stations uniformly distributed in Italy. All series include **monthly mean values** of daily maximum (Tmax), mean (T) and minimum (Tmin) temperatures and monthly total precipitation (P). Monthly series were divided in two groups corresponding to two climatically homogeneous areas - Northern Italy (N) and Central-Southern Italy (S) - that are, respectively, the continental and the peninsular zones of Italy. The analysis covers the years between 1867 and 1996.



Yearly and seasonal temperature, precipitation and daily temperature range trends for northern and southern Italy (period 1867-1996) defined by linear regression coefficient (b) and associated error. Bold numbers: significance level greater than 99%, italic numbers: significance level greater than 95%.

		$b \pm \sigma_b$		
		T (°C/100y)	**P (mm/100y)**	**DTR (°C/100y)**
Winter	**N**	**0.7±0.1**	*8±7*	*-0.10 ± 0.07*
	S	**0.9±0.1**		
Spring	**N**	**0.3±0.1**	**-20±7**	**0.38 ± 0.01**
	S	**0.4±0.1**	**-39±5**	
Summer	**N**		**-7±6**	*0.20 ± 0.08*
	S	**0.5±0.1**	**-17±4**	
Autumn	**N**	**0.5±0.1**	**-28±8**	
	S	**0.8±0.1**	**-33±6**	**0.29 ± 0.06**
Year	**N**	**0.4±0.1**	**-47±17**	*0.17 ± 0.07*
	S	**0.7±0.1**	**-104±12**	*0.09 ± 0.06*

Moreover an other recent study (Brunetti *et al.*, 2004b): using a new data set of 45 **daily precipitation series**, covering quite uniformly Italian territory for the period 1880–2002, was recovered. The principal results are that Total Precipitation shows no trend in northern regions (NW, NEN and NES) and a significantly negative trend in southern regions (CE and SO) with a decrease of about 10% per century in total yearly precipitation. The other results show a negative significant trend in the number of wet days all over Italy, and a positive trend in precipitation intensity, which is significant only in the northern regions. The negative trend in wet days has persisted since the end of 19th century and is due to the marked decrease in the number of low intensity precipitation events. An increase in the number of events belonging to the highest intensity class interval was observed too, but only in northern regions.



For our region, the Regional Meteorological Office presented an analysis for summer and winter precipitation over Emilia-Romagna (Cacciamani *et al*., 2001). The data used in the study are the monthly precipitation amount from 40 rainfall stations located in Emilia-Romagna covering a period from 1922 to 1995. The stations are approximately uniform distributed over the region and their time series could be considered long enough to identify the climate signal concerning the main features of temporal and spatial variability of precipitation. The total amount of summer/winter precipitation was computed using the monthly quantity of precipitation from June, July and August (JJA) and, respectively December, January and February (DJF). An increasing trend of the summer precipitation over the 1922-1995 interval (considering 17 stations) was found in the northern, central and eastern part of the region studied. The climate signal was also present over a smaller area when the analysis was repeated for the 1948-1995 interval. Increasing the number of stations up to 40, a positive trend was detected in the whole region and new small areas with a significant upward trend appeared in the south-eastern area. This result shows that the climate signal related to the trend is strongly dependent on the time interval and the density of stations. A similar analysis was performed for the winter precipitation. A significant decreasing trend was detected in the whole region, more significant in *1960-1995* interval, when data from each station was analysed. Trend analysis applied for each winter month evidences that the *decreasing* is significant especially in *Januar*y.

Hoff (2003) suggests to use an approach "no-regret", (measures no regret are those whose economic rate of return justifies them regardless of future changes in climate). Integrated water resource management requires a combination of four categories: *supply system management*; *demand management*; *resource operation*; *risk management.* We tried to use this approach and the EA Twin track strategy in the Water protection Plan in Emilia-Romagna.

In Emilia-Romagna the increase of temperature from 2000 to 2016 means a modest increase in the domestic water demand (few millions of cubic meter). The irrigation season in Regione Emilia-Romagna is the summer. The demand for irrigation water depends from a lot of factors: temperature, precipitation, wind etc. If we look at studies for north Italy and our region we can see that for summer there is a weak trend for an increase in precipitation and quite no increase in temperature. The increase in CO2 concentration means also a more efficient use of water from the most of the agriculture plants. For these reasons, without a regional modelling of climate change, the Plan decided, as for the industrial demand, to suppose a neutral situation.

On the availability of water our strategy, as the EA for a longer period, assume that for the next 12 years the public systems (also for agriculture) maintain their actual supply, based on the last eleven years average, which was a strongly drought period; this assumption looks like conservative. This approach is based also on the time to revise the Plan (as in the WFD the Plan is revised every six years) and on the process of measures program assessment, which will be implemented with the Plan implementation. The demand scenarios without the actions are for Civil Water uses an 8% population growth, stability in the unitary consumption and a “natural” reduction of water losses from 26% to 20%. The Industry is in reduction from the 70’. For Agriculture there is still a growing irrigation surface, but a growing technological efficiency at the field with an almost stable demand (not clear indication from CAP). With the above conservation measures and assumptions, which mean a reduction of domestic consumption from 170 l/capita/day (l/c/d) to 150 l/c/d in 2016, **Plan measures would allow, at 2016, groundwater abstraction levels essentially depending on recharge capacity, also enabling to progressively off-set today's piezometric anomalies**. As for surface waters, critical aspects are linked to irrigation uses of Apennine waters; Plan measures will foster resource deficit reduction in view of MF application and where necessary there will be at the Provincial level, a **sustainable water basin building programme definition**.

8. REGIONAL PLAN FOR DROUGHT MANAGEMENT

The Plan also outlines the first elements pertaining to the Regional Plan for Drought Management. The report presented by IPCC predicts changes in the regional distribution of precipitation, leading to drought and floods, changes in the frequency of occurrence of climatic extremes, in particular in the frequency of heat waves. Climate changes that were observed during the last decades in our region seem to be consistent with these predictions and produced social impacts even at a local scale. The water regional Plan take care of those aspects in order to define, for the first time in the Regione Emilia-Romagna, a Drought contingency Program at the regional and local levels. Studies realised for the planning show as the last 15-20 years were years of growing drought, using indicators as Standard Precipitation Index (SPI) and others. Anyway this specific Risk must be afforded as in other sectors, as floods etc. with a planning strategy which shall be implemented after the Plan adoption and asking to the local actors to define within 2006 their Contingency Programs following the regional guidelines.

9. FUTURE RESEARCH AND PILOT PROJECT

Discussing the Plan a few suggested that climate change could influence negatively the groundwater recharge. Moreover in the past, and is still in action, there is a certain recharge decrease caused from the strong urbanisation. In this case it is impossible to state e decreasing general trend, for the aquifers seem to be generally recharged, looking at the piezometry. However the extreme events increment could increase the recharge, which generally happens in floods period. About these aspects the Region should finance studies and applied research, starting from the mathematical model developed by the Plan. The Region should yet invest research and Pilot studies and project in the aquifer artificial recharge, specifically in the zone near to the Po River.

10. CONCLUSIONS AND SUGGESTION FOR THE SCARCITY GROUP WORK

The WC approach seems to be mainly based on wise and "not economical" aspects ("close water taps while you are washing your teeth"). On the contrary, the WDM considers more economical and efficient aspects. In general the EEA statement put in evidence that in Europe it seems more useful stress the WDM than the supply side. The next step will be to define a good balance amid WDM and supply management; in this the economic analysis of the WFD is really relevant. Of course we must remember that the WFD approach ask to consider not only the industrial cost of water but also the opportunity and environmental costs. For example, the Office of Water Services (OfWat), which is the economic regulator for the water and sewerage industry in England and Wales, believes that the water losses have to reach the "economical level of leakages", that is the efficiency must be followed until the financial cost of losses reaches in the long time the marginal cost of supply of new water sources. This approach doesn't consider the environmental costs, as the WFD does. Moreover, from a lot of water conservation experiences and initiatives seems that it is crucial to develop together both technological actions and educational actions: in this way only, the results can consolidate and remain to long term.

Finally from the work of the Emilia-Romagna Water Conservation and saving Programme comes that the relation between water and energy and the water conservation can help very strongly to the Kyoto goals; on this matter the results are so interesting to suggest some investigation and works for the CIS.

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Water Management Strategies for Ribeiras Do Algarve, Portugal

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ABSTRACT

Portugal is one of the hydrological richest countries in Europe although suffering from several water shortages especially during summer. This is mainly due to the spatial and irregular distribution of precipitation, which is aggravated in the Algarve region by the tourism activity during those months. In that region, the lack of adequate infrastructures and of a sustainable management of water resources are the main factors that contribute to water deficiency problems, particularly on the coastal area where the impact is more significant. Until the end of the last decade, urban and agricultural water demands were essentially dependent on groundwater resources. The aquifers overexploitation led to their degradation such as salinisation and water quality deterioration, transforming most of it into a non-reliable water source. The development of a primary water supply system based on surface water use reduced the groundwater exploitation for domestic use. This allowed aquifers' water levels to recover and stabilize, enabling to reconsider their use as part of a strategy for a sustainable management of the water resources in the Algarve region. In order to analyse the problems framed on that reality and formulate adequate water resources management criteria, two strategies resulting from a tentative timeframe of water management options combination were applied and are presented with the main goal of mitigating the water shortages identified in the river basin.

Keywords: Algarve, Water Resources, Decision Support System, Sustainable Management, Water Strategies.

1. INTRODUCTION

Up to the 60's, the Algarve region was essentially dependent on traditional agriculture and fishing, presenting a slight development. This region went through deep changes in the last decades especially due to tourism development, encompassed by agricultural emphasis on water intense horticulture and orchards production. Both tourism and agriculture activities are concentrated on summer months, leading to water shortage during these months. The development of tourism activity, together with the migration of population to coastal areas, brought also an expansion of urban areas and diversification of economical activities, increasing the pressure over the existing water resources.

The region possesses a high availability of groundwater resources (21 aquifers were identified according to the River Basin Plan and to the Commission of Coordination and Regional Development of Algarve: 17 of high productivity along the south coast; 4 of low capacity in the west coast and inland, Figure 1), which still currently have a key role in the region although at a lesser extent than before (the end of the 90´s), when the domestic and agricultural demands were mostly satisfied by groundwater resources. Groundwater resources are generally exposed to pollution sources especially from agriculture and, at a less extent, by industry. In fact, the increasing concentration of nitrates in groundwater resources and the pollution of soils are a major consequence of non-point sources that results from the intensive use of fertilizers in agriculture. The majority of the aquifers is located by the sea and is essentially constituted by carbonated rocks, and the combination of natural processes and aquifers overexploitation led to groundwater salinisation and water quality deterioration, contributing also to aquifers progressively becoming a non-reliable source of water supply. Furthermore, some aquifers not affected by those problems often also suffer from overexploitation, like the case of the one in Monchique municipality as it is the only water supply source for both farmers and domestic users in the region.

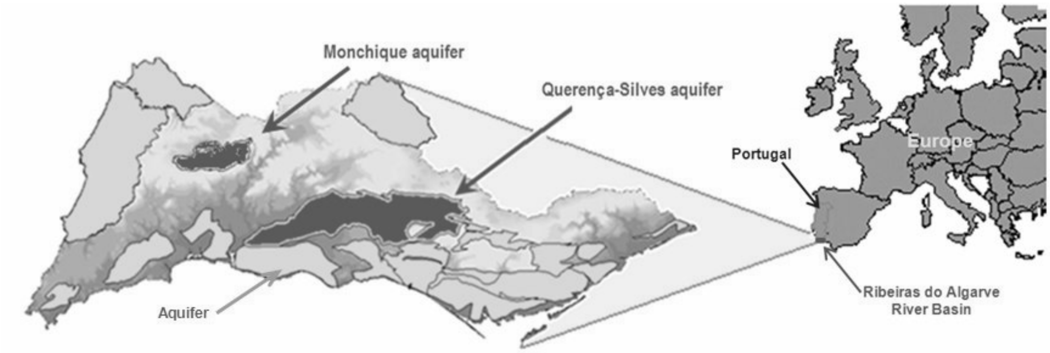

Figure 1: River basin's aquifer locations

Aiming to secure reliable water supply for tourism (as well as for resident population) and agriculture, a water scheme was elaborated to dispose and transport water with surface origin. A system was built for the Sotavento region, based on a two dams' system (Odeleite-Beliche) located in the lower part of the Guadiana River Basin, from which water is transported by pipeline to the Ribeiras do Algarve River Basin, for domestic and agricultural uses. A similar system was planned for the Barlavento, based basically on (i) Funcho dam, for domestic use and also for agricultural use (complementing Arade dam, built in the 50's for agriculture use) and (ii) on Odelouca dam, this last not yet built.

In parallel, by mid 90's, two inter-Municipal companies were created looking to satisfy the urban demand mostly with surface water abstractions. Those companies had a 30 year concession to implement, exploit and operate the primary urban water supply system, delivering treated water at a fixed rate to all the supplied municipalities. Thus: "Águas do Barlavento Algarvio" supplied the West part of the river basin (Barlavento region), having as main water source the Funcho dam complemented by the Bravura dam (allocated to agriculture); and, "Águas do Sotavento Algarvio" supplied the East part (Sotavento region) with an importation of water from the Odeleite-Beliche system. In order to improve the demand coverage and increase the efficiency of the water supply systems, in 2000, these two companies merged forming "Águas do Algarve S.A."

company which has the concession of the primary water supply system. This system (Figure 2) is constituted by the two previously referred systems physically connected allowing (limited) water transfer from one side of the basin to the other. Since 2001, Águas do Algarve S.A. has also the concession of the primary network for wastewater drainage and treatment.

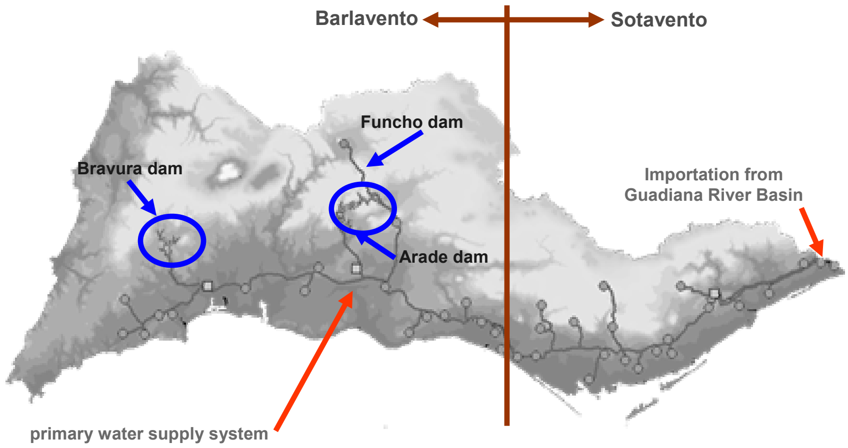

Figure 2: Supply sources and layout of the primary water supply system of Águas do Algarve S.A.

Distribution to consumers by secondary network systems (as well as sewage water collection and treatment) is under the responsibility of the Municipalities which fix the consumer price for water (variable by Municipality), similarly to what is in practice all over the country.

Currently, the primary water supply system supplies with surface water 29 of the 51 secondary water distribution network systems existing in Algarve's River Basin, to which corresponds more than 85% of the total urban water consumption in 2002. The remaining 22 secondary network systems are supplied by groundwater under Municipalities responsibility (PBHRA, 2000). Due to the introduction of the primary water supply system of Águas do Algarve S.A., a great increase of domestic demand was observed in the last years (about 9% per year).

Concerning agriculture, which represents the most important water sector user (65%), presently, both surface and groundwater are used, the latter representing the main supply resource, used in 86% of the irrigated area. The efficiency of irrigation methods is, on average, about 60% in public irrigation sites, mainly supplied by surface water, and 80% in private irrigation sites, using mostly groundwater. An increase of 69% of the public irrigation sites area until 2006 and a growth rate of 1,3% per year until 2020 for private irrigation sites is expected (PBHRA, 2001).

Tourism accelerated the tertiary sector economical development especially on the coast. The almost uncontrolled building during the 80's led to a "quality tourism" strategy development throughout the 90's. Golf courses implementation was part of this strategy, so that by the end of 2003 about 25 golf courses already existed in the Algarve River Basin, representing approximately 41% of the total existing in Portugal. New licensing applications are currently on hold by the regional water authorities in order to evaluate the possible influence on notorious degradation of the water quality and also to assure the sustainability of existing groundwater abstractions, which represents an important concern of the CCDR Algarve. In fact, most of those golf courses are supplied by groundwater abstractions in aquifers located within a critical area which was delimited on the south coast and for which specific licensing criteria has been defined (by the, CCDR Algarve). Within that critical area, any new abstractions are forbidden, except for domestic use or replacement of already existing ones. Presently, as the number of boreholes and the volume abstracted have diminished (due to the introduction of the primary water supply system of Águas do Algarve S.A.), aquifers reached more acceptable groundwater levels, enabling CCDR Algarve to eventually reformulate the critical area perimeter.

As a consequence of the situation previously described, all the main sector water uses current and prospected development urge finding new water sources or increase water abstractions from the existent ones. Additionally, infrastructure deficiencies, large areas with poor groundwater quality, high values of secondary water supply network losses (16% to 61%) and inadequate irrigation methods, urge the combination of different water management measures. Moreover, although the primary water supply system spatial coverage range does essentially concentrate on the south coast, pressures on quantity and/or quality do exist both on the inland and along the coast. On the other hand, a strong public opposition to "large water works" is present in the society.

According to the current paradigm, the implementation of a new structural measure is planned: the construction of the Odelouca dam. This investment would allow an enhancement in water quantity and quality, increasing the overall domestic demand coverage in the Algarve, especially in the Barlavento region. Although the construction has already begun, it has been contested at the national and European levels, and was interrupted. Following that, and due to the necessity to increase the water availability, other options had to be considered. Following stakeholders' consultation, namely Águas do Algarve S.A., some possible options were to explore large scale supply sources, namely: - to exploit reliable groundwater sources, meaning the Querença-Silves aquifer (Figure 1) as the only one owing water in quantity and quality to be considered for a significant sustainable water abstraction, although possibly for a shorter time horizon than Odelouca (in fact, since 2004 Águas do Algarve S.A. is already exploiting it, by means of abstraction boreholes of limited capacity); or, - to import water from the existent Santa Clara dam, located in the Mira basin (west coastal basin, bordering Ribeiras do Algarve River Basin) and allocated to agricultural use, profiting from the fact that a small volume is currently abstracted from it, even in dry years, when the available volume for abstraction can reach almost 70% of its storage capacity.

Alternatively, the implementation of localized measures, in order to solve water quantity and/or quality problems at the local scale would be desirable. Additionally, as the scarcity problems verified in the last years are obviously increasing in frequency and quantity, new measures never tested or implemented in Portugal are being discussed. Some measures were analysed with local stakeholders, namely Águas do Algarve S.A. and CCDR Algarve, in accordance with some of their problems and needs. The first one to be considered is the implementation of desalination units to supply population water

needs or even golf courses, similarly to other southern European countries. Specifically for golf courses, water re-use is also an option to be taken into account. In a short term, also demand management options should be implemented, and that should consider not only (i) advertising campaigns intending to alert and make the population conscious about water scarcity problems and to the need of reducing the waste of water but also (ii) measures to restrict or reduce certain water uses, like the use of more efficient water devices (e.g., taps and flushing cisterns) and sectoral water pricing increase.

2. STRATEGIES DEVELOPMENT

After the individual analysis of the different options considered, as referred, one has chosen to develop two strategies aggregating a selected set of options to an intervention timeframe. This timeframe is structured taking into account the contacts with stakeholders and the River Basin Plan (RBP) planned implementation measures timeframe. Although some different combination of demand and hydrological scenarios were analysed to meet stakeholders simulation needs (namely Águas do Algarve S.A. and CCDR Algarve), the one presented on this paper corresponds to: a steady demand increase scenario (BAU), in correspondence with an expansive scenario presented in the RBP, and a hydrological scenario (Normal) representative of the series of years observed in the last decades. A simulation period of 35 years was considered, including all period of the current concession of Águas do Algarve S.A. and enabling complete amortization of the costs of the structural options implemented.

The formulation of these two strategies intended to achieve the following main goals concerning demand coverage percentage, all over the year: (i) 95% for domestic use; (ii) for irrigation use: 90% for public irrigation sites and 80% for private irrigation sites. Concerning golf courses, the objective was to attain 90% of demand coverage during summer months. Besides, a maximum use of 80% of aquifers recharge is targeted in order to promote the sustainable use of groundwater resources.

Therefore, two alternative strategies, each based on a different paradigm, were formulated and compared between them and against the so called reference case (i.e., correspondent to the current situation and options). Strategy 1 is based on the implementation of structural options and the exploitation of surface water (namely Odelouca dam), reflecting the dominant paradigm as defined by the RBP and taking into account local stakeholders' opinion, as registered on a previous phase of the study. Strategy 2, although not representing a radical turn from structural to non-structural options, reflects the new paradigm necessity of considering other alternatives to usual water supply sources (much emphasized by the water shortages increase in the recent years) and the shift from regional options to small scale and localized management measures (namely on golf courses areas). This new approach intends to achieve a sustainable combination of surface and groundwater resources use (this last increased by means of intensifying Querença-Silves aquifer exploitation), and also taking advantage of demand management measures.

Figure 3 presents the tentative timeframe of the water management measures considered in each strategy: (i) strategy 1 in the upper half of the figure and (ii) strategy 2 in the lower half. The implementation of the interventions considered ends in 2020 although the simulation period lasts until 2035, allowing the depreciation of all the investments made and the achievement of all main goals set. Table 1 succinctly presents all the management options already individually described and evaluated (except "conservation measures") in the study presented by Maia (2005), in accordance with the approach defined in the WSM-DSS Tool (WaterStrategyMan Decision Support System) (ProGEA S.r.l., 2004).

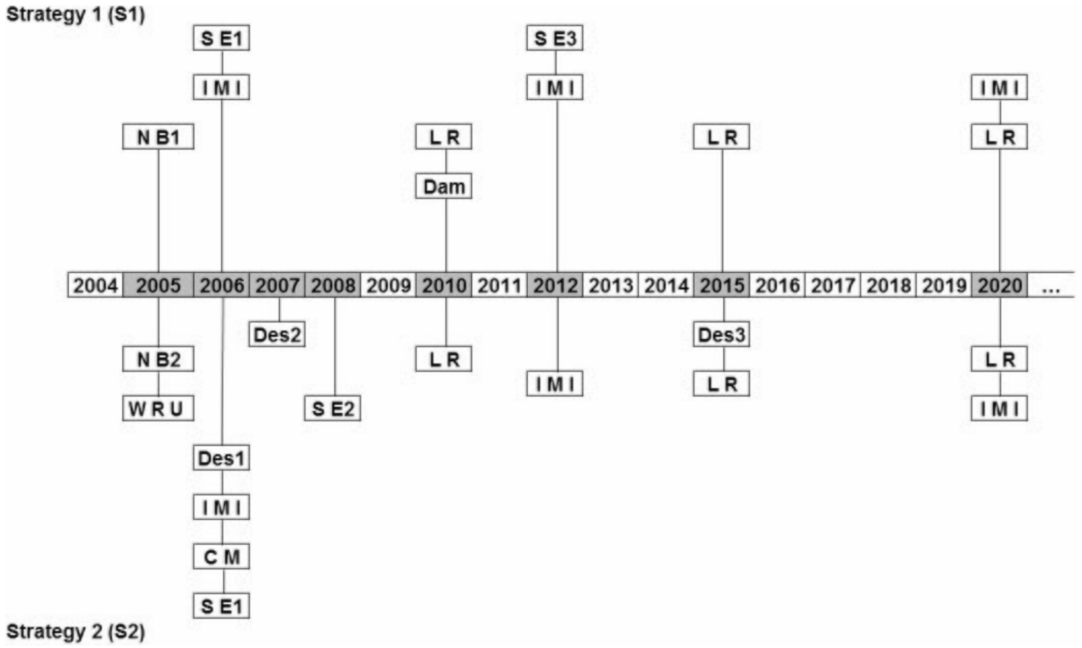

Figure 3: Tentative timeframe of interventions within dominant (S1) and new (S2) paradigm strategies

Table 1: Water management options description and identification

Abbreviation	Water management option		Description
NB	New boreholes	NB1	Abstraction in Querença-Silves aquifer(0.6 hm^3/month)
		NB2	Abstraction in Querença-Silves aquifer (1 hm^3/month)
WRU	Water re-use		In 4 golf courses
SE	System enhancement	SE1	System enhancement in Loulé and Almancil Municipalities
		SE2	System expansion in Monchique Municipality
		SE3	System expansion in Aljezur and Monchique Municipalities
IMI	Irrigation method improvements		Differentiated for public and private irrigation sites
Des	Desalination	Des1	Desalination unit in Aljezur Municipality for domestic use (seawater)
		Des2	Desalination unit in Loulé Municipality for golf courses (seawater)
		Des3	Desalination unit in Portimão Municipality for domestic use (seawater)
CM	Conservation measures		In 1/3 of the hotels through the substitution of taps and flushing cisterns
LR	Losses reduction		5% reduction
Dam	Dam construction		Construction of the Odelouca dam

As previously explained, strategy 1 (dominant paradigm) is based on the implementation of structural measures, namely on Odelouca dam implementation. As this option may only be implemented by 2010, abstraction on Querença-Silves aquifer ("new abstraction boreholes" option) is considered only to satisfy the demand up to when the Odelouca dam operation starts. Strategy 2 (new paradigm), in addition to using "desalination" for domestic use and golf courses (which, although being a structural measure, is far from the conventional options normally implemented) and "water re-use", also uses Querença-Silves ("new abstraction boreholes" option) although with a more important volume of water abstracted, intending to diminish the dependence on surface water for domestic supply. The small scale strategy implementation is also accentuated by the introduction of some system enhancements in strategy 2. Furthermore, the application of "conservation measures" for domestic use emphasizes the need to introduce demand side management measures that also rely on the population awareness to water scarcity problems.

3. RESULTS

As referred before, the two proposed strategies were simulated using the WSM-DSS tool. In order to expose the obtained results, both strategies are compared with the reference case.

Figure 4 presents the domestic demand coverage during the simulation period. The analysis of the Figure shows that the domestic demand coverage for the reference case drops to 73% by the end of the simulation period, with an important decrease in 2015-2017 related to the dry period then verified. For that case, during this dry period the volume that can be abstracted from Funcho dam to supply the primary water supply system is limited, increasing the domestic unmet demand. However, the application of both strategies 1 and 2 manage to maintain the domestic demand coverage above 97% all over the simulation period, showing no problem to achieve the goal's target previously defined (95%). This fact is mostly associated to the Barlavento region where the domestic demand coverage verified in the reference case was only 77% on average, for all the simulation period. The small difference observed between the two strategies from 2030 on is mostly related to the diminution in domestic demand verified with strategy 2, due to the implementation of the "conservation measures" option. By the end of the simulation period (2035), strategy 2 guarantees 94% of unmet demand improvement relatively to the reference case, to which compares 91% for strategy 1.

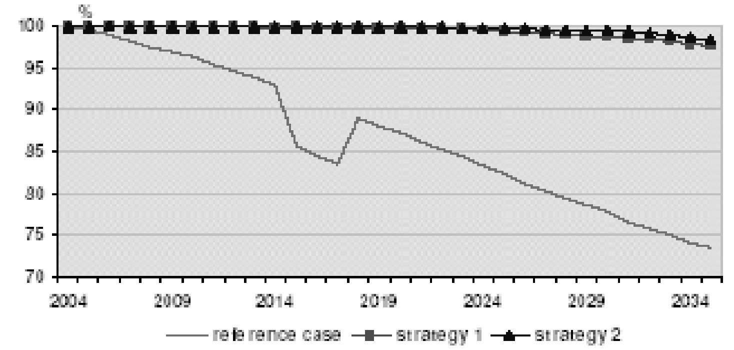

Figure 4: Domestic demand coverage

Figure 5 presents the irrigation demand coverage showing both strategies similar behaviour and better performance (than the reference case) for all the simulation period, the best corresponding to strategy 2. The demand improvement is particularly visible during the dry period of 2015-2017 where the lowering peak observed for the reference case, which corresponds to a water shortage originated by Arade dam (see Figure 2) supply capacity insufficiency, is eliminated. However, in what concerns the irrigation demand coverage decrease verified from 2024 on for the reference case associated to Monchique aquifer private irrigation site, none of the strategies formulated is able to mitigate the correspondent cause, i.e., the overexploitation verified in the Monchique aquifer. However, it should be emphasized that despite the differences observed, both strategies and the reference case present values for irrigation demand coverage always above 95% during all the simulation period.

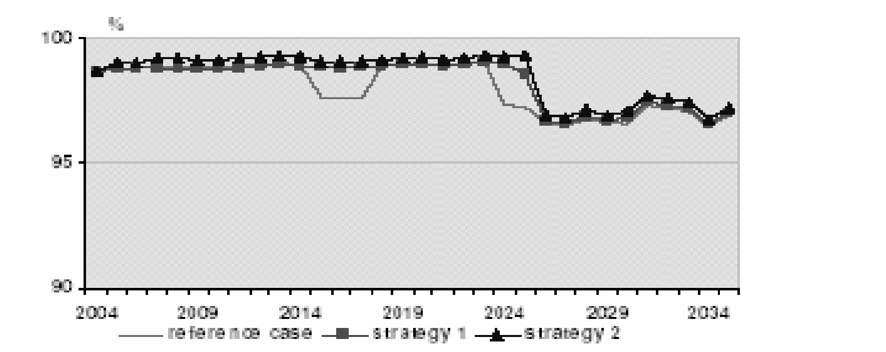

Figure 5: Irrigation demand coverage

Concerning Querença-Silves aquifer, the differences observed in terms of groundwater exploitation index between the reference case and both strategies are insignificant, reaching 1,5% on average for all the simulation period. The application of strategy 1 translates into a slight increase of the aquifer's stored volume (more visible up from 2027, in Figure 6) in response to surface water exploitation enhancement, whereas strategy 2 shows a diminution of it, as expected, due to the higher volume abstracted for domestic use during the simulation period.

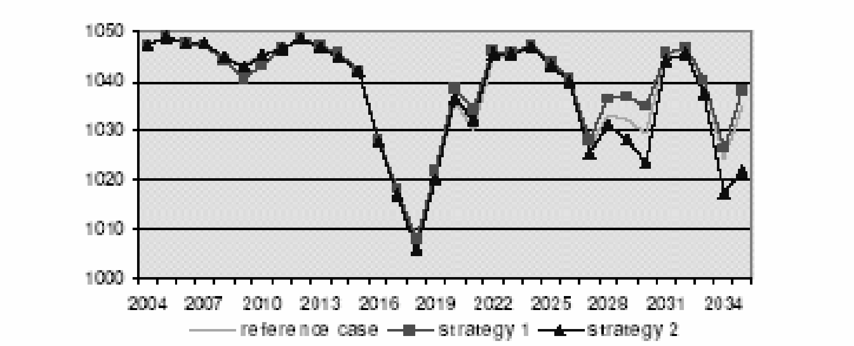

Figure 6: Time evolution of the volume stored in the Querença-Silves aquifer (hm3)

As previously referred, both strategies manage to solve the majority of the water supply insufficiencies. However, the very distinctive options introduced in each strategy do not allow a full and direct comparison between them. That way, taking advantage of the WSM-DSS tool possibilities (NTUA, 2004), one has chosen to compare both strategies and the reference case in terms of effectiveness, Present value (PV) direct costs, Present value (PV) environmental costs and total value to users. Concerning the evaluation of effectiveness (demand coverage of domestic and irrigation use) and environmental sustainability (groundwater exploitation index), the indicators were assigned with (i) a satisfactory range of values in accordance to the main goals defined for the river basin and (ii) weights according to the priority given to the performance of each indicator

(Maia, 2005): 0,4 for domestic demand coverage and 0,3 for each of the two other indicators referred.

Table 2 resumes the comparative performance of both strategies and the reference case. Concerning the effectiveness, the highest value is observed for strategy 2, meaning that this latter presents a better performance in terms of the chosen indicators. This better behaviour can be explained by the introduction of the "conservation measures" option that, through the reduction of the domestic demand, allows an increase of domestic demand coverage. In terms of economic efficiency, once more, strategy 2 appears to be the best as both direct and environmental costs are lower than the values obtained for strategy 1. Strategy 2, through the implementation of small-scale localized alternative measures, appears to be able to better achieve the main goals defined previously, compared to strategy 1, which emphasizes structural options use and consequently, associates higher investment costs.

Table 2: Strategy evaluation table

	Effectiveness	Economic efficiency		
	(relative performance index for demand coverage)	Environmental cost PV, million	Direct cost PV, million	Total value to users PV, million
reference case	0,3	692	1690	9779
strategy 1	0,57	700	2361	10206
strategy 2	0,63	667	2253	10078

The enhancement in domestic supply combined with an equal water value to domestic users after the implementation of both strategies caused an increase in total value to users (TVU) comparatively to the reference case. Moreover, the lower value of the TVU under strategy 2 relatively to strategy 1 reflects the introduction of conservation measures for domestic users and a consequent decrease in domestic demand.

With the purpose of achieving water uses' economical sustainability, aiming at Water Framework Directive compliance, a cost recovery scheme for domestic water use was applied to both strategies, in a similar way as described in Maia (2005). Therefore, an increase of water prices for domestic users was considered, aiming the following cost recovery targets: - a 100% recovery of direct cost from 2020 onwards, - a targeted minimum cost recovery of 70% associated to environmental costs by 2025.

Table 3 presents the re-evaluation of strategy 1 and 2 under the cost recovery scheme. One can observe that both strategies achieve the same value of effectiveness. Nevertheless, both PV direct costs and PV environmental costs are still lower for strategy 2 than for strategy 1.

Table 3: Strategy evaluation table (under cost recovery strategy)

	Effectiveness	Economic efficiency		
	(relative performance index for demand coverage)	Environmental cost PV, million	Direct cost PV, million	Total value to users PV, million
strategy 1	0,70	647	2137	9681
strategy 2	0,70	628	2074	9679

In terms of TVU both strategies are now equivalent and its values have diminished compared to before the implementation of the cost recovery strategy (Table2) due to the decrease in domestic demand as a direct consequence of the water price increase for domestic users.

4. CONCLUSIONS

After a brief description of the Ribeiras do Algarve River Basin and of the spatial and temporal identification of regional water shortages, two strategies were defined considering the implementation of a selected set of options within an intervention timeframe. The latter took into account regional stakeholders' aims, namely: Águas do Algarve S.A. emphasis on the need to implement Odelouca dam in order to, at medium-term, solve the unmet domestic demand; and CCDR-Algarve concern about golf courses related issues, critical area definition and aquifers protection.

The implementation of these strategies enables to achieve the main goal of the water management options, i.e., to effectively contribute to eliminate the existing deficit concerning urban and irrigation supply. Although strategy 1 which includes the more traditional, structural options is effective, strategy 2 proves that the introduction of small-scale water management options would also be able to solve the existing water shortages but attaining lower both capital and environmental costs. Furthermore, strategy 2 would allow reducing the current dependence on surface water supply, increasing the importance groundwater abstractions once had, but now in a sustainable way, i.e., without significantly affecting the current groundwater exploitation index. Finally, it should be pointed out that the cost recovery strategy implementation enabled to achieve the set cost recovery targets and resulted in a better domestic demand coverage performance. A similar process should be carried out for irrigation use although it would imply the current institutional framework to be modified.

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Italian approach to water quantity aspects; Key national studies

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1. INTRODUCTION

Water is a primary resource for human survival and economic development; the availability of the resource remains constant while water demand increases with the growth of populations and economies. Shortages cause water use conflicts, both in terms of quantity and quality.

Institutions responsible for water resources are under increasing pressure to take a complete, integrated approach to the development and management of water. They achieve the integration of technical, social, economic and institutional aspects using the available resources.

There is substantial variation across European countries in laws and institutions related to water, and the ability for project planning and implementation is not uniform.

Main innovations in the field of water management and pollution control, introduced by legislation in Italy in the last decade, derive from a few general social trends, such as the awareness of the need for environmental protection and demand for improved public services management.

The present paper aims to review the progress of the Italian water legislation throughout last few decades in order to identify the main innovative principles introduced to water planning regulation, water service management, and pollution control. The relationship between Italian legislation and the European Directives is examined in some detail.

Furthermore, particular attention is given to the examination of two key studies:

- Wastewater reuse: Sardinian experience
- Aretusa project in Cecina Pilot River Basin

2. COUNTRY PROFILE

Italy, with a surface area of 301,341 km2, is situated in Southern Europe at a central location in the Mediterranean basin with a high latitudinal extension, and linked to central Europe through the mountains of the Alps and the isle of Sicily which lies in front of the African coast.

The country is characterized by a wide physiographical variation represented by the Alps chain, extending from the west to east; the lowland of the large basin of the River Po and its 141 tributary streams of first and second order; the peninsula, 800 km long, including the central Apennine mountains running from North to South and the coastline (7,500 km long) bordering the Adriatic sea in the East, Ionian sea in the South-East and the Tyrrenian sea in the West; the two wide isles of Sicily and Sardinia are located at the South and the West of the peninsula, respectively.

The Alps act as a protection barrier against the cold wind blowing from the North, giving rise to a climatic pattern different from that of Central Europe.

The urbanisation process is gradually absorbing territory in Italy. The total amount of unproductive land tends to be absorbed further by the spread of built-up areas and infrastructure.

There are four major river basins in Italy: Po, Tevere, Adige, Arno. In the North East of the country, the rivers Adige, Brenta, Piave, Tagliamento and Isonzo from the Alps flow into the Adriatic sea. From the Central Apennines, the rivers Reno, Metauro, Tronto flow into the Adriatic sea while those of the Arno, Tevere, Volturno, Garigliano and Sele discharge into the Tyrrhenian sea. From the Southern Apennines, the streams Pescara, Sangro, Biferno, Fortore and Ofanto flow into the Adriatic sea while Bradano, Basento, Agri reach the Ionic sea. In the isle of Sicily, the Alcantara river reaches the Ionic sea while in the Sardinia isle the Flumendosa river flows from the northern region into the Tyrrhenian sea.

The water received by the whole land in Italy is approximately 296·109 m3 per year. Rainfall is extremely variable in the Country, both spatially and temporally. The surface flow is about 167 x 109 m3 per year (of which 12·109 m3 per year is of groundwater).

Considering the existing water storage systems in Italy (dams, reservoirs, etc.), the total exploitable water resources in Italy are estimated at approximately 40÷44 x 109 m3 per year and the total amount of groundwater available in Italy is about 12 x 109 m3 per year.

The climate varies widely among the several Italian regions, characterised by extremely variable conditions across more than 10 degrees of latitude between the Alps and Mediterranean Sea. A wide climate range results in differences in water resources availability. About 65 % of the total exploitable water resources of the water availability are in the Northern regions, 15% in the Central regions, 12% in the Southern regions and 8% in Sicily and Sardinia.

The mountainous nature of a large part of the Italian territory reduces the scope and technical feasibility of internal water transfers, forcing many regions to rely on their own water resources due to the high costs of accessing water otherwise. In fact mountainous and hilly regions cover over 75% of the whole territory; furthermore the country shows a hydrographical grid essentially made of a high number of torrential streams with very short branches.

The global national needs for water can be roughly estimated as 740 m3/person per year. Most of this volume is devoted to agriculture (48%), the remaining is used by industry and municipal water supply (19%) and energetic field (14%).

The annual amount of water used by the municipal water supply systems in Italy is about 7.86 x 109 m3, for about 373 litres/person per day. The water for civil use is obtained from groundwater (50%), springs (40%) and surface water (10%).

The increasing demand is part of a more complex national situation, which has rendered the water resource availability a more difficult problem in the past years. To cope with the increasing demand of water resources, besides the search of new available resources which however appears to be quite difficult today in Italy, and the occurrence of drought events, it appears to be of fundamental importance to achieve the optimisation and rationalization of the water now available and used.

Drought produces a complex weave of impacts that spans many sectors of the economy and reaches well beyond the area experiencing physical drought. Impacts are commonly referred to as direct or indirect. Reduced crop, rangeland, and forest productivity; increased fire hazard; reduced water levels; increased livestock and wildlife mortality rates; damage to wildlife and fish habitat are a few examples of direct impacts.

Of the many problems concerning water use in Italy, two of them have been particularly noticeable in the last decade: the scarcity of the resource, and its pollution.

Generally the biological and chemical quality of the largest rivers is extremely poor, and the number of polluted sites has increased, even spreading beyond highly urbanised areas.

High pollution in the North and the Centre is mostly due to industrial and agricultural activities, particularly in the coastal plains, along the basin of the rivers Tevere and Po, where nitrate concentrations are very important.

Furthermore soil contamination, mostly due to landfills and abandoned industrial sites, but also to direct discharge and to the use of polluted fertilisers, determines water pollution from bacteria and heavy metals.

In other regions, particularly in the southern part of Puglia, or in the coastal plains of Campania, Calabria and of the island of Sardinia and Sicily, the main problem is salt intrusion. In these cases over-abstraction can be attributed to private abstractions for agriculture and, at a local level, to public water supplies.

3. THE EVOLVING ITALIAN LEGISLATIVE FRAMEWORK

Italian policy in the water sector has been much modified in the last decade by a number of legislative acts. Since the early ‘90s the higher degree of complexity and decentralisation achieved has been leading to some conflicting attempts to integrate the water policy regimes.

Tentative efforts to integrate occur at two separate and conflicting levels: at the water basins level, through the creation of the Water Basin Authorities (AdBs), responsible for water planning in the water basins under their authority, and at the local level, through the creation of the Optimal Management Areas (ATOs), responsible for setting up locally the *integrated water services*.

The individual River Basin Authorities are required to set up specific rules for rivers under their responsibility. The slow and difficult process of institutional reform of the State has influenced the evolution of water policies, being partly responsible for the contradictions that we observe in the tentative process of integration of water policies.

We will briefly illustrate the main features of the water laws which did contribute to the recent evolution of water policies:

- Law 183/89 on water and soil conservation is aimed at adopting an integrated approach to water and land conservation problems. Both planning and management of water and land conservation must be conceived within a single vision for the whole territory of each hydrographic basin. It introduced the River Basin Plan concept, which was established as the main tool to collect relevant information and to identify the actions necessary for hydraulic defence and soil conservation, utilization of water resources, and pollution control of water bodies.

The law established that River Basin Authorities be entrusted with the coordination of all the planning, construction and control activities in water fields within the river basin.

Furthermore, it has reformed the National Technical Services, transferred under Prime Ministerial jurisdiction, assigning also the task of organising and managing the Information System on hydrometeorological data. Later on, three Technical Services were transferred to various Ministries (e.g. Hydrographic Service to the Environment Ministry, Dams Service to the Infrastructure Ministry)

- With law n.225 of 24th February 1992, Italy has organised the civil defence as a National "Service", coordinated by the Prime Minister's Office and composed, as stated in the first article of the law, by State administrations, central and peripheral, by the regions, by the provinces, by the local councils, by the national and territorial public authorities and by every other institution and organisation, public and private, existing on national territory.

The Department of Civil Defence intervenes, jointly with the competent Ministries and with those Regions involved, in events that, due to intensity and extension, must be faced with exceptional means and powers. It prepares, jointly with the Regions and local institutions, water emergency plans and gives guidance to Commission delegates for the destination of the available resources. Lastly, with the D.P.C.M. n.59 of 27/02/2004, the authorities are identified with whom rests the decision and responsibility of alerting the civil defence system at various levels. The institutional bodies and the territorial units involved in the activity of risk forecast and prevention and emergency management are defined. The tools and modalities with which the information relative to the manifestation and evolution of hydrogeological and hydraulic risk, associated with the manifestation of particularly intense meteohydrological events have to be recorded, analysed and made available to the authorities.

- Law 36/94 has removed the exceptions to the general principle that all surface and groundwater resources must be considered public, and has introduced important innovations asserting that water resource use must achieve the criterias of efficiency and of effectiveness, also taking into account the criteria of solidarity and of environmental protection. Besides, the law confirms that the management of the infrastructures pertaining to water (water mains, sewers, treatment plants) must be traced to single management at the ATO level and the land reclamation consortia are responsible for the construction and management of water networks for irrigation purposes, for the reuse of treated wastewater, and for rural water mains. Law 36/94 has been followed by decree 47/96, that issued some guidelines for the identification of the areas under risk of water crisis, unfortunately not yet accomplished.

- Legislative Decree 152/99 (amended by Legislative Decree 258/2000) has been established in order to adopt into Italian legislation the European Directives 91/271 on Urban Wastewater Treatment and 91/676 on the Protection of Water from Agricultural

Pollution. It also rearranged all previous Italian legislative framework on pollution control, replacing fundamental law n.319/86 (Merli act).

Finally, it has defined the stages for achieving environmental quality objectives, including the analysis of present conditions and classification of environmental status, the identification of restoration objectives and the implementation of the necessary actions in water bodies.

Focus: Minimum Vital Flow Decree

The definition of the quantitative state of water bodies is one of the pillars of integrated qualitative and quantitative water body protection and is a fundamental survey element for the water protection plans organisation.

Law n.183/89 gives that "rational surface water and ground water use" shall be set among the planning objectives "in order to ensure that the abstractions will not compromise the minimum vital flow in the downstream catchments".

The "Galli Act" (Law n. 36/94) develops this concept and gives that the River Basin Authorities shall set out a "water balance". The water balance is a strategical river basin planning tool which is introduced in order to assure both the satisfaction of human needs and a water flow capable of protecting water body hydromorphology, water quality and the typical biocenosis of the natural local conditions. The Article 3.3 deals with this matter and establishes that "in the catchments subject to huge water abstraction or water transfer [...], the abstractions shall be regulated in order to assure the flow level needed to support life in the downstream river beds so that water resources, environmental livability, agriculture, aquatic fauna and flora, geomorphological processes and hydrological equilibrium are protected".

The Galli Act definitions are also included in Legislative Decree n.152/99, which gives indications for the definition of the minimum vital flow which shall be defined by the Regions (in the Water Protection Plan) on the basis of the "water balance" as determined by the River Basin Authority. These three legal acts constitute the framework of the Ministerial Decree 2004 July 28th which, as established in the Legislative Decree n.152/99, defines the guide lines for the arrangement of the water balance, including the criteria for the uses census and for the definition of the minimum vital flow.

This Decree takes into account the previous legal acts on water planning and management and gives accurate indications for the water balance definition; in particular it specifies: the spatial and temporal scale, the basic data, the information flow management and the activities required for the evaluation of natural water resources. Furthermore the water balance equilibrium condition is defined through the following:

$Ru - \Sigma Fi + Rreu + Vrest > 0$

Ru = useful surface and ground water resurces in the river basin

ΣFi = human needs as a whole (potable, agricultural, industrial, hydroelectric, etc...)

Rreu = water resources re-used in the river basin

Vrest = water volumes restored from activities placed inside the river basin

Also, the Ministerial Decree establishes that the useful water resources shall be calculated taking into account the M.V.F.; Ru shall be equal to the Potential Water Resources (which are the natural resources rectified with the abstracted water and with the water derived from other catchments) less the M.V.F.. The M.V.F. is defined as the instant flow - calculated in every homogeneous section of the water course - which ensures the preservation of its natural evolutionary trend (morphological and hydrological), of the water quality status (according with the quality objectives defined in Legislative Decree n.152/99) and of the biological communities typical of the considered area.

Finally the Ministerial Decree gives accurate indications for the data collection and for the selection of the method for computing the M.V.F. value.

4 WASTEWATER REUSE

There is, moreover, a growing interest in the reuse of wastewater from various sources and in treatment processes aimed at decreasing pollutant loads. Although theoretically no particular problems exist in this field, practical application tends to be characterised by several difficulties ranging from the obtaining of sufficient resources to problems of quality. The latter would appear to be particularly true with regard to quantity, in low rainfall areas.

Sardinia, like many other Mediterranean regions, suffers from a shortage of water, especially good quality water, on account of recurrent droughts. In spite of the fact that traditional surface and groundwater resources continue to diminish, little has been done in the way of recycling sewage plant effluents which are usually discharged into rivers or into the sea, creating environmental problems associated with eutrophication.

Two kinds of intervention have been realised in the Sardinia Region: one at district level and the other at local level.

The first experience within the sphere of the INTERREG IIC community project, the complete implementation, was foreseen of the intervention named "Connection of the urban wastewater treatment plant of the Cagliari area and neighbouring municipalities (Arenas Is) to the Simbirizzi basin".

The implementation of the intervention has ended discharges to sea, although purified, of the wastewater from Cagliari and neighbouring municipalities. The wastewater is now used only for irrigation purposes. The idea of implementing the intervention was backed by a study of non conventional techniques for wastewater treatment through pilot plants, within the sphere of a convention between the Ente Autonomo del Flumendosa, activator of the intervention, and the Joint Research Centre, ISPRA.

This project will make possible the reclamation and reuse of the wastewater effluent from Is Arenas plant for irrigation purposes using either direct or indirect methods. Specifically, about 40 Mm3/year of Is Arenas effluents will be recycled in irrigation areas of southern Sardinia (8000 hectares). The recycled volume represents about 80% of the present irrigation volume requirements.

The project consists of two main interventions:

1. to connect the wastewater treatment plant of Is Arenas with the reservoir which will be used as a big storage tank for the water to be reused for irrigation purposes, when the indirect reuse is applied.
2. to carry out a tertiary treatment line of the effluents from Is Arenas plant with the following two aims:

a) *for indirect reuse of the effluent in irrigation, the process must be capable of reducing the phosphorus (Ptot around 2.5 mg/l) to sufficiently low levels for preserving the already precarious trophic state of Simbirizzi reservoir (Ptot around 0.2 mg/l) as well as the bacteria content.*

b) *for direct reuse in irrigation the process must be capable of reducing bacterial content to below 2CT/100 ml (which is the present Italian restriction for wastewater used for irrigating crops to be eaten raw-2000).*

In the second experience, financed by European Community within the sphere of the Envireg programme for the protection of the environment in the sub-programme Propenv 1 and co-financed by the Council for the final arrangement of the distribution network and the activation of the service, the Villasimius (CA) council implemented a project of a system of reuse of treated water. The overall system is made up of a biological treatment plant using activated sludge with final disinfection and discharge into the Foxi river (prior to the reuse project) and a refinement plant made up of: pumping section, pressure filter, ozonization, final disinfection with PAA or sodium hypochlorite.

The works, which commenced in 1995 and were completed in 1999, have permitted the implementation of a treatment plant capable of regenerating 6.000 cu. m. of purified water a day and a distribution network capable of serving 250 hectares of agricultural land and about 150 hectares in tourist areas.

The reuse system came into operation in the summer of 1999 and distributed, in two months, 40,000 cu. m. of treated water for the watering of the green areas of two hotel infrastructures. In 2000, following the encouraging results obtained in the experimental stage, distribution began on all the areas served by the network, creating significant interest on the part of the users.

These activities have been carried on in the frame of the SEDEMED project.

5 ARETUSA PROJECT

One of the major problems which characterises the Cecina River is the lack of water during the summer months. The river has always had an unstable stream flow, causing it to flood during the winter months and dry out during the summer months. However, the phenomenon has been much more acute during the last few years due to the heavy abstractions to which the river is subjected. These abstractions are for various reasons, such as for drinking water, agricultural and industrial uses. Most certainly, it is the abstractions made by the industrial sector which impact more heavily on the water resources of the river. Of these industries, Solvay uses the greater amount of groundwater. In order to limit the phenomenon of summer drought, due also to industrial abstractions, the ASA water manager together with the Solvay group, has considered the possibility to reduce abstractions through waste waster re-use technologies. It was in this context that the Aretusa project, which is based on the re-use of waste water from the Cecina and Rosignano treatment plants, was developed.

The treated water from the two treatment plants will be channelled to a post-treatment plant situated near the Solvay plant at Rosignano, which then supplies the treated water directly to Solvay. According to the ASA estimate, on the basis of the capacity of the two treatment plants, the Cecina plant must supply about 2.400.000 cubic meters and the Solvay plant 2.453.000 cubic meters of water per year. Once the project is operational, the Solvay group must not withdraw more than that of the river bed well, the same quantity of water which the treatment plant will be able to supply. The estimate given during the study phase foresees that with this project Solvay will extract no less than a minimum of 3,8 and a maximum of 4,16 cubic meters per year.

At present the post-treatment plant and its connection to the Rosignano wastewater treatment plant have been completed and within the end of this July they will be tested. The connection of the post treatment plant to the Cecina wastewater treatment plant is not yet realized.

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Past and Future of Drought management in Spain

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1. FORMER REGULATIOMS ABOUT EXCEPTIONAL SITUATION AND DROUGHT CRISIS MANAGEMENT

Droughts and floods are the most frequents hazards in Spain and provoke the greatest damages due to natural catastrophes.

The Spanish legal framework determines the way to face the problem for the Public Administration and stakeholders. In the past, this has been treated applying exceptional measures during the crisis but few of them regarding with preparedness, mitigation and previous planning.

The former Water Act (1985) gives certain powers to Reservoir Committees of River Basin Authorities in case of water shortage, in accord with water rights.

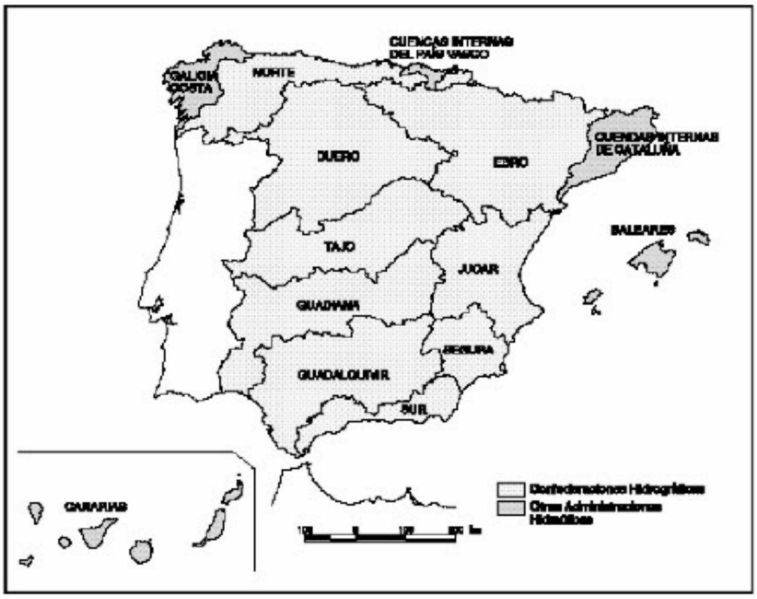
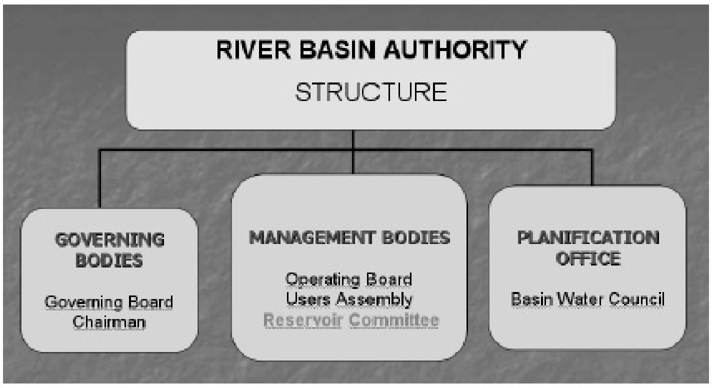


Figure 1: Spanish River Basin Authorities

Reservoir Committee draws up and discusses proposals to be submitted to the Basin Authority Chairman with regard to filling and emptying reservoirs and aquifers, according to the rights of the different users and the current hydrological situation.



Exceptional case (Water Act, Section 58): In circumstances of unusual drought, the Government may adopt **exceptional measures** in order to address the situation, even if concessions (rights of water use under certain conditions) have been granted. Such measures may include the building of emergency infrastructure.

The experiences acquired during the last droughts suffered in the country have showed how this concept was inappropriate and demonstrated the necessity for new regulations and an adequate drought risk management.

Analysis of the drought management policies indicates that decision-makers react to the drought episodes mainly through a crisis-management approach by declaring a national drought emergency programme to alleviate drought impacts, rather than on **developing comprehensive, long-term drought preparedness policies** and plans of actions that may significantly reduce the risks and vulnerabilities to extreme weather events.

Drought planning tendencies nowadays drifts towards moving from crisis to risk management.

2. HISTORICAL DROUGHTS AND ECONOMIC IMPACTS: LESSONS LEARNT FOR A NEW CONCEPT ABOUT DROUGHT PLANNING AND MANAGEMENT

Although droughts have not been studied in necessary detail and the records of the major droughts that have occurred in Spain are not sufficiently accurate (Menéndez

1997), the moste recent have been described in "**Libro Blanco del Agua en España" (MIMAM, 2000).**

The irregular Spanish hydrologic regime makes water a special scarce resource, with restricted availability and strong regional and time contrasts, situation not comparable to the rest of EU. In Spain the mean relationship between natural global resources and water demands for consumptive uses is 3 times minor rest of EU, while available resources represents 8 % of total resources (40-50 % in central EU countries).

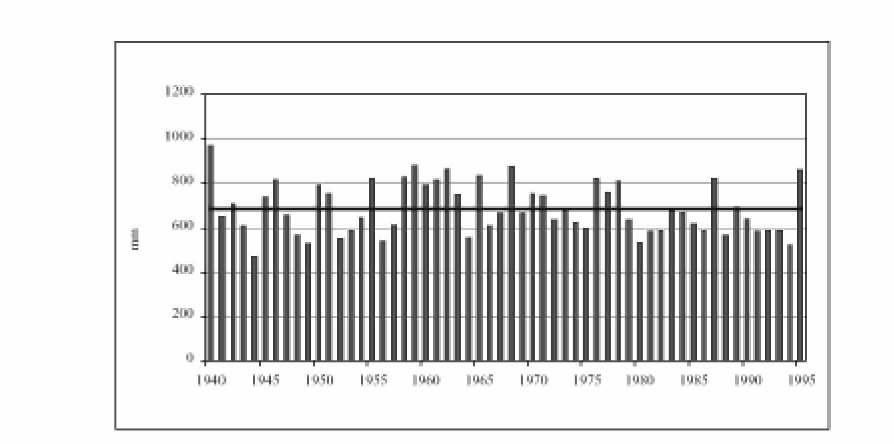


Figure2: Mean rainfall time series variability in Spain (1940/41- 1995/96)

Spanish water resources occur with high irregularity in time (inter-annual and annual) and in space (humid north regions versus arid Mediterranean regions).

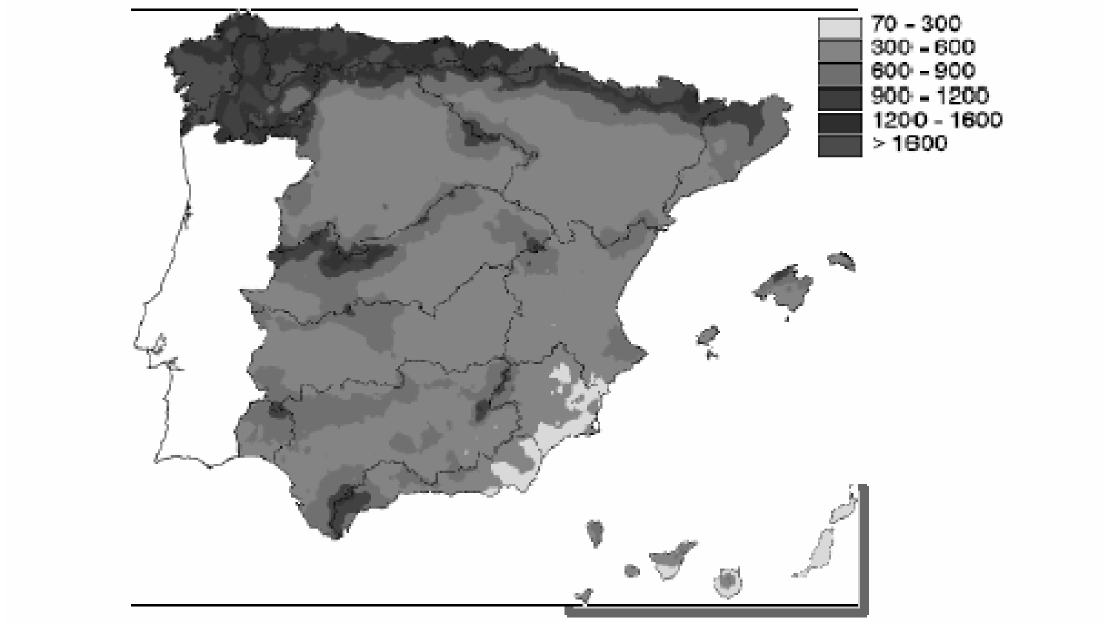
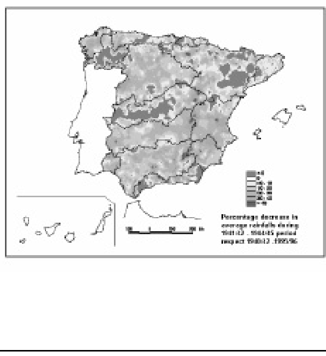
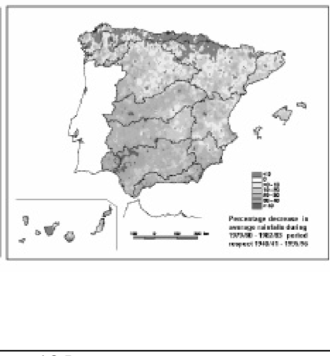
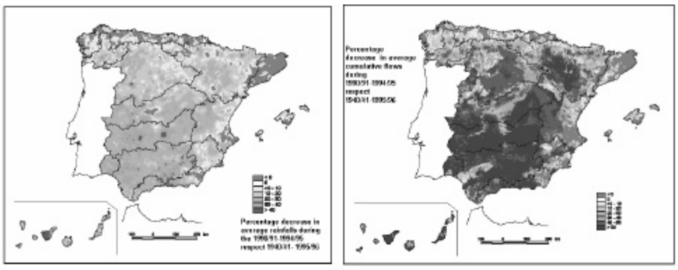


Figure 3: Mean rainfall territorial variability in Spain (1940/41- 1995/96)

The below figures taken from "Libro Blanco del Agua en España" (MIMAM, 2000) show some examples of the decrease in rainfalls compared with the average rainfall during the worst three droughts that occurred in the 1940/41 to 1995/96 period: the one which took place from October, 1941 to September, 1945; the one which started in October, 1979 and finished in September, 1983; and the drought which took place from October, 1990 to September, 1995.

These three droughts were considerably extensive, and affected most of Spain’s territory. In basins such as Guadiana, Guadalquivir or South they resulted in about a 30% decrease in rainfalls. If we observe the geographic distribution of these percentages, it is clear that the highest decreases take place in areas which are strongly influenced by humid fronts coming from the Atlantic Ocean, which seems to suggest that the occurrence of an extensive drought might be conditioned by the variability of these types of fronts



It is important to take into account that the aforementioned comments on rainfall cannot be directly applied to runoff, because the ratio rainfall-runoff is not linear. As can be observed in the figure, during the latest drought there was a major reduction in the runoff generated in most of Spain’s territory (about 40%). This reduction amounted to more than 70% of the average interannual cumulative flow of the Guadiana and Guadalquivir basins. In the South and Tagus basins, the reductions amounted to 60 and 50%, respectively, whereas the Douro, Segura, North I and Ebro basins suffered decreases ranging from 20 to 40%. In the remaining basins, the variation was hardly significant, and in the Catalonia Inland Basins there was an increase with respect to the average figures (about 15%), which means that, instead of a drought, this area went through a humid period.

In addition to the impact on water ecosystems, the direct effect of these reductions, from the point of view of the water allocation system, is the limited availability of the water supplied to populations –even resulting in the imposition of restrictions–, the reduction in agricultural productions, both in unirrigated and irrigated land, and the decrease in hydroelectric output.

In “**Libro Blanco del Agua”**, prepared with data compiled by Villalba Sánchez (1995) and data from MAPA [1998], the following pictures show the evolution of the hydroelectric energy deficit and the evolution of the agricultural production in irrigated and unirrigated land, expressed in constant trillion pesetas (6010 M euros) at their 1996 value, on which the supply series (non-dimensional, where 1996=1) for two major urban supply systems (Madrid and Mancomunidad de Canales del Taibilla water supply), are superimposed. and its associated cost during the 1988-1994 drought period.

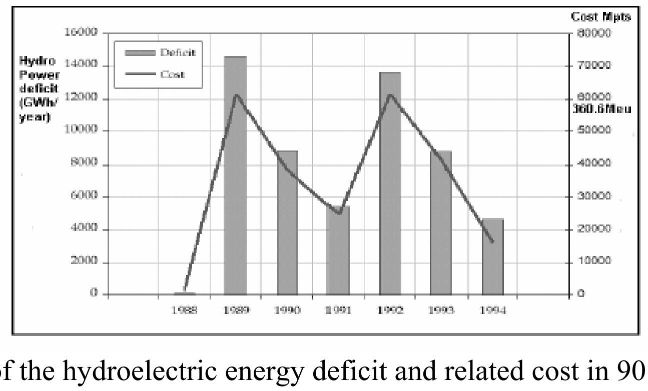


Figure 4: Evolution of the hydroelectric energy deficit and related cost in 90’s drought

The most common measures taken to face drought were:

- The early imposition of restrictions and **special procedures for exchanges between users**.
- The localisation and exploitation of new groundwater resources and the use of non-conventional resources.
- The execution of works for connecting basins.

The search for new groundwater resources was carried out on a large scale, supplying or adding water to cities (Granada, Madrid, Santander, Pamplona, Burgos, Segovia, Ávila, Alcoy, Benidorm, Jaen, Málaga, Costa del Sol…).

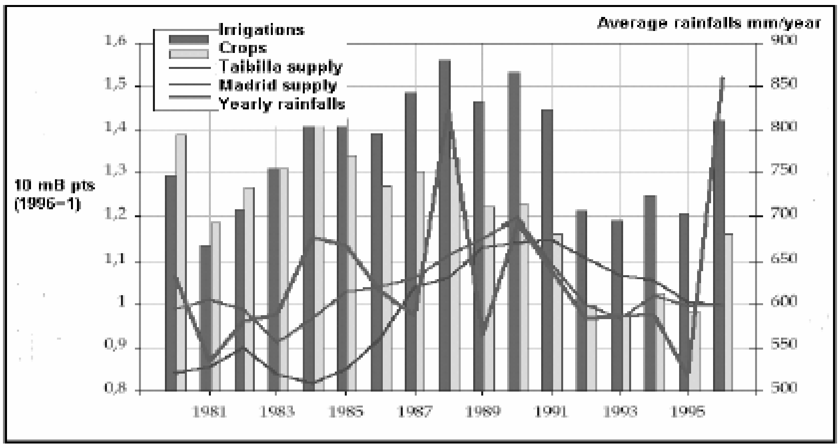


Figure 5: Evolution of agricultural production in irrigated and unirrigated land in 80's and 90's droughts

By using groundwater, it was also possible to mitigate the effects of the drought in the irrigated land, with drought wells constructed by River Basin Authorities and authorized users. To execute all these actions, specific regulations on drought wells were approved for the River Basin Authorities, such as Segura basin. Only in the Segura basin, nearly 2,000 requests for opening wells were processed, and the over-exploitation of aquifers increased by about 166 hm3/year.

A full summary of the emergency actions for extracting groundwater was issued by MIMAM (1999).

During this drought, other non-conventional methods were applied, such as the **mixture of insufficient quality resources with better quality ones**. This practice was carried out in the summer of 1995, to supply water to Malaga and the Costa del Sol, where the highly saline reserves in Conde de Guadalhorce and Guadalteba reservoirs were used, mixed with water from the Viñuela reservoir and from aquifers. There was an increase in the **reuse of treated waste water** from coastal cities, such as Almería, Murcia, Cartagena or Alicante, and water was even transported by boat to Mayorca and Cadiz.

Other **desalination** stations were also planned, but most of them were never constructed.

An interesting example of this situation and of the measures adopted was issued by EMASESA (1997a, 1997b), Sevilla public water supply agency, establishing **agreements with irrigators** in order to make supplying water to Sevilla possible, which faced a very worse situation.

The first type of measures included the construction of a large number of water pipes and channels, which increased the flexibility of the systems used for urban water supply. There are several examples of this type of measures, such diverting water from of the Alberche river with the aim of assuring Madrid water supply.

All these measures adopted in the different areas were implemented in accordance with a considerable number of regulations, approved under section 56 of the Water Act mentioned before.

In light of these circumstances, one **conclusion** which has to be drawn, from the legal point of view, is the existing gaps in our former law system. During the 1990-95 drought, no previous plans specifically designed for this type of emergency situations were implemented; on the contrary, the different actions were gradually conceived and executed –by each River Basin Authority– as the drought continued and its effects became more serious.

If we take into account the public awareness, the social perception of the shortage, and the moderation and responsibility of the demands for water, It also had some positive effects.

The occurrence of this 1990-1995 drought period was taken into account to draw the **basis for future drought management plans.**

3. NEW REGULATIONS FOR DROUGHT PLANNING AND MANAGEMENT

Mainly, the new legal framework deals with drought planning and management through:

- Modifications introduced in the **Water Act**. Different Sections of current Water Act (Texto Refundido Real Decreto-Legislativo 1/2001) including modifications to former Water Law. One of them is that the Government may authorize the River Basin Authority to set up Water Interchange Centers (**Water Bank**) to enable user rights to be waved by voluntary agreement (Water Act Section 71)

Specific legislation about drought: **Law 10/2001** Plan Hidrológico Nacional, Section 27 “Droughts management”. This law establishes the following obligatory process:

- Ministry of Environment: establishes a Global **Hydrological Indicators System** (HIS)
- River Basin Authority (Confederación Hidrográfica) prepares a Special Plan submitting it to the River Basin Council and the Environment Ministry for approval.

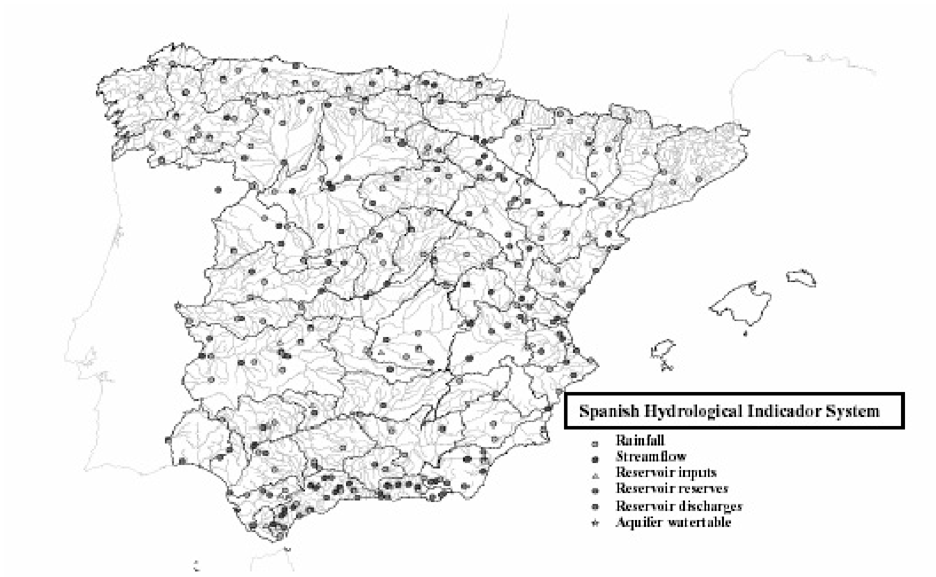
This **Special Plan** includes water supply (more than 20.000 inhabitants) directives in case of drought or drought warning.

River Basin Authority declares state of Drought or Drought Warning, according to the HIS threshold, initiating the measures included in the Special Plan.

- The institutions responsible for water supply (more than 20.000 inhabitants) have to draw up a **Drought Emergency Plan** and implement it when the state of drought or warning has been declared by the River Basin Authority.

Currently the hydrological situation is monitored monthly by the Environment Ministry, including:

- Rainfall
- Streamflow
- Water storage reservoir
- Aquifer water levels
- Snow (in progress)



Different indices are applied in order to control drought appearance and evolution.

4. DROUGHT BASIN SPECIAL PLANS. JUCAR RIVER BASIN EXAMPLE

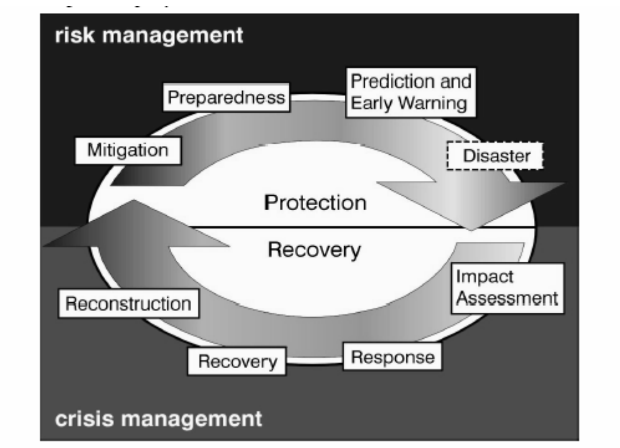
Drought planning tendencies nowadays drifts towards moving from crisis to risk management.

A drought plan will provide a dynamic framework for an ongoing set of actions to prepare for, and effectively respond to drought, including: periodic reviews of the achievements and priorities; readjustment of goals, means and resources; as well as strengthening institutional arrangements, planning, and policy-making mechanisms for drought mitigation.

Effective information and early warning systems are the foundation for effective drought policies and plans, as well as effective network and coordination between central, regional and local levels.

In addition to an effective early warning system, the drought management strategy should include sufficient capacity for contingency planning before the onset of drought, and appropriate policies to reduce vulnerability and increase resilience to drought.

These are the basic elements of a drought preparedness and risk management strategies that guide Drought Special Plans.



Nowadays the River Basin Authorities in Spain are drawing up their Special Plans, including early warning systems and measures to mitigate drought effects. Presently these Plans are only in effect at the Júcar basin.

The Júcar River basin, located in the eastern part of the Iberian Peninsula, covers an area of 42 989 km2 and includes part of four Spanish Autonomous Communities:

Castilla-La Mancha, Comunidad Valenciana, Aragón and a small area of Cataluña.

The area presents a characteristically Mediterranean climate with hot-dry summers and mild winters. It has a mean annual precipitation of 500 mm, varying from 320 mm in the driest years to 800 mm in the most humid ones. Extreme rainfalls in autumn commonly exceed 300 mm in 24 hours, which reflects the irregularity in precipitation (MIMAM, 2004a). According to the UNESCO climatic index, defined as the quotient between precipitation and potential evapotranspiration, there are three types of regions in the Júcar basin: semiarid, sub-humid and humid regions.

Population increase is considered the major pressure over natural resources. Total population in the Júcar, which has had an important increase in the past years, has overcome estimations made by the National Institute of Statistics (INE) at the beginning of the 90's. The population of the area was 4.571.938 inhabitants in 2003, in addition to about 1.580.147 equivalent inhabitants due to tourism. This increasing trend calls for a better water planning, water shortage infrastructures, and the use of alternative solutions, as it is the case of desalination.

Agriculture is another important aspect affecting water management in the Júcar Basin. In fact, it accounts for the highest water consumer in the area (75.7%), followed by urban (20.3%) and industrial demand (4%). Irrigated agricultural areas account for 36% of the area, while the non-irrigated cover 10%. RBAs work tightly with irrigation associations (users groups) in the creation of basin plans. In fact, users are part of the Water Basin Council in charged of approving important decisions affecting the Hydrological Basin Plan (1999) and associated Hydraulic works.

Figure 6: Drainage system and populated areas in the Jucar River Basin

Drought main patterns, temporal and territorial variability, are represented in the following pictures:

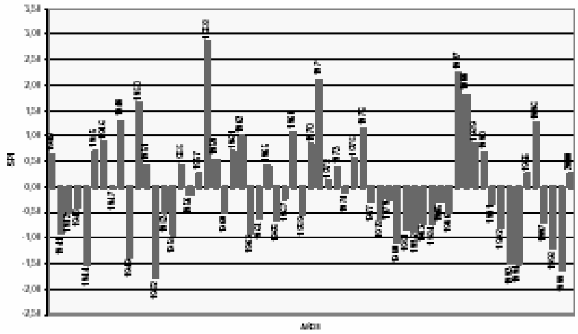
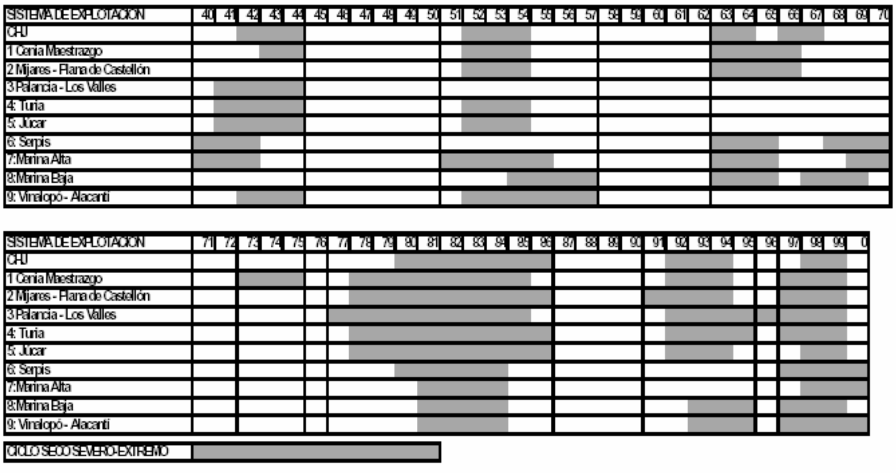


Figure 7: Standarized Precipitation Index SPI (1940/41-1999/00). Jucar River Basin

Table 1: Extreme Drought Meteorological Cycles and territorial pattern. Jucar River Basin



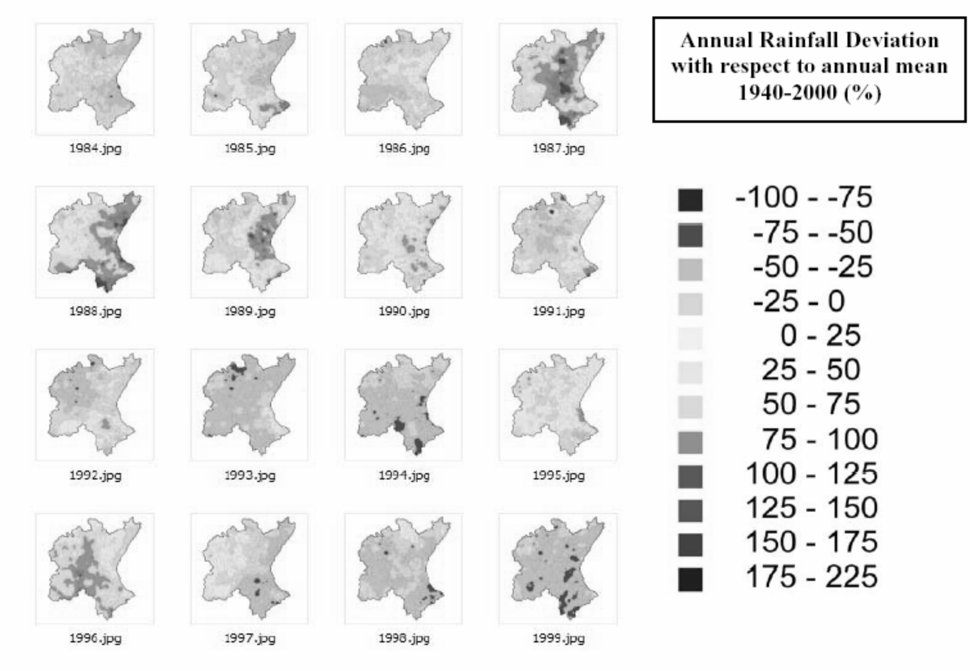


Figure 8: Territorial drought variability in Jucar River Basin

The objective of Jucar River Basin Special Plan is to anticipate ourselves to droughts, and foresee solutions to satisfy demand, avoiding situations of undersupply. Special Plan is based on:

- Indicators that will provide with a quick drought status early enough to act according to the Plan's forecasts.
- Knowledge about the resources system and its elements' capability to be strained during scarcity situations.
- Knowledge about the demands system and its vulnerability towards droughts, organised by priority degrees.
- tructural and non-structural alternatives to reduce drought impacts, and adaptation according to the indicators' status.
- Cost of the implementation of measures.
- Adaptation of the administrative structure for its follow-up and coordination among the different Administrations involved.
- Public information plan and plan for the staff in charge of the water supply systems.

The Jucar River Basin Hydrological Indicator System is based on a linear combination of the following types of gauges in each sub-basin: rainfall, streamflow, water storage reservoir and aquifer water levels. The contribution of each indicator to sub-basin and global basin index is weighted according to demand supported and water resources represented.

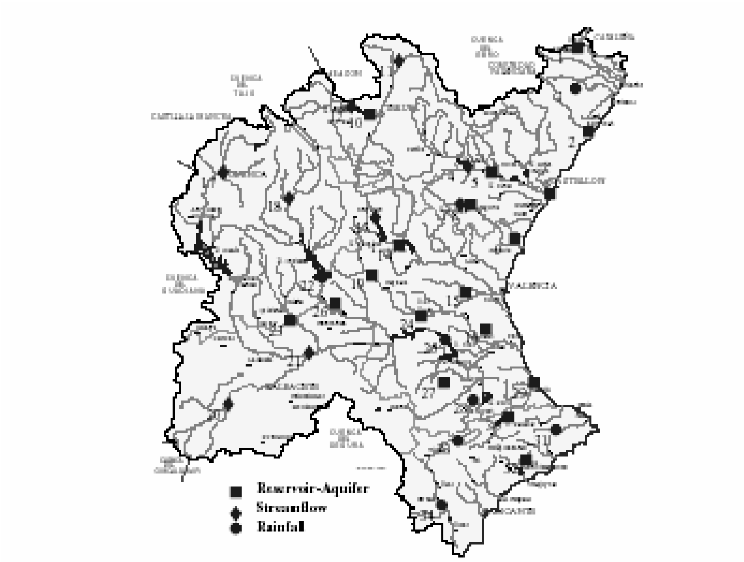


Figure 9: Jucar River Basin Drought Hydrological Indicator System. Gauge location

The attached figures show territorial distribution of different types of indicators and global Jucar River Basin composed Index evolution (green = normality, yellow = prealert, orange = alert, red = emergency situations).

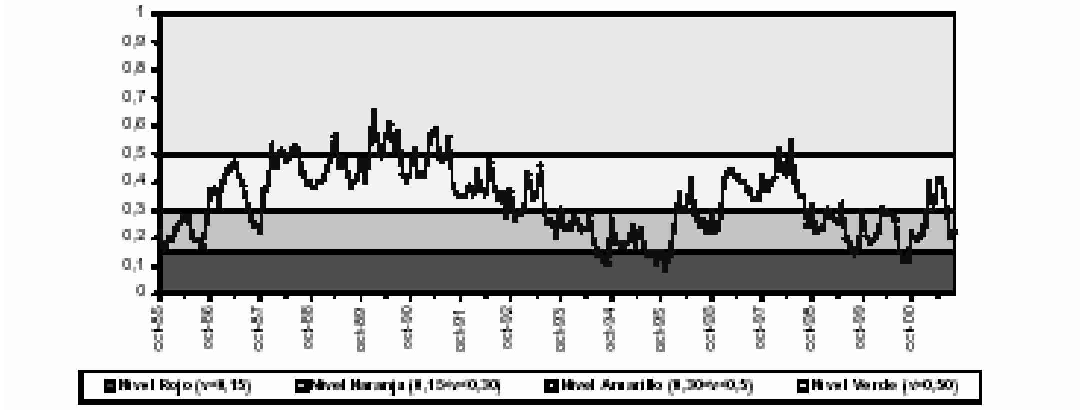


Figure 10: Jucar River Basin Drought Hydrological Indicator System. Global Index plot

The following figures illustrate drought characterization in Jucar River Basin.

Table 2: Drought triggers in Jucar River Basin

GLOBAL DROUGHT CHARACTERIZATION PARAMETERS JUCAR RIVER BASIN							
Indicator	1 - 0,5	0,5 - 0,4	0,4 - 0,3	0,3 - 0,2	0,2 - 0,15	0,15 -0,1	0,1 - 0
State	Normality	Prealert		Alert		Emergency	
Objectives	Planification	Control		Conservation		Restrictions	
Deficit (%)	0	0-8	8-17	17-27	27-32	32-36	36-46
Storage (hm^3)	1604-813	813-667	667-500	500-333	333-250	250-167	167-0

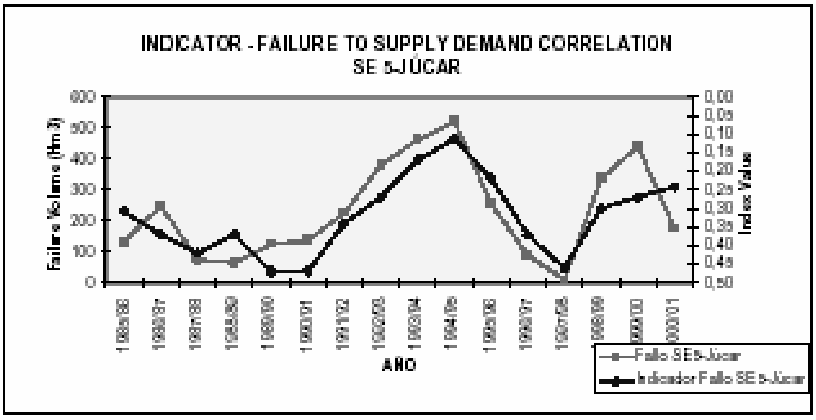


Figure 11: Correlation between Failure in Demand Supply (pink) – Drought Index (blue). Jucar Sub-basin

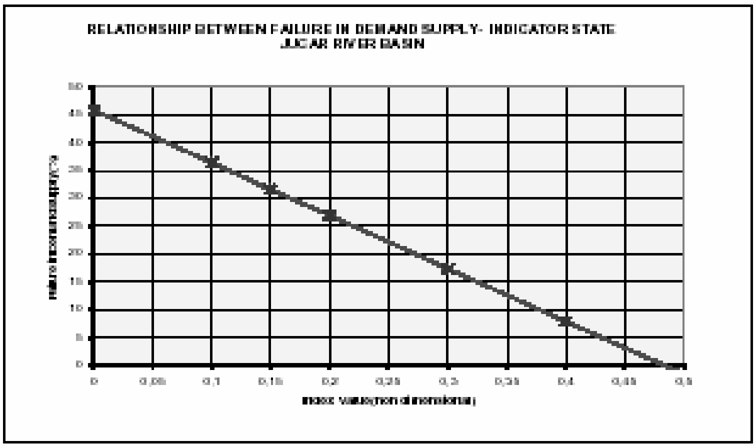


Figure 12: Relationship between Failure in Demand Supply – Drought Index

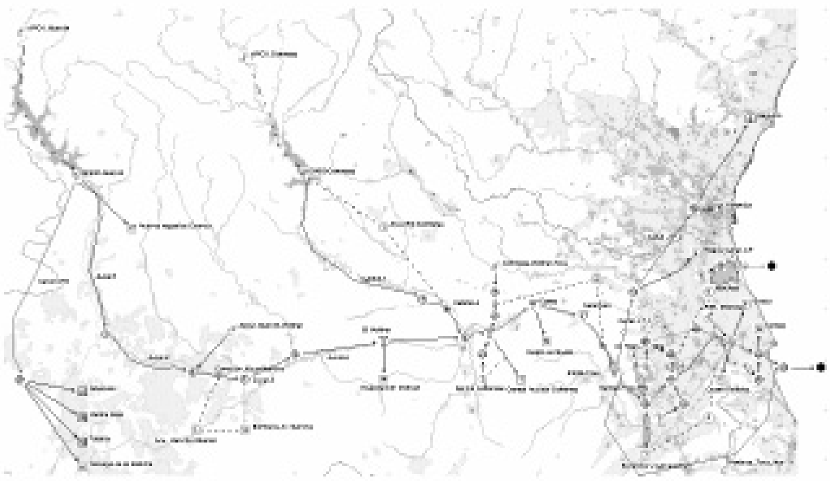


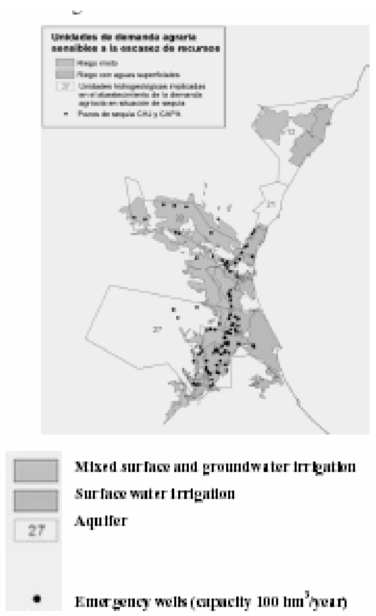
Figure 13: Jucar River Sub-basin Simulation Model. Rules and restrictions

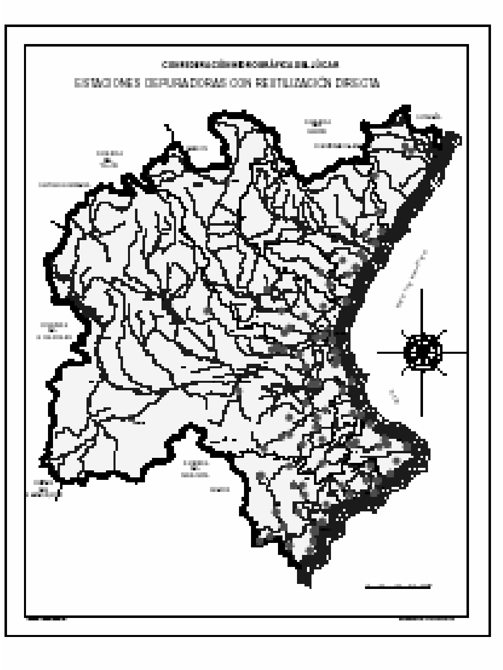
The planned actions for the Special Plan in Jucar River Basin are the following:

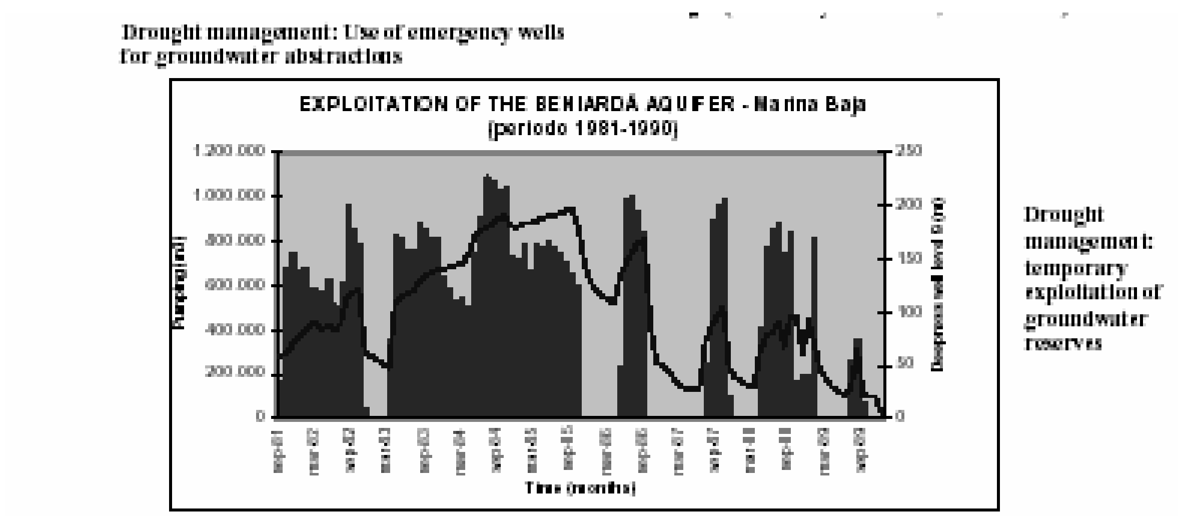
- Approval of exploitation rules and use restrictions
- Aquifers of strategic reserve
- Temporal exploitation of the reserves
- Emergency wells
- Desalination
- Reuse of treated wastewaters
- Transfers of external resources

Furthermore, the Drought Special Plan must activate and serve as boundary condition for water supplying Emergency Plans for towns over 20,000 inhabitants.

Some of the planned actions for drought mitigation are represented in the following figures.







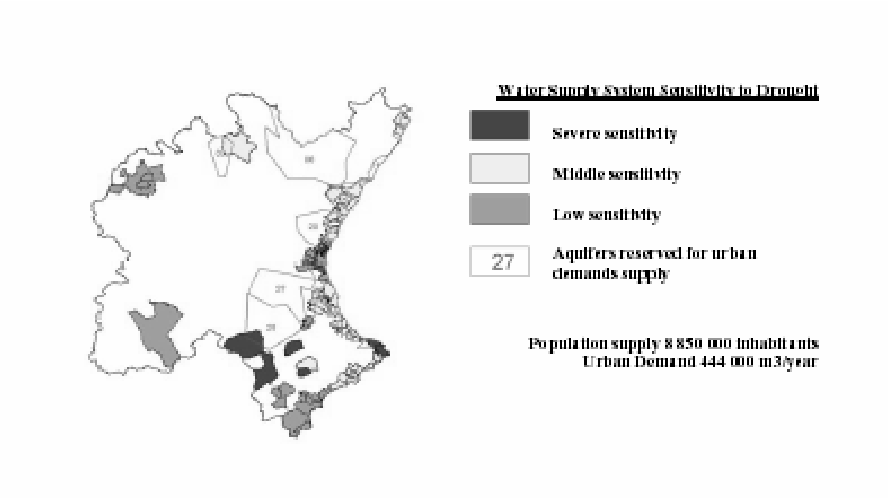


Figure 14: Drought management: Activation of Emergency Plans (municipalities/systems > 20.000 inhabitants)

The mitigation effect of the Drought Special Plan is summarized in the following table.

Table 3: Drought Special Plan Effect

DROUGHT MITIGATION PARAMETERS	% Demand
Urban and Agrary Demand (3 380 hm3/year)	100,00
Alert State (I<0.3)	
Initial Deficit	17,00
Water Conservation Measures	5,68
New Available Resources	5,00
Emergency State (I<0.15)	
Initial Deficit	32,00
Water Restrictions	22,37
New Available Resources	5,53
Total New Available Resources(Pre-Alert, Alert and Emergency)	
Wastewater reuse	7,34
Irrigation systems modernization	5,83
Desalination	1,80
Aquifer reserves abstractions	3,40
External transferences	0,15
Total	18,52

Planned conservation resources suppose a delay in the appearance of alert and emergency threshold and the development of new available resources to face drought represent 18.52 % of Jucar River Basin demands, acting as new offer in normality and pre-alert states, and as mitigation resources in alert and emergency states.

5. CONCLUSIONS

Drought planning tendencies nowadays drifts towards moving from crisis to risk management.

Developing comprehensive, **long-term drought preparedness** policies and action plans may significantly reduce the risks and vulnerabilities associated with extreme weather events.

It should include **prevention** – in order to reduce the risk and effects of uncertainty- and **mitigation** – measures undertaken to limit the adverse impacts of hazards- strategies.

Drought impact assessment involves, at least, the specific effect on the economy, social life and **environment**, vulnerable to event.

Basic elements of a drought preparedness and risk management strategies that guide Drought Special Plans are the following:

- Effective information and early warning systems are the foundation for effective drought policies and plans, as well as effective network and coordination between central, regional and local levels.
- Drought management strategy should include sufficient capacity for contingency planning before the onset of drought, and appropriate policies to reduce vulnerability and increase resilience to drought.

The problem of drought requires a **proactive management** developing actions planned in advance, which involve modification of infrastructures and laws and institutional agreements and the improvement of public awareness.

In Spain the legal framework regarding to drought has evolved from crisis management to risk management. It is desirable enhance the long term measures of the Special Plans concerning to River Basin Management Plans and enhance the linkages with **Water Framework Directive.**

SCAPT: A Strategic Catchment Analysis and Planning Tool

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ABSTRACT

SCAPT, or Strategic Catchment Analysis and Planning Tool, provides a powerful tool for investigating the effects and impacts of a series of water resource scenarios for the Hérault catchment, S.France. SCAPT comprises components addressing catchment hydrology, land use cover change and urban water use profiles. SCAPT is targeted as a teaching and research tool which allows water resource managers and planners to investigate the combined impacts of human and natural events at the catchment scale and is therefore well suited as a basis for developing catchment management plans under the EU Water Framework Directive. SCAPT is a novel software tool conceived to explore and document the causes and effects of adaptive intervention and co-evolution of the combination of factors at play within the selected catchment. SCAPT is developed within the wider Aquadapt project (EVK1-CT-2001-00104).

1. INTRODUCTION

The EU Water Framework Directive WFD (Directive 2000/60/CE) has at its core the aim of introducing responsible and sustainable water resource management at the catchment scale. One of the mechanisms for achieving this, noted in Article 13, is through the definition of river basin management plans. Although this clearly recognises the need to produce detailed programmes at sub-basin and sector level, a key importance to WFD is the recognition of the whole catchment as a management unit. The river basin management plans as defined in Annex VII call for a clear summary statement as to the pressures and impacts of human activity on the status of catchment surface and groundwaters as well as clearly defined environmental objectives. This approach demands water resource managers and planners deploy novel tools that clearly place whole catchment management at their centre. Such tools should be able to present clear statements as to management options available and the implications of their selection, whilst at the same time accommodating such long-term externalities such as the effects of climate change with all its attendant effects – such as the increase of extreme hydrological events. The tools developed should also be accessible to a wide range of stakeholders and provide information likely to support debate and dialogue between parties involved in water management, as required by Article 14 of the WFD (which identifies that stakeholders be actively involved in the preparation of water management plans and that the public be consulted on those plans before final approval by the relevant authorities).

SCAPT, or Strategic Catchment Analysis and Planning Tool, addresses these two issues. SCAPT is a stakeholder software decision support tool, developed within the wider

Aquadapt project (EVK1-CT-2001-00104), being designed to allow investigation of the consequences of different management decisions affecting strategic water requirements in the semi-arid catchment of the Hérault catchment, S. France. The end-user of SCAPT is envisaged to include water resource managers and planners, elected officials representing societal structures, the academic science and humanities research communities, non-governmental organisations representing environmental interests and members of the general public. For each of these segments, SCAPT attempts to provide a framework to allow the exploration of the impacts of decisions taken within the catchments and the likely long-term consequences.

SCAPT has been developed as a custom-written software tool aimed to address many of these issues, and offers a coherent catchment-based modelling system drawing together interactions of hydrology, land use cover change and urban water usage. SCAPT further allows the user to define a series of 'possible future' scenarios based both upon water management decisions as well as significant environmental impacts such as climate change. The model is designed to operate on a gridcell basis over a period of up to some 20 to 30 years hence. The model presents the user with a series of interactive feedback mechanisms, and also permits the storage of model run results for subsequent analysis and discussion. Together the scenarios made possible and the data outputs of SCAPT are intended to inform the debate concerning 'co-evolution' as a conceptual model for seeking sustainable modes of water resources management (Jeffrey & McIntosh, 2002).

2. CASE STUDY AREA AND METHODOLOGY

2.1 The Hérault catchment: natural and socio-economic context

The Hérault catchment in S.France, covering 2,582 km^2, extends 117 km inland across the Languedoc region, draining to the Mediterranean Sea some 5km downstream from the town of Agde, close to Montpellier. Geologically the catchment has four quite distinct regions. The upper catchment comprises crystalline basement formations, giving way to Palaeozoic then Mesozoic Karstic limestone, with a Tertiary sedimentary basin filled by Quaternary alluvial deposits falling to the sea. This region is semi-arid with an average annual precipitation ranging from 2,000 mm in the inland mountainous region to less than 600 mm in the southern coastal region. The topography of the catchment stretches from the coastal plains to the mountainous interior, with Mt. Aigoual the highest point at 1,565 m. The natural vegetation of the catchment is typical of the Mediterranean region, having extensive upland forests, with garrigue coverage in the middle karstic regions. The lowland area is highly fertile and is extensively developed for viticulture as well as having been urbanised, but in this region there is little other industry.

During the last two decades, the Hérault catchment has been subject to rapid socio-economic changes which are expected to intensify further in the coming years. The population has grown dramatically in the middle Hérault valley (at up to 3% per year), where small villages host an increasing population of commuters working in Montpellier (located outside the catchment). This increase of population, mainly due to positive migration fluxes from other regions and from Northern European countries is accompanied by a change in water use patterns by households (e.g. development of swimming pools and irrigated gardens) and by municipalities (increasing irrigated public areas such as public gardens and road features such as roundabouts etc.). Experts forecast this trend will continue over the coming 15 years, mainly because the Languedoc and

Roussillon regions represent the only areas where population growth can continue, the Eastern part of the coast (Côte d'Azur) now becoming saturated. This will lead necessarily to an increasing exploitation of fresh water resources and to significant changes in land use. Added to this, the pressures on water resources are likely to be exacerbated further by the effects of climate change.

Within the catchment, local public decision makers (including the River Basin District Agency, county council, public water supply companies, municipalities and government agencies) are increasingly concerned by the speed at which these changes are occurring. There are efforts to identify the potential strategic policy responses that could be implemented using the water and land use policy instruments at their disposal. However, these agencies lack appropriate tools that could be used to simulate the impact of alternative water and land use management scenarios on water resources at the catchment management level. The research presented in this project attempts to fill this gap through the development of a prototype Strategic Catchment Analysis and Planning Tool (SCAPT). Following an assessment of its relevance, its adequacy for stakeholders as well as the strategic needs of decision maker, SCAPT is applied to the Hérault catchment region.

2.2. Methodology

SCAPT development was conducted in three successive steps:

- Development of a conceptual model of the Hérault catchment: this consisted firstly in the delineation of the main water resources units (soil reservoirs, different aquifer types, tributaries, river stretches, and artificial water bodies such as irrigation canals, as well as major water abstraction points) and then in representing water flows between these different units. A typology of land use classes was further carried out and all the factors of land use change were identified and described. This included noting 'allogenic' (e.g. policy and planning factors) and 'autogenic' (e.g. natural change due to succession, climate change, forest fire) factors of change;
- Development of a spatial representation of the conceptual model, using a variety of different information sources (geological map, remote sensing images, etc.) and the development of a grid-cell based model;
- Development of numerical models and integration of these models into a single program, using the object oriented programming language 'Java'. Calibration of the integrated model and sensitivity analysis are currently under way;
- Design and implementation of an intuitive graphical user interface, including dynamic link with GIS features and a scenario generator module which allows the user to change parameter values and to define specific action scenarios.

3. DESIGNING THE SCAPT MODEL

3.1 Aim of the tool

The overall purpose of SCAPT is to integrate process-based human water use with the river basin water cycle to analyse how water supply, demand and usage change dynamically in response to socio-economic and physical environmental condition variables. The case study adopted in the Hérault catchment (S.France) is considered highly representative of a range of Mediterranean basin catchment environments each with similar issues. The SCAPT model seeks to simulate the impacts of water usage on water quality and availability within the Hérault catchment by enabling the end user to explore and determine appropriate strategies for the quantitative and qualitative management of water at the catchment scale, by modelling the impacts of actions taken concerning:

- land use change;
- development planning;
- climatic variation;
- urban and industrial technological and methodological change in water use, and;
- anticipated population change in the catchment.

SCAPT could be used by policy scientists to explore possible scenarios with the aim of mapping bounds of behaviour under different policies, identifying potential unexpected problems and identifying robust, adaptive water management strategies within the wider context of regional policy. A powerful aspect presented within SCAPT is the inclusion of scenario-driven 'possible futures', whereby the user can explore the consequences of a range of natural and societal changes which might occur within the catchment over the next 20 to 30 years.

The operation of SCAPT allows the user to develop scenarios for investigation and the model output provides information on impacts on the water resource throughout the catchment in a manner capable of indicating the significance of the result, for example a traffic light system of 'acceptable', 'warning-borderline' and 'failure'. The model provides semi-quantitative results, allowing the user to conduct a qualitative comparison of alternative scenarios but not a precise assessment of the impact of a given set of assumptions.

The output presentation is designed to inform debate concerning levels of sustainability of the water supply locally and throughout the catchment in terms of quantitative availability and qualitative suitability for use, the ability of the environment to tolerate changes in quality under changing utilisation or environmental conditions. Given the explicit process representation of water use within SCAPT it is possible to examine sustainability margins of the water resources for water use practices within the catchment from whole catchment, individual water use and cross-sector perspectives. The dynamics of the SCAPT model are intended to represent the consequences of changes in the human environment both spatially and behaviourally, and the impacts upon the hydrological system of the catchment of these changes. SCAPT also simulates the land use changes and societal responses to resource availability by constraining or promoting the development of land areas of water dependent socio-economic structures (housing, industry, agriculture, viticulture) either in response to water availability or to independent variables (e.g. planning constraints). The resultant model is able to simulate a catchment water use system with output suitable for exploring: resilience, adaptive potential, lock-in and co-evolution.

3.2 Conceptual model of the catchment

The model is based on a simplified representation of the catchment, being considered as a complex system whose dynamics are explained by interlinked hydrological, climatic, land use change and socio-economic processes. The processes included within the SCAPT model remit are shown in Figure 1.

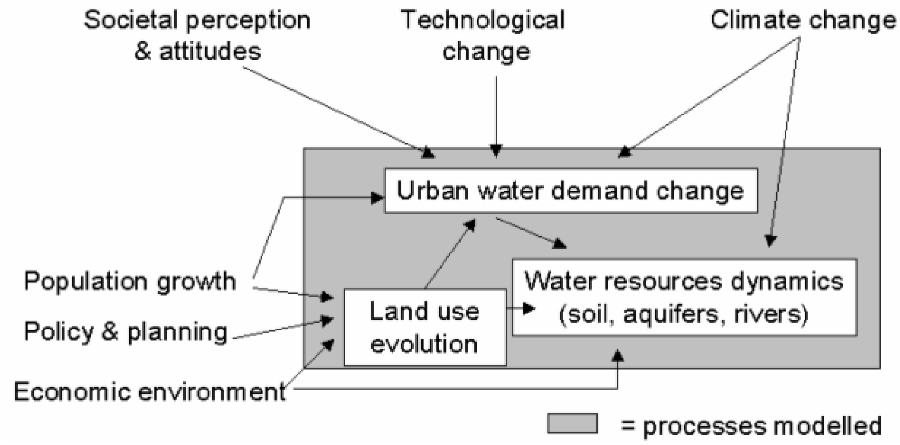

Figure 1: Processes modelled by SCAPT

3.3. Overall structure of the SCAPT and integration of numerical models

The SCAPT model structure has three inter-linked individual model components (fig. 2):

- A hydrological model defining the environmental distribution of water throughout the catchment (in the surface and within the aquifer);
- A land use cover change model (LUCC), representing spatially the land use type, transition rules, suitability and critical water requirements (CWR);
- A water use profile (WUP) model, generating the characteristics of societal water use in terms of demand and qualitative impacts, water storage and treatment processes.

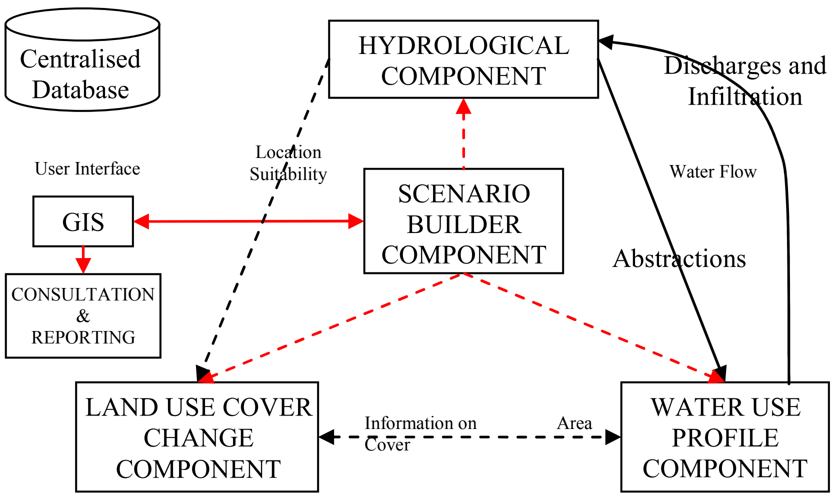

Figure 2: Conceptual SCAPT model structure

The land use model defines the areal distribution of land use types. These land use types determine the Water Use Profiles (WUPs) that demand and utilise water. The WUP model draws upon the hydrological model to determine the availability of the different sources of water available and simulates the use of the water for various societal purposes. The WUP component consists most importantly of the water dependent processes (WDPs) (Boyce et. al., 2002) - including garden watering, washing, consumption, cleaning among others for households and rinsing, cooling etc. for industrial use - that combine to form a single functional or economic entity. It is these processes and their relationships to one another either singly or as a group that define the water use impact of the structure as a whole. The characteristics of these processes define the impact that the land use type has upon the resource of water in the catchment.

3.4 Hydrological Modelling

In operation the SCAPT model operates a compartmentalised hydrological model reflecting the main aquifer types in the Hérault, namely crystalline, karstic, sedimentary and alluvial. Precipitation is handled by the Soil-Climate-Land Use component and according to the underlying aquifer, atmospheric returns and rates of epidermic/overland and effective infiltration flows are computed. Aquifer components discharge to river or adjacent aquifer components. Abstraction is observed either from the river or aquifer reservoir.

The catchment has been divided into a set of sub-catchments, corresponding to aquifer reservoirs. The delimitation of these aquifer reservoirs has been made through the intersection of different information and criteria:

- the cutting of the aquifer units at the scale of 1:50,000, previously established by BRGM (fig. 3),
- the difference in hydrological comportment between the different types of aquifer (e.g. between the karstic and alluvial aquifers),
- the strategic interest of some aquifers, that has justified a specific cutting (for example, some aquifers that are planned to be used for the future water supply of important proximal cities),
- the surface sub-catchments defined for the Hérault river and its tributaries,
- the available information on river flow output at particular gauging stations on the Hérault river and its major tributaries, which can be used for the calibration of the model.

As a result, 23 aquifer reservoirs were defined covering the whole Hérault catchment (fig. 4). These 23 aquifer reservoirs are what, in SCAPT, are termed ‘Gardenia boxes’, as a direct reference to the BRGM GARDENIA[1] hydrogeological model, based on reservoirs in series (Thiéry, 2003). The principles and flow equations of GARDENIA have been implemented in the SCAPT hydrological model (fig. 5):

- the GARDENIA boxes are divided in three superimposed reservoirs acting in series, representing, from top to bottom, the ‘soil’ layer, the ‘unsaturated zone’ layer, and

[1] modèle **G**lobal **A** **R**éservoirs pour la simulation des **DE**bits et des **N**iveaux **A**quifères.

the ‘saturated zone’ layer, this latter corresponding to the ‘aquifer groundwater reservoir’,

- in the ‘soil’ reservoir, hydrologically efficient rain is calculated from the input data of rain and potential evapotranspiration (PET) as a function of the classical method of connected balances of Turc and Thornthwaite (Thornthwaite, 1954),
- in the ‘unsaturated zone’ reservoir, the balance is calculated between direct runoff to the river (considered as rapid flow) and aquifer recharge.
- in the ‘saturated zone’ reservoir, the aquifer emptying to the river is calculated (considered as delayed flow).

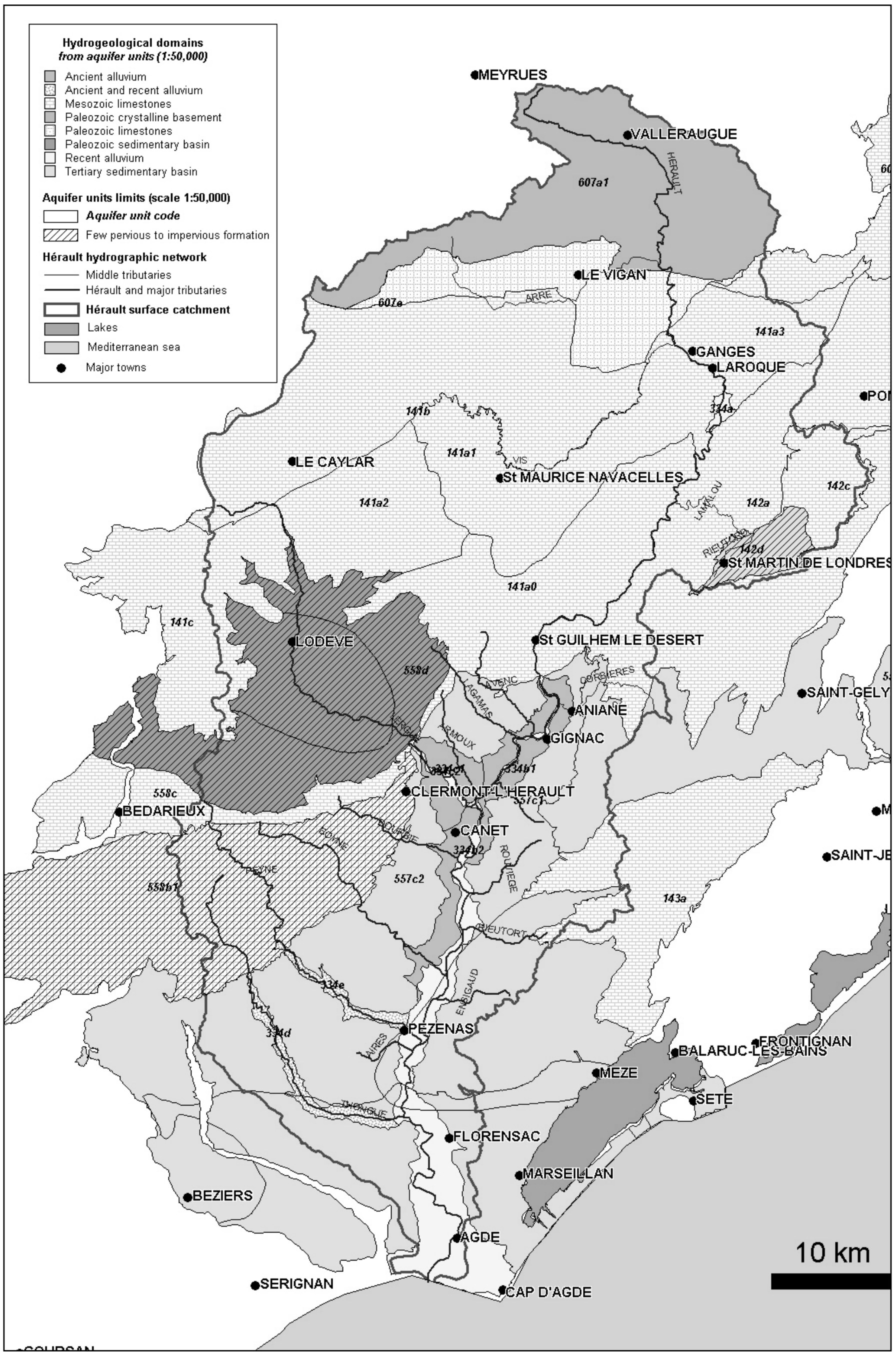

Figure 3: Main hydrogeological domains (based on the cutting of the aquifer units at scale 1/50,000.

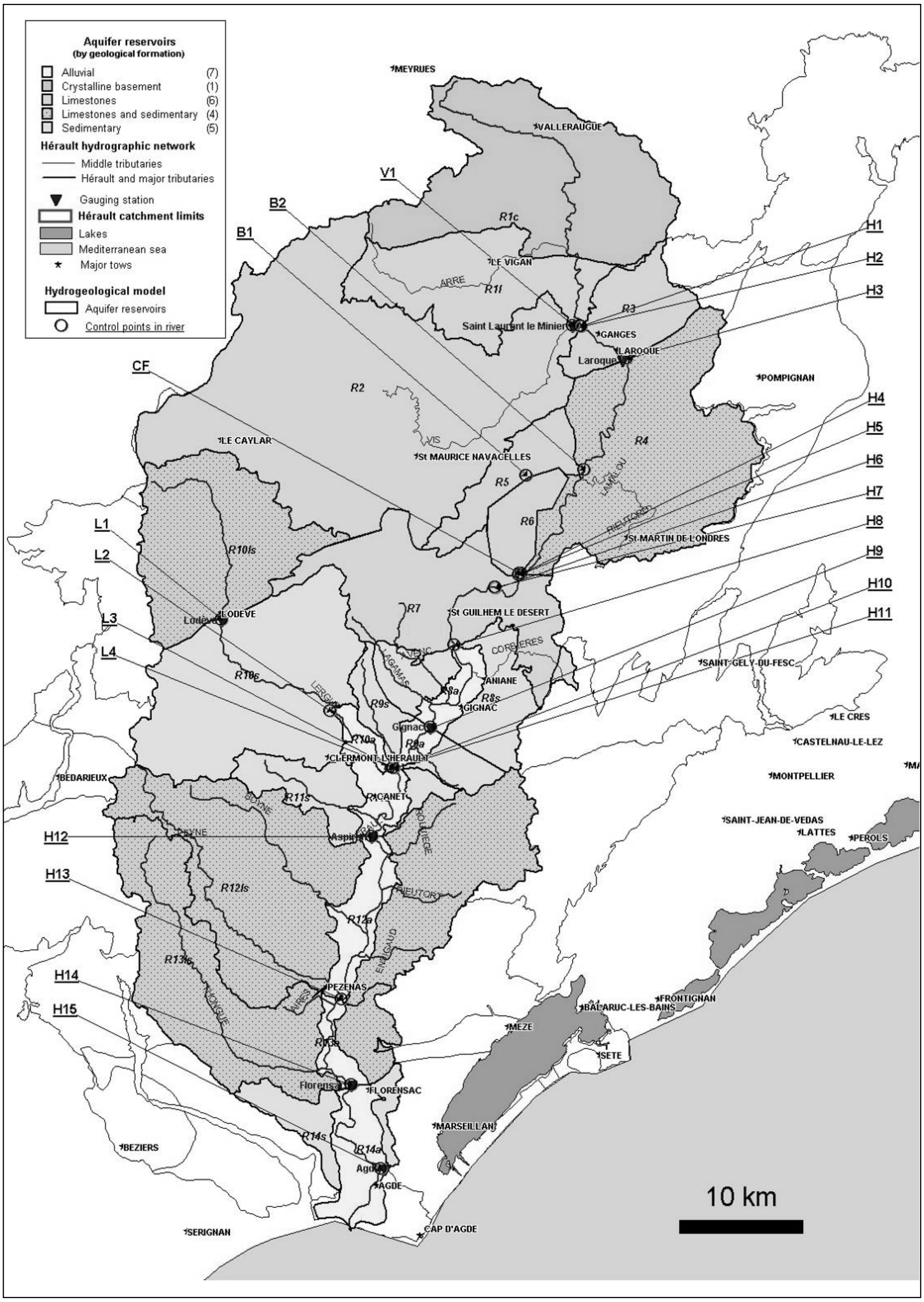

Figure 4: Aquifer reservoirs and control points defined in the SCAPT hydrological model

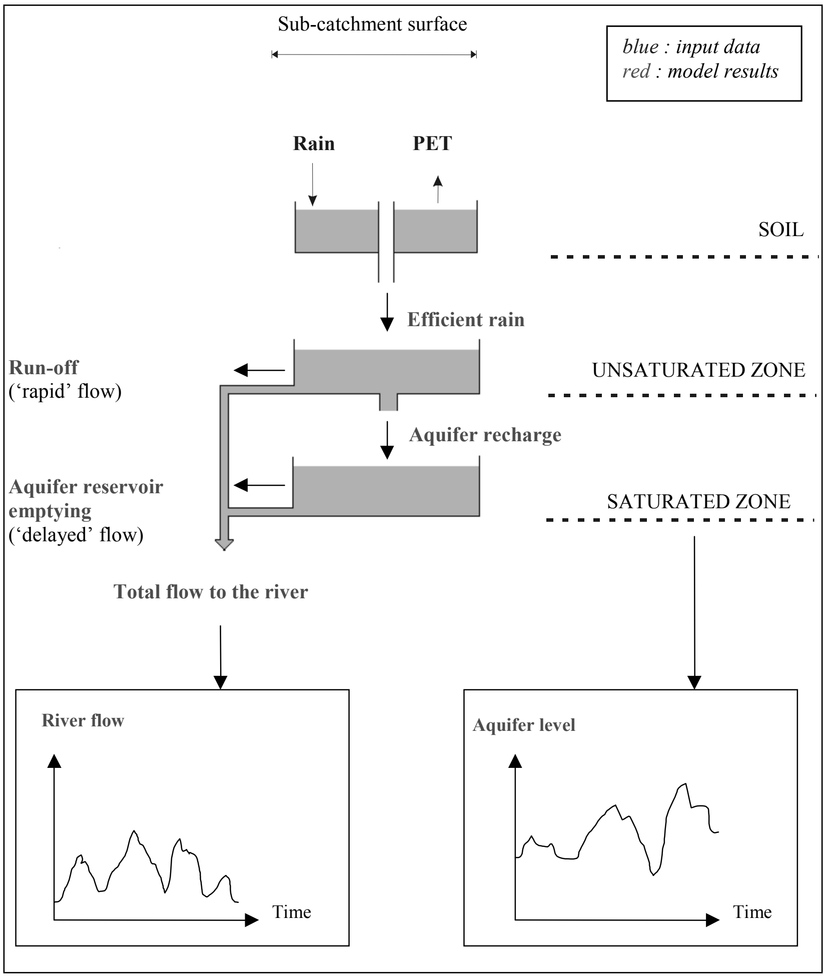

Figure 5: Principles of the GARDENIA model

3.5 Land Use Cover Change Modelling

The land use cover change (LUCC) component models the dynamics of different land use and land cover types across the Hérault catchment in response to hydrologic stress, planning zonation, external pressures (e.g. demographic change) and processes of ecological change. Natural vegetation, agriculture, viticulture and urban land use cover types will be considered to represent the variety of natural, semi-natural, managed and built landscapes present in the Hérault.

The SCAPT model employs two user-configurable Land Use Class Change (LUCC) matrix templates. A separate copy of each of these matrices exists for each discrete geomorphological zone within the catchment. One matrix relates to 'internal' change and response – for instance the natural succession cycle, which land use would be subjected to in the absence of external input; this is the 'autogenic' LUCC matrix. The second matrix relates to the response to 'external' inputs – for instance directed land use or planning policies; this is the 'allogenic' LUCC matrix. The latter allogenic matrix is applied where a particular land use is increased within a SCAPT gridcell ('allogenic additive' matrix). SCAPT also manages circumstances where specific land uses are decreased within a gridcell. In both circumstances, the likely responses are managed for other land use classes in the given gridcell. The appropriate responses are calculated by comparing the external change required against the existing land use proportions in the gridcell at the time and whether the required change would lead to an increase, a decrease or to no change.

The matrices take the general form presented below (Table 1), where a given transition (read as 'Changes From' to 'Changes To') is accompanied by a response specified as a percentage allocation. Note a '*status quo*' is allowed for by a percentage >0% for the intersection of a land use class on itself.

Table 1. Generic form for the LUCC matrices

		Changes To				
		LUC 1	LUC 2	LUC 3	LUC 4	LUCn
Change From	LUC 1	0%	90%	10%	0%	
	LUC 2	0%	0%	85%	15%	
	LUC 3	0%	0%	0%	100%	
	LUC 4	100%	0%	0%	0%	
	LUCn					

In sequence, allogenic factors are processed first, followed by autogenic. This allows the model to reflect at any timestep the full implications of any scenario being run. Allogenic transitions are driven by and reflect the various scenarios that the SCAPT model is running. These 'exogenous' factors include:

- Supposed land use class area growth and decline;
- Supposed increases and decreases in water demands;
- Supposed trends in climate and surface hydrology.

The allogenic matrices govern how the LUCC model reacts to imposed additive (e.g. urban growth) and subtractive (e.g. land abandonment) changes in land use proportionality in a given cell. The scenarios themselves will be driven externally to the LUCC model (e.g. from a scenario file) and will identify increases or decreases sought in land use class allocation. For such an allocation, the model will consult the appropriate allogenic transition matrix to identify the land use class changes implication. For instance an imposed scenario increase of 10% Urban might be accommodated in the matrix by a simultaneous 5% decrease in Grassland and a 5% decrease in Garrigue. The operation of subtractive actions are analogous to additive ones, but with the processes of addition and subtraction being undertaken separately.

Changes sought in land use change allocations may be constrained by a series of factors, such as water availability, and these constraints are imposed before any land cover reallocation occurs. For example one scenario may permit urban growth to occur only where there is adequate groundwater. The demand from the urban land use being calculated by the water use profile model. In this case the relationship between hydrology and water use profile is one of capacity of supply against desired demand.

3.6 Water Use Profile Modelling

Water demand expressed by an urban population cannot be represented in the same way as an agricultural crop due to the fact that people reside in buildings and the water use is from a pressurised system in the majority of cases. The scenarios for development and change of urban land cover are conceptually very different to those of agricultural, silvicultural and natural land covers due to the diversity of water use characteristics and planning actions of the residential urban population.

The Water Use Profile (WUP) component of the SCAPT involves the interaction of an external demand simulation model that focuses on Water Dependent Processes (WDP). Referred to as cross-sectional studies (Aitken *et al*, 1991), micro-simulation (Williamson *et al*, 2002) or micro-component analysis, the focus is upon characterising the water use profile of components of household demand that can be quantified volumetrically and by incidence of use over time. The WDP model applies this method spatially by up-scaling the simulation results by classifications compatible with recorded census data. There is however a strong requirement for validated data for each of the micro-component parameters (Hobson *et al*) but the benefits of such an approach can potentially reveal demand patterns that may be clouded by external issues such as leakage (Clarke *et al*, 1997) and depending upon the requirements of the model, the causes of extreme demand such as tourism, power showers or garden irrigation may be made more evident.

This micro-component simulation model has been developed using Avenue within the ArcView 3.3 GIS package to provide catchment wide urban demand at commune level and at the 2x2km grid scale required by SCAPT. The WDP model combines water dependent process parameters such as shower and washing machine use incidence and volumes with geo-demographic data such as number of occupants per household derived from the INSEE 2000 French population census. It utilises respondent data collected by Work Package 2 of the Aquadapt project (see www.aquadapt.net) to characterise the water use behaviours where possible.

The intention has been to achieve spatial representation of urban residential demand distributed across the catchment surface area. To do this the regional data concerning water use behaviour (*market penetration* of devices; *usage rates* of showers, toilets, washing machines; and *applicable efficiency parameters* such as old vs. new devices, dual flush toilets and power showers) has been used to generate a generic household demand profile for that region, class of 'number of persons living in the household' (1-6) and household structure (by indoor and outdoor use).

This demand profile is then attributed to the commune population using the proportion of occupancy rate classes for each commune identified in the census (fig. 6). This establishes residential demand for the catchment at the commune level (a). The demand then has to be applied to the 2x2km grid segments (b) to work within the SCAPT. This is achieved by the development of 'GridComs' (d) which are produced by sectioning the urban land cover area clusters (c) which have commune data applied by grid cell boundary.

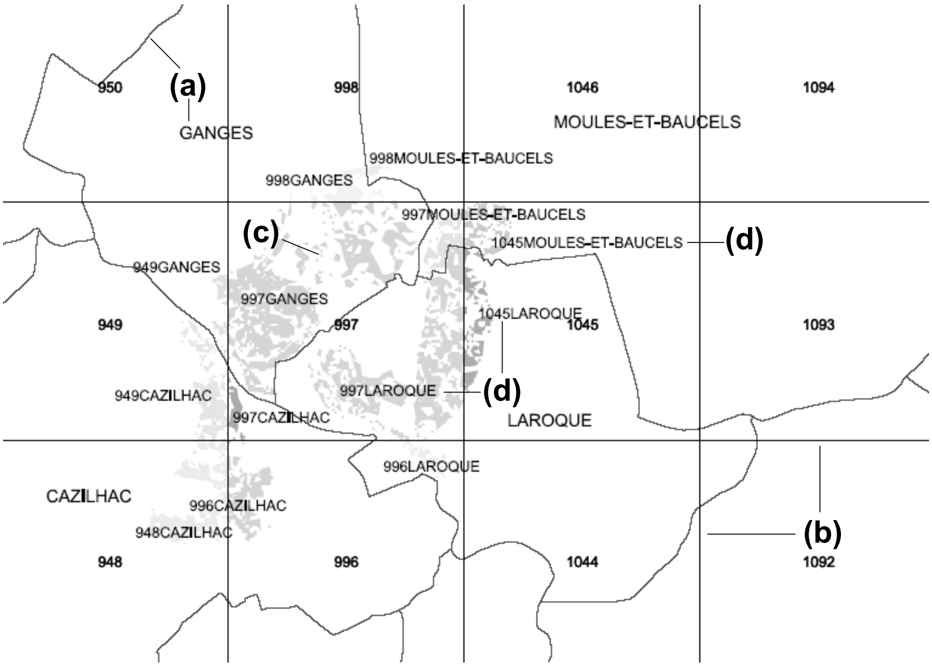

Figure 6: Spatial scales of data: Commune (a), Grid Cell (b), Urban land cover area (c), Grid Com (d)

The resultant GridCom is then identified with both Grid and Commune. Previously calculated urban area demand is proportionate to the fraction of GridCom to original urban area. Therefore the demand for Grid Cell 997 is the sum of the proportionate demand attributed to GridComs 997Ganges, 997Moules-et-Baucels, 997Laroque and 997Cazilhac. The output data from the WDP model feeds into SCAPT in two ways. Firstly it provides the initial spatially distributed baseline values for the residential population of the Hérault in mm (litres per m^2). Secondly, it supplies the volumetric data that can be entered into the WUP scenario builder, to give the programmed new urban developments a demand value based upon the density of the housing development by unit area, the number of inhabitants and the demand mitigation practices that are available. This results in a 3 dimensional data set from which the user of SCAPT may select classes of urban development and enter selected values into the scenario builder (fig. 7).

The values are expressed as volumes compatible with SCAPT for each combination of classes. The efficiency 1 to 5 and class A to E matrix is derived directly from WDP model output as applied for a single household with the corresponding profile of occupants and their efficiency behaviour. Density A to E simply disperses the demand over the determined land area unit and the resultant volume is expressed in mm.

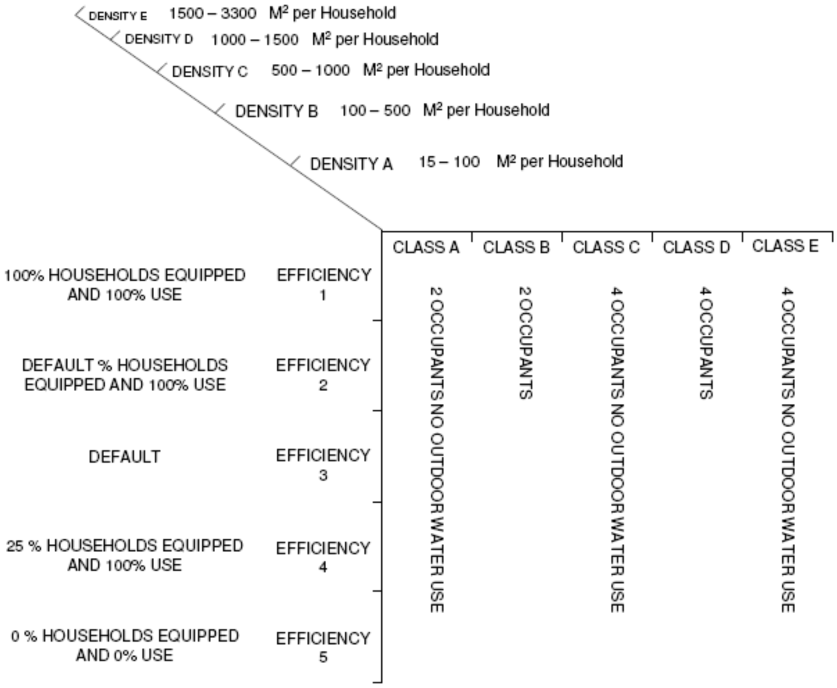

Figure 7: Scenario option 3 dimensional matrix

The SCAPT user may select the form and intensity of urban development that suits their requirements. They may prefer to use the look up tables to tailor the urban growth profile. One need not make all occupancy class selections different as density may be the parameter of interest.

4. SCAPT IMPLEMENTATION

4.1. Programming language and interfaces

SCAPT was custom-written and implemented using the Java computer language. In Java, scenario 'events' are implemented using software 'object classes' each having a set of properties (e.g. type, amount, target, 'super-timesteps', 'super-cells' etc). Such events also hold full details of their functionality and how this should be executed; triggering such events is therefore simply managed. The user interface of SCAPT is built using GIS 'class libraries' permitting the inclusion of a spatial map-based interface for working with geographical regions for scenarios (fig 8). Further schematic representations of the catchment processes are developed using standard Java graphic primitives. Distributing versions of SCAPT in Java has proved both easy and effective, and since Java is also well suited for cross computer platform development future developments are facilitated. Overall, Java has proved an effective means to implement and distribute SCAPT. Along with the Java code in SCAPT, the model also uses 'extensible markup language' or XML, to hold and manipulate scenario configurations. Scenario events, or 'actions', created through the GUI tool, are saved out to disk in an XML scenario file. A scenario file can be loaded and edited at any time using the same GUI. XML was used as a format for specifying these scenario files for a variety of reasons: firstly, XML has a broad universal compatibility – there are many data interchange standards; secondly, Java has a good programming interface with XML; and thirdly using XML avoids a number of programming tasks such as file manipulation and string tokenisation.

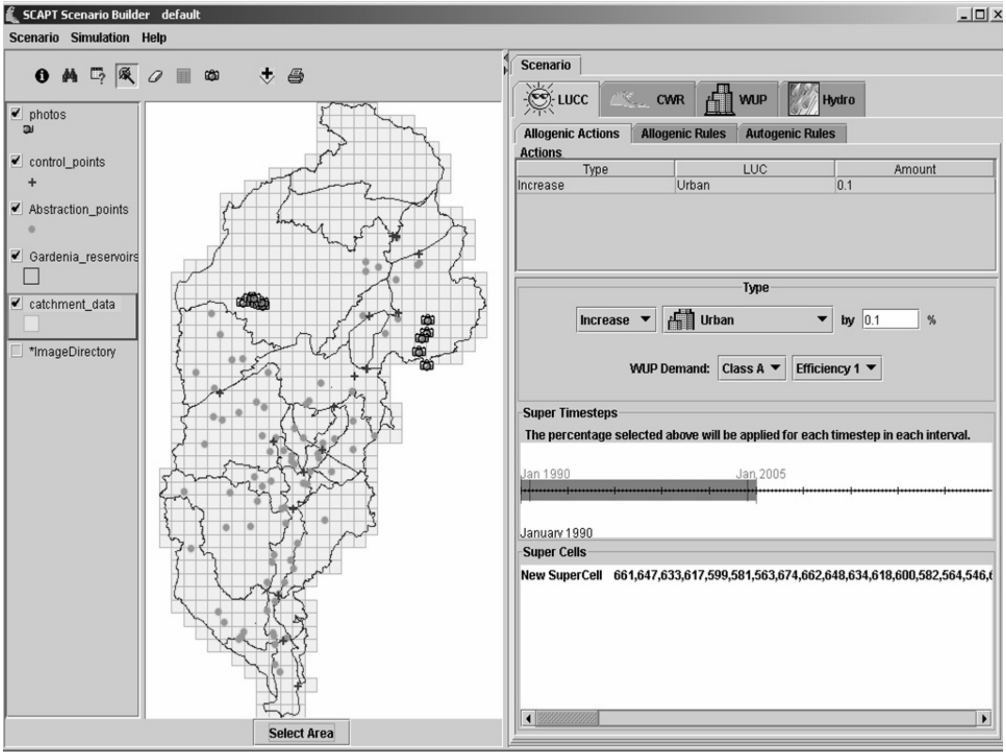

Figure 8: SCAPT scenario module interface

The format of the XML scenario file resembles figure 9, in this case the user has specified an increase of urban coverage in the land use cover change model, with the change sought targeted at available grassland:

```
<Scenario>
        <Action type="Increase" Amount="50" LandUse="Grass"
          Target="Forest" Avoid="Urban">
                        <SuperTimestep begin="10" end="20" />
                        <SuperTimestep begin="105" end="107" />
                        <SuperCell begin="200" end="250" />
                        <SuperCell begin="1000" end="1100" />
                        <SuperCell begin="1300" end="1450" />
        </Action>
        …
</Scenario>
```

Figure 9: XML Representation of a SCAPT Scenario event

A set of custom macros, written in the language VBA are included with SCAPT allowing scenario output to be analysed subsequently in MS Excel. A simple data manager interface permits the user to co-ordinate these actions. SCAPT also outputs data in a format directly compatible with further spatial analysis and presentation using external GIS software.

4.2. Representation of space and time

The SCAPT model represents space using gridcells of 2x2km across the catchment, and timesteps of 1 month. The SCAPT scenario module allows the user to construct a series of 'actions' each of which represents a specific 'allogenic' decision (e.g. an increase in urbanised area in a given grid cell). Each action has a location (gridcell) and timing (model timestep) attached to it. A scenario may consist of multiple actions, 'stacked' and applied as directed during a model run. A further feature allows the user to apply decisions concurrently both to adjacent and non-contiguous 'blocks' of grid cells (termed

'Super-Grids') as well as across entire groups of timesteps (termed *'Super-Timesteps'*). This allows the user to manage efficiently the large number of degrees of freedom that the SCAPT model possesses. Super-Grids also prove useful in addressing all the gridcells related to a particular aquifer, or to cells exceeding certain urban proportions by example. Super-Timesteps prove useful in assigning constant rates of growth or decline to land use classes across a number of months or years of simulation time. Super-Grids and Super-Timesteps are used in conjunction, further simplifying scenario specification. This approach affords the user a powerful and intuitive means to effect significant changes within a scenario with minimal effort. The model resolves SuperCells and SuperTimesteps during its operational sequence.

4.3 Scenario Development

Operating the SCAPT model involves a sequence of three interlinked and related stages, relating firstly to the pre-determinations of the scenarios run through SCAPT, secondly to the model run operation itself and thirdly to the ultimate interpretation and inter-comparison of the model results (fig 10).

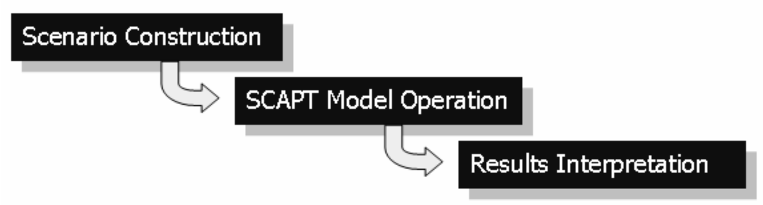

Figure 10: General operational sequence of SCAPT

The Scenario Construction Module allows the production of a series of scenario input files for the subsequent SCAPT Model Operation Module. It facilitates the production of scenario documents representing highly complex permutations of parameter inputs and outputs in space and time for any given model run. In addition to allogenic decisions applied in time and space as noted above, the user may also configure the rules applying to natural processes occurring within the catchment, represented by internalised 'autogenic' directions. These latter rules are managed through tables representing probabilities of land use cover change and succession, differing hydrological parameters and the specification of new societal water usage classes. Validation checks are undertaken to ensure that such definitions are bounded correctly for any specified changes effected. Figure 11 shows a schematic overview of the points at which scenarios can be applied within SCAPT.

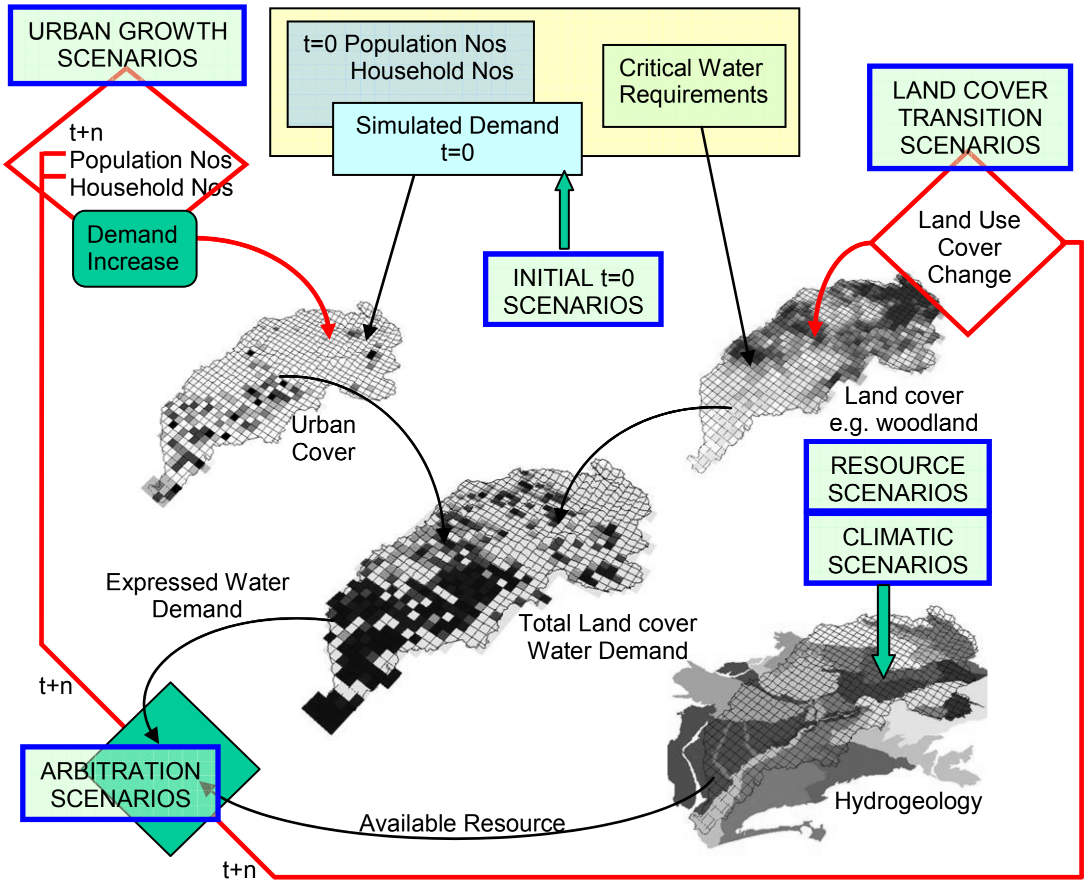

Figure 11: Logical position of SCAPT scenarios

5. SCAPT MODEL OUTPUT

A final component of the SCAPT model is the results interpretation module. This accepts scenario files created by the scenario construction module and will use these to direct, where appropriate, the flow of the model operations. Where specific allogenic instructions do not exist, for example for a given gridcell/timestep combination, a series of 'internal' rules are consulted to determine the outcome. These autogenic directions are based upon rules both of natural succession and of Critical Water Requirements (CWR) for the land use cover classes involved. For any given SCAPT model run, machine-readable results and log files are compiled detailing the exact circumstances of the outcomes.

This module will accept as input a model results file from a SCAPT model run and will be able to present it in a manner easily understood and interpreted by the SCAPT end-user. In addition to analysis and presentation of one specific model run inter-comparisons may also be undertaken between the results of several model runs (fig 12).

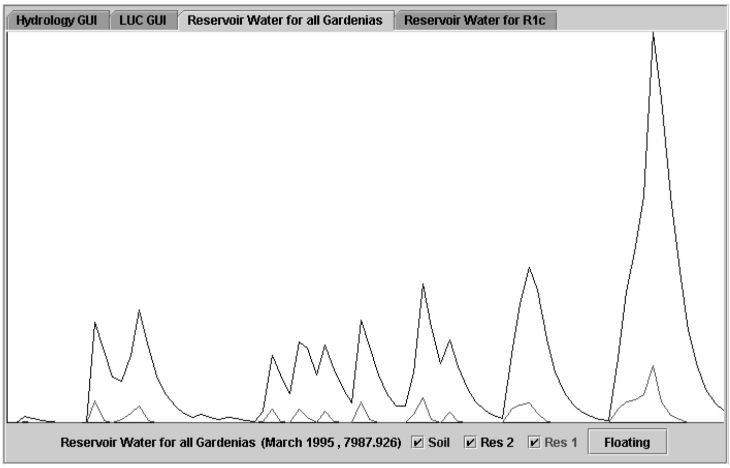

Figure 12: Example dynamic results output graph

Prior to operating the model, the user is given the option to select the output variables to log during the model run. Whether the user wishes to log all variables for each grid cell at each time-step or select a summary of critical values at the end of each year or season, the model will export a spatially referenced table (by the grid identifier GID) that can be analysed statistically and graphically presented using external GIS software (fig 13).

Timestep	GID	LUC 1 % area	HYDRO-BOX Reservoir (x) volume
1	034	26.3	Mm
1	045	35.6	
2	034	32.7	
2	045	31.6	

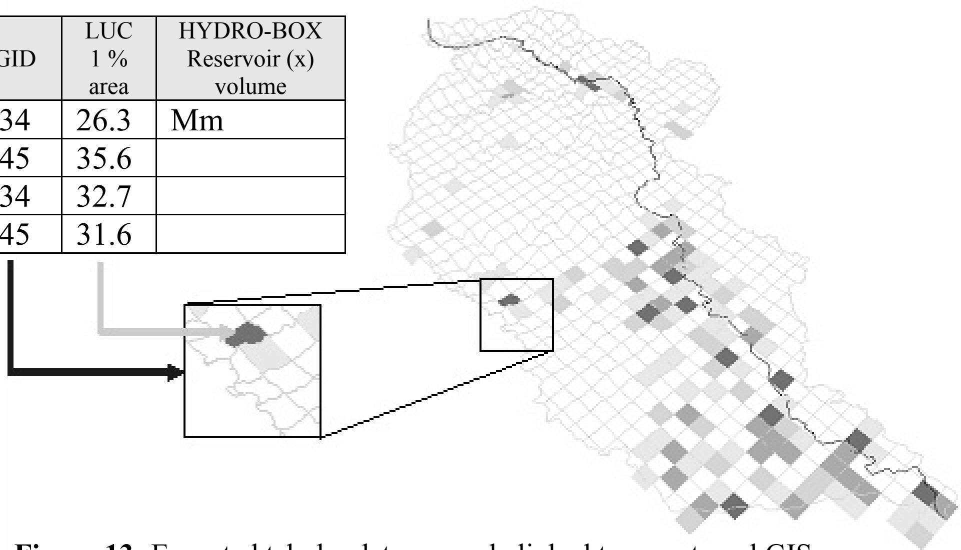

Figure 13: Exported tabular data example linked to an external GIS

6. CONCLUDING REMARKS

The Strategic Catchment Analysis and Planning Tool developed in the Aquadapt project is not intended to produce precise quantitative information to assess the impact of very specific scenario, but rather to provide a wide range of stakeholders with qualitative (or semi-quantitative) information that could be used to foster the debate which, according to Article 14 of the Water Framework Directive, must accompany the development of water management plans. To achieve this objective, and make the tool accessible to non specialists, user-friendly model interfaces have been developed, including the dynamic link with a GIS, an interactive scenario generator module and a gridcell-based interface for specifying input parameters and scenarios.

One very innovative element of SCAPT is its ability to jointly simulate the impact of integrated land use and water management scenarios. It recognises that planning water resources management at the catchment level cannot be conducted independently from land use planning as the evolution of the two resources are driven by similar forces. For instance, population increases lead to both water use increase and to space consumption. Changes in the farming sector have an impact on land use and on quantitative and qualitative aspects of water management. Furthermore, changes in lifestyle (e.g. willingness of people to live in detached houses) both increase *per capita* reciprocal water demand (e.g. garden watering, swimming pools) and *per capita* space consumption. This integration of land use and water resources management planning is likely to increase the attraction of the tool for stakeholders and public decision makers whose primary focus may be related normally only to one of these two domains. In that respect, SCAPT pushes the concept of "integrated water management" one step further than in current general practice through the integration within the same model of various water resources (groundwater, rivers, artificial water bodies, etc.) and their uses. A good example of such an approach implemented in the Hérault catchment can be seen in Lanini *et al*, 2004.

This approach, however, still requires validation by real end-user stakeholders. Once completed it is intended that SCAPT be submitted to the scrutiny of stakeholders of the Hérault catchment through demonstration sessions. This has been found a highly effective means of stakeholder engagement; for an example of such an approach in the Hérault catchment see Pereira *et al*, 2003. This review and the evaluation of the tool should then be continued by tests conducted in a real decision context, where various stakeholders would use the tool to assess the impact of alternative water resources and land use management scenarios.

Three principle challenges exist, forming the basis for future work: (i) validation, which can be done using hydrological data. This will confirm that predicted river discharges with past and current conditions fit with empirically observed values; (ii) an ongoing review of the SCAPT by potential end-users and verification that it is correctly adapted to the targeted public of stakeholders; (iii) development and design of a protocol for the use of the tool in real decision-making contexts. This will examine how the tool would be introduced to users, and how the tool could be assessed both by individuals and groups of stakeholders.

Users are permitted to establish the impacts and consequences of a series of possible futures and compare the respective result sets and SCAPT operations to date have involved the development of a series of model scenarios resembling the conditions of a selection of plausible futures. Overall SCAPT offers a powerful research tool for investigating the effects of undertaking water resource management, mitigation and intervention measures at the catchment scale, being designed to inform the creation of river basin management plans demanded by the Water Framework Directive.

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Sustainable Development of Water Resources on Small Islands through MakingOptimum Use of Local Available Water Resources, Storage Options and Renewable Energy

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ABSTRACT

The growing use of fresh water per capita, increased pressures and impacts of climate changes require new development strategies for land and water resources. In particular very small islands (<1000 km^2) face an increasing constraint of freshwater resources, both in terms of quantity and quality, due to the small size, and specific geological, topographical and climatic conditions, islands. For example, in case of coral islands, the natural groundwater supplies are limited, while in case of islands with irregular rainfall patterns, access to clean water is often limited due to restricted storage and adequate supply systems and treatment. This applies particularly to coastal regions and very small islands. Also, the socio-economic characteristics of very small islands offer specific limitations and opportunities for water resources development.

1 INTRODUCTION

The natural water resource of very small islands is generally restricted and is often considered a limitation for economic development and tourism. In many cases there is a general tendency to desalinate seawater as a complementary source of water. A side effect of this development is that existing local water resources are not further developed and existing water conservation techniques disappear. Yet, the Acacia Institute believes that development of local resources offers sufficient potential to guarantee fresh water supplies.

Practices such as rainwater harvesting, water conservation, and subsurface storage are often not being fully utilized, especially in combination with renewable energy sources (sun, wind, tides). In fact, some of these practices can be regarded as modernized versions of local, but often abandoned techniques. Moreover, new technological development in bio-saline agri-culture and low cost desalination offer new opportunities for the use of brackish water. Also modern drilling and monitoring technologies increase the feasible development of marginal water resources. The great advantage of very small islands is the social cohesion and the commitment of the communities and enterprises to problem solving and, of course, their local knowledge. Therefore Acacia wants to involve the local organisations and enterprises already in the initial phases, rather than operating according to classical, top-down controlled engineering approaches with the government as a single client.

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2 METHODOLOGY

The Acacia Institute offers a quick scan to review the potential for development of local water resources in combination with the use of renewable energy and opportunities for bio saline agriculture. Local expertise will be strongly involved during the quick scan.

Figure1: Typical very small island (Bonaire)

A quick scan comprises a one time intervention that provides a systematic overview of the potential development options for water resources, based on locally available information and data, complemented with an assessment of the hydrological and socio-economic situation. The quick scan is a short term service for a fixed price and includes:

- Inventory of existing data (2-4 days)
- Island survey (7-12 days, including travel):
    - Discussions with client and others (local organisations, enterprises, individuals)
    - Assessment of water demands, geology, natural and artificial water resources systems, water related ecosystems, local energy potential, local water management techniques etc. (see figure 2 and 3)
    - Limited set of measurements and fieldwork to complement and verify the existing data
    - Short workshop (on demand) to present and discuss initial findings.

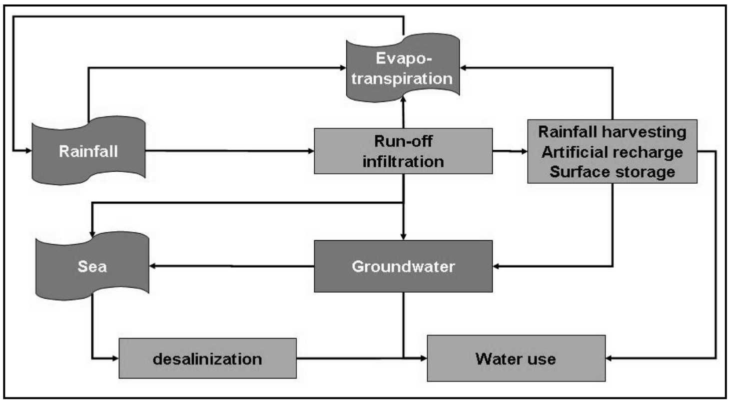

Figure 2: Typical water balance of very small islands

- Concise report an PP presentation:
    - Present and future hydrological system (and the impacts of climate change)
    - Ecosystems at risks,
    - Present and future water demands, water users and water practices
    - Water supply, energy supply, waste water collection systems,
    - Proposals for sustainable water supply and water management strategies,
    - TOR for further water resources investigations or feasibility and design studies.
    - Options for sustainable use of resources (see figure 4) and demand management

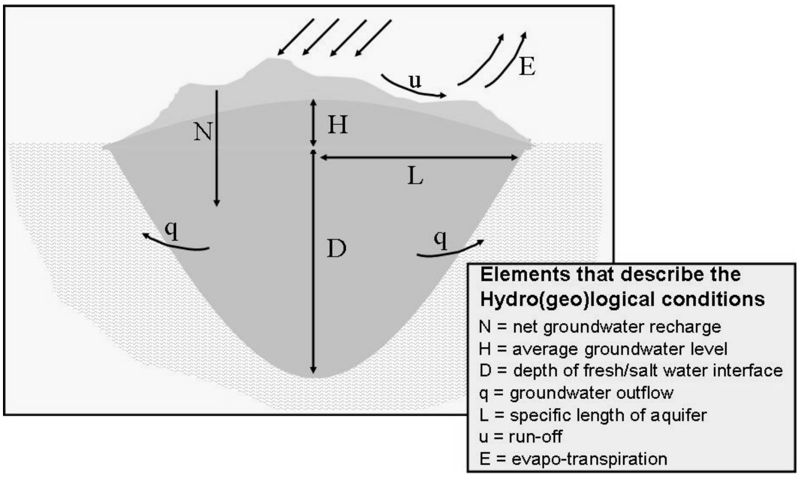

Figure3: Elements that describe the hydro(geo)logical conditions of a typical very small island

How can de results of the quick scan be used?

- The quick scan will include a list of small-scale interventions (or pilot projects) that can be implemented directly by interested organizations and individuals (pearls).
- The quick scan result could be a basis for more in depth studies of the physical and chemical behaviour of the natural land and water resources systems as a basis for land and water planning and for the preparation of larger projects.
- It may also identify more technically oriented feasibility and design studies.

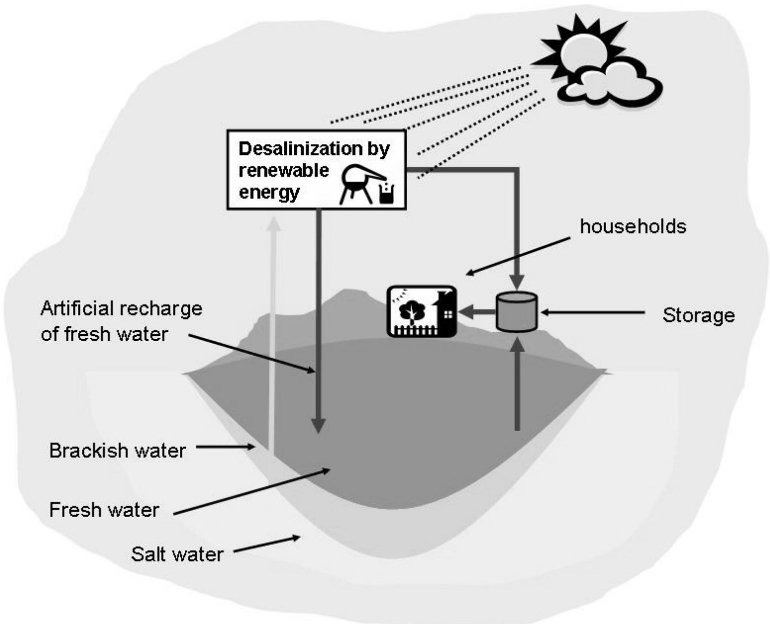

Figure 4: RENewable Energy and Water sources (RENEW), an integrated small scale system of wells, dams, windmills, solar panels and reverse osmosis units

ACACIA INSTITUTE

The Acacia Institute "for solutions in groundwater" is a self-supporting foundation associated with the Vrije Universiteit Amsterdam (Faculty of Earth and Life Sciences). The Institute has an international scope and operates as a network organization.

The mission of the Acacia Institute is to promote the important role of groundwater in integrated water resources management through:

- Knowledge exchange in groundwater for all stakeholders,
- Promoting the role of groundwater in land and water planning
- Innovative solutions in groundwater

Acacia discerns three fields of activities:

- Applied research in the Acacia themes
- Strategic advise (consultancies) and process management ,
- Education in support to the Faculty of Earth and Life Sciences

Further information can be found on our web site; www.acaciainstitue.nl

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Water Recycling and Reuse. A Water Scarcity Best Practice Solution

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ABSTRACT

Europe depends on appropriately treated wastewater to protect the environment and ensure that freshwater is available for all applications. Water recycling and reuse through surface and groundwater bodies is common practice and public health is protected through potable water standards. The reuse of water for non potable applications or potable substitution has been proven internationally in water stressed regions to be a drought proof source of water and one of the most effective water scarcity solutions. The benefit can be substantial as 30-70% of abstractions are for public water supply. The EU Wastewater Directive states that wastewater should be reuse wherever appropriate but there is no clear definition of what is appropriate. Safe water reuse increases the availability of water, reduces nutrient discharge to surface water and can reduce manufacturing cost for industry. Europe needs to define which applications and qualities are appropriate through the development of best practice guidelines so that the member states can safely take advantage of this drought proof and valuable source of water.

Key Words: water reclamation, drought proof, potable substitution

1. INTRODUCTION

The hot and dry summer of 2003 in Europe has once again drawn attention to the importance of reliable water supplies. Freshwater resources in Europe are unevenly distributed and every country has a tailored solution for satisfying its water demand. The experience of temporal or regional water scarcity highlights the importance of sustainable water management (economic, environmental & social).

Establishing sustainable water management practices and regimes requires a responsible use of water resources while at the same time assuring sufficient water supply to different users. Due to scarce resources this is not easy to achieve in some regions. Reconciling competing demands calls for expanding the supply and managing demand more wisely.

Water stress is increasing due to population density, diffused pollution, unreliable precipitation, short-term population increases due to tourism and increased demand for irrigation to improve agricultural productivity. At the same time, the Water Framework

Directive requests an analysis of water use, which in some regions or basins could lead to a reduction of 15 to 20% of abstraction licenses, in order to protect surface and groundwater quality and quantity.

In this context, water reuse opens up an alternative dependable water resource. Reusing treated wastewater basically compresses the hydrological cycle from an uncontrolled global scale to a controlled local scale. Water reuse is a proven and appropriate tool in managing scarce water resources.

Throughout the centuries, wastewater reuse has evolved from a simple method to dispose of polluted water by irrigating and manuring field crops with untreated wastewater to a sophisticated process of reclamation allowing agricultural, industrial, urban and even domestic reuse.

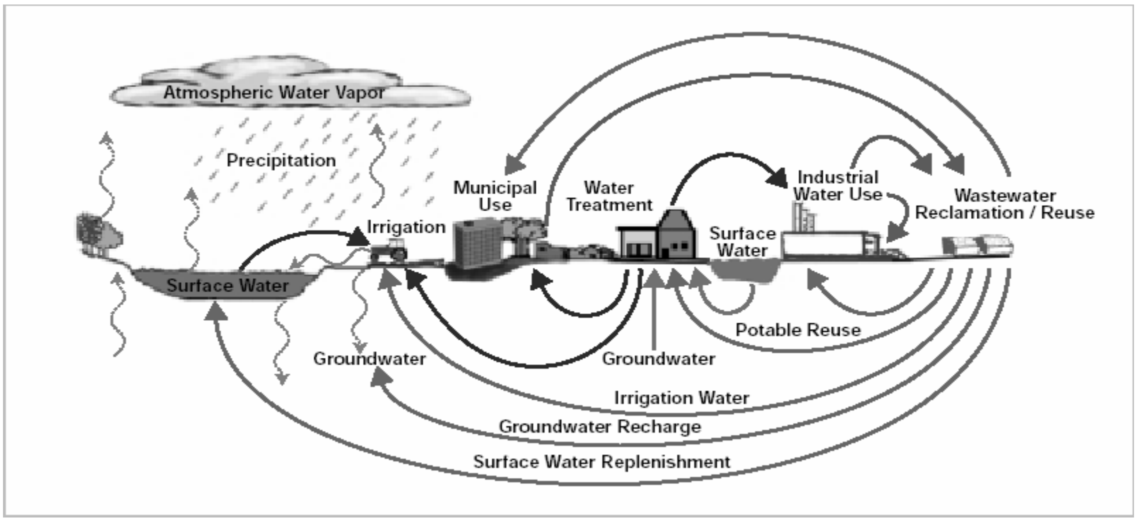

Figure 1: Water reuse applications (Asano 1989).

Reclaimed water can be used as an acceptable and safe substitute for many traditional uses of drinking water and water from sources that provide raw water for drinking water production. (potable substitution). Such use can help conserve drinking water resources by replacing drinking water or water taken from drinking water sources and by enhancing drinking water sources such as reservoirs and groundwater. The improvements in technology for wastewater and drinking water treatment have ensured that a range of new and emerging challenges from both microbial and chemical contaminants are met. Hence, the indirect recycling developed in many parts of the world for many years is demonstrated to be safe (UKWIR 2004).

Water recycling and reuse: definitions

Reclaimed water Treated wastewater suitable for beneficial purposes such as irrigation.

Reuse The utilization of appropriately treated wastewater (reclaimed water) for some further beneficial purpose

Recycling The reuse of treated wastewater

Potable substitution. The reuse of appropriately treated reclaimed water instead of potable water for non potable applications

Non-potable reuse The use of reclaimed water for other than drinking water, for example, irrigation.

Indirect recycling or indirect potable reuse The use of reclaimed water for potable supplies after a period of storage in surface or a groundwater.

Direct potable reuse The conversion of wastewater directly into drinking water without any interim storage.

In other semi-arid regions of the world with similar climatic conditions as the Mediterranean, local authorities have adopted an institutional framework that helps the implementation of beneficial solutions (cooperating regulators, water quality and best practice guidelines, financial incentives). In Australia, an achievable target of 20% reuse of wastewater by 2012 has been set in some territories to highlight the importance of reuse and focus regional strategies.

2. APPLICATIONS

Although treated wastewater has been an important means of augmenting river flows in many countries and the subsequent use of such water for a range of purposes constitutes indirect reuse of wastewater, it is becoming increasingly attractive to use reclaimed or treated wastewater more directly. In addition, reclamation of wastewater is attractive in terms of sustainability since wastewater requires disposal if it is not to be reclaimed (UKWIR 2004).

Treated wastewater may be used as an alternative source of water for irrigation in agriculture. Agriculture represents up to 60% of the global water demand while the requirements arising from increasing urbanisation such as watering urban recreational landscapes and sports facilities also creates a high demand. Water scarcity in Mediterranean countries historically led these countries to use appropriately treated wastewater in agriculture.

Treated wastewater may also be used as an alternative source of water for irrigation of golf courses and other green spaces, including those used for recreation in which individuals may come into contact with the ground. It can be used to supplement artificially created recreational waters and for reclamation and maintenance of wetlands for which there can be a significant ecological benefit and a subsequent sense of benefit to the community.

Finally, an additional use may be the direct supplementation of drinking water resources through groundwater infiltration and by adding it to surface water. There are several cities in northern Europe that rely on indirect potable reuse for 70% of their potable resource during dry summer conditions. It is even technically possible for it to be used as a direct drinking water source, although acceptability to the public may not yet be achievable (UKWIR 2004).

The AQUAREC project identified over 3,300 water reclamation projects. The review considered seven geographical regions: a) North and b) Latin America, c) Europe, d) Mediterranean Region and Middle East, e) Sub-Saharan Africa, f) Oceania and g) Japan. Japan has the largest number of reuse project (over 1,800), followed by the USA (over 800), which is the largest producer, with a volume of reused water estimated at close to 6.5 Mm^3/d. In the EU the past decade has witnessed a fast growth with over 200 projects. Almost 100 sites were identifiable in the Mediterranean and Middle East area, with more than 50 in Latin America and 20 in Sub-Saharan Africa (Bixio et al. 2005a).

The number of municipal water reclamation facilities identified throughout the world – sorted by application – is shown in Figure 2. The applications are split in five categories: a) agricultural irrigation; b) urban, recreational and environmental uses, including aquifer recharge; c) process water for industry; d) direct and indirect potable water production; e) combinations of the above (mixed).

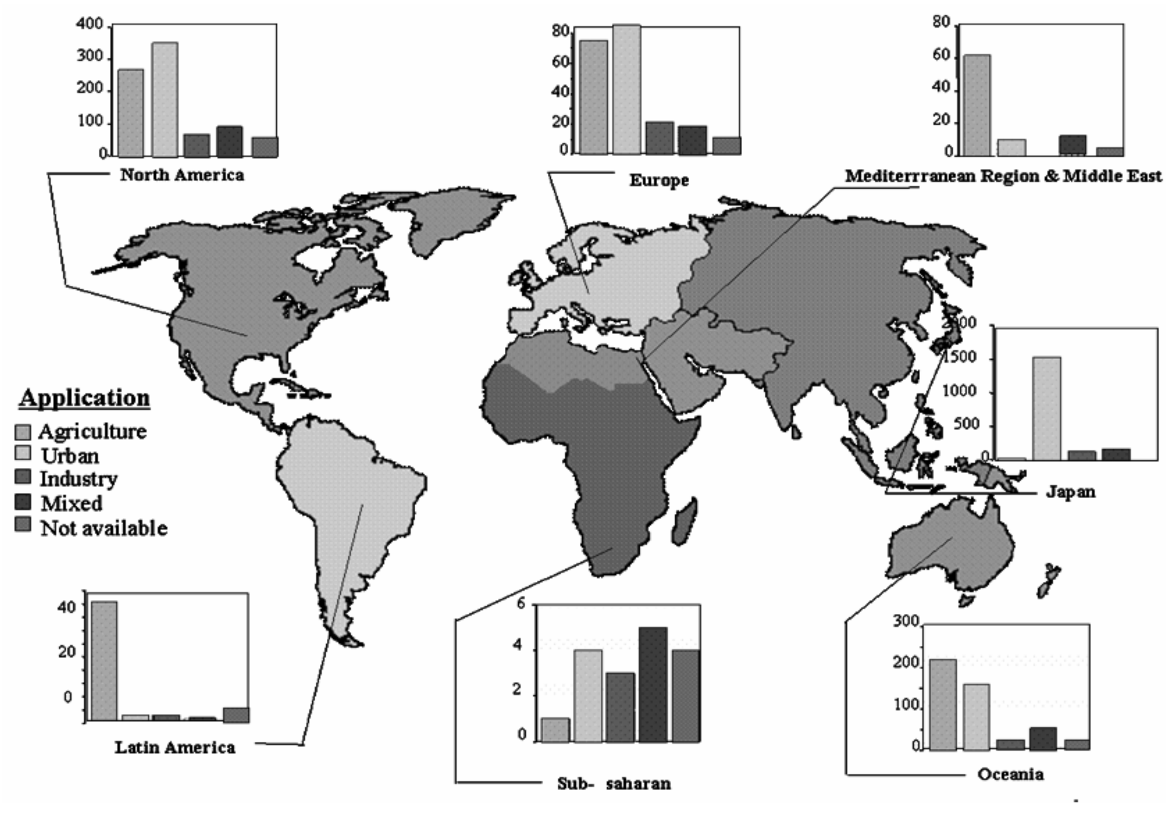

Figure 2: Number of water reuse projects distributed according to their application (adapted from Bixio et al. 2005a).

Note that these numbers are destined to become quickly outdated as many projects were identified at an advanced planning phase.

An example from the Costa Brava

The Costa Brava Water Agency (Consorci de la Costa Brava, CCB) is a supra-municipal institution formed by the 27 coastal municipalities of the province of Girona, in NE Spain. CCB was created in 1971 and is considered to be a pioneering organization of its kind in Spain because of the early (for Spain) construction of wastewater treatment plants (WWTP) and for its understanding of the water cycle as a whole. This vision led to the implementation of the first planned water reuse project in 1989, which consisted of the supply of disinfected secondary effluent from the Castell-Platja d'Aro WWTP to the Mas Nou golf course. The creation of the Catalan Water Agency (ACA) in 2000 has also given a new boost to the construction of tertiary treatments in the Costa Brava area, adding three facilities of this kind to the nine already existing. Reclaimed water volumes are increasing with every passing year, reaching 5.7 hm^3 in year 2004 out of 37 $hm^{3,}$ or 15% of wastewater treated in the area. The applications include irrigation for agriculture, golf and landscape, restoration of wetlands for flood protection, enhancement of the local environment and aquifer recharge (Sala et al. 2004).

3. THE STATUS AND NEED FOR WATER REUSE IN EUROPE.

In 2004 it is estimated that 700 Mm^3/yr of water was reused in Europe which is less than a fifth of the estimated potential for water reuse. The AQUAREC project developed a model-based approach which is able to quantitatively assess the potential for wastewater reuse using effluents from wastewater treatment plants. The approach was applied to quantify the European water reuse potential and compared well to existing estimates.

Figure 3 illustrates that Spain shows by far the highest reuse potential, the calculations suggesting a value of over 1,200 Mm^3/yr. Italy and Bulgaria both exhibit estimated reuse potentials of approximately 500 Mm^3/yr. Wastewater reuse appraisals for Turkey amount to 287 Mm^3/yr, whereas Germany and France are supposed to reuse 144 and 112 Mm^3/yr respectively. Portugal and Greece account for reuse potentials of less than 100 Mm^3/yr (67 and 57 Mm^3/yr). Overall, the estimates suggest a wastewater reuse potential of 3,222 Mm^3/yr (Hochstrat et al. 2005).

The need for alternative sources of water was emphasized by the 2003 drought which resulted in a 30% reduction in agricultural production. This drought was a dramatic example of the measured 20% reduction in annual precipitation from 1900 to 2000. It has been calculated that the economic impact of the 2003 drought in Europe is valued at US$ 13 billion and this is a larger economic impact than the floods (EU 21553 2005).

It is essential that the development of water reuse in agriculture and other sectors be based on scientific evidences of its effects on environment and public health. Although several studies have been conducted on wastewater quality and for different purposes, at this time, there are no guidelines, best practice or regulations of water reuse at an EU level other than the Urban Wastewater Directive which states that "treated wastewater should be reused whenever appropriate". Further work is needed to develop the suitable guidelines and definition of "whenever appropriate". The valuable regional initiatives in

Spain, France, Belgium, UK and other countries could be used as a base to develop water reuse guidelines.

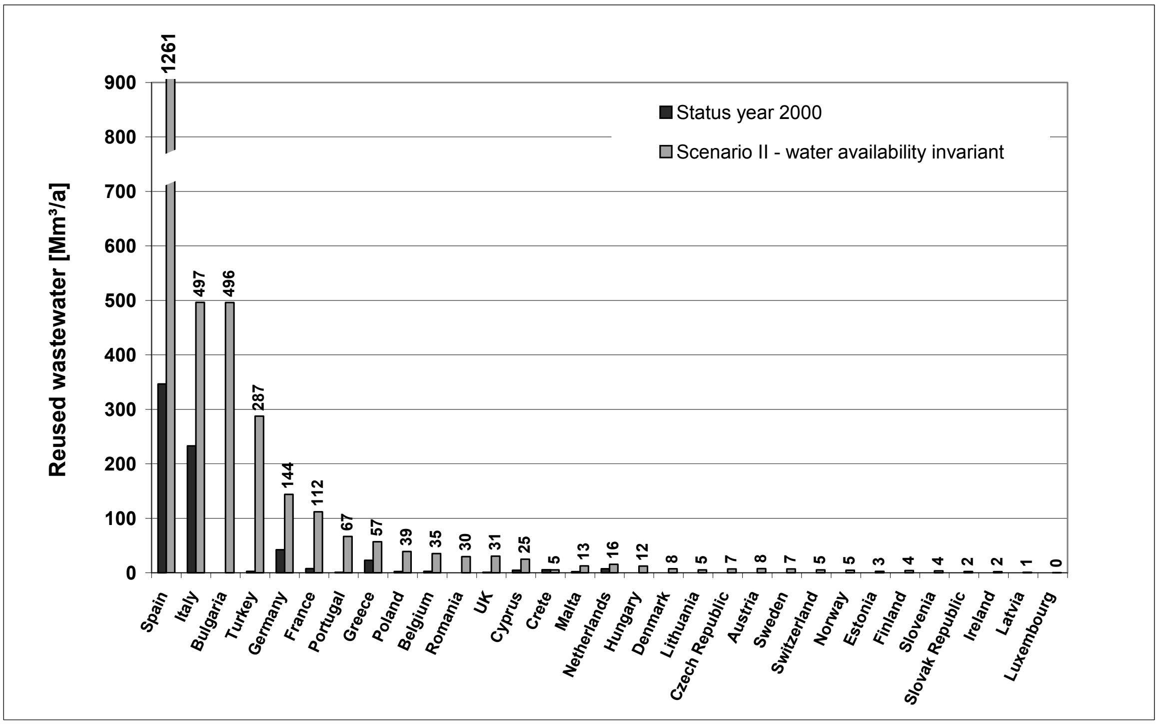

Figure 3: Model output for wastewater reuse potential of European countries; projection horizon 2025 (Hochstrat et al. 2005).

The 15 European countries with the highest estimated increase in water demand include North Western, Central and Southern Europe. The conservative interim estimates of growth from 2000 to 2025 range from 1.3 to 14 fold increase in capacity with an average of 2 fold increase. This current and conservative estimate of water reuse activity in Europe emphasises the need for clarification of the appropriateness of water reuse through water quality and best practice guidelines (EUREAU 2004). Water reuse and potable substitution can increase the availability of water for public water supplies. This includes northern countries where the water availability is assumed to cover the needs but authorities may be faced with water stress situation. In London the population density and the rainfall of 690mm per year results in the water availability of only 265m^3/capita/year demonstrating the need for alternative sources of water (Planet Water 2003).

The European water abstraction data states that public water supply is 18%, agriculture 30%, industry 14% and electricity industry 38% (EEA 2000). However, if we agree that the majority of the electricity industry (cooling water) abstraction is returned rapidly to the surface water then the water abstraction for public water supply accounts for approximately 70% of the total water demand. Potable substitution can potentially have an even greater impact on water resource availability if we consider the 70% of water abstracted for public water supply rather than the 18% normally considered.

4. BENEFITS OF WATER REUSE AS A WATER SCARCITY MITIGATION OPTION.

There is an opportunity to use potable substitution to provide savings on public water supply which is the largest abstraction capacity in Europe. In addition through irrigation for agriculture and landscapes water reuse can provide a direct benefit to the local economy. Europe can take advantage of the benefits of water reuse and potable substitution to manage the water resources in the same way that many other regions have been for decades.

Water reuse benefits
1 - Decreases net water demand and adds value to water
2 - Potable substitution – keep potable water for drinking and reclaimed water for non potable use
3 - Lower energy costs compared to deep groundwater, importation or desalination
4 - Reduce manufacturing industries costs by using high quality reclaimed water
5 - Valuable & drought proof alternative water for industry & irrigation
6 - Reduce nutrient removal costs to protect the surface waters through irrigation
7 - Reduces nutrient discharge to the environment and loss of freshwater to the sea
8 - Increases land value when developing brown field sites and with drought proof irrigation
9 - Increase local ecological benefits, flood protection and tourism through the creation of wetlands, urban irrigation, bathing beach protection and reduces the need & cost of long sea outfalls
10 - Control the problems of over abstraction of surface & groundwater
11 - Manage the recharge of surface and ground waters to optimise quality and quantity
12 - Integrates with all parts of the anthropogenic water cycle to enable cohesion between all regulators and industries across Europe.

The EU should be able to implement water recycling and reuse projects with EU technology and expertise to create export opportunities based on the credibility in our home markets. EU needs to have in place the regulatory and institutional framework tailored to suit local needs to take advantage of the water recycling and reuse opportunities and to help overcome the water shortage problems. Also, EU needs clarity over quality, ownership and real costs to enable viable water recycling and reuse projects to proceed (Bixio et al. 2005b). Wastewater reclamation and reuse needs to be embedded into the integrated management of the water cycle and should be included in the cost recovery policies that the EU member states will have to promote to ensure adequate incentives for users to exploit water resources efficiently by 2010 (Bixio et al. 2005a).

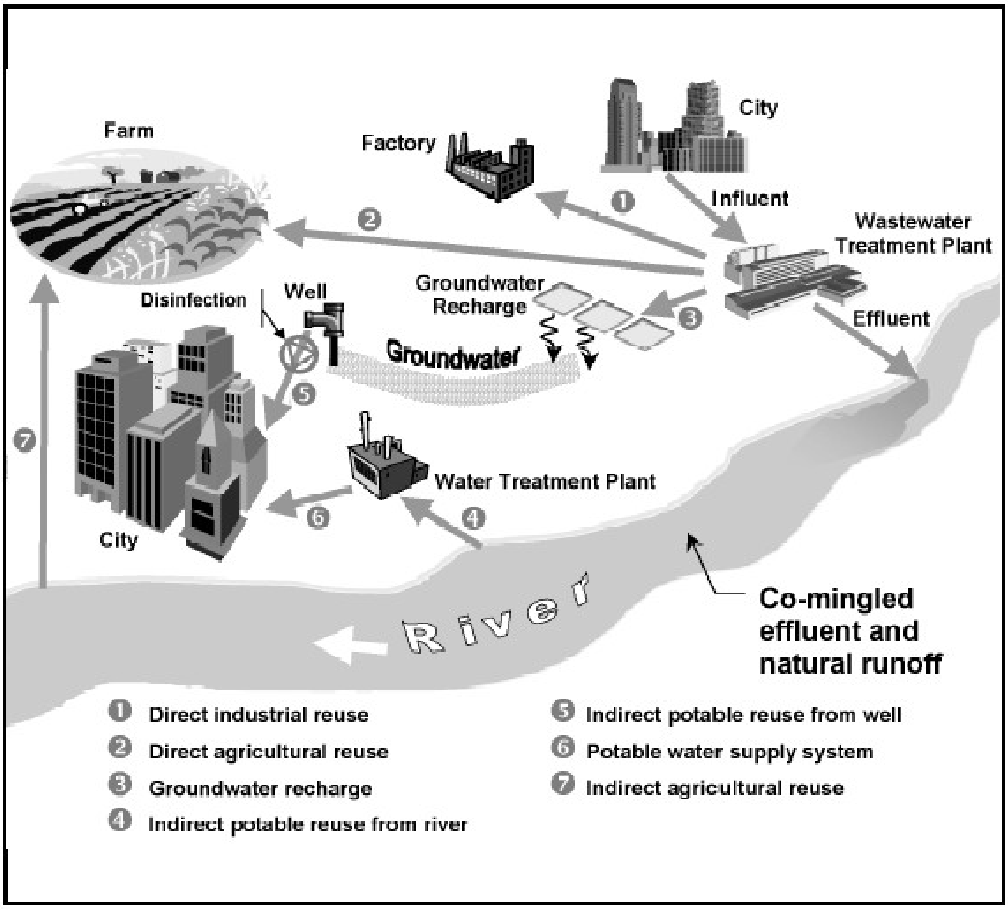

Figure 4 Water reuse applications (WateReuse Association 2004).

5. RECOMMENDATIONS

a) Water recycling and reuse should be recognised as common practice and an essential method of drought protecting our environment and economies throughout EU through the development of guidelines and best practice documents on quality criteria, public health and environmental protection.

b) National or EU wide water quality and good practice guidelines need to be agreed to enable water reuse to be implemented for all environmental, social, public health or economically beneficial applications. Initiatives are already being developed in Spain, Belgium, Italy, France, Greece, Portugal, and the UK. These need to include community and stakeholder participation from the start.

c) Project viability should be based on environmental, social and economic benefits using whole life, sustainability and cost effectiveness tools that provide a fair way of evaluating the benefits.

d) Projects should be able to take advantage of existing or new financial incentives to build skills and confidence in each country.

e) Wastewater reclamation and reuse needs to be embedded into the integrated management of the water cycle and should be included in the cost recovery policies that the EU member states will have to promote to ensure adequate incentives for users to exploit water resources efficiently by 2010.

f) Innovative projects should be encouraged to promote cohesion, international leadership and export opportunities.

Water reuse benefits all segments of the anthropogenic water cycle. It should be considered as a horizontal application that pulls together the normally segregated disciplines of potable water and wastewater treatment for public health and environmental protection. Water reuse reduces the competition for water between agriculture and public / industrial supplies by increasing the water resource available and can be used as an effective cohesion tool across Europe.

EUREAU water reuse group is keen to help the member states of Europe to clarify National or EU wide water quality and best practice guidelines to enable water reuse to be implemented for all environmental, social, public health or economically beneficial applications. These guidelines will clarify of the meaning of the statement in the Urban Wastewater Directive that **"treated wastewater should be reused whenever appropriate"**.

ACKNOWLEDGEMENTS

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The EUREAU water recycling and reuse working group, who represent 10 member states of Europe, is acknowledged for their contributions to this paper.

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The reuse of treated urban wastewater: case studies in southern Italy

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ABSTRACT

This paper describes the background and contents of the study “Definition of technical, economic and operational optimisation of wastewater treatment finalised to be reused in Apulia” commissioned by the Italian Ministry of Environment and Territory and carried out by Sogesid, with the ultimate objective to promote the conservation of water resources in quantity and quality and to reduce water consumption in regions that have a water scarcity emergency. The study was based on the following phases:

- identification of non conventional water demand and treated wastewater sources;
- analysis of best advanced treatment technologies available for the reuse of wastewater; economic analysis of additional treatment costs;
- evaluation of case studies.

The results obtained in the study and particularly with the case studies, underlined the advantages of reutilisation projects in areas with existing water scarcity or stress, especially where environmental benefits are also generated.

1. INTRODUCTION

The problem of water supply in the south of Italy and particularly in Apulia, has been addressed since the end of the eighteenth century when, following national reunification, it became evident that the scarcity of resources affecting the region and representing a constraint on social and economic development, had to be solved. A large canal (Canale Principale), one of the largest water transport and distribution projects in Europe, was built in the first half of the nineteenth century in order to transfer major volumes of water from the regions Campania and Basilicata to Apulia.

The rapid development of these regions, the changes in traditional agriculture practices and land use, the over-abstraction of groundwater (causing intrusion of sea water into the water tables) together with the climate changes, have led to frequent water shortages in Apulia and in the coastal areas of Basilicata, causing tenseness in the relations between the two regions.

Over the last four decades, the response to these problems has included improvements of water infrastructures and the construction of large reservoirs meant to regulate resources allocated for uses other than drinking water (irrigation, hydroelectric, industrial). The present stress on the groundwater resources in Apulia, addressed the attention of planners in promoting all possible actions of water demand management and the use of non conventional water in order to reduce the demand for fresh water.

Sogesid has carried out a study, commissioned by the Italian Ministry of Environment and Territory, for the "definition of technical, economic and operational optimisation of wastewater treatment finalised to be reused in Apulia"[1].

2. TERRITORIAL CONTEXT

The necessity to optimise the reuse of treated wastewater is mandatory in Apulia as the region is affected by cyclical water shortage and serious problems of stressed groundwater resources, due to low rainfall and high water abstraction for agricultural and industrial activities.

Apulia (Fig.1), the easternmost region of Italy, has a surface area of roughly 19,350 square kilometres and is predominantly flat or only slightly hilly, with mountains occupying only 1.5 % of its area. Precipitation is very low (400 mm/year). The hydrographical system is very limited, without any significant watersheds and with only two major watercourses: the Ofanto River, which flows into the Adriatic sea after having crossed the Campania and Basilicata regions, and the Fortore River, which crosses Campania, Molise and Apulia, flowing into the Adriatic sea.

The population numbers approximately four million inhabitants, concentrated in the major towns or in smaller urban settlements scattered throughout the territory.

Apulia has an outstanding level of economic development for southern Italy, and agriculture, despite the difficult climatologic conditions, is still the primary economic resource. Industry is based on large steel and petrochemical infrastructures, although small and medium-sized industry recently has registered significant growth.

Tourism represents an important source of income with excellent prospects for the future, limited only by the restraints of existing infrastructures.

Figure 1: The Territorial Context

3. WATER SCARCITY IN APULIA

The two areas in Apulia suffering particularly from water scarcity are the "Tavoliere" plain and "Salento" (Fig. 2).

[1] The study has been carried out with the contribution of Sogesid experts (Dr. Eng. G. Ferrari and Dr. V. Specchio) and the support of sector specialists (Prof. G. Boari, Prof. A. Piccinni, Dr. V. Santandrea)

Tavoliere

The sources of supply, used primarily for irrigation, consist almost exclusively of groundwater. 70% of the water necessary for irrigation (estimated at 290 million m3/year) comes from groundwater. This has led to over-abstraction of the Tavoliere aquifers (average supply deficit is more than 100 million m3/year). Over the last 15 years the declining of groundwater levels (more than 15-20 m) has been registered in the central eastern portions of the coastal area.

Salento

The only available water source consists of groundwater, which is extracted to satisfy demand (drinking water, irrigation and industrial) estimated at a total of 300 Million m3/year.

The coastal aquifer, due to over-abstraction, shows evident signs of progressive saline contamination. As a consequence, in the near future, it will be impossible to use the water even for most part of irrigation. This phenomenon is already a reality in many places along the Ionian coastal strip.

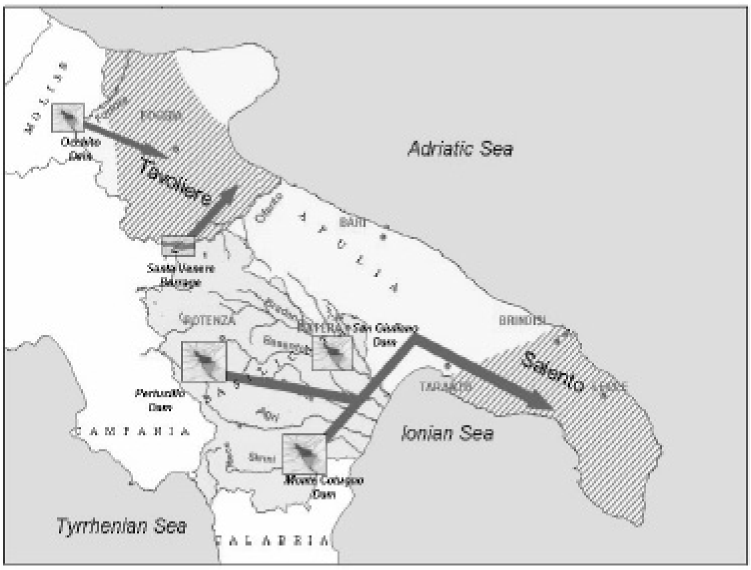


Figure 2: The critical areas in Apulia and main water transfer from other regions

The situation described above evidences that groundwater resources, formerly considered as a strategic reserve to be used only in drought periods, has become a source of basic supply in the region, in order to meet the increased water demand. The situation has become even more critical due to the recent years of drought. There is therefore an urgent need to increase the quantity of water transferred from Basilicata (Fig. 2), presently amounting to some 500 Mm3/year, to replace what's produced locally together with an

intensification of actions already undertaken in terms of reuse of treated wastewater.

The recent infrastructure projects, together with initiatives of water demand management, are important to assure long-term prospects for sustainable development. This need is felt particularly in the following sectors:

- Tourism: the number of structures, and consequently the demand for water services, are forecasted to increase notably, even in areas of elevated naturalistic value, urging the need to address the applied constraints on pumping from water tables;

- Agriculture: the sector will become more competitive, especially as the elimination of duties in the Mediterranean basin draws nearer (2010). In this framework, it is essential to assure water supply and maintain low water rates to remain competitive. Additionally it is very important that the real impact of the "Common Agricultural Policy", linked to the implementation of decoupling (shift funds from product to producer support), is thoroughly analysed.

4. THE STUDY COMPONENTS

The study ***"Definition of technical, economic and operational optimisation of wastewater treatment finalised to be reused in Apulia"*** commissioned by the Italian Ministry of Environment and Territory, has the ultimate objective to promote the conservation of water resources in quantity and quality and to reduce water consumption in regions that have a water scarcity emergency.

In order to do this, the study examined possible forms of reuse taking into consideration the requirements of recent Italian regulations to implement the Water Framework Directive (2000/60/EC) and the various aspects that condition the different scenarios. These scenarios for reuse of treated wastewater in the region depends not only on the definition of level of quality of the effluents, determining how advanced will be the treatment process required, but also on the costs involved and the environmental risks and benefits connected to it.

The study has been subdivided in following different interconnected phases:

- Identification of non conventional water demand areas and treated wastewater sources;
- Analysis of best treatment technologies available for the reuse of wastewater;
- Economic analysis of additional treatment costs;
- Evaluation of case studies.

The definition of non conventional water demand was carried out for the whole region, giving priority to the areas with already stressed water resources, identifying the water treatment plants as well as the potential users and other possible benefits (environmental, social, etc…) deriving from the reuse. Twenty-two case studies were identified and studied, creating preliminary planning over required additional process stages, treatment techniques and operational costs, water convey pipelines and distribution infrastructures, social and environmental benefits and any other element interesting the feasibility of the project.

The analysis aimed to identify an economic threshold below which the additional investments needed for advanced treatment are justified by the expected advantages.

The use of some incentives, defined at local level, could help in lowering the said threshold. This is especially the case where the local conditions make it possible to obtain valuable environmental benefits and revenues from the additional water resources become available.

5. WATER DEMAND AND SELECTION OF TREATMENT PLANTS

The major water users in the region are represented by the “Land Reclamation Consortia” which cover most of the territory, (see Fig. 3).

Regarding the non conventional water production, Fig. 4 demonstrates the distribution of the wastewater treatment plants in Apulia.

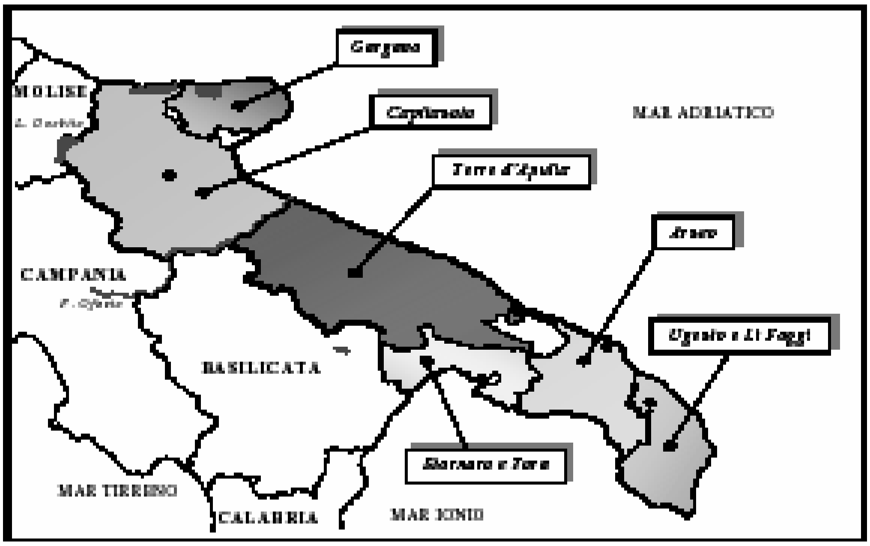


Fig. 3: Territorial distribution of the “Land Reclamation Consortia”

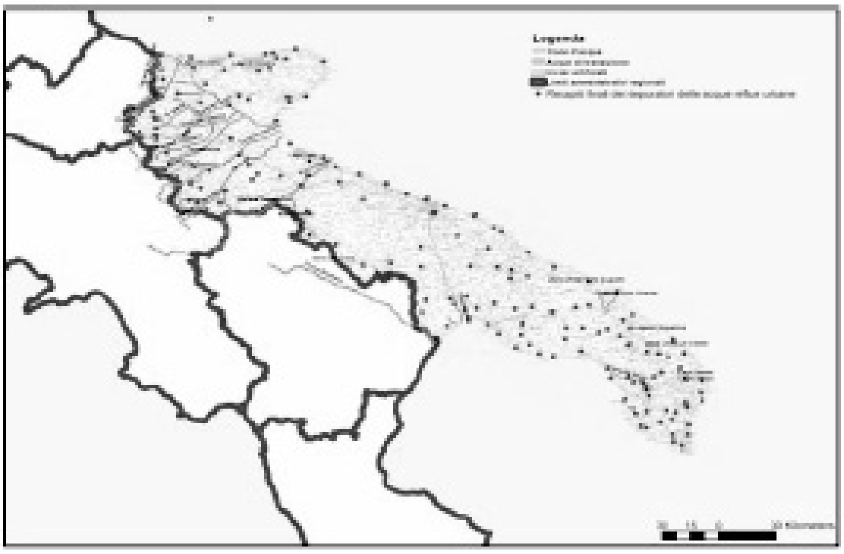
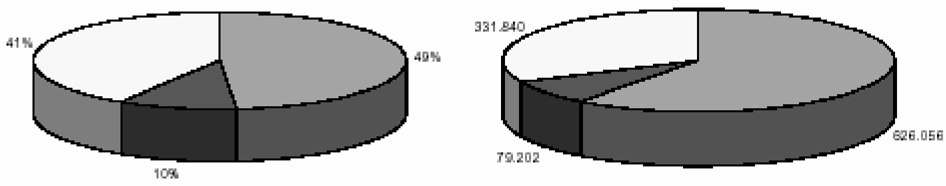


Fig. 4: Distribution of wastewater treatment plants in Apulia

The number of treatment plants, the volumes of treated water is synthesised below, subdivided according to the type of disposal site of the treated effluent.



Number of treatment plants (total = 185) *Total Treated Volumes: 1.037.098 m3/day*

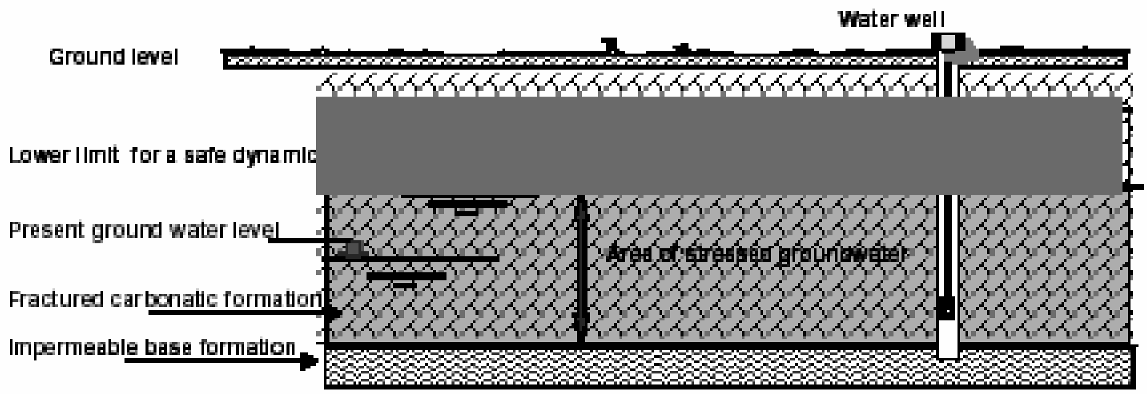
Table 1 Effluent disposal in water courses

Table 1 & 2 Effluent disposal in sensitive areas

Table 4 Effluent disposal over soil

The evaluation of total water demand in agriculture and industry using ground water resources, compared with the total water tables capacity and recharge - evaluated in a recent modelling of the aquifers over the last 15 years (Sogesid, 2004) - gives an estimated deficit of some **300 million m3/year**, a clear indicator of the magnitude of stress condition of the groundwater resources in critical areas.

In other words the over-abstraction of aquifers in stressed areas, have lowered the dynamic level of the groundwater table below the safe limit. The reconstruction of safe dynamic aquifer volumes requires several years and in coastal areas, this phenomenon has led to salt water intrusion .



In selecting the areas to study, priority was given to the most water stressed ones as the advantages of reuse were likely to be greater.

The objective of this study must be considered as subsidiary to the actions already taken by the Apulia regional government, which has programmed and partially implemented a programme for reuse of treated effluents from the major treatment plants requiring rehabilitation works in order to meet the limits prescribed by the new regulation.

Table 1 resumes the total amount of water expected to be reused in Apulia, indicating the volumes of treated wastewater by the plants identified in the study of Sogesid (twenty plants out of twenty-two were studied), together with those expected from other plants where the reuse already has been programmed/financed by the region in the past. The expected percentage of non conventional resources to be reused is estimated in an average of 54%.

Table 1: Expected volumes of reuse of treated wastewater

Reuse in Apulia	n. of Plants	Treated volumes	Reusable volumes	% of reuse
Plants identified with Sogesid Study	20	54	27,9	52%
Other Plants with reuse programmes in Apulia	49	222	122	56%
Total	69	276	149,9	54%

6. ANALYSIS OF BEST TREATMENT TECHNOLOGIES AVAILABLE FOR THE REUSE OF WASTEWATER

This section of the study provides a comprehensive analysis of best technologies and processes (secondary and tertiary) available for obtaining the quality of the effluent required by italian regulation (Decree 152/99) and those necessary for the reutilisation in agriculture (Decree 185/03) including a comparison with major international regulations.

Below are summarized the main national and international law references.

Italian legislation

- Law N° 319/76 **;**
- Resolution of the " Comitato Interministeriale per la Tutela delle Acque" (CITAI) of 1977;
- Legislative Decree N°152 of 1999
- Ministerial Decree n.185 of 12/06/2003

International Regulations

- "*Regulation Governing Use of Sewage for Irrigation Purpose*" and "*Wastewater*
- *Reclamation Criteria*" edited by the *California State Board of Public Health*,
- "Guide lines for the reuse of water in agriculture*"* edited by the "World Health Organization", the "*Rapport Engelberg"* by the United Nations Environment program, World Health Organization, World Bank and United Nations Development Program*,*
- Regulation of some states of U.S.A and Canada.

EU Regulation

- Framework Directive 2000/60/CE instituting a common implementation strategy in the water sector
- Directive 91/271/CEE concerning the treatment of urban wastewater;

Regulation of some EU states (France, Spain Germany)

Regulation of some Mediterranean states (Israel, Cyprus, Tunes)

The possible sector of reuse of treated wastewater and aspects which have been taken into account in the study are summarised below:

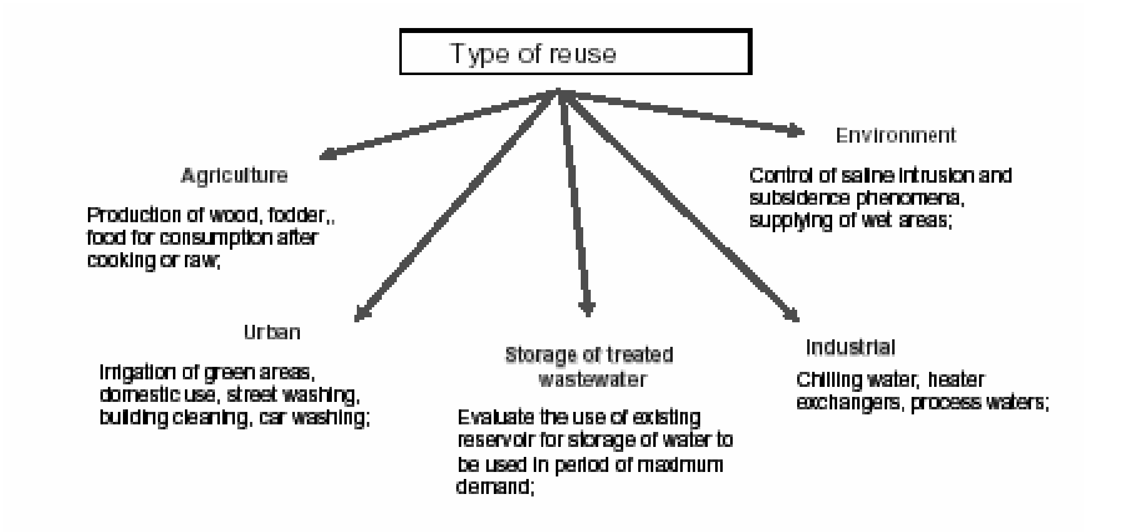


Table 2. shows, for the main classes of contaminant, the limits for the relevant parameters that must be respected in the treatment process, depending from the type of receiving waters of the effluent, namely: effluent disposal in surface water courses (Table 1), over the soil (table 4) or reused in irrigation or industry Decree 185/03).

Table 2: Effluent limits according to type of effluent receiving waters

Class of contaminant		parameter	unit	*D.L. 152/1999 e D.L. 258/2000*		*D.M.A.T.T. 185/2003*
				Table 1	*Table 4*	
				Discharge in surface water bodies	Discharge over soil	Reuse (Irrig. & civil)
Suspended solids		*Total solid suspended*	*mgSST/l*	35	25	10
Organic Load		*Biological Oxygen Demand, BOD_5*	*mgO_2/l*	25	20	20
		Biochemical Oxygen Demand, COD	*mgO_2/l*	125	100	100
Macro Nutrients	Nitrogen	Nitrogen total	*mgN/l*	--	15	15
		Ammonia-nitrogen	*mgN/l*	30 % total nitrogen	4,5	1,6
	Phosphorus	Phosphorus *total*	*mgP/l*	--	2	2
Microbiologic load		*Escherichia Coli*	*UFC / 100 ml*	5.000	5.000	10

7. ECONOMIC ANALYSIS OF ADDITIONAL TREATMENT COSTS

The technical-economical analysis concerned:

- Identification and estimate of costs for additional treatment required to adapt the limits prescribed (tab. 1 and tab. 4 of Annex 5 to Decree 152/99), to the new parameters introduced by Decree 185/03 (limit for reuse in agriculture of treated wastewater effluents).
- The implication connected with the operation of the system process-reuse plant, as well as with administrative organisation, tariff and political aspects.

This last aspect is very sensitive because presently there are three different potential subjects in the reuse chain :

The analysis of additional costs for advanced wastewater treatment, has been carried out taking into consideration the following two main categories:

- **Investments/capital costs**, estimated financed by the financial market.
- **Operational costs.**

The two categories have been subdivided respectively in:

- **Fixed costs** –independent from the type of treatment. These costs *do not change* with the volumes of treated wastewater.
- **Variable costs** –dependent from the type of treatment. These costs *change* with the volumes of treated wastewater.

The following basic criteria have been considered for the economic analysis:

- Type of reuse (irrigation, integrated irrigation, industrial);
- Improvement works required in the plant, in presence or without primary treatment;
- Additional advanced process treatment;
- Estimate of costs with reference to the plant dimensions and served equivalent population.

Below are resumed the main result of the analysis indicating: for type of reuse and class of plant, the additional costs/m3 (Table 3) required for improving the effluent quality from limits of Table 1 and Table 4 of Decree. 152/99 to the limits of Decree. 185/03 (reuse in agriculture); the costs necessary to provide additional advanced treatment required for improving the effluent quality from limits of table 1 to reuse requirements (Tablee 4 and Figure 5); the additional costs necessary to provide advanced treatment required to improve the quality of the effluent from limits of table 4 to reuse requirements (Table 5 and Figure 6).

Table 3: Additional cost/m3 required for type of reuse and class of plant

Type of reuse / pop.	2.000	50.000	500.000
	Table 1		
industry	0,55	0,16	0,10
Irrigation integrated	0,95	0,22	0,12
irrigation	1,14	0,27	0,14
	Table 4		
industry	0,18	0,08	0,07
Irrigation integrated	0,28	0,09	0,07
irrigation	0,32	0,10	0,07

Table 4: Additional costs required to improve the limits of table 1 (D.L. 152/99) regarding reuse limits in agriculture (DM 185/03)

	Operational Costs p. e.	2.000	50.000	500.000
A.	Fixed Costs			
A.1	Operational Costs	36.801	78.728	230.218
	Personnel	30.720	23.040	15.360
	Maintenance	6.081	55.688	214.858
A.2	Financial Costs (1)	22.131	227.892	1.317.411
	civil works	2.903	67.974	980.773
	electromechanical works	19.228	159.918	336.638
	TOTAL (A.1+A.2)	58.932	306.620	1.547.629
B.	Industrial Use Variable Costs	12.771	384.096	3.817.732
	Electric power	4.926	122.606	549.112
	Chemical reagents	7.845	261.490	3.268.620
C.	Irrigation (Integrated) Variable Costs	6.845	205.875	2.046.304
	Electric Power	2.640	65.717	294.324
	Chemical reagents	4.205	140.158	1.751.980
D.	Irrigation Variable Costs	5.604	167.465	1.664.531
	Electric Power	2.184	53.456	239.413
	Chemical reagents	3.420	114.009	1.425.118
	TOTAL (A+B) Industrial Use	71.703	690.716	5.365.361
	TOTAL (A+C) Irrigation (Integrated)	65.777	512.495	3.593.933
	TOTAL (A+D) Irrigation	64.536	474.085	3.212.160

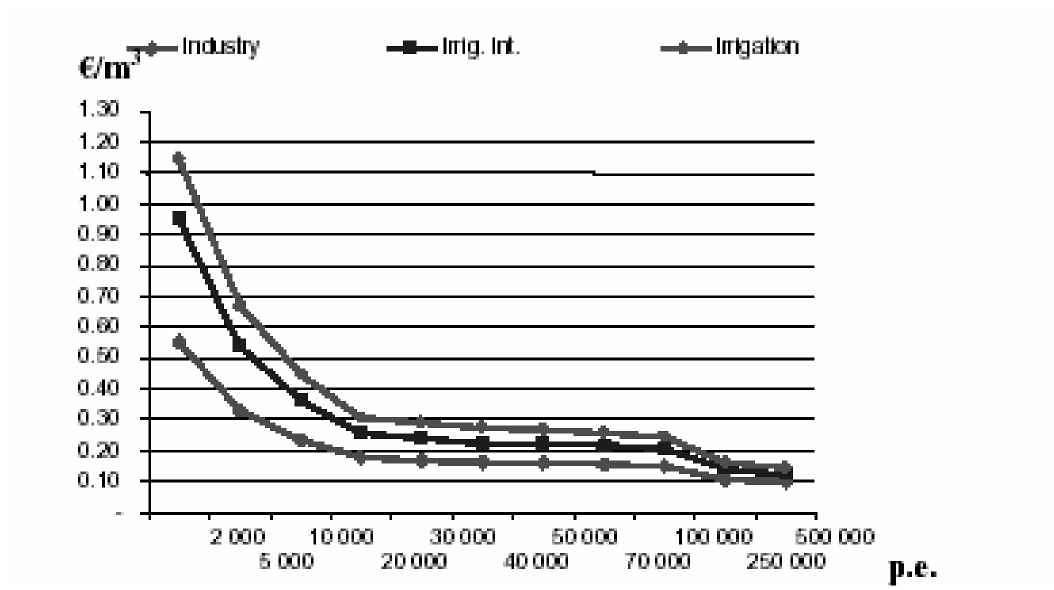


Figure 5: Additional Costs required to improve the limits of table 1 (D.L. 152/99) to reuse limits in agriculture (DM 185/03)

Table 5: Additional costs/m^3 required to improve the limits of table 4 (Dlgs 152/99) to reuse limits in agriculture (DM 185/03)

	Operational Costs / p.e..	2.000	50.000	500.000
A.	Fixed Costs			
A.1	Operational Costs	6.276	16.449	29.512
	Personnel	3.840	3.840	3.840
	Maintenance	2.436	12.609	25.672
A.2	Financial Costs (1)	8.156	42.208	85.851
	civil works	-	-	-
	electromechanical works	8.156	42.208	85.851
	TOTAL (A.1+A.2)	14.432	58.657	115.363
B.	Industrial Use Variable Costs	8.745	276.190	3.452.520
	Electric power	900	14.700	183.900
	Chemical reagents	7.845	261.490	3.268.620
C.	Irrigation (Integrated) Variable Costs	4.687	148.037	1.850.550
	Electric Power	482	7.879	98.570
	Chemical reagents	4.205	140.158	1.751.980
D.	Irrigation Variable Costs	3.812	120.418	1.505.298
	Electric Power	392	6.409	80.180
	Chemical reagents	3.420	114.009	1.425.118
	TOTAL (A+B) Industrial Use	23.177	334.847	3.567.883
	TOTAL (A+C) Irrigation (Integrated)	19.119	206.694	1.965.913
	TOTAL (A+D) Irrigation	18.244	179.075	1.620.661

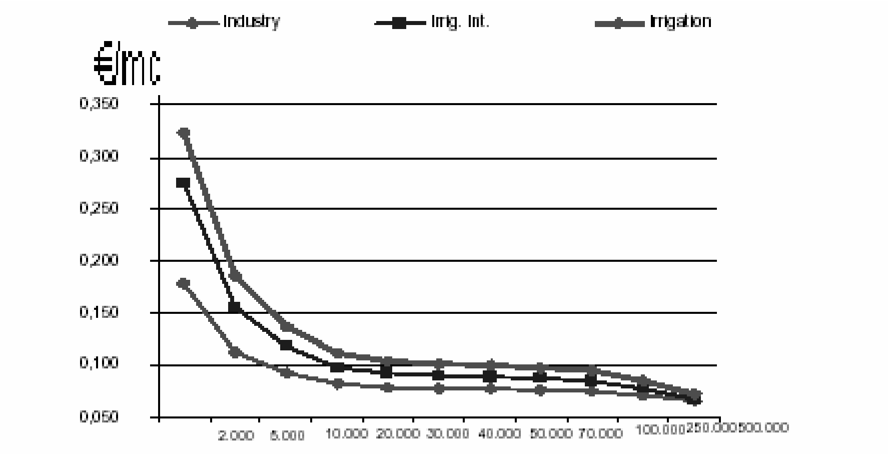


Figure 6: Additional costs required to improve the limits of table 4 (Dlgs 152/99 regarding reuse limits in agriculture (DM 185/03)

The result of the analysis can be summarised as follows:

The costs for advanced wastewater treatment required for improving the plant effluent quality, in order to respect the limits required for disposal in surface water bodies, is ranging from a maximum of 79 € per capita for plants of 2,000 p.e. to a minimum of 20 € per capita for plants of 500,000 p.e.

- The additional costs for improving the effluent quality of the treatment plant, in order to respect the limits required for disposal over soil (in arid regions without defined water courses), are negligible.
- The difference between the additional costs in the two cases described above is dramatically reduced with the economy of scale obtained in large treatment plants (above 100,000 p.e.)
- The cost-benefit evaluation depends from the size of the treatment plant and from a well defined tariff policy (incentives and income from additional fresh water made available).
- Any project in arid or semiarid regions with non conventional water demand (agriculture, industry, environment), presents considerable benefits from the implementation of a wastewater reutilisation policy.
- The environmental benefit plays a central role in a comprehensive evaluation of a reuse project, (in our case a value is given to the damages caused by overabstraction of stressed aquifers).
- The appropriateness of reuse project varies when compared with treatment plant size and conditions regarding the disposal of the treated effluent.

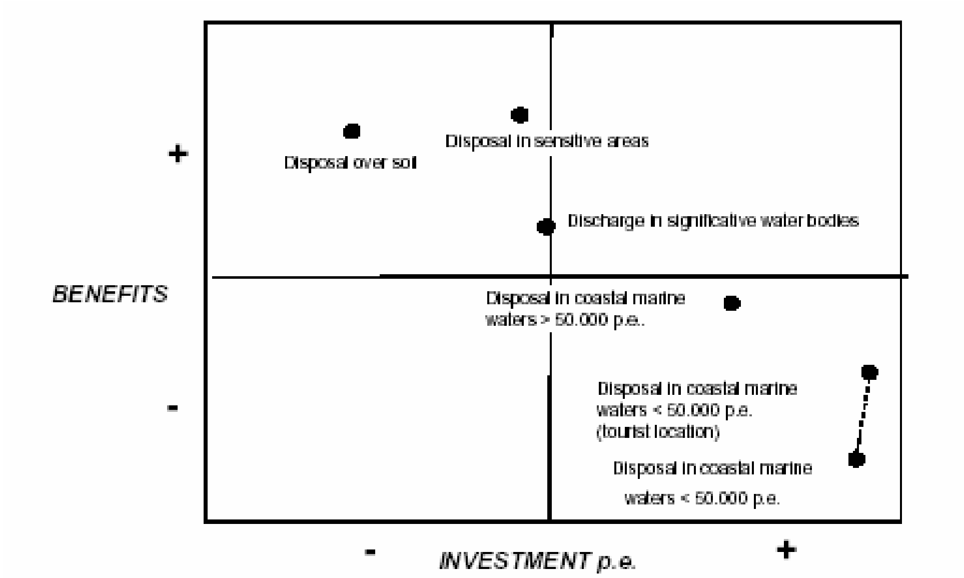


Figure 7: The appropriateness of reuse project compared with th e size of treatment plants and type of effluent disposal.

8. EVALUATION OF SOME CASE STUDIES

The treatment plants identified in the Sogesid study are listed in Table 6, together with volumes of treated wastewater, type of disposal and prevailing use. Figure 8 indicates the location of the 22 treatment plants investigated, concentrated to the critical areas affected by water stress.

Table 6: Treatment plants studied by Sogesid

Project		Treatment Plant			Availability of non conventional water resources (Mm³/year)	Reuse integrated with natural resources	Availability of consumers / state of infrastructures	Prevailing use
Province	code	Name of served agglomerate	Quality limits of effluent	Treated volumes (m³ / day)				
Bari	BA-1	Altamura	Table 4	14.191	10,4	Surface water	Average/High	Irrigation
		Gravina in Puglia	"	8.341				
		Santeramo in Colle	"	6.900				
	BA-2	Acquaviva delle Fonti	Table 4	4.921	8,9	Groundwater	High/High	Irrigation
		Casamassima	"	3.360				
		Gioia del Colle	"	8.279				
		Putignano	"	5.919				
		Sammichele di Bari	"	2.214				
	BA-3	Locorotondo	Table 4	2.837	1,0	---	Scarce / High	Irrigation/industrial
Lecce	LE-1	Copertino	Table 1	13.635	5,0	---	High/High	Irrigation
	LE-2	Supersano	Table 1	3.214	1,2	Groundwater	High / Low	Irrigation
Brindisi	BR-1	Brindisi "Fiume Grande"	Table 1 e 2	18.903	6,8	Groundwater	Low / High	Irrigation/industrial
	BR-2	Carovigno	Table 1 e 2	19.858	7,0	---	Medium / Medium	Irrigation
	BR-3	Ceglie Messapica	Table 1	5.890	8,1	Groundwater	Medium /Medium	Irrigation
		Francavilla Fontana, Latiano, Mesagne	Table 4	16.393				
	BR-4	Fasano "Forcatella"	Table 4	8.769	3,2	---	High/High	Irrigation
	BR-5	Oria	Table 4	3.885	2,6	---	Low / Basso	Irrigation
		Torre Santa Susanna - Erchie	Table 4	3.891				
Foggia	FG-1	Manfredonia	Table 1	11.596	4,2	Surface water	Low / High	Irrigation/industrial
	FG-2	Ischitella	Table 1	1.659	1,7	Spring waters	Good / Medium	Irrigation
		Rodi Garganico	"	1.348				
		Vico del Gargano	"	1.820				

The selection of the projects was based on final objective of increasing the amount of good quality water resources available for primary uses. For each selected project a detailed investigation was carried out, regarding the technical characteristics of the plants (existing level of treatment, effluent quality, type of disposal), the potential users of non conventional resources and any other aspect relevant to environmental condition in the area and possible advantages that could be generated through the project. The possibility to store the treated effluents during the autumn and winter seasons, was also evaluated. The total volumes available for reuse was estimated as indicated in Table 7:

Table 7: Total volumes of treated wastewater available in Apulia

Projects per Province	Annual volumes (Mm^3 / year)	Percentage respect to total of Province (%)	Percentage respect to total in the region (%)
Bari	20,3	22,6	–
Lecce	6,2	7,4	–
Brindisi	27,7	75,3	–
Foggia	5,9	9,0	–
Total	60,1	–	14,1

A synthetic description will follow for two projects (Figure 8) that, for their characteristics, the results, advantages expected and measures planned, are to be considered as examples of good practice.

The two projects are:

- ”Reuse of effluents from the Carovigno Treatment Plant for agricultural purposes and at the same time protecting the “Torre Guaceto Reserve”.
- ”Reuse of effluents from the Gravina in Puglia Treatment Plant for agricultural purposes, using the already existing Saglioccia reservoir for storage of the treated wastewater”

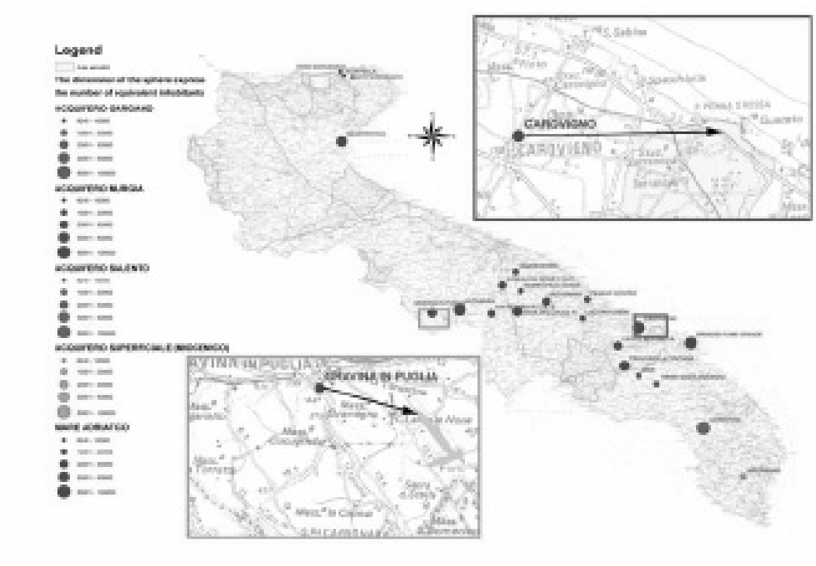


Figure 8: Location of the 22 treatment plants included in the Sogesid Study and the “Torre Guaceto” and “ Saglioccia” projects.

8.1 Reuse of effluents from the Carovigno Treatment Plant

8.1.1 Territorial context

The project is located along the Adriatic coast of the Brindisi Province (Figure 9) and is characterised by the presence of the natural reserve site of "Torre Guaceto". The reserve, having an extension of 1,144 hectares, is considered a wetland of international interest by the Convention of Ramsar, a Special Security Zone (Z.P.S.) as well as a marine reserve and Site of Communitarian Interest (S.I.C.). Moreover the reserve of "Torre Guaceto" has been included in the "Census of priority habitats", implementation of the community directive 92/43/CEE.

Figure 9: Location of Carovigno Treatment Plant and Torre Guaceto Riserve

The extensive agricultural activity represents one of the major components of the local economy in this area, extending from the coast up to the town of Carovigno. The presence of an efficient "Land Reclamation Consortium" and a widespread irrigation network, has oriented the agricultural production to intensive crops and consequently to a higher water demand.

The agricultural area inside the reserve (Fig. 10) represent approximately 864 ha (78%) and the naturalistic area 250 ha (22%).

Figure 10: Land use areas of Torre Guaceto, olive plantation and seminal crops

The inadequate management of the aquifer, with over-abstraction and consequent reduction of the safe extraction volumes, is the principal cause of the present environmental deterioration affecting the "Wetland" of "Torre Guaceto Reserve". The very high concentration of salt in the groundwater has led to the reduction and even extinction of some very particular and rare macro-invertebrate species (Triturus italicus, tree frog, Emys orbicularis, murshland turtle, etc).

8.1.2 The project

Near the reserve, the Carovigno Treatment Plant, presently under construction, represents a potential source of non conventional water resource that could be utilised in the agriculture zone of "Apani", presently supplying the irrigation system from the ground water with elevated saline content. The treated effluent is planned to be disposed into the "Canale Reale" that, according to the Decree 152/99, is a "sensitive water body". The advanced treatment processes required are therefore designed to fulfil the limits of table 2 of annex 5 to Decree 152/99.

The annual volume of treated wastewater in the Carovigno Treatment Plant is approximately **3.7 million m3/year**, the available volume during the irrigation period is estimated to some **2.8 million m3 /year** with a monthly distribution as follows:

Plant	March	April	May	June	July	August	Sept.	October
Carovigno	309 876	299 880	309 876	359 880	433 876	433 876	359 880	309 876

The total demand for irrigation water in the "Torre Guaceto Reserve" is estimated to be **0.7 million m3/year** with a maximum in July (165.000 m3) and a minimum in March (12.000 m3), while the estimated total water demand for the environmental rehabilitation of the Natural Reserve is estimated to some **2,9 million m3/year**.

In order to reach the required effluent quality, the project foresees additional treatments, consisting in increasing the sedimentation capacity with the adding of coagulant for extended removal of suspended solids and reduction of BOD5, disinfection for the reduction of bacteriologic load, and other works like rehabilitation/extension of irrigation network and pumping stations, monitoring system, storage tank, emergency marine pipeline for disposal of untreated effluent in cased of plant out of order etc.

The reutilisation of the treated effluent for recharging the water table, must be considered experimental and includes a complex management programme for the whole "Wetland Area". This programme is planned by the "Land Reclamation Consortium" and includes monitoring of effluent volumes and quality.

The effluent supplied to the Wetland Area will be conveyed near to the outlet of "Canale Reale" through a disposal area with overland flow treatment technique, using vegetative biotypes like *Phragmites australis* or similar.

The total estimated cost of some 1.8 million € has a very positive cost – efficacy ratio, taking into consideration the invaluable advantages of the environmental rehabilitation of the Natural Reserve Area.

Expected effects of the project:

- reduction of water abstraction from stressed aquifer;
- limitation of the saline contamination of wetland;
- protection of this important habitat, critical for the survival of the existing fauna.;
- recharge of the water table of the wetland with a controlled effluent disposal;
- reduction of the supply of nutrients to the “sensitive area”;

8.2 Reuse of effluent from the Gravina in Puglia Treatment Plant

8.2.1 Territorial context

The project is interesting the Murgia region (50 km from Bari), an area characterised by peculiar geomorphologic characteristics, with terrain slightly undulated showing outcrops of the calcareous mesozoic substrate, undefined watershed with fossil hydrographic system and ground elevation ranging between 300 and 500 m.a.s.l.. This situation causes serious problem to the disposal of treated effluents of treatment plants because the quality of effluent must respect the limits of table 4 of annex of Decree 152/99 (disposal over soil).

8.2.2 The project

The project is finalised to utilise the treated wastewater, fulfilling the irrigation demand of the area (especially in peak irrigation season) and at the same time providing a proper disposal of the treated effluent. With the aim to optimise the use of available volumes of treated wastewater, the effluent will be conveyed to the existing reservoir of “Tempa Bianca” on the Saglioccia stream during the non irrigation seasons, using the available storage capacity of this reservoir (Figure 11).

Figure 11: The “Saglioccia” Reservoir

Three project solutions have been investigated regarding the utilisation of three different treatment plants present in the area.

1) reuse of effluents from the treatment plant of Altamura;

2) reuse of effluents from the treatment plants of Altamura e Gravina di Puglia;

3) reuse of effluents from the treatment plants of Altamura, Gravina di Puglia e Santeramo.

Table 8 shows the daily average discharge of treated wastewater and total volumes treated by the three plants.

Table 8: Daily discharge and total volumes of treated wastewater in the area

Parameter	unit	Treatment plant		
		Altamura	Gravina in Puglia	Santeramo in Colle
Population	*inhabitants*	**64.167**	**42.154**	**26.050**
Daily average discharge	m^3 / *day*	**11.229**	**7.377**	**4.559**
Volumes of effluent in the period of storage	Mm^3	**1,7**	**1,1**	**0,7**
Volumes of effluent in the irrigation period	Mm^3	**2,4**	**1,6**	**1,0**

The total treated wastewater available is resumed in Table 9.

Table 9: Total volumes of treated wastewater available in the area

	Natural flow (*)	Hypothesis 1 Altamura	Hypothesis 2 Altamura e Gravina	Hypothesis 3 Altamura, Gravina e Santeramo
Available Volumes (m^3)	**0.9**	**4.6**	**5.8**	**6.6**
Irrigable Agricultural Area (ha)	**270**	**1500**	**1900**	**2200**

(*) determined as the volumes of water to be stored in the average year

Figure 12: Agriculture in the project area

The effluent from the existing plants will be collected to an advanced wastewater treatment plant, tentatively located in the vicinity of the Saglioccia reservoir; this solution has been selected in order to reduce the construction costs and optimize the operational costs. The level of treatment required will be designed in order to fulfil the limits indicated in Table 4 of Annex 5 of Decree 152/99 (disposal over soil).

The proposed project plans to discharge the treated wastewater from the Altamura Treatment plant into the Saglioccia Reservoir during the months without irrigation (November to March) with the advantage of dilution with the meteoric water flowing to the reservoir. The reservoir will release the stored volumes in the irrigation period helping in meeting the peak demand. During the irrigation period the treated effluent of the three plants will be conveyed directly to the irrigation network. The long period storage of treated wastewaters in a reservoir, will represent as well a pilot monitoring project finalized to study the effects (eutrophication, organic and microbial control, etc…) and correction measures to be taken.

Expected effects of the project:

- Reduction of water abstraction from stressed aquifer
- Identification of a proper disposal of effluent
- Utilisation of complete capacity of Saglioccia reservoir
- Supply of volumes necessary to meet the peak demand for irrigation water

How to deal with irrigation demand in a context of water scarcity and water uncertainty: an example of combining tools in the Charente river Basin in France[1]

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ABSTRACT

In period of low water level, some river basins face an imbalance between the available water resource and the uses. In France, the development of the irrigation since the years 1970 is an important cause of this imbalance. The water needs can exceed the natural water supply. Favoured by the 1992 French water act, rending the metering progressively obligatory and that recommend dialogue among water actors, a volumetric management (VM) mechanism has progressively been implemented. A VM consists in finding a equitable distribution of the water in defining, according to its state, some access rules among users. VM already exists in systems where the water supply is foreseeable with a good probability (tablecloth or dam). The Upstream Charente river basin in France face an important imbalance added to high sensitivity of the resource to the climatic conditions. However, a VM is implemented in this basin since the creation of Mas-Chaban dam in year 2000, which allow to resupply the river. This article presents the VM instruments implemented in this basin and discusses their effectiveness and their social acceptability.

1. INTRODUCTION

In France, during the course of the last 20 years, conflicts involving water usage have multiplied. In many regions, under the combined influence of community agricultural policy (CAP) and local policies for land development, the agricultural demand for irrigation water has seen a strong increase.

Therefore, the minimum base flow of some rivers cannot always be guaranteed. The most common consequences are a reduction in the absorption capacity of waste water from heavily populated areas, possible damage to the aquatic flora and fauna, and adverse effects on the economy when the resource supports tourism and recreational activities.

In the above contexts, the institutions charged with resource management can put Volumetric Management (VM) tools in place. This was the case in France regarding management of the groundwater in Beauce and in the Neste and Charente resupplied river systems.

Management is called volumetric when the balance between supply and demand is determined by a device based on the knowledge of the volumes withdrawn (Sixt, 2001) in a supply of the foreseeable resource. The main characteristics of the type of management consist of (i) allotting a water quota for each farming operation, (ii) instituting a calendar

[1] Paper presented by Jean-Philippe TERREAUX (UMR G-EAU, Cemagref, Montpellier, France)

for the distribution of this water quota during periods of low water, (iii) developing rules for restrictions based on the state of the resource and (iv) setting up a system for monitoring the irrigators' practices.

The purpose of this paper is to present the type of volumetric management in place in the sub-basin of the upstream Charente and provide trails for evaluating its efficacy. After presenting the case study, we will examine in the second chapter the measures that have been implemented so that water supply and demand are suitable. In the third chapter, we will attempt to evaluate the efficacy of management tools before concluding and suggesting avenues for improvement.

2. PRESENTATION OF THE UPSTREAM CHARENTE BASIN AND THE MANAGEMENT STAKES OF THE RESOURCE

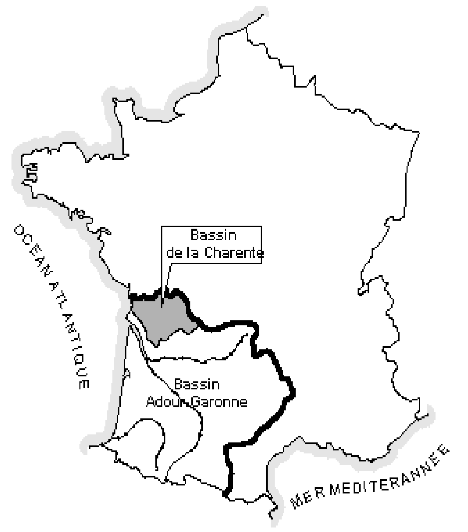
2.1 Geographic and hydrological characteristics

The Charente basin is located on the ocean façade of France (figure 1) and drains an area of approximately 9300km[2]. The Charente, which is the principal river in the basin, has its source in the foothills of the Massif Central at an altitude of 300 meters. Along its course of some 380km, the river is fed by the waters of four main tributaries before supplying fresh water to the Marenne-Oléron oyster-farming basin. The hydrological system of the Charente and its main tributaries is oceanic-rains type, i.e. by strong outflows in winter due to the influence of oceanic rains, and by periods of severe low water during the summer.

It is, however, in the Upstream Charente basin (UC) (upstream from the city of Angoulême), and in particular in the UC unit called "restricted" (Figure 2) that the greatest imbalances can be observed. This unit, which has an area of 1640 km, is composed of the river and its accompanying groundwater. Downstream from the city of Angoulême, the river's rate of flow is supported in large part by a karstic aquifer whereas upstream, the Charente flows on a fractured carbonated karstic substratum, making its rates of flow very dependent on its accompanying aquifer. Since the inertia of this aquifer is weak, the flow of river can be interrupted entirely at certain points as was the case during the summers of 1989 and 1990, for example.

Under such conditions, the yields of irrigated crops are affected, aquatic life is at risk, the development of tourism is difficult, and oyster-farming activity downstream from the basin is at stake and the drinking water supply for the city of Angoulême is disrupted[2].

[2] Up to 20% of the withdrawals of drinking water for the 45,000 inhabitants of the city of Angoulême did come from the Charente Rive till 2001, but because of the uncertain character of this resource, this harnessing has been abandoned.



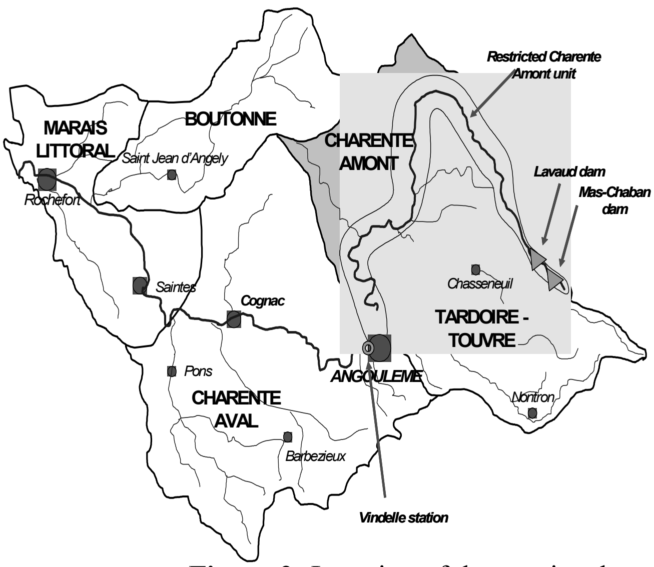


Figure 1: Location of the Charente basin

Figure 2: Location of the restricted upstream Charente unit

2.2 Economic and agronomic characteristics

The department of Charente, where 90% of the basin under study is located, is marked by the economic importance of its agricultural activity, which represents 11% of the employment and 5% of the GDP. Agricultural production systems are diversified; half of the agricultural area is used for cereal crops that are oleaginous and rich in protein, and the other half is prairie and feed crops. Irrigation is particularly well-developed in this sub-basin. The irrigated area represents one third of the utilized agricultural area[3]; and each farming operation that uses irrigation irrigates on an average 34h each year.

Under the combined effects of community agricultural policy and local policies that support the development of irrigation, irrigated areas have continued to increase since the 70s. In 1979, in the upstream Charente basin, there were 2000 hectares being irrigated, 5500 in 1988, and nearly 9000 in the year 2000. Today, 90% of this area involves crops that are eligible for CAP subsidies, of which 85% is corn[4].

3. MEASURES FOR SUPPLY / DEMAND ADEQUACY

Faced to this increase in irrigated areas, and in spite of the Lavaud Dam building in 1989 with a net capacity of $10Mm^3$, chronic imbalances remain between availability of the resource and uses during low flow periods. Frequently, the desired rate of flow during periods of low water is often not reach. From that point on, several solutions are available to managers of the resource: (i) impose rules for a decrease in withdrawals up to the observed deficit, (ii) create new resources or (iii) implement deficit management tools.

In the restricted UC basin, as a result of negociations, all the actors involved, including representatives of the agricultural profession, decided to combine the 3 solutions (Hardelin, 2003). Consequently, in the year 2000, the Mas-Chaban dam, with a net capacity of $12.4Mm^3$ was created to support the low water levels of the river and two management tools were implemented: a pricing system for agricultural water and a VM mechanism. Various follow-up measures of an advisory, training, and informative nature

3 It should be noted that the area equipped to be irrigated represents 45% of the UAA (utilized agricultural area).
4 6% involves high value-added crops such as melon, seed crops, orchards, or tobacco.

for the benefit of the irrigants were also implemented to increase the effectiveness of the previously mentioned tools. In cases of water stress, which intensity is measured by the river flow downstream, the volumes allocated to agriculture can be reduced up to a completed pumping interdiction if needed.

3.1 Tools for managing demand

The implementation of VM mechanisms and pricing were in large part favored by the gradual installation of water meters beginning in 1992, when the French water act began to require metering.

The choice of VM procedure, whose characteristics will be examined below, are in large part a result of the observation that two-part pricing of the river water and its accompanying groundwater is only effective[5] beyond a price per cubic meter above 0.09€ (Montginoul, 1997). However, the users fee negotiated with representatives of the agricultural profession consists of a fixed rate of 12.2€/ irrigated hectare and a variable[6] rate of 0.003 or 0.006€/m^3 used. So this price scale does not motivate water economy but is calculated in such a way as to ensure a balanced budget for the dam management (Montginoul, 1997).

Thus, it is the resource VM that must make it possible to manage water scarcity. In the restricted UC basin, the following principles apply.

- Each farming operation is allotted a maximal volume of water that is not to be exceeded during the irrigation season. This volume, called "reference" is determined by the area that the farmers declared as having irrigated in the year 2000 and is calculate on the basis of the theoretical water needs for the cultivation of corn on three types of soil[7]. Table 1 describes the distribution of reference volumes by type of soil in the UC basin[8]. Thus, a farmer who has declared an irrigated area of 20h in 2000, divided evenly among topsoils and average soil will be attributed a reference volume of 53,000m^3 (10x2900 + 10x2400), regardless of crop rotation and the area being irrigated the year considered.

Table 1: Distribution of reference volumes by soil type in the UC basin

Type of soil	Maximal available water storage	Area (ha) in upstream Charente	Reference volume base corn (m^3)	Volumes attributed for the basin (in Mm^3)
Superficial	Low	8000	2900	23.2
Middle	Average	1500	2400	3.6
Deep	High	500	1000	0.5

- The use of the reference volume is regulated nonetheless. Between mid-June and mid-September, the irrigation season is subdivided into 10 periods[9]. Before each period, the State organism communicates to the irrigators an "IrrigInfo" bulletin defining volumes they are advised not to exceed (expressed in percentage of

[5] Here we mean efficiency in terms of water economy per parcel and not efficiency with regard to low water level objectives.
[6] The members of the "Agricultural Cooperative for water management of the upstream Charente", responsible for collecting fees on behalf of the Interdepartmental Institute for the Development of the Charente River, get the lowest price.
[7] The three types of soil are determined based on the maximal available water storage.
[8] The means of calculating reference volumes is the same for all units in the upstream Charente.
[9] These periods last from 6 to 20 days, the shortest being during the months of July and August.

reference volume) during the following period, taking into account the water needs of the crops specified for the three previously mentioned soil types.

- In the event that, notwithstanding above distribution calendar for reference volume, there is the risk that the desired rate of flow might not be adhered to at the Vindelle station (Figure 2), that is 3 m^3/s, 4 types of restrictions can be decided upon before each period. When the rate of flow is less than 4 m^3/s and 3.3 m^3/s (level 1 and 2 alerts) it is decided to forbid pumping during 1 and 2 days respectively. When the outflow is less than 2.8 and 2.5 m^3/s (level 3 and 4 alerts), the farmers are required to reduce their withdrawals by 50 and 100% respectively (in other words, a total ban on irrigation).
- The monitoring system implemented is based on the reading of meters by the irrigators at the conclusion of each of the periods; the reading is then sent to the organism in charge of water policy (DDAF). The farmer generally does not incur any sanctions when he uses more than the recommended volume per period. When total usage over the irrigation period exceeds the reference volume, the price per cubic meter of water is multiplied by 10[10] and the excess in consumption can be deducted from his reference volume for the following year. The agents for water policy can do inspections to verify the accuracy of declarations and, if necessary, give just a warning or else financial sanctions that are leaved to the State services judgment.

3.2 Characteristics of supply

The Charente River has structural works (dams and hillside reservoirs) that modify the availability of the water resource in space and time, making up the supply of the basin slope by adding to natural outflows. The Lavaud and Mas-Chaban dams have gate outflows of 2 m^3/s each (for a total of 4 m^3/s), making it possible to resupply the river to maintain the desired rate of flow during periods of low water levels at Vindelle (3 m^3/s) and irrigation with pumping capacities estimated at 4.5 m^3/s in the upstream Charente. The UC basin also has available private or collective hillside reservoirs, with an available capacity for irrigation of 5.2 Mm^3, but they are situated mainly in units other than the restricted UC.

Resource management for the two main dams is done through a combined effort among the various partners in water management (the General Council of Charente administrative region, the Basin Institute, the Chamber of Agriculture and Irrigators Union). Using a "weekly update" based on consumption, the rains recorded, and foreseen consumption, and on simulations using a hydrological model and water demand, the partners agree upon releases to be made once or twice a week to maintain the desired low water level at Vindelle.

Despite this management device, foreseeing low water levels and adhering to desired low water levels in the Charente remains difficult due to complex dynamics or external events that are difficult to quantify. The interactions of the Charente with the aquifer, part of which is karstic, are not well-known. In addition, the transfer time between the dams and Vindelle can range from 4 to 8 days depending on the river's rate of flow.

[10] This corresponds to a price of 0.03 or 0.06€/m^3, which is still below the threshold of 0.09€/m^3, the level above which farmers could benefit from a change in practices (Montginoul, 1997).

3.3 Follow-up measures

For the past twenty years or so, several technical support steps for irrigation have been developed aimed at optimizing the contributions of farmers towards a better utilization of the available resource. These steps are often initiated by institutions representing the agricultural profession itself (Chamber of Agriculture, Charente Irrigators Group…), and in partnership with government services, territorial collectivities or the Adour-Garonne water agency, which can participate financially in these steps when they register within the framework of its action programs.

There are two categories of action (Giry, 2004): (i) those for the piloting of irrigation, aimed at helping the farmer define the quantity of water to bring to the crops and the corresponding period and (ii) those involving equipment for optimizing each supply of water.

- ***Several advisory actions for piloting exist***; but the most noteworthy is the development and diffusion of an irrigation warning. During the course of a corn irrigation season, a weekly bulletin is sent free of charge to all the Charente irrigators. This bulletin, "Irrig'Info" provides data relating to local climatology, but also to potential evapotranspiration of the plant, as well as start and stop orders for irrigation, the irrigation doses to be done during the week in progress. The information presented comes from around thirty agricultural parcels chosen to represent the diversity of soils and situations in the slope basins. This bulletin also informs farmers on the condition of water resources and restrictions that have been made.
- ***Actions for equipment*** are varied. The farmers can take advantage of financial aid for acquired equipment in order to improve the functioning of 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 the parcel and reduce overdosing. These first two actions are all the more important since the equipment fleet is relatively old and the hose reels are the most heavily-used equipment 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 substitute reservoirs, with priority given to collective actions.
- The other actions surveyed are not limited to the Charente region. They are really 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.

4. EFFICACY OF VOLUMETRIC MANAGEMENT MEASURES

Judging the efficacy of VM measures implemented in the UC is especially tricky because not enough time has passed for us to learn lessons of a general nature, and furthermore, a number of uncertainties remain.

Since the year 2000, when a VM system was put into place in the restricted UC basin, the farmers' actual consumption is clearly lower than the total authorized volume (Figure 3). Several causes can be put forward to explain this fact: restrictions, precipitations and real irrigated area. In a wet year (2000 for example), a portion of the crop needs is covered by precipitation and the irrigators do not have to use the entire volume that is allotted to them at the beginning of the season. In a dry year (2003 for example), restrictions do not allow farmers to use the entire authorized volume. Lastly, the area that was declared as irrigated in 2000 and that have been used to calculate the reference volume was overestimated. In fact, it is estimated that the real irrigated area was around to 8900 hectares and that 5 to 10% of this area did concern spring crops for which, a large part of the water consumption is made out of the reference period (mid-June to mid-September). The overestimation of the area, and then the volumes, would range between 15 to 20%. Based on this observation, a controversy over authorized volumes arises among irrigators who feel they are acceptable and those for whom a reduction is not feasible, the Charente River institute, and certain environmental protection associations who are demanding a reduction of these volumes.

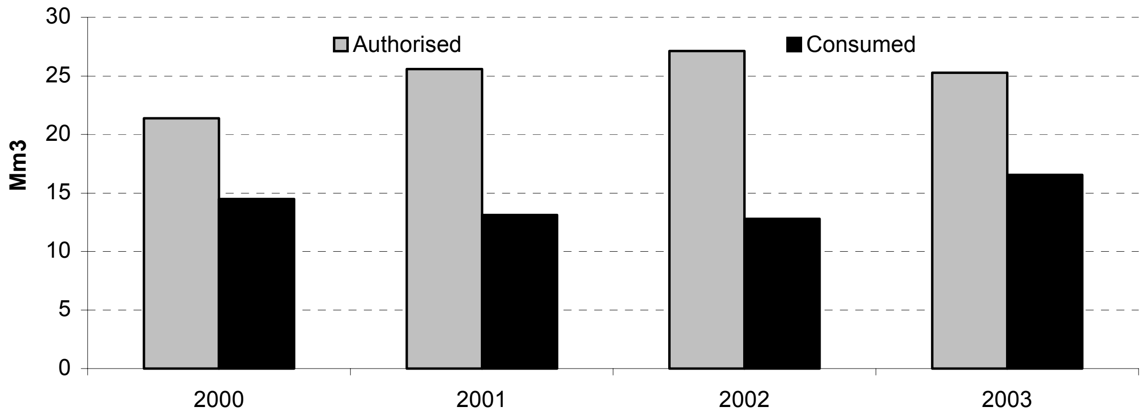


Figure 3: Authorised volumes and consumed volumes in the upstream Charente basin

The resources in the Charente basin continue to demonstrate their limitations and the system's fragility, which makes it impossible to secure water usage in years of deficit (EPTB Charente 2004). However, when comparing two very dry climatic years (1990 and 2003), the first with the Mas-Chaban dam and the second without it, we observe that the total number of alert days was reduced by nearly 40% (Figure 4). Similarly, for the climatic years 1999 and 2002, which were relatively wet, the reduction in number of alert days dropped by nearly 50% (Figure 4).

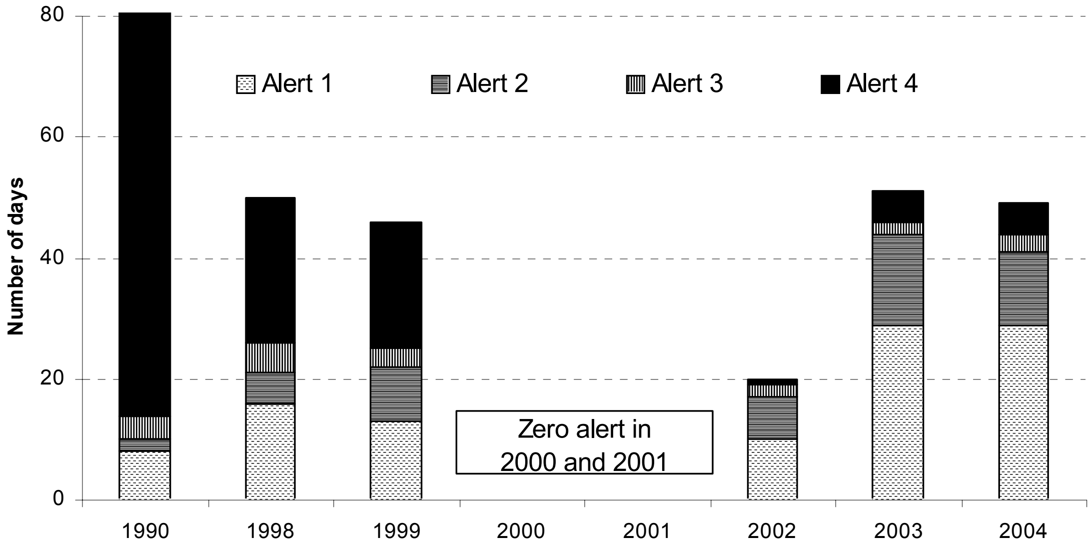


Figure 4: Number of alert days over 8 climatic years

Nevertheless, it has been shown that bans implemented at alert levels 1 and 2 were inequitable and ineffective. Inequitable because the number of farmers having more pumping equipment than necessary could compensate technically and economically for the effects of 1 or 2 days of bans without having to make significant changes in the watering calendar, whereas the farmers who are less equipped or attached to a moderate-sized collective irrigation network could only stagger their water turns or sacrifice a crop (Garin, Morardet et al. 2000). These levels were inefficient on the resource because the overequipped farmers either foresee days when bans will be in place and irrigate more abundantly on preceding days, making the situation worse, or irrigate more intensely once the ban is over, with the risk of exceeding the level 1 and 2 alert thresholds . It was therefore decided that:

- level 1 and 2 alerts would in the future result in volumetric restrictions of 15% and 30% of allotted periodic volumes;
- these volumes, which were “advisory” would become “authorised”, and exceeding them would bring about an automatic reduction of the same authorised volume during the same period the following year;
- these mechanisms of volumetric management would apply from April 1st to September 30th rather than from June 15th to September 15th.

Studies also show that the hydraulic efficiency of the system can be improved. Real-time regulatory approaches to free surface hydraulics systems[11] on irrigation canals (Goussard 1989) and rivers resupplied by dams (Piquereau and Villocel 1982; Trouvat 1991; Litrico, Georges et al. 1998), can offer useful solutions for the optimisation of supply utilisation, especially for releases from dams with a view to adhering to desired low water level at Vindelle. On the irrigation canals, the utilisation of these techniques makes it possible to improve hydraulic efficiency by more than 40%, going from 50%, or even less, for a canal that is traditionally managed, to more than 90% for a canal with modernised management. On the rivers, gains in efficiency are also very significant, nearly 25%, as shown in a study on the Gimone River (Gers, France) (Litrico 1999). Considering that the active storage of the dams for support in periods of low water levels is 22.4 Mm^3, an increase in efficiency of only 10% would make an additional 2.2 Mm^3 available for support during periods of low water levels. This volume is larger than the deficit recorded in 2003 and 2004, to satisfy the DOE at Vindelle during the entire irrigation season with deficits of 1.45 Mm^3 and 0.46 Mm^3 respectively. For non-deficit years, this would make it possible to ensure better filling of the dams on the order of 30 to 40% by the end of April 2005. Furthermore, automatic regulatory techniques for free surface systems provide the most significant increases per cost of m^3, which are among the least expensive of all possible options (Victorian Government 2004).

Other studies show that advisory and training activities can contribute to resource economy. Historical analysis of diagnostics done on traveling rain gun systems between 2001 and 2003 show that it is possible to save 25 m^3/ha/year with a better regulated equipment (Giry, 2004). Thus, saving 1 m^3 of water would cost around 0.15 €/year whereas the average storage cost in a standard hillside reservoir is around 0.082 €/year. The price of the m^3 of stored water does not, however, take into account the environmental costs and the irreversibility of this type of investment, which it would be necessary to estimate to be able to really make a judgment. From the irrigator’s point of

[11] These techniques are based on systems analysis, modeling and adjustment of regulating algorithms that make it possible to satisfy management constraints.

view, there seems to be little economic advantage to paying for diagnostics. In order to save 1 m^3 of water with a diagnostic, he must pay 0.079€ (with a valve life of 3 years), whereas in the upstream Charente, 1 m^3 of water is billed at 0.006€, which is 13 times less. Even in cases in which the authorized volume is exceeded, where the cost of the m^3 of water is multiplied by 10 (thus 0.06€), the cost of savings remains higher.

5. CONCLUSION

The creation of extra resources in the Charente river basin favored the respect of minimum low flow constraints without harming farmers. The main question concerns the effectiveness of the VM instrument itself. Only 4 years after its implementation, it has required profound adaptations: replacement of the advised volumes by authorized ones, modifications of the rules applied for the first 2 levels of alert to reduce the effects of the adaptation capacity of the irrigators (over equipment in pumping material) and increase the reality of the sanctions in cases where theses measures would not be respected.

Theoretically, VM is an easy instrument to implement in a context of known withdrawals and the foreseeable storage of the resource. However, in the case of the Charente, many uncertainties remain for each of these elements. In the absence of knowledge on the exact irrigated area, even if the volumes are known, it is impossible to assess the effort consented by farmers to tackle water scarcity, rending this behavior opaque and then much debated. Secondly, groundwater/river and rains/outflows relationships for the main ones would require more in-depth studies in order to limit the uncertainty relative to the availability of the resource from a quantitive as well as a temporal and spatial point of view.

Since the irrigators are more sensitive of the changes in CAP, world markets prices or land management policies than they are of the resource's VM measures, it is desirable to develop an observatory for agricultural practices in this area. The idea of implementing observation projects such as these in irrigated zones is beginning to take root in France. The goal would be to research real vehicles for change in irrigated agriculture, by separating effect from management tools, general prices policies, technological progress or irrigators support programs. The knowledge of these elements, together with a detailed knowledge of irrigation practices and the importance of irrigation for the objective of securing revenues, is a necessary step to be able to judge the long and middle-term changes in irrigation dynamics.

The real usefulness of this management style is in having built the foundations of the first management system based on the dialogue. But it remains some profound dissensions among water actors (Granjou, Garin et al., 2004). The dominant perspective within irrigators is to make the VM a tool for social integration and the development of irrigation practices. Irrigators consider the VM as a proof of their good intensions, a constraint they accept in compensation of a policy for water resource creation (hillside reservoir supplied outside the low flow periods), the only solution to resolve conflicts in creating extra resources. But dialogues around the day to day implementation of the VM is sharply denounced because of the irrigators hegemony and the influence they exert on the administrative staff and the elected persons. Some voices coming from the environmental NGOs and also from farmers opposed to the dominant agriculture syndicates, denounce not only the high inertia in the decision taking for alerts during low flow periods, but also challenge the development of the irrigated corn itself, which economic profitability is an illusion since it is largely sustained by the CAP. Many non-irrigants believe the VM do not exempt of measures limiting severely the development of the irrigation in Charente and regret that irrigation alternatives are never envisaged nor discussed.

VM appears as unsatisfactory in the long term for all actors. This instrument brings up to date, more than it solves, the debate that remain in the heart of the water management in Charente.

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Towards Drought Simulation on the European Scale
Experiences with ERA40-driven LISFLOOD Modelling Results

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ABSTRACT

Simulations with the hydrological model LISFLOOD driven by meteorological input data of the re-analysis dataset ERA40 of ECMWF produced 44 years of daily soil moisture on the pan-European scale for the period 1958 – 2001. These data have been analysed for their potential to serve as a basis of the evaluation of current and future drought situation in Europe with respect to soil moisture deficits. The modelled soil moisture data allowed for the identification of deficit periods and – after normalization of the data – for the comparison of soil moisture deficits in different European regions.

Key Words: soil moisture, climatology, normalization, drought period, SSM/I

1. INTRODUCTION

Droughts have been recognized as a major natural hazard throughout Europe, and have created large damages to natural vegetation, agriculture, and society. The drought of 2003 in central Europe has been responsible for an estimated economic damage of more than 12 billion Euro (Munich Re 2004). Currently, in southern Portugal and Spain a new drought situation seems to be developing. Moreover, studies on regional climate change are predicting a considerably higher probability for the occurrence of drought situations throughout Europe during the next decades, as the climate moves towards increased air temperatures, a modified distribution of rainfall with dryer summers and wetter winters, and especially towards a higher variability with consequently higher chances of extreme climatic events (Meehl and Tebaldi 2004, Schaer et al. 2004).

The Weather-Driven Natural Hazards (WDNH) group of the Institute for Environment and Sustainability (IES) at the Joint Research Centre of the European Commission is currently running a European Flood Alert System (EFAS) on the pre-operational basis (De Roo and Thielen 2004). Due to the increased need for consistent and timely information on droughts on the European scale, WDNH-IES is performing a feasibility study as to how far the current system for flood forecasting can be adapted for drought forecasting, detection, and monitoring.

EFAS is consisting of the hydrological distributed LISFLOOD model (De Roo et al. 2000), various static datasets, meteorological forecast data reception from the European Centre for Medium-Range Weather Forecast (ECMWF) and National Weather Services (e.g. DWD), and a suitable technical infrastructure to manage and process data and run the model several times daily for different forecasts (figure 1). While the existing datasets and infrastructure are a good starting point, the LISFLOOD model has to be examined carefully as to how far the spatio-temporal characteristics of droughts in Europe can be addressed with.

Drought studies commonly focus on the disciplinary view to characteristics of this hazard, i.e. the perspectives of meteorological, hydrological, or agricultural droughts. However, only the comprehensive image of drought from all these perspectives together will allow for a thorough evaluation of a potential drought situation. This approach has been already followed successfully in the frame of the U.S. and the North American Drought Monitor (Svoboda et al. 2002).

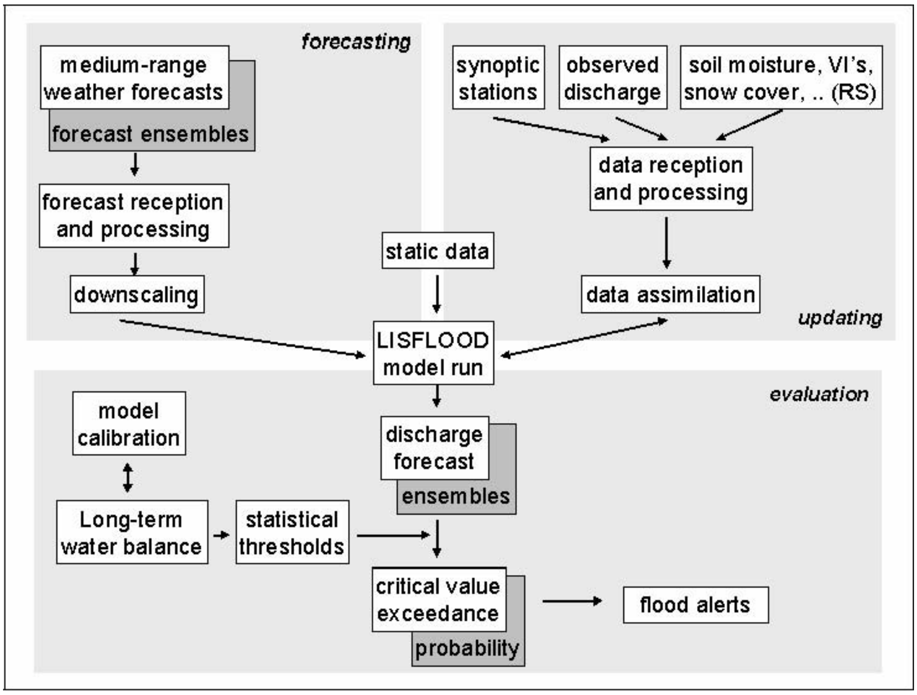

Figure 1: Overview of the European Flood Alert System (EFAS).

While meteorological droughts can be addressed by various readily available meteorological data products on precipitation, hydrological drought is described usually by the analysis of stream-flow data. Here, after careful calibration, the hydrological model LISFLOOD might contribute to a forecasting of low flows by predicting discharge as it is already being doing for the prediction of flood events in major pan-European catchment areas.

Soil moisture drought and water stress of vegetation as the more general view of an agricultural drought are more difficult to address, as both phenomena show a high variability in space and time and are difficult to measure directly. Remote sensing data can help to characterise the state of vegetation and soil moisture content (e.g. Parde et al. 2003, Wigneron et al. 2003), but need additional information for calibration and validation especially for the latter parameter (Wagner et al. 1999). Here, the continuous modelling with LISFLOOD within EFAS can contribute to a comprehensive, spatially distributed image of soil moisture pattern in Europe, as the model can produce daily maps of soil moisture content on the pan-European scale. Accordingly, the exercise presented here concentrates on the potential to derive a climatological basis for soil moisture estimates in Europe on which current and forecasted future drought situations can be evaluated.

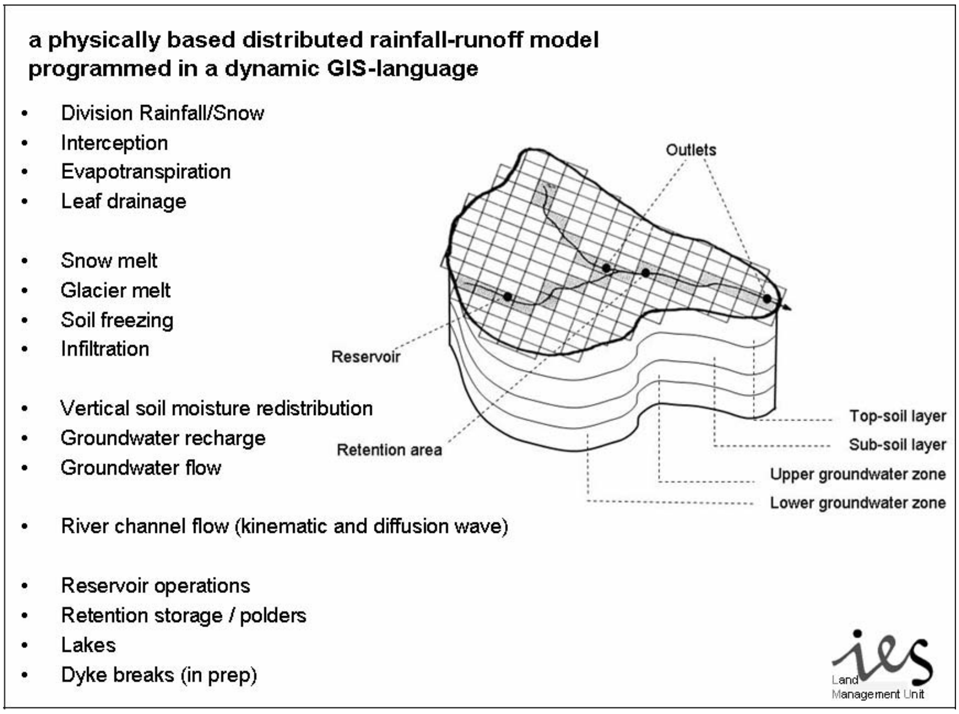

Figure 2: General structure of the LISFLOOD model.

2. METHODOLOGY

The LISFLOOD model has been driven by daily meteorological data of the ERA40 dataset produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) for 44 consecutive years. ERA40 is a re-analysis dataset of meteorological forecast data with most up-to-date assimilation techniques, resulting in a consistent global dataset of meteorological variables for the period 1958 – 2001 (Betts and Beljaars 2003). Daily ERA40 full-resolution surface analysis and surface forecast data have been extracted for Europe on roughly 90 km x 120 km, and subsequently re-projected and re-sampled and to a 5 km spatial resolution.

The LISFLOOD model is a distributed hydrological model that is run pre-operationally within the European Flood Alert System at IES-JRC on a 1 km and 5 km spatial resolution (De Roo and Thielen 2004). It comprises modules for the modelling of vegetation, soil, groundwater, snow cover, runoff generation, and stream routing in major European rivers (figure 2). Basic pan-European datasets applied for modelling with LISFLOOD in 5 km spatial resolution include the European Soils Map and the CORINE land cover classification.

The soil compartment of LISFLOOD consists of a two-layer soil model. Infiltration of effective precipitation, soil evaporation and plant water uptake takes place from the upper soil layer, while the lower soil layer represents essentially a storage term that produces a slow runoff component and recharges the groundwater compartment (see figure 3). Accordingly the soil moisture content of the upper soil layer mirrors well the balance of water between precipitation supply and climate and vegetation demand, and is examined further in detail.

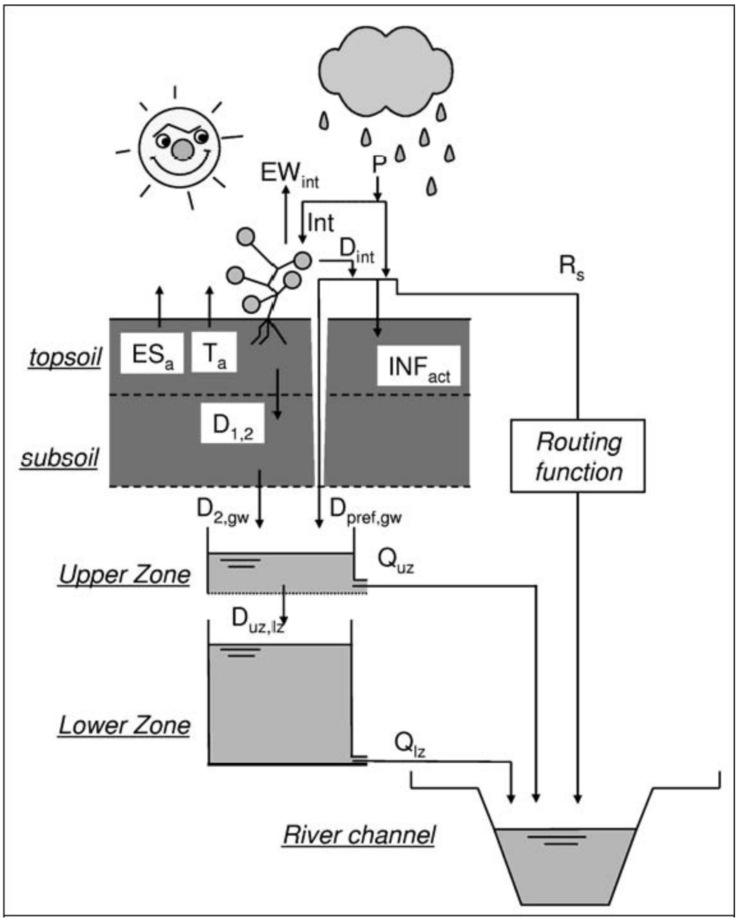

Figure 3: The soil component of the LISFLOOD model (Van der Knijff et al. 2004).

The LISFLOOD model runs produced daily maps of soil moisture for a 5 km spatial resolution on the pan-European scale. The first year was initialised after a separate 1-year model run with standard initial values. The soil water content was converted to soil suction values (pF) in order to be able to compare the moisture state of the different soils throughout Europe. In a next step the 44 years of daily data were reduced to a pseudo-climatological average for each day of the year. Accordingly a calculated daily value of a grid cell can be compared to the average value of the last 44 years in this particular location.

In order to account for the varying magnitude and range of pF-values throughout Europe and to allow for a comparison between different regions in Europe, daily values have been normalized by their mean and standard deviation. The normalization also allows for a better identification of drought periods and the evaluation of their magnitude.

As for the validation of the derived spatio-temporal soil moisture dataset, independent surface wetness and top-soil moisture products from remote sensing have been considered. This work is still ongoing, but first results of the comparison with the experimental weekly wetness product of NOAA SSM/I, available for the period 1988 – 2003, are shown (NCDC 2005). As a second independent dataset, the Global Soil Moisture Archive from ESA ERS Scatterometer Data provided by the University of Vienna will be considered and analysed (Wagner et al. 1999).

3. RESULTS AND DISCUSSION

Figure 4 shows typical distributions of modelled soil moisture in Europe for four days in different seasons. The spatial extent of the modelling exercise is currently limited to the setup of EFAS which focuses on the major European catchments. For the purpose of drought simulation, the Mediterranean region will be included completely in the future.

The general tendency of a strong moisture deficit in summer for the soils in the Mediterranean is well visible, as well as in the Pannonian plain and the lower Danube catchment area. In Northern Europe some errorneuos areas indicated as very dry are visible (Iceland, Scandinavia in spring) which are the result of the soil parameterization in case of open water bodies and snow melt processes; in both cases the soil is assumed as sealed which produces very low pF-values. On the other hand, the regional differentiation in most European countries reflects very well the expected, realistic patterns and orders of magnitude of soil moisture content.

The temporal evolution over the 44-year period on the two single regions Algarve/Portugal and Veluwe/The Netherlands is given in Figure 6. Instead of using the original 5 km spatial resolution data, soil moisture data have been averaged regionally on the basis of the administrative NUTS3 regions (Eurostat 2003), in order to emphasize the regional character of the modelled parameter rather than the site-specific values. In the future, also sub-catchments and climatic regions will be considered for regionalization.

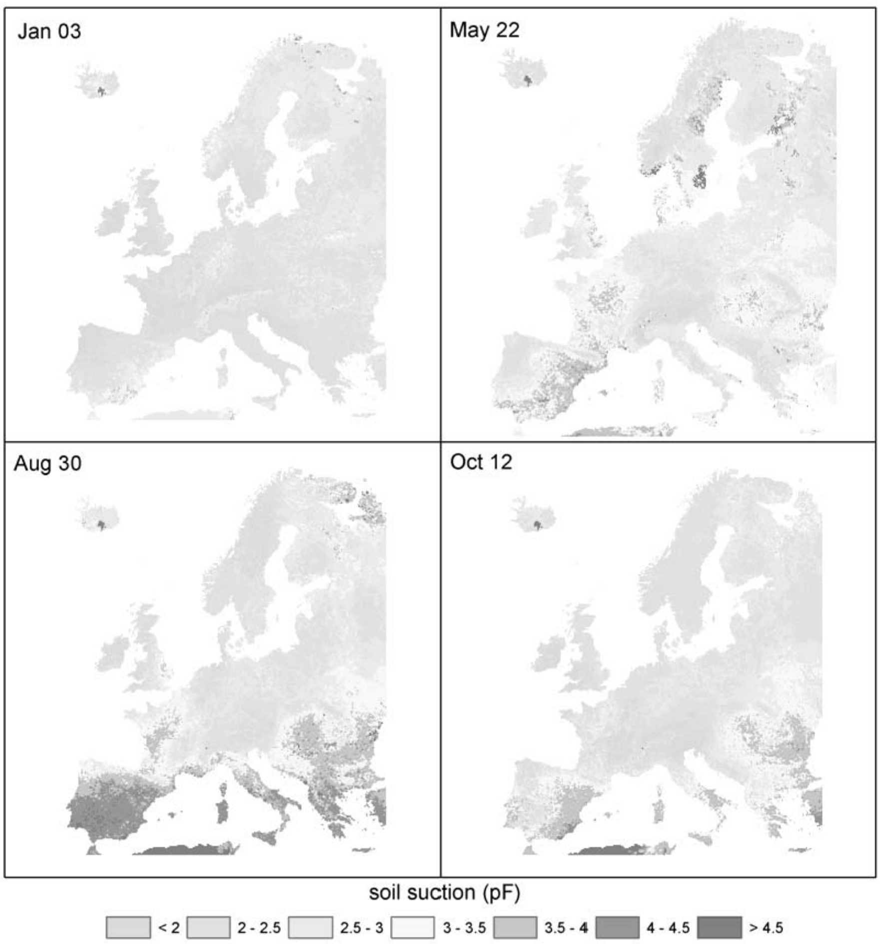

Figure 4: Modelled soil moisture for Europe on single days in 1960.

The pronounced annual course of the soil moisture content as determined mainly by the precipitation input and the radiative demand can be recognized in both graphs, as well as differences in the magnitude of the soil moisture deficits for single years. Clearly visible is e.g. the well known drought summer in Western Europe of 1976. In general, the soil moisture content in the Algarve region shows a much higher intra-annual variability as compared to the development of soil moisture in the Veluwe region, and reaches regularly pF-values of larger than 4 in summertime. However, the peak value itself as well as the duration of the peak period ("width of spikes") varies from year to year.

The graph of the Dutch region shows generally pF-values between 2 and 3, while the increased values of the two years 1959 and 1976 are the result of an exceptionally warm and dry summer. Interestingly, the period 1990 to 1996 has almost consistently higher maximum values of soil suction than the 60s, 70s and 80s, which corresponds well to the observation that the 90s in Western Europe have been the warmest period recorded so far (Luterbacher et al. 2004).

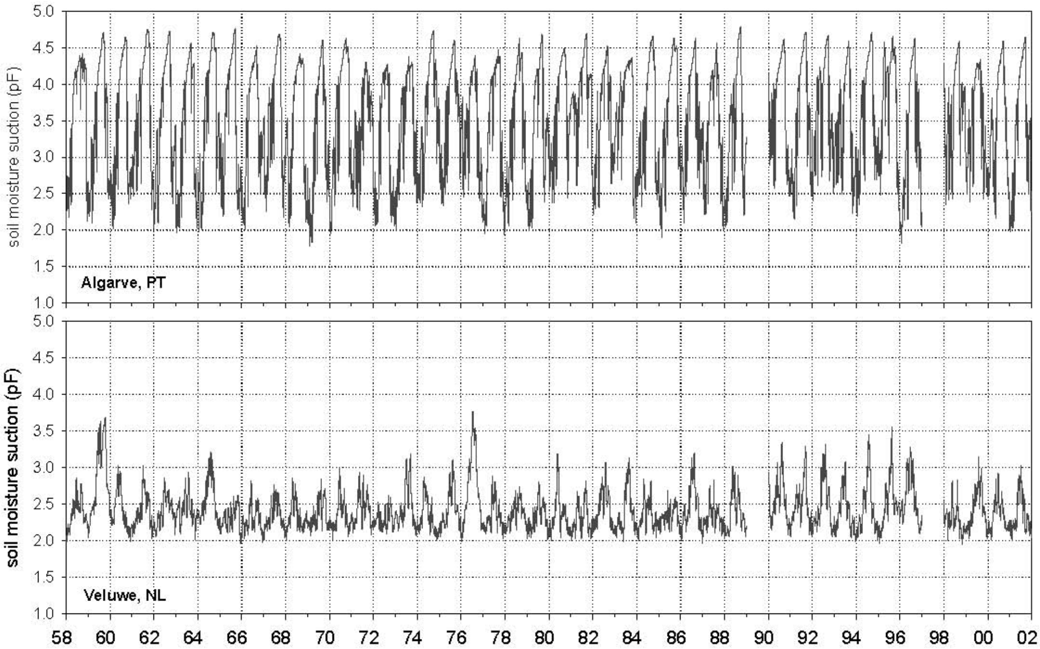

Figure 5: Time series of soil moisture averaged over the NUTS3 regions Veluwe/NL and Algarve/PT for the period 1958 – 2001.

Results of the normalization of soil moisture values are shown in figure 7 for the regions Badajoz/south-west Spain, Irakleio, central Crete/Greece, Marne-e-Loire/west France, and Veluwe/The Netherlands. The average value of each time series is zero, and values larger than 0 indicate dryer, less than 0 wetter conditions than the average. For a better orientation, the boundaries of +2 and -2 are indicated as well, in which the majority of soil moisture values can be found. The years 1989 and 1997 produced erroneous results and have been excluded so far; however, they also influence the initial conditions for the two following years 1990 and 1998, as can be seen in most graphs.

All normalized time series allow for a clear distinction of normal, dry, and extremely dry periods. Data of the French region confirms the previous observation for The Netherlands of a relatively dry period at the beginning of the 60s and 90s. However, the period with the highest annual maximum values is from 1976 to 1986 when the threshold of 2 is exceeded five times, while the majority of days during these ten years remain below average.

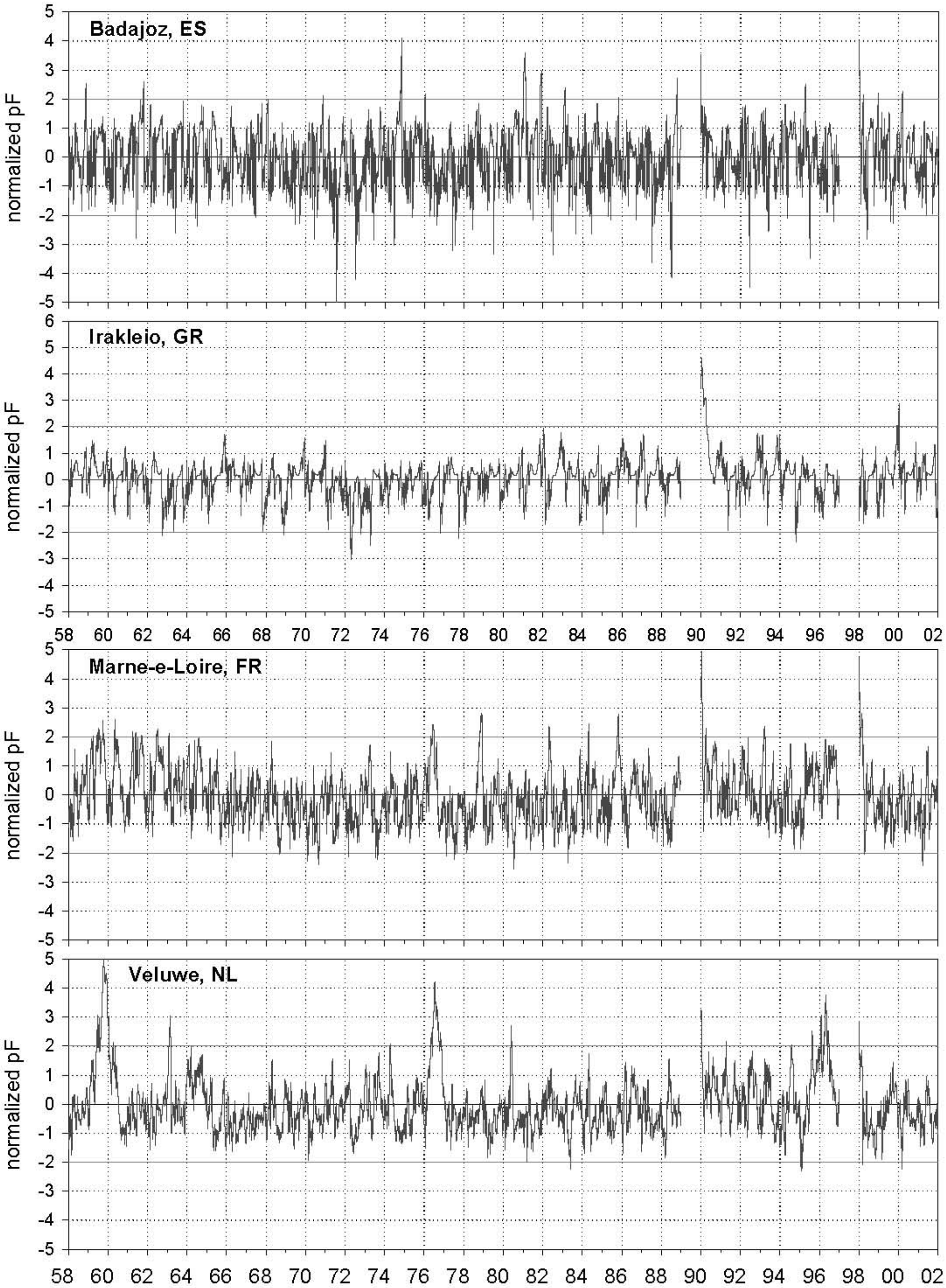

Figure 6: Time series of normalized soil moisture for the regions Badajoz/Spain, Crete/Greece, Marne-e-Loire/France, and Veluwe/The Netherlands.

Central Crete is showing a fairly low variability over the entire period of time, and exceeds the threshold value of 2 only in the year 2000. This lower variability in peak values of soil moisture can be explained by the fairly stable weather conditions in summer in the eastern Mediterranean that produce very low soil moisture contents on a very regular basis.

A first qualitative comparison with independent data for validation has been performed with the wetness index derived from SSM/I data and published by the NCDC. As the spatial resolution of the SSM/I products is approximately 30 km, the wetness index has been compared to the spatially averaged soil suction data as described before. The temporal resolution of the SSM/I data is weekly as compared to daily values produced by LISFLOOD. Values range from 0 to 100, indicating a very low (0) or very high (100) probability to have a wet land surface. An example of the wetness index can be seen in figure 8. Obviously the wetness index includes information on the sea along the shoreline as well as on inland lakes, therefore a comparison to soil moisture data has to be performed in regions without large open water bodies.

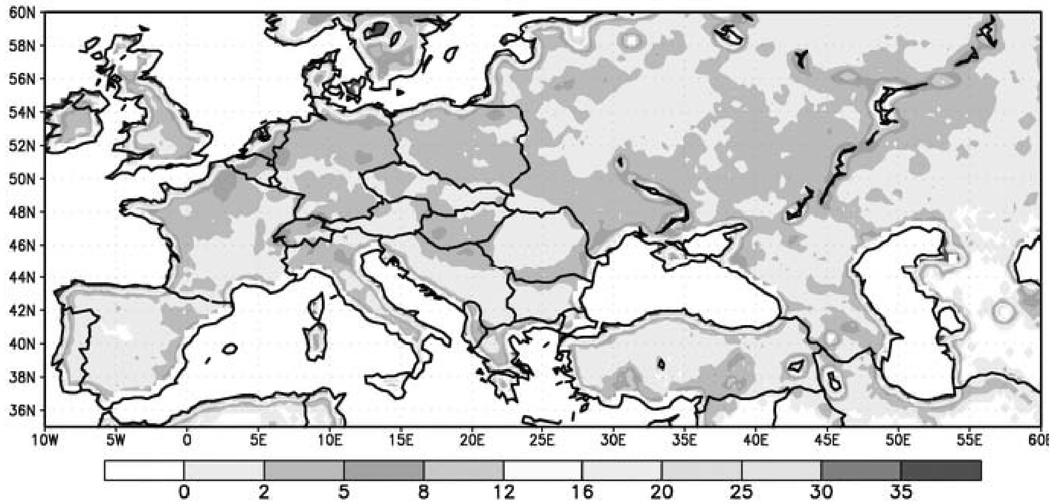

Figure 7: Weekly satellite-derived surface wetness product for Europe, Aug 20-26, 1994, as provided by the U.S. National Climatic Data Center.

The comparison of time series extracted for the Badajoz region in south-west Spain in figure 9 shows a general correspondence of the two datasets; dry and wet periods are commonly identified. The warm summers of 2000 and 2001 are reflected in both graphs as pronounces peaks with even a temporary wetter period in spring visible in both datasets. However, the distinction of the two fairly different summers of 1998 and 1999 cannot be recognized in the SSM/I dataset. On the other hand, the very wet period in the winters of 1996 to 1998 as identified by the SSM/I wetness index cannot be traced in the modelled soil moisture data. Obviously, the two datasets, while both describing the moisture state of the land surface, have the focus on the opposite ends of extreme events. While the soil suction values level off around two, hence not distinguishing very much between wet and very wet periods, the wetness index saturates for dry periods and distinguishes better the wet periods. Consequently the SSM/I data might better serve as complementary information for the description of winter conditions rather than validating the summer-oriented soil suction data.

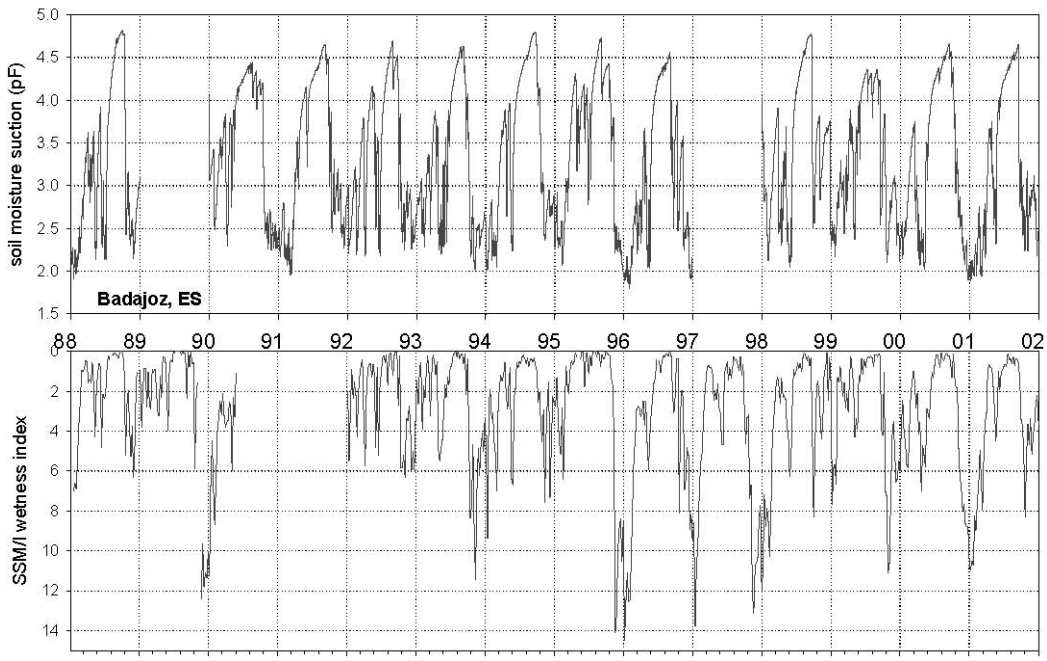

Figure 8: Comparison of LISFLOOD modelled soil moisture with the wetness product of SSM/I. The latter is scaled between 0 for dry and 100 for wet conditions of the land surface.

4. CONCLUSIONS AND OUTLOOK

Soil moisture as modelled by LISFLOOD gives a good insight into the spatio-temporal evolution of the parameter on the pan-European scale. Using the 44-year ERA40 dataset, a pseudo-climatology could be derived that defines the basis on which modelled soil moisture data for current and future conditions can be evaluated. Areas can be identified on which the modelled soil moisture information is not very reliable such as water bodies or snow-covered areas in northern Europe; these will be treated separately in the future. Further validation analysis will concentrate on the soil moisture archive derived from scatterometer data from ERS, as it reflects a very similar parameter as compared to the upper soil layer moisture content of LISFLOOD. In addition, it has to be taken into account that the calibration of LISFLOOD for EFAS is still ongoing, probably improving the soil moisture estimates for a future drought application as well.

As the next step, the period from 2002 onwards will be modelled with measured and forecasted meteorological data, in order to achieve the link between the past and current datasets. The simulation of the drought summer of 2003 will be another important evaluation of the quality of the forecasted moisture conditions.

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AQUAREC Seeks For Best Management Practices In Water Recycling And Reuse

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ABSTRACT

In Europe the last two decades witnessed growing water stress, both in terms of water scarcity and quality deterioration, which prompted many municipalities for a more efficient use of the water resources, including a more widespread acceptance of water reuse practices.

This paper shows the status and extent of European water reuse practices and sets out the map of the water reclamation technologies and of the reuse applications. The information is based on a conventional literature survey, on an in depth survey of a large number of European water reuse projects and on the findings of a dedicated international workshop.

The preliminary evaluation indicates that for an increased utilisation of reclaimed wastewater, clearer institutional arrangements, more dedicated economic instruments and the setup of water reuse guidelines are needed, technological innovation and the establishment of a best practice framework will help, but even more a change is needed in the underlying stakeholders' perception of the water cycle.

1. INTRODUCTION

The water sector in Europe as well as in many other parts of the world is in a transitional phase with unique opportunities for water reclamation and reuse to be implemented on a larger scale as a sustainable practice within a framework of integrated water management. In Europe, water reuse could be one of the useful measures to implement the Water Framework Directive or the Protocol for Water and Health. Water reuse can be a drought-proof alternative to conventional water supply while lessening the stress on freshwater resources.

There are now very many water reuse schemes operating all over the world and the practice is expanding rapidly. Yet, the information available is very dispersed or open to misinterpretation. Even information for a straightforward mapping of such basic indicators as facility location, treatment train and performance, is difficult to collect, not to mention of basic management practices attached to the scheme including financing, community consultation, environmental management and aspects such as operation, maintenance and quality control alike.

There is much we can learn from the international experiences and the need to establish a best management practice framework is real and urgent:

- First of all, current technical feasibility can provide water quality that can meet any prescribed standard other than zero. However, aiming for complete safety may impose heavy compliance costs, that are not always justifiable (e.g. [2]) and that can lead to discard the project because of lack of funds.
- Second, no matter how advanced the applied technology will be, a sub-optimally managed project may in any case result in adverse health, environmental or financial outcomes that may quickly shade away enthusiasm for water reclamation, hindering its further development in the region. Increased levels of compliance reporting, safety requirements, accountability cost efficiency combined with the pressure to optimize operating budgets, are but few of the challenges.
- A third point is that investors need clear references and they need to be comforted that they take the right decision.

The AQUAREC project aims to contribute to the setting of best practices for business and public administrations to reduce risks and liabilities to acceptable social, economic and environmental levels. It is worth noting that acceptability is generally very location-specific and therefore does not fit within international guidelines (Anderson et al., 2001). Thus, there is a need to reach international agreement on standard practices rather than on the definition of acceptable levels of risks.

2. The AQUAREC project

The AQUAREC project on "Integrated Concepts for Reuse of Upgraded Wastewater" is funded by the European Commission within the 5th Framework Programme as well as in Australia by the Commonwealth Department of Education, Science and Training. The project is coordinated by RWTH Aachen University and the project consortium is composed by 17 partners (www.aquarec.org).

The general objective of the AQUAREC project is to provide knowledge to support rational strategies for municipal wastewater reclamation and reuse as a major component of sustainable water management practices. The approach is interdisciplinary and broad, addressing issues of strategy, management and technology (Figure 1). The project aims at

- Defining criteria to assess the appropriateness of wastewater reuse concepts in particular cases and to identify the potential role of wastewater reuse in the context of European water resources management. The Urban Wastewater Treatment Directive claims that treated wastewater must be reused "whenever appropriate" [3], demanding the determination of appropriateness, a still legally undefined term. This is carried out by the Work Packages 1, 2 and 3 (cfr. Figure 1)

- Providing guidance for end-users facing decisions in the planning, implementation and operation of wastewater reuse schemes as well as for public institutions at various levels. This is carried out by the Work Packages 4, 5 and 6 (cfr. Figure 1).
- Evaluation, selection and standardisation of technological concepts and components for wastewater recycling. This is carried out by the Work Packages 7 and 8 (cfr. Figure 1).

The project started in March 2003 and will finish in February 2006. The project structure is summarised in Figure 1, while a list of the completed and the planned deliverables is given in Table 1.

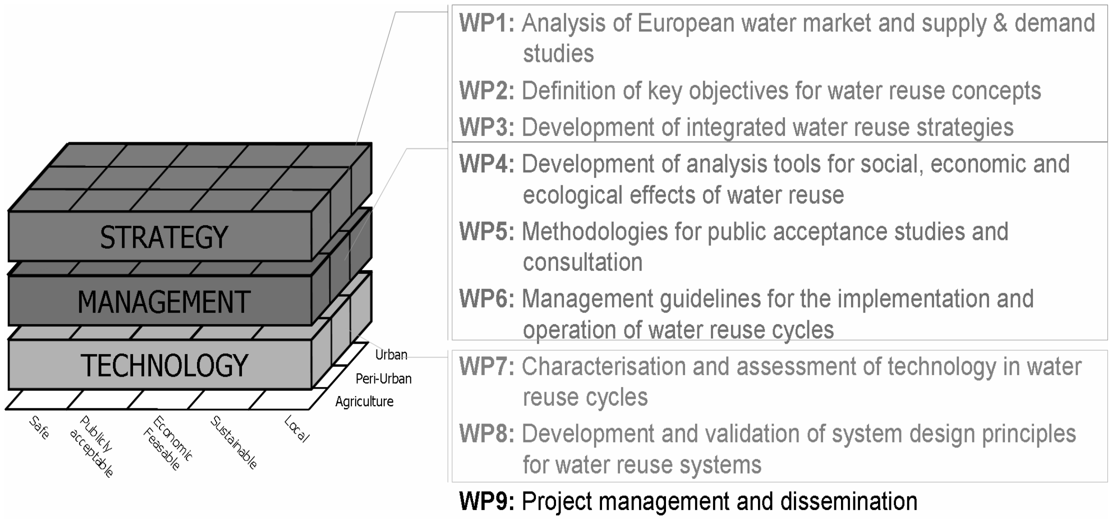

Figure 1: Project structure, application contexts, evaluation criteria and work packages (WP's)

Table 1: Overview of the completed and to be completed deliverables

	Completed deliverables	Final deliverables
WP1	General maps on water supply & demand	Report on determination of cost margins
WP2	Report on the definition of key quality parameters	Guideline for quality standards for water reuse in Europe
WP3	Knowledge Network "Wastewater Reuse"	Report on integrated water reuse concepts
WP4	Report on the survey on conducted feasibility studies	Handbook on feasibility studies for water reuse systems
WP5	Conference proceedings on public consultation	Published guidelines on stakeholder engagement
WP6	Review report on management survey	Water reuse systems management manual
WP7	Report on water treatment matrix of current technologies	Proposal of standard treatment in water reuse systems
WP8	Simulation software for reuse systems	Design support software for water reuse

The manual on the management practices (Work Package 6) aims at providing a single source of comprehensive information on good practice in the implementation and operation of water reclamation schemes. Note that only commonly applied or applicable techniques for reclamation and reuse are being dealt with in the document. The handbook is being compiled based on extensive review of management practices consolidated in the management review report. Underneath you will find a summary of the methodology and results of this latter deliverable.

3. REVIEW OF MANAGEMENT PRACTICES: METHODOLOGY

The review is based on:

1. An inventory of full scale wastewater reclamation and reuse cases. A database of municipal reuse schemes containing basic system data such as field(s) of application, process train, size, years in operation and possible relevant public documentation attached to it was compiled. Data were collected from regional databases, national experts and literature. Seven geographical regions were analysed: 1) North and 2) Latin America, 3) Europe, 4) Mediterranean Region and Middle East, 5) Sub-Saharan Africa, 6) Oceania and 7) Japan. More than 3,300 schemes were identified.
2. An extensive literature review on management practices. The European Union and overseas experience, existent and latent problems, and factors promoting successful management of water reuse projects were reviewed through a survey covering implementation and operational aspects such as type of ownership and financing, cost optimisation, process operation, maintenance and quality control, failure and failure management. Approximately 200 publications from the last 15 years were reviewed. Key universal issues and experience were identified.
3. To determine where present day practice lies in relation to what is seen as "best practice", an enquiry on management practices was conducted through questionnaires, interviews and site visits. Water reclamation facility managers were solicited through a dedicated questionnaire. Sometimes the elicitation through questionnaires was followed by a site visit. Only reuse schemes larger than 2,5 million m^3 a year for secondary treatment and 0,5 million m^3 a year for tertiary or quaternary treatment were considered. Forty projects participated to the survey.
4. Specific data gaps were discussed in a dedicated international workshop. The workshop was co-organised with EUREAU, the European association representing water suppliers and wastewater services in Europe.

4. RECLAMATION AND REUSE OF MUNICIPAL WASTEWATER IN EUROPE – CURRENT STATUS

The mapping study revealed that more than 200 water reuse projects exist in Europe and many others are in an advanced planning phase. Figure 2 shows the geographic distribution of water reuse projects identified and collated by the AQUAREC project, including their size and details of the water's intended end use.

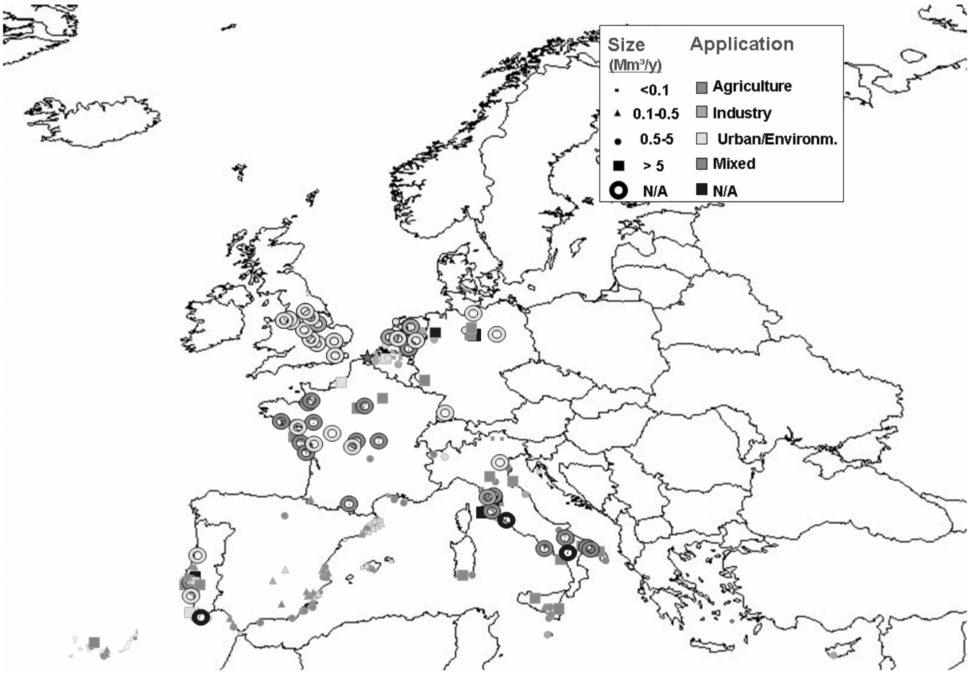

Figure 2: Identifiable water reuse projects in Europe, incl. their size and intended use (N/A stands for Not Available)

In Figure 2, the types of reuse application are divided into four categories: 1) agriculture; 2) industry; 3) urban, recreational and environmental uses, including aquifer recharge and 4) combinations of the above (mixed uses). The scale of the projects is also split into four classes: very small (<0.1 Mm^3/a), small (0.1-0.5 Mm^3/a), medium (0.5-5 Mm^3/a) and large (>5 Mm^3/a).

Much of the recent expansion in the number of reuse schemes has occurred along coastlines, on islands off the semi-arid Southern regions, and in the highly urbanised areas of Northern and Central Europe. Figure 2 shows that the use of reclaimed water is quite different in those two regions: in Southern Europe, reclaimed wastewater is reused predominantly for agricultural irrigation (44% of the projects) and for urban or environmental applications (37% of the projects); in Northern and Central Europe, mainly for urban or environmental applications (51% of the projects) or industrial (33% of the projects) uses.

The distribution of application types reflects quite well the sectoral water use of the different countries (Figure 3), with the exception of France.

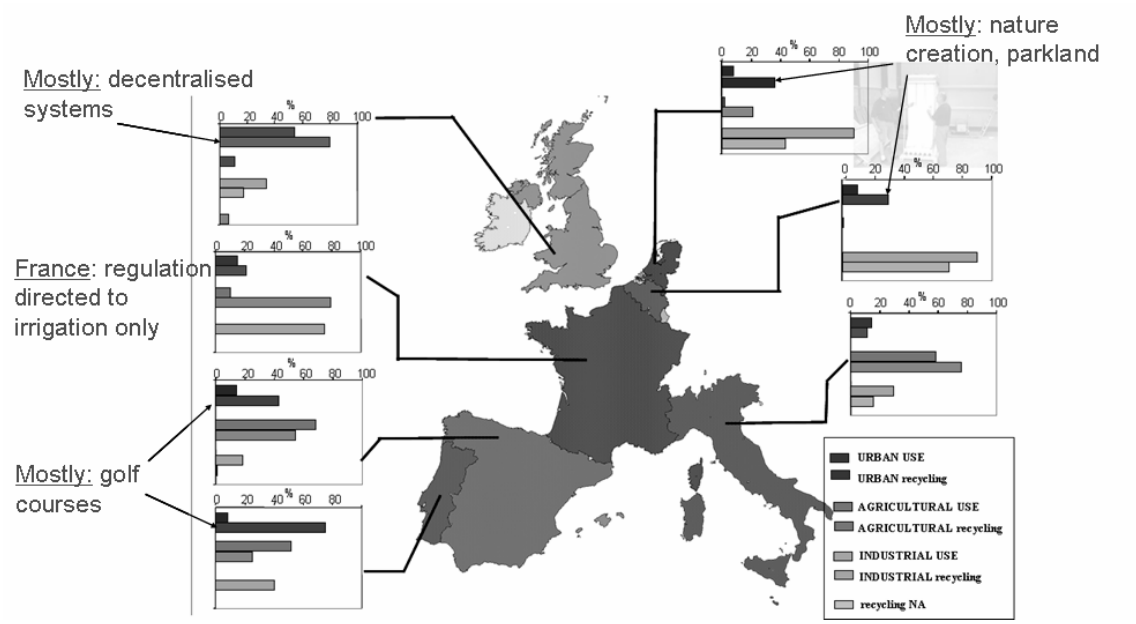

Figure 3: Sectoral water use for conventional water [4] and distribution of reclaimed water projects in Western Europe according to the Aquarec mapping study

The level of treatment is consistent with the US EPA guidelines [14], with increasing level of treatment provided to increasing levels of human exposure. Tertiary/advanced treatment is provided to approx. 70% of the European projects [5].

5. RECLAMATION AND REUSE OF MUNICIPAL WASTEWATER – IDENTIFIED CHALLENGES

Despite the fact that water reuse is already becoming an essential and reliable water supply option for many municipalities, there is still significant potential for increased utilisation of reclaimed wastewater [6].

If the water reuse potential of Europe is to be tapped to its fullest potential, a variety of deployment or implementation issues will have to be tackled. A preliminary evaluation of the large number of European water reuse projects that have been screened by the AQUAREC project indicate that several common issues exist. Some of these issues are briefly described in the following paragraphs.

5.1 Re-orientation of the water governance towards integrated water management

Although the practice of Integrated Water Resources Management (IWRM) is still in early development phase in several Member States, the implementation of the Water Framework Directive is progressing and will provide a basis for further steps in IWRM at catchment scale [7]. The WFD is a soft legal document, i.e. it sets forth the principles to achieve sustainable water governance, but not the means. In developing appropriate mechanisms to achieve IWRM both disciplinary expertise and interdisciplinary understanding needs to be nurtured. Too often water reuse options are excluded from IWRM scenarios, regardless of whether such opportunities are financially or technologically realistic. The challenge here is to better inform all the important stakeholders about viable options which bridge the tight but somewhat artificial isolation (in management terms) of water supply and wastewater treatment systems. This lack of an integrated perspective often produces a considerable time lag between feasibility studies related to reuse options and their realisation in practice, especially (but not only) for those regions where water and sanitation services are run by different entities.

5.2 Need to strengthen cooperation among stakeholders

There has been extensive debate on how water reuse projects should be managed, in particular who should take the initiative in project planning, and how responsibilities/liabilities should be divided.

An analysis of successful case studies covered in the survey suggests that the details of ownership is not a significant issue per se, but does influence access to financing and cost allocation. An example is the Tilburg water reuse project in the Netherlands, where the water supply and the wastewater services joined together to set up an ad hoc water reuse company under an administrative and legal framework that has tax advantages while at the same time having the ability to allocate funds at the lowest interest rate.

Another preliminary conclusion of the survey is that communication and collaboration between the water and the wastewater sector is always desirable. The Tilburg project for instance benefited from the technical capacities of the two companies, namely: the wastewater treatment company for the management of the water reclamation scheme and the drinking water company for the distribution system and for the customer relations. This is a clear case where the whole is more than the sum of the parts.

5.3 Establishment of guidelines or criteria for wastewater reclamation and reuse

Once the case for water reuse has been successfully made, project development is dependent on the existence of credible and legitimate standards. However, it is not always easy to obtain a permit for the reuse of reclaimed water despite encouragement from the European Union to reuse treated effluent. One of the major problems in Europe is the lack of clear criteria to support decisions on when reuse is desirable and on quality standards for different reuse purposes.

A lack of water reuse criteria forces public administration bodies to adopt conservative assumptions. This, in turn, has led to various types of misunderstanding and misjudgement. An extreme example is an agricultural reuse project where the wastewater treatment plant effluent complied with the strict standards for unrestricted agricultural irrigation, but the public administration released a permit basically referring to the WHO's recommendations on irrigation with raw wastewater. Although this is an extreme case, it illustrates quite well how urgent the need is for the establishment of water reuse criteria.

Despite the fact that no legally binding guidelines or regulation yet exist at European Union level, several countries and federal regions have published their own standards or regulations (Table 2).

Table 2: Existing country/regional water reuse criteria within the European Union

Country/Region	Type of criteria	Comment
Cyprus	Provisional standards, 1997	Quality criteria for irrigation stricter than WHO standards but less than Californian Title 22 (TC < 50/100 mL in 80% of the cases on a monthly basis and < 100/100 mL always)
France	Art. 24 décret 94/469 3 juin 1994 Circulaire DGS/SD1.D./91/n°51	Both refer to water reuse for agricultural purposes; Essentially follow the WHO standards, with the addition of restrictions for irrigation techniques and set back distances between irrigation sites and residential areas and roadways
Italy *Regional authorities*: Sicily, Emilia Romagna and Puglia	Decree of Environmental Ministry 185/2003	Quality requirements are defined for the three water reuse categories: agriculture, non-potable urban uses and industrial uses; Possibility for the Regional Authorities to change some parameters or implement stricter regional norms
	Guidelines	The proposed microbiological standards are similar to those of the Title 22 regulation for Puglia and Emilia Romagna and to WHO standards for Sicily
Spain *Regional authorities*: Andalucia, Balearic Is. and Catalonia	Law 29/1985, BOE n.189, 08/08/85 Royal Decree 2473/1985	In 1985 the Government indicated water reuse as a possibility, but no specific regulation followed. A draft legislation has been issued in 1999, with a set of standard for 14 possible applications of treated water. The proposed microbiological standards range is similar to those of the Title 22 regulations in terms of defined use categories but not as to the standards set for each category.
	Guidelines from the Regional Health Authorities	Developed their own guidelines concerning wastewater recycling, in particular in the field of the irrigation, based on the WHO guidelines of 1989

The AQUAREC project is making an effort to provide a basis for future harmonisation of the various approaches at European level.

5.4 Targeted use of economic instruments

Financing is perhaps the single most significant barrier to wider use of reclaimed wastewater. In order to better match project costs with acceptable volume unit cost, targeted, time-bound subsidies are important and necessary. The subsidy is generally aimed at allowing the project to operate on a commercial basis while achieving certain public programme objectives.

Often water supply benefits alone cannot cover the project costs. One of the reasons is that there still exist distortions of the water supply market. Since the Dublin conference in 1992, the full cost recovery principle is becoming more widespread in the provision of water supply [8]. However, even when the cost recovery principle is applied, externalities such as, for instance, the scarcity of water and the marginal cost of new sustainable sources of water, e.g., where existing sources are at - or beyond - their sustainable limit, are rarely accounted for. Similarly the financial, social and environmental burdens of effluent disposal to the environment are rarely considered in the economic analysis.

In the European Union water reclamation and reuse projects have also benefited from several types of specific financial incentives. Examples include a recent regulation allowing exemption from the user tax for reclaimed water in Costa Brava, Spain [9].

The EU does not have specific subsidies to encourage water reuse but EU financial institutions can play a key role in favouring water reuse schemes. On a case-by-case basis several schemes have benefited from EU subsidies. The predominant programme objective is typically the creation of a framework that supports innovation and competition.

The current transitional phase of European water management practices represents a unique opportunity to correct market distortions while providing, together with water reclamation, a cheaper alternative to applications not requiring drinking water quality. EU Member States will have to promote cost recovery policies ensuring adequate incentives for users to exploit water resources efficiently by 2010 [10].

Cost-benefit comparisons should be made that compare total cost for integrated water resources management alternatives, rather than considering simply cost before and after the project. Moreover, as the costs and benefits of a project are shared among different groups, there is a need for clearer institutional arrangements for the distribution of the effects of the projects. It is not ethically and economically possible that the water reuse consumers have to bear all the costs for the benefits generated by the project.

5.5 Building trust, credibility and confidence

Whilst the development of suitable technologies which provide opportunities for water recycling has moved on apace over the past decade, their practical application will not depend solely on effective and reliable engineering performance. Successful employment of preferred strategies and technologies will require an understanding of the social environment in which they are to be applied. The drivers which promote involvement in recycling may vary between households and cultures, and will certainly be different for domestic, commercial and industrial users.

In exploring opportunities and developing options for water recycling, policy makers, planners and system designers face a number of problems which do not have simple technological or legislative remedies. For example, the use of treated and recycled wastewater in agricultural, municipal, or domestic applications is quite properly a source of concern for a variety of consumer groups. Irrespective of what conclusions the scientific evidence leads to, the impressions and attitudes which the public hold can speedily and effectively bring a halt to any reuse scheme. Consequently, strategic level decisions on the introduction of water recycling schemes need to be informed by knowledge of public attitudes and behaviour towards the technologies and processes involved.

Public and institutional acceptance of water recycling is a social process with a high emotive content. In many existing urbanized catchments the water cycles actually include indirect, unplanned and uncontrolled reuse of - sometimes even untreated - wastewater. However, facts and figures might inflame rather than convince. In some cases the involvement of local NGO's and environmental associations has proven to be a critical success factor, as the case of the Empuriabrava project in Spain clearly demonstrated [11].

A best management practice framework is also needed to provide a basis for structure and transparency in the management and companies, the community and the consumers alike. Otherwise even basic sustainability principles may be disregarded.

In case of failure one might not get a second chance! For example in the Netherlands dual reticulation systems are banned altogether because of one negative experience of cross-connections with the drinking water supply. This need for a best management practice framework is well acknowledged within the European Union according to a recent survey undertaken by the EUREAU Water Reuse Group.

Of particular importance are the management practices to reduce and communicate the risk of human exposure. Management practices relating to quality control and failure management vary considerably from region to region and even from project to project. A common trend in process operation and risk management amongst the surveyed projects was the adoption of extensive quality control practices and in particular the widespread use of instrumentation, control and automation. On the other hand, despite the fact that procedures such as Hazard Analysis and Critical Control Points (HACCP) are increasingly used to direct efforts in process control and monitoring to guarantee hygienically safe reclaimed water [12][13], very few surveyed projects have used them. Another interesting point is that very few plant managers seemed concerned about emerging pollutants such as trace organics.

6. CONCLUSIONS

In Europe, the last decade has witnessed slow but growing acceptance of water reuse practices, and there are now more than 200 municipal water reuse projects in existence, however only a limited fraction of the water reuse potential is actually exploited.

Switching from conventional water resources to reclaimed wastewater is primarily hindered by cost arguments. This would demand the establishment of water prices that reflect the full-cost recovery principle on the one hand, and the monetarisation of the potential environmental benefits of water reuse, on the other.

In addition to "top-down" reforms, any lasting solution will require commensurate "bottom-up" reforms, including an increased awareness of the water cycle and of the consequences of the viable water management options to the water cycle. These are the two interlinked prerequisites of change on a global scale.

Finally, we would emphasise the importance of best management practice frameworks of water reuse project promotion. There is a need to focus on the reliable operation of all aspects of the scheme and not rely on advanced technology to resolve all operational problems.

With the preparation of a handbook on management practices the Aquarec project aims to provide a single source of information on commonly used or applicable management practices in implementing and operating water recycling and reuse schemes. We hope that this information will open up new possibilities for business and public administrations to include water reuse options in the IWRM scenarios and make precautionary judgements, taking into account imperfect but still available information.

ACKNOWLEDGEMENTS

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Socio-cultural influences on water utilisation: a comparative analysis

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ABSTRACT

This paper shows the main results and conclusions obtained from the development of the objectives of the Workpackage 2 of the Aquadapt project. A survey was carried out in four different catchments in Spain, Slovenia, France and the United Kingdom with the aim of understanding the political, socio-cultural, economic and technological determinants of collective and individual water consumption, investigating the attitudes of consumers towards water as a communal resource, as a social right and as a commodity, and understanding the linkages and the differences between four case studies to determine the scope of local, regional and international integrated water management challenges. A comparative analysis among the four case studies is presented here.

Keywords: Aquadapt project, culture of water, water utilisation, water user profiles.

1. INTRODUCTION

The data presented in the following pages are intended to provide insights into the ways in which citizens wish to construct the future use of water in their regions. The innovation introduced by this research lies in presenting a comparative analysis of data from four catchments in France, Spain, the United Kingdom and Slovenia. To date, studies regarding domestic water use have been developed exclusively at a national level. The data provided by the survey reported below provides an opportunity to investigate which local factors may influence the design of strategies for sustainable use of water, and also to start to explore the existence of a common water culture among Europeans.

The broad aim of the study reported here is to expose variations in the determinants of water use at individual, family, community, and catchment levels across four European countries (France, Spain, UK, and Slovenia). We are particularly interested in why and under what conditions individuals might alter or modify their water usage patterns (quantities used, quality required /accepted, and timings of use) in response to changing economic conditions and demand management tools such as price and education initiatives. We investigated the attitudes of consumers towards water (e.g. as a communal resource, as a right, as a commodity) and the use of it for domestic, leisure, industrial and agricultural purposes, focusing on variations in water quality and water availability (in terms of both volumes and the timing of access).

2. DESCRIPTION OF THE CASE STUDY REGIONS & STUDY METHOD

Four case study regions were selected in order to investigate the functions of socio-cultural variables in water use and management: the Herault watershed, France; the Kras plateau, Slovenia; the Marina Baixa region, Spain; and the Nene catchment, UK. (Figure

1). The four case study regions show sharp climatic and geographic differences that determine the quantity and quality of the water that is available for the populations in these regions. The Marina Baixa represents an extreme case characterized by its semi-arid climate, where water is a scarce and valuable resource. The central issue in the Slovenian case study is the difficulty of extracting water from the karst aquifers. In all four regions agriculture is an important sector of the local economy. Industry is also a significant activity in the UK, French and Slovenian cases. The service sector in all four countries is growing rapidly, mainly due to the expansion of the tourism industry (in the Spanish and Slovenian cases) which can trigger water use conflicts among water consuming sectors.

Survey methodology

Survey sample profiling considered socio-demographic variables such as age, gender, geographical area, and (with the exception of the Spanish case) type of living accommodation. This guaranteed a statistically representative sample of the whole population of each area and gave the survey a confidence interval of ± 5% and a confidence level of 95%. Completed and validated questionnaires from each case study gave 421 responses from Slovenia, 400 from France, 411 from Spain and 380 from the British case study. The survey was conducted through an administered questionnaire conducted in respondents' own homes. Questionnaire development involved collaboration between the four regional teams and the final set of questions included a core set of queries common to all four case studies (divided into eight sections: Environmental concerns; Individual perception and knowledge of water resource management; Individual knowledge of the drinking water cycle; Water uses and water quantity; Water uses and perception of water quality; Water prices and related behaviours; and Water saving behaviours) and a set of case study specific questions. Survey translation and piloting was conducted in each case study location.

3. SURVEY FINDINGS

National differences in attitudes to water stress

Data from surveys carried out across Europe suggest that the environment is not a primary concern of Europeans. Data from the survey reported here allows us to put some detail on this rather general trend. Amongst our four sets of respondents, Spanish respondents seem to have the highest level of concern about environmental issues in general, and more specially, with regard to water problems. Conversely, respondents from the U.K. displayed the lowest level of concern about water issues. When asked about the environmental issue that concerned them the most at a global level, it is the Spanish sample that seems to be more concerned with water, rating it in the third place of importance, while the French and Slovenians placed water issues as the sixth most concerning issue.

Whilst a majority of respondents in all four case studies agreed that the main function of water is to support natural life, we have detected some differences among the samples. In the French case, the difference between those who answer that the function of water is to satisfy human needs (43.8%) and those who say it is to support natural life (56.2%) is much smaller than the difference that we found with the Slovenian respondents, of whom only 24.5% selected the first option, in opposition to 75.6% that selected the second one.

An unwillingness to be directly involved in discussions and debates on the management of water resources is also a common characteristic of the four national response sets.

In terms of knowledge of the water cycle and its management, the Slovenian sample most clearly demonstrates an understanding of the water cycle, while the U.K. sample seems to be poorly informed about these issues. This difference might be explained by the predominance of a more rural lifestyle in Slovenia that fosters a direct relationship with the resource.

Although respondents in all four samples do not consider themselves to be high consumers of water, we detected evidence of water saving behaviour in all the cases. For example, the proportion of respondents that ensure that the washing machine and/or the dishwasher has a full load before switching them on is above 80% in the Spanish, Slovenian and French cases. Closing the taps to avoid unnecessary wastage of water was also a commonly articulated behavioural trait among the respondents with between 84% and 91% indicating that they always follow such guidelines. This generally positive attitude towards behaviour modification is confirmed by responses to questions on attitude towards or willingness to accept more personal effort and time consuming measures with the aim of decreasing household water consumption (Table 1, Table 2, Table 3[1]).

Table 1

		Country				Total
		Spain	Slovenia	France	U.K.	
Acceptance of off-peak tariff	Yes	61.5%	67.0%	71.4%	62.3%	65.6%
	No	38.5%	33.0%	28.6%	37.7%	34.4%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table 2

		Country				Total
		Spain	Slovenia	France	U.K.	
Willingess to take measures to reduce water consumption.	Yes	54.0%	28.9%	49.3%	39.0%	43.0%
	No	46.0%	71.1%	50.7%	61.0%	57.0%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%

[1] All tables presented in this chapter show statistically significant data.

Table 3

		Country				Total
		Spain	Slovenia	France	U.K.	
'I would be willing to pay an additional charge in my household water bill to directly support the protection of water in the environment.'	Strongly agree	25.3%	12.8%	16.0%	4.9%	14.9%
	Agree	39.1%	53.7%	33.2%	40.7%	41.8%
	Neither...	16.4%	5.9%	22.8%	18.0%	15.7%
	Disagree	13.3%	23.2%	16.5%	31.1%	20.9%
	Strongly disagree	5.9%	4.4%	11.4%	5.2%	6.7%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%

Profiling consumers with respect to their attitudes towards water use

The construction of characteristic consumer profiles was made difficult by the absence of well-defined socio-demographic clusters. In other words, a combination of socio-demographic variables (age, sex, type of living accommodation, ownership of the property, educational level, occupation and number of people per home) has not enabled the identification of groups of respondents with significant differences with regard to their water saving behaviour, the extent to which they feel themselves informed about water issues, or their level of concern about water issues. Only age and educational level were partially correlated with these aspects of water use.

Level of concern about water issues

A factorial analysis of the data was undertaken and revealed that the population group with the highest level of concern about water issues are young adults with a high educational level. Those who are least concerned about water issues are more likely to be older adults with a lower standard of education.

Water saving behaviour

A two-step cluster analysis was also completed to support analysis of this issue. Analysis focused on the socio-demographic characteristics of the respondents and their more or less active water saving behaviour. The Spanish sample with an age range between 61 and 80 years old are the most active in water saving behaviour. The least active in this kind of behaviour are the British respondents and those between 21 and 30 years old.

We conclude this profile analysis by making some general observations on the relationships between respondent characteristics and the dimensions to water management discussed above. Firstly we would note that younger respondents display the highest level of concern about water issues but also demonstrate the least water saving behaviour, whilst older respondents are the most active group in terms of water saving, although they are the least concerned about water issues. Country by country, Spanish respondents are more likely to be concerned about water issues, whilst conversely, we find that British respondents have a lower level of concern and water saving behaviour.

Are there 'typical' European wide attitudes to water use ?

The relative homogeneity of the results of this survey across the four case study areas indicates a generally positive attitude towards water and its management. Specifically, the findings seem to reflect (1) the existence of shared environmentalist values in the samples, and (2) a special concern about water. We now intend to expand on these findings, drawing on additional data from the survey to support our thesis. Our interest here is the possible existence of a shared perspective on water and its use; a water culture? A European water culture would involve many of the cultural meanings of water, a set of perceptions, attitudes and behaviours towards water which are shared by most of the European population. Although the Aquadapt survey has been confined to four specific basins that limit this hypothesis, the high level of coherence shown by the responses from these four samples from four distant and little-related river basins seem to indicate at least a kernel of coherence and commonality.

As stated earlier, the environment is not a priority concern for our respondents. In all four countries, "Law and order" is ranked as the highest concern. We would characterise these issues as *strong* issues or *hard cultural concerns* for the European culture. The environment is ranked sixth by the French, Slovenian and the English respondents, while for the Spaniards it is ranked fifth. Concern about environment, housing issues, or international policy are placed into the category of *weak issues* or *weak cultural concerns*.' (O'Riordan, 1976)

The coherence of results across the four case studies seems to indicate a shared European culture, at least with regard to: a) environmental issues (Tables 4 and 5, below), b) agreement on the need to reduce water consumption (Tables 1, 2 and 3), and c) water saving behaviour undertaken by the respondents from the four countries (Table 6).

Table 4

		Country			Total
		Spain	Slovenia	France	
At national level, I´m concerned about...	Law and order	35.3%	43.7%	32.0%	37.0%
	Education	19.8%	9.0%	27.0%	18.5%
	Economy	5.4%	18.5%	10.8%	11.6%
	Employment	13.1%	22.7%	20.2%	18.6%
	Health and SS	17.3%	5.4%	6.0%	9.6%
	Environment	7.9%	.5%	3.8%	4.0%
	International policy	1.2%	.2%	.3%	.6%
Total		100.0%	100.0%	100.0%	100.0%

Table 5

		Country				Total
		Spain	Slovenia	France	U.K.	
The function of water is to …	Satisf. human needs	36.7%	24.4%	43.8%	42.6%	36.9%
	Sustain natural life	63.3%	75.6%	56.2%	57.4%	63.1%
Total		100.0%	100.0%	100.0%	100.0%	100.0%

Table 6

			The most / the least active in water saving behaviours		Total
			The most	The least	
Country	Spain	% Country	78,5%	21,5%	100,0%
		% The most / The least	33,3%	22,6%	30,2%
	Slovenia	% Country	70,7%	29,3%	100,0%
		% The most / The least	37,9%	38,7%	38,1%
	U.K.	% Country	64,7%	35,3%	100,0%
		% The most / The least	28,8%	38,7%	31,6%
Total		% Country	71,2%	28,8%	100,0%
		% The most / The least	100,0%	100,0%	100,0%

4. EMERGENCE OF A COHERENT EUROPEAN WATER CULTURE

Our research leads us to conclude that people display water saving behaviours in a more consistent way than would have been expected if we observe the attitudes related to this kind of behaviour. Moreover, it can be asserted that the water saving behaviour has been internalised by the surveyed population. A possible explanation may be related to the multiple meanings and uses of water. In terms of the whole population and their attitude towards water, it would appear that water is not only a natural resource, but also a valuable and scarce economic resource. This fact is reinforced by their daily behaviour. It could also explain the generalization of post-materialistic values among the respondents.

Taken in total, we would propose that these results not only demonstrate that there is a shared European culture of water, but also that environmental values, attitudes and behaviours have been internalised - although at a superficial level - by most of the population.

The European water culture clearly has contact with local water cultures. These local cultures are the result of the interaction of local populations with water, of their socio-cultural history and of the local environmental characteristics of water with regard to its quantity and quality. Along with this reality of local cultures, in constant dialectics and interaction with the global culture, is the beginnings of an explanation for those differences we find when comparing the results of the four case studies and the internal coherence that the results illustrate when they are analysed at a regional scale.

For example, the 'basic resource' perspective would anticipate the results obtained from the point of view of the local culture, as we find that the respondents from the Spanish sample are the main components of the group with the most concern over water issues and that are the most active in water saving behaviours (Tables 7 and 8).

Table 7

			Country				Total
			Spain	Slovenia	France	U.K.	
The least / the most concerned about water issues	The least	% The least / the most concerned about water issues	14,6%	14,6%	35,8%	34,9%	100,0%
		% Country	24,4%	32,1%	60,5%	83,2%	48,4%
	The most	% The least / the most concerned about water issues	42,5%	29,0%	21,9%	6,6%	100,0%
		% Country	75,6%	67,9%	39,5%	16,8%	51,6%
Total		% The least / the most concerned about water issues	29,0%	22,1%	28,6%	20,3%	100,0%
		% Country	100,0%	100,0%	100,0%	100,0%	100,0%

Table 8

			Country			Total
			Spain	Slovenia	U.K.	
The most / the least active in water saving behaviours	The most active	% The most / the least active in water saving behaviours	33,3%	37,9%	28,8%	100,0%
		% Country	78,5%	70,7%	64,7%	71,2%
	The least active	% The most / the least active in water saving behaviours	22,6%	38,7%	38,7%	100,0%
		% Country	21,5%	29,3%	35,3%	28,8%
Total		% The most / the least active in water saving behaviours	30,2%	38,1%	31,6%	100,0%
		% Country	100,0%	100,0%	100,0%	100,0%

However, it is not only scarcity or the difficulty of abstracting water which add value to this resource. As responses to the questions about measures to reduce the consumption of water in the future demonstrate, there must be other elements that increase the value of this resource. These values promote a pro-sustainable attitude amongst the users. For example, when questioned if they would be willing to accept an increase in their water bills if the additional charge was used for the protection of water in the environment, British respondents most readily agree with this kind of measure. In this sense, when asked about the option of shifting water consumption to off-peak times, the French respondents offer the highest number of affirmative answers, while, contrastingly, the Slovenians are most likely to resist this measure. Therefore campaigns aimed at improving the water use at a household level should take into account these local differences. Campaigns should be adapted to local water cultures and be extremely sensitive towards the kind of relationship, symbolic perception and physical interrelation that citizens maintain with water.

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Integrative Research: Why the Whole is Sometimes Less than the Sum of its Parts

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1. INTRODUCTION

Integrative research is the process of creating knowledge across the boundaries of epistemic communities. It is usually undertaken by and for professionals and so can assume a high degree of motivation and competence. *Multi-disciplinary* research is a knowledge patchwork in which each community accepts the beliefs of the others uncritically or ignores them. *Unified* research requires a shared knowledge base for the whole group. Integrative research occupies the middle ground - an expedient alliance of epistemic communities, valuing disciplined diversity but minded to co-operate if possible.

A group's receptiveness to new ideas is determined by intellectual competence, knowledge and temperament. Intellectual competence is highly variable, but can be changed within limits by education and training. There are instruments that bear on knowledge and temperament too, but they pull in different directions.

Multi-disciplinary approaches change the 0erceptions of participants by making unfamiliar knowledge available to each. Many people believe sustained multi-disciplinary initiatives create a flow of innovations but the historical evidence is unclear. Driving disciplines together produces sustained culture-shocks that reduce receptivity and cause schism. If there are strong incentives to persevere (financial subsidies, perhaps) the result is either a unified knowledge system or a schism. The fusion of biology and chemistry illustrates this process perfectly. As botany departments queued up to reinvent themselves as schools of molecular biology, systematics, ecology and environmental science gradually fell off the curriculum. They tend now to be taught in environmental research institutes, schools of geography or Quaternary science.

Similar stories can be told in many study domains; the collapse of geography into human and physical subsets, the schism between pre- and proto-historians in archaeology and the divergence of hard- and soft- system approaches all suggest that no matter how generous the funding incentives are, multi-disciplinary meta-sciences seldom thrive as such.

The analogy with biological dynamics is striking. Just as intensified exploitation of an ecosystem can reduce resilience by destroying biodiversity and fragmenting habitats, so intensified knowledge production can reduce adaptive potential by destroying epistemic diversity and fragmenting communities.

Indeed, funding initiatives often create conflicts between the basic human need for effective communication and the centralised demand for constant adaptive change. These conflicts are usually de-fused by polite obfuscation. Any minor adjustment is hailed as an innovation when, in fact, it is at most a slightly new variation on a very old theme. The pretence of adaptation is one of the commonest defence mechanisms of any agency paralysed by a centralised demand for unremitting revolution. The agency simply meets its innovation quotas by pretending it is already adapting as fast as any institution can.

This behaviour is correlated with historical pendulum-swings between a centralised command economy for knowledge services and a distributed demand economy. Universities emerged in the twelfth century as a spontaneous response to demands for educational services that could not be met by monastic schools. Cathedral schools were established to which peripatetic teachers and students were drawn. The universities were scholarly trades unions that negotiated contracts between teachers and students and kept order. As the need to regulate them became apparent they were granted charters, given privileges and placed under constraints to audit quality and keep the peace between town and gown. By the early fourteenth century centralised control had turned the universities into systems for accrediting orthodoxy.

A similar story can be told for the last fifty years. A burgeoning demand for educational services has been regulated and gradually converted into a command economy by successive governments and supra-national agencies. As the number of students passing through has increased, accreditation and orthodoxy have once again become prime concerns, but the direction in which latter-day scholars are driven by centralised demand is different. Mediaeval scholars committed to adaptive change had to defend themselves from the charge of heresy by claiming they were re-discovering timeless truths. Latter-day inquisitors are more likely to accuse scholars of failing to innovate, so academics now defend normative behaviour by claiming they are really ‘innovating’ all the time.

Recent academic literature on post-modernism, post-feminism, new archaeology, new geography, new systematics, post-structuralism and the rest; the silly marketing speak of Post-War science and the changing demands of funding agencies, are understandable responses to the unsustainable command economy for knowledge that demands endless innovation without any clear indication of what innovation is, or why we might want so much of it.

Professional academics who prosper in contemporary markets are those who degrade the distinction of adaptive from normative dynamics, write impenetrable prose and market every piddling change of emphasis as an earth-shattering revolution. This nonsense takes the heat out of socio-political conflict but it also prevents academics explaining the simplicity and antiquity of great ideas

As the volume of scholarly and scientific literature has grown and the incentive to write clearly has been eroded, the impact of any one publication has become negligible. The twentieth century ‘information explosion’ is not, as the bean-counters pretend, evidence of progress, but of a stagnant, centrally driven knowledge economy that has gradually paralysed our universities.

The secondary effect of this process has been a shift from rolling research programmes to project-based research. A *project* is a short-lived alliance of researchers with a start-date and end-date and a deliverable. The growth of project-based multi-disciplinary initiatives (the Mode 2 revolution, Gibbons *et al*, 1994) is an artefact of post-war ‘big science’, accelerated by graduate unemployment in the late 70s. It caused a dramatic shift in the balance between teaching and research in universities which must now accommodate two different business patterns in a single administrative structure.

Mode 1 business (teaching and scholarship) tends to be focussed in a single discipline and institution. A large proportion of the costs are fixed, the business cycle is slow and job security good. Mode 2 business is run by institutional consortia and demands multi-disciplinary input. It has a rapid business cycle, variable costs and lousy job security. Few institutions can accommodate both business cycles successfully.

Multi-disciplinary revolutions are transient perturbations - nudges that change the course of history, but carry within themselves the seeds of their own destruction. Differential funding and career opportunities create tensions between the soft and hard sciences, tenured and non-tenured staff, pure and applied subjects, Mode 1 and Mode 2. People are torn by conflicts of interests, by loyalty to the research team(s) of which they are members, to their employers, their academic peers and funding agencies. These tensions create epistemic factions that prime the scholastic trap. As they compete for resources and status, researchers re-present the tension between doubt and certainty as conflicts between progressive and reactionary tendencies.

Soon the whole programme stands on the authority of a single epistemic community, often protected by institutional or national statute. New disciplines replace the old ones. Institutions are purged of those whose work is seen as anachronistic or peripheral. Epistemic diversity is reduced and the scholastic trap is sprung.

2. WHY STUDY INTERACTIVE RESEARCH?

A research team is a manageable microcosm of the wider world it is constituted to study. The team comes together to create and integrate knowledge that helps it co-operate in a complex socio-natural domain. That domain already contains other people (residents, if you will) themselves creating and integrating useful knowledge. The process of research and the subject being researched are qualitatively similar. However, researchers often leave at the end of the project; residents, one hopes, will not be forced to do so. Researchers have (or should have) well-structured aims and flexible knowledge bases; they can tune their knowledge to serve those aims. Residents often face weakly structured problems and may be unable to compromise without violating their own sense of identity or risking social exclusion. Their aims, broadly speaking, are to continue doing what they are already doing while achieving (or maintaining) a desired quality of life.

Researchers in applied or policy-relevant projects are there to reflect on the consequences of human behaviour and maybe help people search for new, more sustainable lifeways. This is a tremendous responsibility. Researchers are willing participants in a process that helps determine the course of history. In a democratic society they should not have a disproportionate role.

Research is often directed across epistemic boundaries and one of the key tasks of a research co-ordinator is to coax colleagues into a more reflexive mode. Many academics do not enjoy this. Just as motorists sometimes curse and lean on the horn when other road users force them to take conscious control, so academics sometimes become openly aggressive when tacit beliefs are challenged. This may be acceptable in a pure research setting, but raises ethical dilemmas when livelihoods are at stake. Tensions within the team may amplify stresses experienced outside. Some fragile rural ecosystems and deprived urban neighbourhoods have been so disrupted by academics, residents have become openly hostile.

All human beings, whether they are conscious of it or not, are making history. Human knowledge (the shared beliefs of a community) determines human behaviours, which, in turn, impact on the biophysical environment creating opportunities and threats to which humans respond by re-negotiating knowledge. These cultural ecodynamics are at once an important research domain and a valuable source of managerial insights.

Indeed, we can turn this self-referentiality to good advantage - learning a lot about cultural ecodynamics without braving the ethical challenges of sociological or anthropological fieldwork simply by studying academic knowledge creation, both in the past and the present. A strong case can be made for equipping large research projects with a skilled participant observer whose task is to assist in the process of knowledge creation and prepare a research report on the process. Where a biologist may use a laboratory or greenhouse to test theories in a way that would be ethically indefensible in the field, we can test theories on ourselves.

3. KNOWLEDGE AND INFORMATION

Humans negotiate knowledge by communicating with each other. We seem to be programmed to try to understand sensory experiences, especially those associated with other people, using our highly developed empathic skills to negotiate a congruence of beliefs with our neighbours. Young people are more receptive to unfamiliar beliefs than older people so linguistic structures are conserved and transmitted between generations. However, errors are made, ideas are sometimes rejected or communicated imperfectly so knowledge is not static.

Human beliefs are conditioned by basic human needs. Certain types of situation recur, and people can be expected to gravitate towards similar beliefs in those situations. These common interests create consistent associations of personal interest and shared belief. If circumstances are persistent, linguistic and epistemological structures will be conserved from generation to generation. However, if they disappear and then return, the same structure will be expressed in very different terms. These epistemological resonances (ideas) can indeed be apprehended by disciplined contemplation. They represent regions of dimensional coherence - universes of discourse - that are discovered and re-discovered in successive generations. However they are not divine templates, independent of human belief, but natural responses to recurrent types of circumstance.

Knowledge is shared belief. My personal knowledge consists of all the beliefs I share with myself. Yours is defined similarly. Our (collective) knowledge consists of all the beliefs we share. Our beliefs are shaped by our experiences. As your beliefs or mine change, the knowledge we share re-forms at the intersection of our respective belief-sets. This is so by definition and can be extended to communities of three or more people without loss of generality. If beliefs diverge, trust can break down and social exclusion results. This is a common experience among the children of blue-collar workers in higher education, for example.

Observations are sensory experiences articulated with prior knowledge. A lot of sensory stimuli are systematically ignored or baulked. Sometimes we baulk observations because we do not know what to make of them, or they challenge cherished beliefs. Often we baulk experience that seems insignificant.

Information, as I have already indicated, consists of observations that change the knowledge state. Some information is consistent with pre-existing beliefs and simply adds knowledge to the store. Other information challenges pre-existing beliefs leading to an epiphany. Information that challenges beliefs in this way and is propagated through a substantial part of society often leads to widespread innovation - new perceptual structures and adaptive behaviour.

In the political science literature, the word 'innovation' is often used to represent socio-economic change. National and supra-national investment in research is often funded because people believe activities that add new knowledge can be expected to enhance economic performance. The evidence does not support this view, as debates in the U.S. about the future of space research and, in Europe, about the low level of economic spin-off from successive Framework Programs have highlighted.

Rapid economic development seems invariably to follow innovation, and innovation often arises from research. However, many research projects do not innovate and most innovations have no economic spin-off. It is possible to manage research projects so as to maximize the probability of innovation and, once an opportunity has been recognized, to design technical projects that exploit it. However, it is often impossible to move from innovation to exploitation on demand. It takes time for new beliefs to be communicated to and assimilated by an influential group of people. Notwithstanding the protests of politicians and scientists with a vested interest, the dynamic linkages are weak.

Innovation implies relative novelty. The idea need not be absolutely new. What matters is that the information triggers an epiphany that changes the recipient's mind-set. Swamping the recipient with data dulls the senses and may actually reduce the likelihood of innovation. The distinction is that between *So What*? and *Aha!* When I tell you that scientists have found a blade of grass growing between two paving stones, you may baulk this as a useless or trivial communication. *So what?* If, for some reason, you were interested in these paving stones, you might note the presence of grass but it would hardly qualify as an epiphany.

However, if I were to tell you that scientists had found a blade of grass growing on Mars (and you believed me) your beliefs about life on Mars might be challenged. The moment that challenges belief is seldom repeated in a simple way because knowledge is dynamic: yesterday's *Aha!* is tomorrow's *So what?*

There are many epiphanies in the first decade of life, rather fewer in the seventh. As we become elders of the communities that sustain us, our beliefs cease to be monitored and knowledge becomes fixed. We baulk experience that might lead to innovation and switch from a learning- into a teaching mode.

Teachers often try to challenge beliefs, but the graveyard slot in the early afternoon, often finds students unreceptive. Half of them are asleep; the rest are daydreaming (technically awake but operating with too many cognitive filters off-line to make sense of anything). We complain of course, but suspect that adult creativity is nourished by such childish joys as watching the summer grass grow, or dust spinning in sunlight. If humans couldn't lower their cognitive filters from time to time we would be trapped by our beliefs and unable to observe anything that did not make sense immediately.

Many people can testify that childhood experiences often lie dormant in memory until 'the penny drops' and we make sense of them as adults. These epiphanies are not always traumatic (repressed memories in the Freudian sense) they are merely uninterpreted observations.

It is often helpful to contemplate a spectrum of beliefs from culture to theory. *Cultural Beliefs* are so deeply engrained in us that we do not monitor them. In practice, culture is best identified negatively in terms of the things we do not think of doing and the observations we are not capable of making. When we receive information that challenges cultural beliefs, we may cringe with embarrassment or even respond defensively because culture defines our identity. People who regularly challenge cultural beliefs are always mistrusted and often disliked. Cultures are usually *closed* to information.

Creedal Beliefs are deeply embedded but explicit. Information that challenges creedal beliefs is often baulked. *Theories* are a weaker type of belief, created in provisional form and monitored for coherence, consistency and utility. We often depend on theories in our daily work while recognizing that they are not secure. Information that challenges a theory is less likely to elicit a hostile response. People are *open* to information that challenges theories.

Beliefs enable us to make sense of our experiences and co-operate with others by forming coherent knowledge communities. Different knowledge communities often have logically irreconcilable belief systems and members vary in their openness to external information by age and temperament.

Integrative research requires representatives of two or more communities to co-operate, but they can only do so if they are prepared to make temporary compromises and learn from each other. The people best qualified to represent a knowledge community are usually mature, but mature people are not necessarily those best equipped to learn and compromise. A *knowledge system* (k-system) is a formal map of the knowledge communities contributing to a research activity. The prefix k- indicates that these systems are not real things, but domains of study requiring expert knowledge. This can be a great liberator in integrative research. Many people who question the reality of classical systems participate freely when it is explained that k-systems are domains of expertise and interest.

Sometimes a k-system represents the knowledge domain of a research project and we populate it by recruiting people to represent interested knowledge communities. They are subdivided into k-sub-systems, each of which represents a recognisable theme or program of work. These k-sub-systems are often called *workpackages*. Some people serve on more than one workpackage; others specialize. Workpackages are sometimes subdivided thematically into k-sub-sub-systems or *workgroups*. Workgroups are typically small and rather coherent in belief and purpose. As one moves down the hierarchy, the level of dimensional coherence increases, but small-world bias increases.

Recall that knowledge is shared belief. This means that as one moves up the system hierarchy from the workgroup to the project, the number of people working together increases but the amount of knowledge decreases. K-systems are like the biblical tower of Babel. The higher we climb, the harder it is to communicate because dimensional coherence is reduced. The bigger the system, the less we know. As we move down the hierarchy dimensional coherence (and knowledge) increases, but the probability that a policy implemented in respect of that knowledge will solve the problem at hand is reduced.

Scientists can never construct a God-like omni-science, but, with careful design and thought, can sometimes get a useful picture of the world. However, every time one adds a level to the integrative hierarchy, or increases the size of a k-system, one makes the work of integration harder.

Clever research design can help, but there are structural constraints that we ignore at our own risk. In practice, people have to accept some discipline to work in groups. Students and policy makers often speak confidently about the ‘obvious’ advantages of inter-disciplinary research and believe that high fliers are those who avoid getting corralled in narrow knowledge domains. These melting-pot ideas do not work very well in practice because knowledge communities are logically unconnected. You actually need distinctive perspectives to get a clear understanding of cultural ecodynamics on many spatial and temporal scales.

If you really need to see across knowledge boundaries, you can do so and what you see can change the world, but you do not fly; you build. Knowledge systems are founded on trust, mutual respect and common purpose. If they are well designed people can move from one vantage point to another, speculating, theorizing, transmitting and receiving information. This does not mean that researchers must discard all the specialist knowledge that cannot be transmitted across community boundaries; it merely requires them to think carefully about signal to noise ratios when communicating with colleagues. You must take possession of (and responsibility for) your own specialism and communicate sparingly, especially in contexts where dimensional incoherence is operationally significant.

In recent years it has become fashionable to assume that the most useful research into cultural ecodynamics is always integrative. However, both theory and practice suggest this is not so. Governance structures are k-systems too. As their spatial extent increases, their ability to valorise objects changes. They usually compensate for this by becoming sectorialised. As one moves up the hierarchy from local to supra-national, one encounters agencies that are constitutionally incapable of responding to integrative science. In practice, the deepest knowledge hierarchies are usually those constructed by small teams working to inform policy on a micro- or meso-scale, Local and regional policy makers are able to valorise a wider range of objects than their national or supra-national counterparts.

Position in the knowledge hierarchy should not be equated with status or merit, though there is little doubt that inexperienced researchers should spend most of their time working near the bottom. Younger researchers need to learn and this is the level at which knowledge pictures are richest and information flows very easily. A person cannot contribute meaningfully to integration who has not accepted the discipline of becoming well-educated and this is the best place to get that education.

By well-educated I do not mean holding a lot of data, but having absorbed the core beliefs of a knowledge community and spent enough time applying that knowledge to have developed a mature intellectual position. Researchers need that education before they can serve effectively as ambassadors of a knowledge tradition. This is especially true if the work involves non-academic out-reach. If you claim to know nothing, but seem to have opinions about everything, stakeholders are less likely to take you seriously.

The task is to construct a strategic alliance that capitalizes on perceived strengths without compromising the rational coherence of the whole. In practice, this means that people must be organized pragmatically and everyone must expect to pick up a reasonable share of the most difficult tasks. Rich information flows must be possible (and needed) within a workpackage or workgroup, but relatively poor and infrequent information flows suffice across boundaries.

What is information for one person, to another may be dimensionally incoherent noise. An engineer designing a sewage treatment plant, for example, may be irritated by questions about the social construction of meaning. Restrict information flows so that the only messages passing are potentially interesting to the recipient. Failure to constrain information flows stifles innovation by forcing recipients to baulk unwanted communication. Stafford Beer’s *viable systems theory* provides many insights into this process.

Once information constraints are in place, people can focus on tasks involving easy communication. Endless culture shocks are exhausting and the irritation they engender in a research team may de-stabilize the systems it is to study. However, researchers must come together to plan and integrate. An effective way of managing this is to arrange small ‘milestone meetings’ for non-routine information flow.

The heart of this process is an ‘appreciative cycle’ (Winder, 2005, Vickers, 1965) in which deconstructionists gather and interpret data, constructionists develop theories and specify AWPPs and reductionists convert AWPPs into policy options. In practice, of course, there are usually many appreciative cycles running in parallel. As soon as a policy option is chosen and implemented it becomes necessary to monitor it for unforeseen consequences - the deconstructionists come back in again. If boundary conditions are violated, the constructionists must re-think and this, in turn, creates more work for the reductionists.

The project itself may have a start date and an end date, but the management of cultural and natural life-support systems demands a repeating cycle (sometimes called ‘multiple-loop learning’). It is not a once-for-all task.

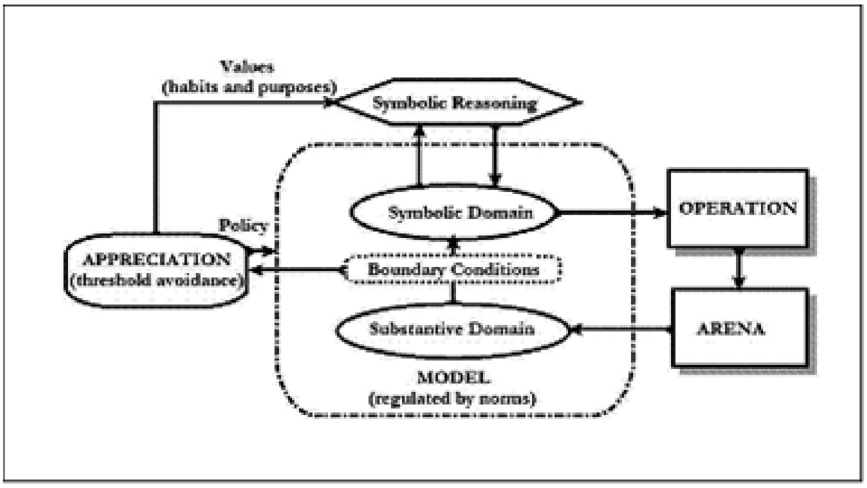
The art of managing integrative research consists of bringing all these cycles into phase for the milestone meetings. Focus the meeting on a *product* (an annual report, say, or a joint publication) not on a *process*. Keep the group small (ideally no more than seven people). Exclude the press, spectators, professional facilitators, academic figureheads and anyone else not actively involved in the work of knowledge creation.

Though one might think of innovation as a response to stress, people who feel their beliefs are threatened find themselves in a bind: under pressure to abandon the knowledge community that sustains them. They usually withdraw to their cultural high ground and lay down a defensive barrage of rhetoric and common sense. Innovation takes time, demands trust and common purpose. Arrange informal social events, but avoid extravagant hospitality. Facilitate breakout meetings but never lose sight of your goal. Your aim is to help people feel safe enough to initiate focussed discourse across knowledge boundaries, not to demolish the boundaries themselves.

4. REGULATORY NOISE ABATEMENT

Funding agencies focus almost all their attention on products rather than processes, they monitor deliverables, budgets and deadlines and their intervention in the process of research is usually directed towards these. However, from time to time policy norms change and these epiphanies disrupt the research process by changing the values and norms to which researchers must respond.

A project’s policy environment is created through the regulator - the outward facing facility responsible for the project’s relationship with academic peers and external stakeholders. The policy environment is often set by an explicit negotiation between external stakeholders and consortium members. External stakeholders sometimes need access to the whole team, but should only influence the project through the regulator. It is the regulator’s task to provide advice and authorise or veto decisions that have not been delegated under the terms of the contract.



Any external agency that disrupts the research process may be held responsible for failure to meet the terms of the contract arising through that action. Consequently, regulators and external stakeholders should not intervene in any legitimate managerial decision unless they are prepared to accept liability for that action under the contract. This is widely understood both by regulators and (especially) by managers, but there seems to be no formal model of the continuing appreciative process that monitors the impact of a project on external stakeholders that can distinguish management from regulation.

Every project is based on an effort of abstraction in which a substantive domain representing reality- and operational judgments is mapped on to a symbolic domain of words or numbers analogous to it in some significant (i.e. valuable) respect. This analogy, as we have seen, is a model.

Information gathered from the socio-natural arena in which the team works is fed into the model. The rules of symbolic manipulation are used to negotiate executive actions. These rules always stand outside the model itself. Hard scientists often interpret this lozenge on my diagram (below) as containing rules of logic and mathematics, but the way these rules are applied is determined by policy.

Information is transmitted from the model to the domain of executive action, that impacts on the arena, which responds by passing information back to the model. This feedback loop is important. Arena contains external stakeholders and their response to executive action may be unexpected. The team delivers the required product by managing this recursive learning process effectively.

Policy consists of norms that bound the research domain by presenting some reality judgments as axioms. This is operationally necessary. It is certainly possible to debate the value-, reality- and operational judgments that underpin fishery policy, for example, but if the group breaks off half way through to argue about the social construction of a kippered herring, the project may collapse. However a model that becomes culturally embedded can cause problems as the older consensus creates unforeseen difficulties. It is equally necessary, therefore, to keep reality-, operational- and value judgments under continuous review.

The engagement of stakeholders and pressure groups means that this process can easily become very noisy and dealing with it can over-stretch the managerial competence of the team. Excessive noise must be filtered out. Boundary conditions (pre-agreed indicators of policy compliance, system behaviour and system health) must be set. If these conditions are satisfied, the boundary judgments can be sustained. Checks and balances are needed to ensure boundary conditions are neither too lax nor too sensitive.

If the boundary conditions are violated, the model has lost dimensional coherence. The regulator must then re-evaluate the project's conceptual basis and negotiate new beliefs. The group involved should be small and non-confrontational but must involve external stakeholders as well as consortium members. The re-started appreciative process may simply negotiate new boundary conditions, but it could innovate, producing a completely new model.

In a blame-free environment, killing a project is only justified in cases of incompetence or irretrievable collapse - complexity happens. Killing a model, however, should be encouraged and, if innovation is genuinely valued, openly rewarded. Best scientific practice requires theories to be empirically testable, but a rift yawns between best and common practice. Far too many failed models are conserved, usually because regulators have invested too much in them and will not write that investment off. Macro-economic predictions, for example, commonly fail and senior politicians lose elections as a result, but the appreciative setting of politicians and economists is so rigid the models have no explicit boundary conditions. These models are so deeply embedded in political culture as to appear immortal.

Economic boom-bust cycles and the pendulum-swings of political fortunes are artefacts of democratic rhetoric have trapped Western society in an erratic, short-period Phoenix Cycle. Almost every disagreement is reduced to a clash of ontologies. Even our policy-relevant scientists have more faith in their own theories than in the empirical evidence and defend them against all comers. We (the citizens) could be better served, but this would require experts to assume a sceptical position in respect of their own beliefs. That won't happen until we assert that an unshakeable faith in the rightness of one's own beliefs - the hallmark of political high-fliers in every age - is actually proof of incompetence.

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Economic Valuation Methods for Efficient Water Resources Management

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ABSTRACT

Water resources are often undervalued, leading to excess demand and the inefficient use and allocation of water. This paper presents an overview of the economic valuation methods that are available to estimate the non-market benefits of water resources. These include revealed preference techniques such as Hedonic Pricing and the Travel Cost Method, as well as stated preference techniques such as Contingent Valuation Methods, and Choice Experiment Methods. These are illustrated with specific applications to surface and groundwater resources, lakes, and wetlands to evaluate both water quantity and water quality aspects.

Key Words: Economic Valuation, Water resources management, non-market benefits

1. INTRODUCTION

Water scarcity issues are a cause for serious concern in arid and semi-arid regions and existing water shortages are predicted to escalate in both frequency and duration over the next century (UNEP, 2003). Water shortages are due in part to the under-pricing of water resources as more often than not, current prices do not take into account the non-market benefits of water. This paper briefly presents the non-market benefits of water and then provides an overview of the valuation techniques that are available to price water resources more efficiently. The methods are illustrated with examples of applications to water resources including surface and groundwater, lakes, and wetlands.

2. NON-MARKET BENEFITS OF WATER

In any aquatic system a number of processes may be occurring to a greater or lesser extent. These may be of a physical, chemical, biological or ecological nature. As a consequence of the occurrence of such processes, aquifers will perform a number of ecosystem preservation functions. For example, the process of water storage in an aquifer may result in a wetland, which is performing the function of flood attenuation, while the processes of denitrification and plant nutrient uptake may contribute to the ability to perform the function of water quality maintenance through the removal of nutrients from surface water and shallow groundwater. Plant uptake of nutrients may also result in the performance of other functions such as the provision of support to the food web and habitat, demonstrating that an individual process may contribute to a variety of wetland functions.

The benefits of these water resources functions to the society (and social welfare), however, are not confined to their physical functions. For example, they may be supporting wetlands used for recreation such as sailing, shooting and fishing; be held dear as intrinsic parts of landscapes or as wild places; and be valued, as habitats, for their biodiversity. Moreover, water storage in aquifers may provide direct economic benefits but the value of aquatic systems, like that of nature in general, also has cultural and social dimensions. Such values, constituted through social processes, represent as much ethical, aesthetic and cultural concerns as scientific knowledge. In particular, nature's popular significance resides largely in meanings and values other than those bestowed by scientific understanding. But the physical functions performed by an aquatic system take place with or without the presence of society, usually as part of a self sustaining ecosystem (intrinsic features), whereas other aquatic systems values require the presence of society (extrinsic features), and these will vary over time and space while the functions may not.

It is widely accepted today that decisions about environmental and groundwater resource management related policies and projects should not be made on scientific and/or economic (including financial, management, restoration costs and benefits) grounds alone; social and cultural aspects also need to be heeded. For the integration of these values policymakers have to explore water values held by 'ordinary' citizens in the context of developing a non-monetary approach to valuation and suggest how these values should be integrated in water resources management policies.

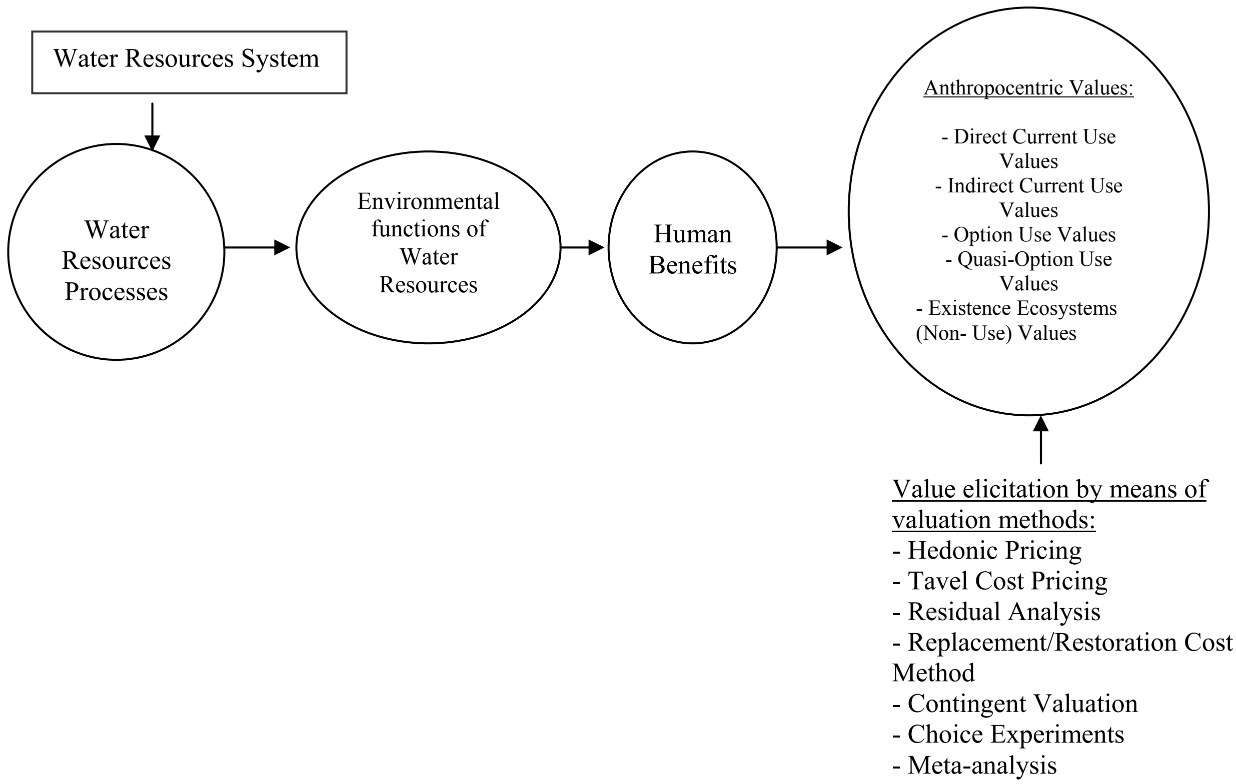

Figure 1: A simple framework relating water resources to environmental functions, human benefits and anthropocentric values

In economics, the basis of value is determined by individual preferences. Preferences reflect the utilities that are expected to be derived from the consumption of resources, given the needs, wants and wishes of consumers. In order to correctly evaluate a given resource, one needs to consider the Total Economic Value (TEV) of the resource i.e., the whole class of values that have a basis in human preferences. TEV is composed of direct and indirect use values, as well as non-use values. Current use value derives from the utility gained by an individual from the consumption of a good or service, or from the consumption of others (e.g. parents may obtain utility from their children's consumption). Current use value is composed of direct use value (commercial and recreational) and indirect use value (such as amenity value or general ecosystem support). Option Value derives from retaining an option to a good or service for which future demand is uncertain. If we are not certain about either our future preferences or about future availability, we may be willing to pay a premium (the option value) to keep the option of future use open. The option value an additional value to any utility that may arise if and when the good is actually consumed. Existence Value derives from human preferences for the existence of resources as such, unrelated to any use too which such resources may be put. Individual preferences may exist for maintaining resources in their present forms even where no actual or future `use' is expected to be made of the resource.

Given that many of these components of value are not reflected in market prices of water, economists will attempt to estimate the true resource value through user willingness to pay (WTP) for a given quantity and quality of supply. Valuation techniques are therefore necessary to assign appropriate prices that will enable water to be allocated in the most efficient manner. A variety of these techniques have been developed over the years to address this issue and are generally classified as revealed preference techniques and stated preference techniques. *Revealed preference techniques* use data on goods or services that are marketed and do have observable prices, in order to value some environmental attribute, which is embodied in the marketed goods and services, but is not traded itself in any particular market. In *stated preference techniques*, individuals are provided with a constructed scenario in which they are asked how much they are willing to pay to changes in environmental quantity.

3. REVEALED PREFERENCE TECHNIQUES

Within the category of revealed preference techniques for water resources, one approach is the R*esidual Value Method* which values all inputs for the good produced at market price, except for the water resource itself. The residual value of the good is attributed to the water input. For example, one can value water as an input in the production of different crops. A problem with this methodology is that only part of the use value of water can be captured.

Another approach is the *Hedonic Pricing Method* whereby implicit prices of characteristics which differentiate closely related goods are estimated [Griliches, 1971; Rosen, 1974]. Suppose that an environmental resource that you wish to value is not itself traded in any market, possibly because the resource is a public good. As a result, no market price exists which can reveal preferences or willingness to pay for the resource. Suppose also that the resource can be defined in terms of services it yields or an `attribute' it embodies. This attribute may be embodied in other goods or assets which are marketed, and which do have observable prices. For example, farm prices in an area with good groundwater availability will be higher than areas with little or no groundwater availability. By comparing farm prices in different areas and accounting for other differences, the remaining difference in farm price can be attributed to groundwater availability. An example of hedonic pricing applied to evaluate water quality in Cyprus is given by Koundouri and Pashardes (2003). Using data on 193 parcels of land on variables such as price, usage (agriculture vs tourism), proximity to the sea, and other variables, they estimate the marginal willingness to pay to avoid a marginal increase in the salinization of fresh groundwater supplies beneath owner's land.

A limitation of the hedonic pricing technique is that it is only capable of measuring that subset of use values for which people are willing to pay and do so indirectly through the related market. It also relies on the assumption that consumers are fully informed about the qualities of the attributes being valued, otherwise hedonic price estimates are of little relevance. There are other problems in that the hedonic price equation and the second-step demand equation impose rather strong assumptions about separability of consumers' utility functions. The functional forms of regression models that are usually chosen impose weak separability, permitting rent-pollution and demand functions to be estimated independently of demand equations for other goods that consumers purchase. However, standard consumer demand theory and evidence from applied studies doubt the validity of weak separability, particularly when large changes occur, as is often the case when dealing with environmental projects.

Travel Cost Models (also known as recreation demand models) is an alternative revealed preference technique which focuses on choice of trips or visits for recreational purposes and looks at the level of satisfaction, time, and money spent in relation to the activity. Patterns of travel to a particular sight can be used to analyze how individuals value the site and for example, the water quality of a river stretch. See Bockstael *et al.* (1987) for an example.

4. STATED PREFERENCE TECHNIQUES

Within the category of stated preference techniques, one can use contingent valuation methods, choice modeling approaches, and meta-analysis. Many water quality evaluation problems occur in a framework for which no value measures can be derived from observing individual choices through a market. This is mainly due to the public good aspect of groundwater quality. Other examples where actual consumer choices are unobservable are cases where the policy change is potential rather than actual. In such cases, respondents are offered conditions simulating a hypothetical market in which they are asked to express willingness to pay for existing or potential environmental conditions not registered on any market. The most common form of questioning on hypothetical futures is called the *Contingent Valuation Method* (CVM). This involves asking individuals directly what they would be willing to pay contingent on some hypothetical change in the future state of the world (Mitchell and Carson, 1989). Alternatively, this can be expressed as the minimum monetary compensation they would accept to go without an increase in that good or tolerate a decrease (willingness to accept compensation WTA).

Thus, an individual's WTP or WTAC will depend on:the description of the contingent market, the information they have about the environmental good,

which depends partly on what they are told about it as part of the CVM survey, their own preferences and their budget constraints, and the availability of substitutes and complements.

In brief, a CVM exercise consists of a description of the environmental change in question and the contingent market, establishing a bid vehicle (e.g. an increase in monthly water bills), and a reason for payment (e.g. to reduce water shortage incidents from three times a month to once a month). The WTP bids can be elicited in a variety of methods including an open-ended format, a bidding game, a payment card or a single or double-bounded dichotomous choice mechanism. Once the mean and median WTP has been estimated, the average bid can be aggregated to a population total value. Pate and Loomis (1997) for example find that WTP for a wetlands improvement program in California, USA is about $215 per household and that this decreases as the distance from the site increases.

There are several problems associated with CVM that may bias the value estimates (e.g. interviewing bias, non-response bias, strategic bias, embedding effects, yea-saying bias, hypothetical bias, information bias), and best practice guidelines for conducting CVM studies have been developed (NOAA, 1993). These recommend for example the use of dichotomous choice formats over other alternatives, that in-person interviews should be conducted as opposed to e.g. mail surveys, and that WTP, not WTAC, measures should be elicited.

Partly in response to these problems, valuation practitioners are increasingly interested in alternative stated preference formats such as *Choice Modeling* (CM). CM is a family of survey-based methodologies (including choice experiments, contingent ranking, contingent rating and paired comparisons) for modeling preferences for goods, which can be described in terms of their attributes and of the levels they take. Respondents are asked to rank, rate or chose their most preferred alternative. By including price/cost as one of the attributes of the good, willingness to pay can be indirectly recovered from people's rankings, ratings or choices. An excellent critical review of CM alternatives and investigation of their potential to solve some of the major biases associated with standard CVM is provided by Hanley *et al.* (2001). In the class of CM alternatives, probably the one receiving the most attention is the choice experiment method (CEM). This is a survey-based technique which can estimate the total economic value of an environmental stock/flow or service and the value of its attributes, as well as the value of more complex changes in several attributes. Each respondent is presented with a series of alternatives of the environmental stock/flow or service with varying levels of its attributes and asked to choose their most preferred alternative in each set of alternatives. CEM eliminates or minimises several of the CVM problems (e.g. strategic bias, yea-saying bias, embedding effects). An example of a choice experiment method applied to wetlands evaluation is that of Carlsson *et al.* (2003), who estimate the values of both use and non-use values of Staffanstorp wetland in Sweden. The selection of attributes and levels that they select include biodiversity (low, medium, high), fish (yes, no), surrounding vegetation (forest, meadow), walking facilities (yes, no), and a cost attribute (varying from SEK 200-850). The choice sets are then constructed using experimental design methods and the survey sent out via mail to 1200 randomly selected individuals living in Staffanstorp. Using econometric models, they find that biodiversity levels and walking facilities are the two greatest contributors to welfare, whereas some other attributes led to a decline in welfare. For another example of wetland evaluation in Greece, see Birol *et al.* (forthcoming).

Recent years have seen a growing interest, both from academics and policy makers, in the potential for producing generally applicable models for the valuation of non-market environmental goods and services, which do not rely upon expensive and time-consuming original survey work, but rather extrapolate results from previous studies of similar assets. Such methods are called *meta-analysis* for the use and non-use values generated by environmental resources. Meta-analysis is the statistical analysis of the summary of findings of empirical studies, that is, the statistical analysis of a large collection of results from individual studies for the purpose of integrating the findings. Meta-analysis offers a transparent structure with which to understand underlying patterns of assumptions, relations and causalities, so permitting the derivation of useful generalizations without violating more useful contingent or interactive conclusions.

The increase in meta-analytical research seems to have been principally triggered by: a) Increases in the available number of environmental valuation studies; b) The seemingly large differences in valuation outcomes as a result of the use of different research designs; c) The relatively high costs of carrying out environmental valuation studies and the increasing demand for transferable valuation results. Brouwer *et al.* (2004) present such a meta-analysis for the use and non-use values generated by wetlands across Europe and North America.

5. CONCLUSIONS

Each of the valuation techniques discussed here are appropriate for estimating different components of the total economic value of water resources. The incorporation of non-market benefits into the user prices for water resources will ensure more efficient use and allocation of water, thus enabling more sustainable use of this important resource. Once appropriate estimates of water resource values are available, it is then necessary for policy-makers to determine which economic instruments and measures are most suitable to provide users with the correct short and long-term incentives for sustainable water resources management.

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Transboundary Water Resources Management in Europe within the Framework of WFD 2000/60

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1. INTRODUCTION

The political dimension of water becomes highly important not only because of its scarcity, but also as a result of its sharing across national boundaries. Approximately 40% of the global population lives in tranboundary water basins, shared by more than one country, emphasizing the need for concerted management of transboundary water bodies and harmonization of policies. Under this view, water should be managed in an internationalized way, integrating methodologies and techniques mainly used in the sciences of international relations and diplomacy.

The principles of sustainable development introduced the need for the innovative "Green" or "Environmental" Diplomacy, which aims at strengthening international co-operation for environmental protection under the framework of good neighboring and management of common goods. In the water sector, this new diplomatic approach is known as "Hydrodiplomacy". The main principles of this new scientific sector are compatible with those of sustainability: effectiveness, efficiency, equality, equivalence and equity.

Management of Transboundary Rivers is a major issue for Greece as the majority of North Greece's rivers originate in neighbour countries. In addition to this fact, Greece is the downstream country in four out of the five shared rivers and roughly 25% of the country's renewable resources are "imported". Inevitably, the applied management policy of the upstream countries affects directly every economic, industrial, in some cases tourist development and the protection of important ecosystems in N. Greece. Since Greece is a full member of the European Union, the European Guidelines provide the platform in which Hydrodiplomacy can be based on. In relation to water management, the new Water Framework Directive 2000/60 introduces river basin management and integrated water management, not only for the European Union members but also for the candidate countries, providing a common framework between countries for the co-operation, planning and management of water resources.

2. THE CASE OF TRANSBOUNDARY RIVER NESTOS / MESTA

The river Nestos/ Mesta catchment area is situated in SW of Bulgaria and in the region of eastern Macedonia and western Thrace in Greece. The 60% of the catchment area belong to Bulgaria while the rest to Greece. The river flows from the mountain Rila (height 2716m) in southern Bulgaria and after a distance of approximately 230Km in both Bulgarian and Greek territories discharges into the Thracian Sea [1]. There are 212 settlements in the basin, 93 in the Bulgarian and 119 in the Greek territory. In total about 176.000 people live in the basin, 133.000 in Bulgaria and 43.000 in Greece, which are mainly occupied in the primary sector. The area is mainly covered by forests and therefore there are a lot of important environmental protected areas (e.g. National Park of Pirin Mountains, Delta of the river).

Figure 1:. Nestos/ Mesta river

The main economic activities in the catchment as a whole are: agriculture, forestry, power industry (only in the Greek territory), cattle breeding and recreation. Nestos river supplies water for four irrigation systems, from which two are in Bulgaria and two in Greece. In the Greek territory, the majority of irrigated land from Nestos flow is sited at the southern part of the basin, at the Delta area. The two irrigation systems, sited left and right to the river, cover an area of 131km^2 [2]. The total irrigated land in the Bulgarian territory covers 174km^2 [2]. Nestos river is also used for energy production. In the Greek territory the Public Power Corporation has constructed two dams for energy production. The first has a total storage volume of $565*10^6$ m^3 and energy productivity of 425GWh. The second is much smaller in size (storage volume $11*10^6$ m^3) and is mainly used for water flow control. In Bulgaria in 1989 construction works for a dam started but stopped in 1990 by a decision of the National Assembly of Bulgaria. At the moment the construction of two small dams on some tributaries of the Nestos river is planned, which will be used for irrigation, industrial water supply, water power production (250 KW and 34 KW respectively) and recreation [2]. Also the diversion of water flow to other basins is projected.

The main problems identified in the Nestos / Mesta basin refer to water management issues, environmental protection and economic development. More specific these are [1,3]:

- Different socio-economic conditions between the two countries. Moreover, Bulgaria is in a new political status where the transition to free market-economy conditions is still unclear.

- No common water resource management and environmental protection plan has been established yet. This is especially hindered by the disparities between national monitoring and legislative systems between the two countries.

- Pollution sources along the river are not quantified, creating therefore a risky environment for the river's management, as well as for the environmental status of the protected areas.

- The lack of integrated water management and allocation leads to inefficient environmental preservation and economic development.

- The agricultural development in the river basin depends directly upon the existence of a joint integrated framework for the management of the river.

- The infrastructure in both sides of the reference area is poor.

- European principles and priorities concerning sustainable development and joint water management have not yet been fully adopted by the Bulgarian government.

Having in mind the problems highlighted, the objective for the Nestos Mesta catchment area is to manage successfully water quantity and quality issues in order to achieve a good environmental status in the area and ensure economic activity.

3. THE GREEK-BULGARIAN AGREEMENT

The late agreement was signed in 22nd of December 1995 and since then both countries failed to show a joint effort to put it into action. The most important concern of the Greek side was to secure a standard amount of water resources. The agreement sets as Greece's rights to the water of Nestos the 29% of the total volume that is generated in the Bulgarian territories [4]. Both parties are bound to exchange information concerning the water status and any development plans that would affect the natural flow of the river. International conventions, standards and European guidance are also applicable for the improvement of water quality and the conservation of the ecosystem. The estimation of the water quality will be done using standards and methodologies suggested by EU and accepted by the two parties. Moreover, a cross-border Commission of Hydroeconomy will be established, responsible for the observation and control of the application of the agreement. The commission will also be the intermediary factor for any possible disputes and in case of failure, the matter will be forwarded to a governmental level**.** The agreement will be in force for 35 years.

Almost ten years after the signing of the agreement, there are still no major changes on the management of Nestos River. Although the agreement constitutes a law for both countries since 1995, no significant steps have been taken towards its implementation. In addition to that, the articles are characterized by generalities without providing specific guidelines for the implementation phase and in the same time serious omissions on subjects not covered by the agreement are observed.

The text of the agreement includes some of the main principles set by the WFD but in practice there are two negative facts. Firstly, the articles of the agreement are characterized by generalities [2]. More specifically:

- It is not specified if the proportion of 29% to be released by Bulgaria refers to monthly or yearly flows. This fact allows provides the Bulgarian side the privilege of taking their own decisions on this matter.

- The agreement does not cover the flow that is essential for the preservation of the ecosystems. In case of extreme droughts a minimum amount of water flowing into the river channel has to be maintained without which the environmental damage would be irreversible. The agreement must cover the case of this amount being more than the current 29%.

- While the co-operation between the countries for pollution issues is promoted, the two countries have not proceeded to the creation of a list with the priority hazardous substances and their limits.
- It is suggested that both countries use the same processes of measurements but without specifying the exact type of measurements, their frequency or the proposed points of sampling.
- No precaution has been taken for alternative scenarios in case of extreme phenomena (floods, droughts)

The agreement contains some of the basic principles set in the WFD, as the spirit of co-operation and the exchange of data. Moreover, the decision for the creation of a joint committee is in accordance with the requirement of the WFD for the formation of a competent authority responsible for the thorough management of the catchment. Nevertheless, serious omissions and generalities characterize the agreement, which remains inactive until today. Hence, there is an urgent need for a more detailed elaboration and a review of the agreed conditions bearing in mind the WFD and the Helsinki Rules (UN Convention 1992).

4. EUROPEAN PROJECTS ADDRESSING TRANSBOUNDARY WATER MANAGEMENT

European Union places a great importance on integrated water management and transboundary co-operation by creating legislative tools, like the Water Framework Directive 2000/60, and promoting Hydro-diplomacy in order to harmonize the methodologies and enhance co-operation. A number of research projects have been funded in this direction. Aristotle University of Thessaloniki has participated in two projects concerning the transboundary water basin of Nestos River in Greece: IRON CURTAIN and TRANSCAT.

4.1 The IRON CURTAIN project

The «IRON CURTAIN» project belongs to the fifth framework programme of the European Union and more precisely to the part «Quality of Life and Management of Living Resources». Is a three years project (2001-2004) in which participated universities, research institutes and agencies from 8 countries (Norway, Russia, Germany, Czech, Austria, Hungary, Greece, Bulgaria).The goal of the project was to develop a methodology leading to standardized tools and procedures for integrated resource evaluation, analysis and management following the principles of sustainable development. This was tested and scaled in six case studies along a European north/south traverse: Pasvik river (NO-RU), Rhon mountains (DE), Sumava catchment (DE-CZ), Euro-region Silva Nortica (AU-CZ), Kekfrankos (AU-HU), Nestos river (GR-BG).

The proposed methodology of the project is presented in figure 2. The starting point is the detailed and structured identification of problems for the reference area. The methodology for problem identification is guided by the recommendations of the Logical Framework Approach (LFA) [5,6] and had been implemented successfully during a sequence of cross-border workshops on regional development. The results of these workshops were problem trees, causal relationships between the problems mentioned, hierarchically ordered in a tree-like manner. Thus, the solution of each problem requests the underlying problem(s) to be solved and shows possible starting points for intervention strategies [7].

The next step is SWOT analysis, which is an effective method of analysis consisting of two parts. It includes the analysis of internal situation (strengths and weaknesses) and the analysis of the external environment (opportunities and threats). The problem tree and SWOT analysis are followed by the objective tree and thus the goal system is formulated for each reference area. The objectives are linked with indicators to display the situation as it is and to assess steps forward into the direction of the ultimate goal, called vision. The solution of the problems is a set of options, combined in scenarios. Scenarios can be market oriented, legal or environmental oriented. Each scenario refers to a change in the current state of the key factors (water resources, agriculture and environment), while also the maintenance of the current situation is also a scenario (status quo scenario).

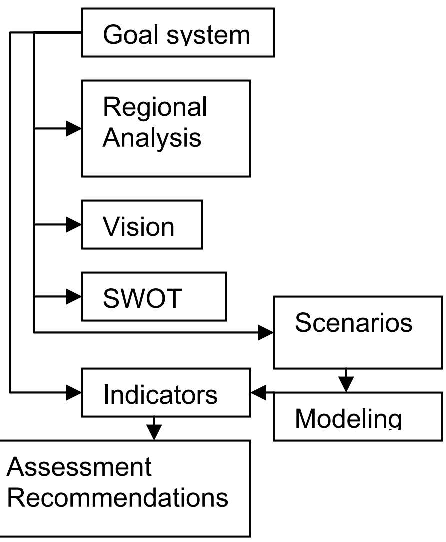

Figure 2.: Project methodology (Friedrich-Schiller-University, Department of Geography, Jena, Germany)

Modeling is used to evaluate the different scenarios in relation to the objective's achievement. A decision support tool developed in the Iron Curtain project was applied, combining Linear Programming with Emergy Analysis, in order to assess agricultural practice with respect to possible scenarios. Emergy analysis is used for the assessment of sustainability (combining its economic and environmental aspects) of crop production, which is an input-output analysis framework, based on the "energy-history (memory)" of all (monetized and non-monetized) contributing inputs and resulting outputs of crop production. The emergies of all inputs, renewable,non renewable sources, and purchased inputs from economy were calculated by using related transformities. Then Emergy indices have been calculated for each crop for each scenario.

The analysis of scenarios revealed that profit from irrigated agriculture can be increased through sustainable use of resources in an optimized crop mix. The ecological scenario was found generally more sustainable, expressed by partly slightly better scores in indices, than the economic scenarios. The legal scenario shows considerable improvements in relation to sustainability compared to the status quo, so it could be a considerable short term alternative.

The conclusions drawn in relation to agricultural practice are:

- The trend of farmers to cultivate traditional crops (with low profit) instead of more economic efficient ones can be ascribed to: 1) the lack of effectiveness of administrative offices to enforce new agricultural practices, 2) the lack of willingness of farmers to be educated in cultivating other crops besides the traditional ones and 3) market and agricultural policy (CAP) limitations. Decision-makers should find ways to inform and educate farmers about the economic sustainability of crop production.

- Crops with high profit have also high Environmental Loading Ratios, due to the increased need of fertilizers and pesticides. So, if their cultivation is to be promoted, it should be combined with guidelines for wise use of fertilizers for environmental protection purposes. An integrated evaluation of agricultural practices should include a, both economic and environmental, cost-benefit analysis.

- Changes in crop mixes can lead to higher profit and less water demand, but sometimes also to a decrease in the number of people employed in agriculture. In such case alternative income sources should be found. Eco-tourism can be one of them.

- The analysis results showed that even with a 50% decrease of the river flow, irrigated agriculture can still be profitable with a proper crop mix. This finding emphasizes the need for “monitored” agriculture, where decisions on what to be cultivated are based on resources availability criteria and not on farmer’s habits. Agriculture administration offices should have this role.

So it is clear that for overall sustainability, all sectors should be taken into account.

For the integrated water management of the river basin some key aspects should be taken into account:

- Effective cooperation between the two countries is feasible if it is based on the principles of good neighborliness and reciprocity. The treaty signed between the two countries, international laws and directives can provide the framework for the development of a common river basin plan.

- A thorough water mass balance, in the whole catchment has never been done in a formal basis. Such an analysis can provide information for the allocation of the water between the two countries and a better distribution of the water resources in the different uses.

- The current infrastructure not only related to the management of water resources but also to social welfare, is very poor in the area. Actions for the amelioration of the infrastructure are of great importance.

- The major economic activity is agriculture. Since irrigated agriculture is the biggest consumer of water resources, steps should be made in transforming current agricultural practices to more sustainable ones.

- A plan for ecosystem management has not yet been formulated and so an effort should be made in this direction.

- SC involvement in formulating development actions should be encouraged, as they can provide the necessary information.

But under the principle of river basin-wide management, all these actions should be integrated in transboundary level.

4.2 The TRANSCAT project

Integrated water management in transboundary catchment areas in Europe is among the major issues to be addressed in the future. The new WFD offers the conceptual framework for this purpose. TRANSCAT aims at the development of the technical tools needed to support decisions for integrated water management in cross border catchment areas.

More specifically the project's objective is the design and development of a prototype for an operational integrated DSS of a comprehensive character, including multilingual facilities, interactive visualisation interface, and the possibility of plugging in numerical models, particularly of the cross-border water resource system. Decision support tools will address problems ranging from operational management, involving information basis and modelling, dominating the day-to-day catchment management work, to strategic decision analysis and making, with the use of multiple option and multiple objective assessment tools, as well as distributed decision instruments facilitating participative management. The system will be tested for the conditions of the transboundary pilot areas.

TRANSCAT also contributes to the enhancement of Public Participation and in the analysis of the legal and institutional status in the Pilot Areas. More specifically, the sub-objectives are:

1) Contribute to the identification of relevant existing and potential differences in transboundary water systems.
2) Contribute to the individuation of legal and institutional problems related to the transboundary water management in the framework of the implementation of the WFD and to support European Policies for water resources optimisation.
3) Promote awareness among the stakeholders about the need to pursue and achieve an integrated water resources management, under the aegis of the WFD and in compliance with the concept of International River Basin District.
4) Contribution to the discussion about the harmonisation of integrated catchment modelling and promoting and moderating discussion on it, with the aim to support the implementation of the EU WFD.

TRANSCAT is comprised by 10 Workpackages (WPs) as reported in the diagram below, which have been distinguished into "horizontal" and technical WPs. The "horizontal" WPs are lasting over the whole project, feeding and influencing the other WPs as well as the right progress of the project activities.

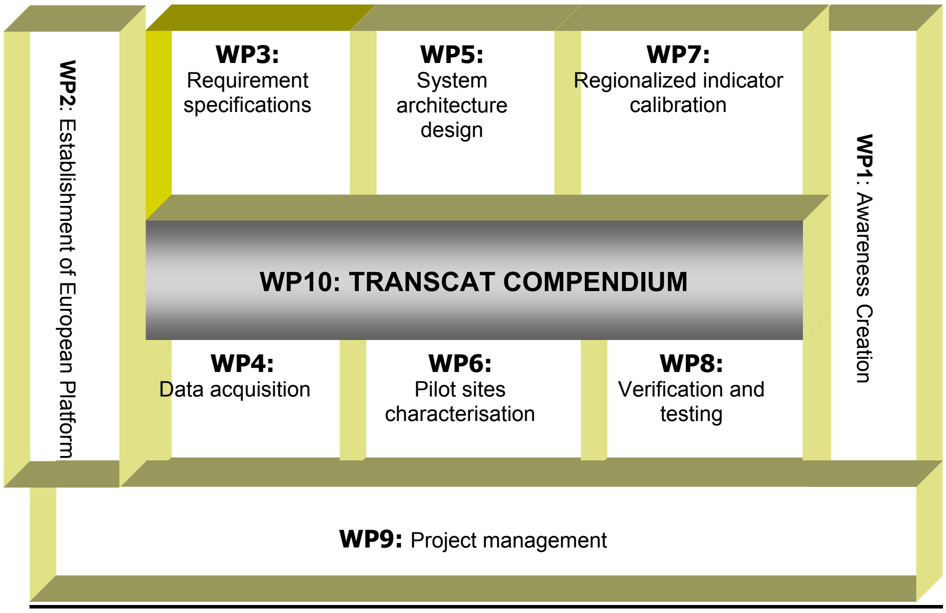

Figure 3: Transcat's WPs

The developed multi-lingual DSS will comprise an innovative tool for the management of transboundary catchments, incorporating environmental, socio-economic and cross-border issues. Nine European countries participate in the project and five pilot sites have been selected in order to provide a good contrast in transboundary area typology. River Nestos shared with Bulgaria was chosen as the Greek reference area where the DSS is primarily focused on water quantities issues and socio-economic models with the possibility of extending its functions to incorporate water quality models.

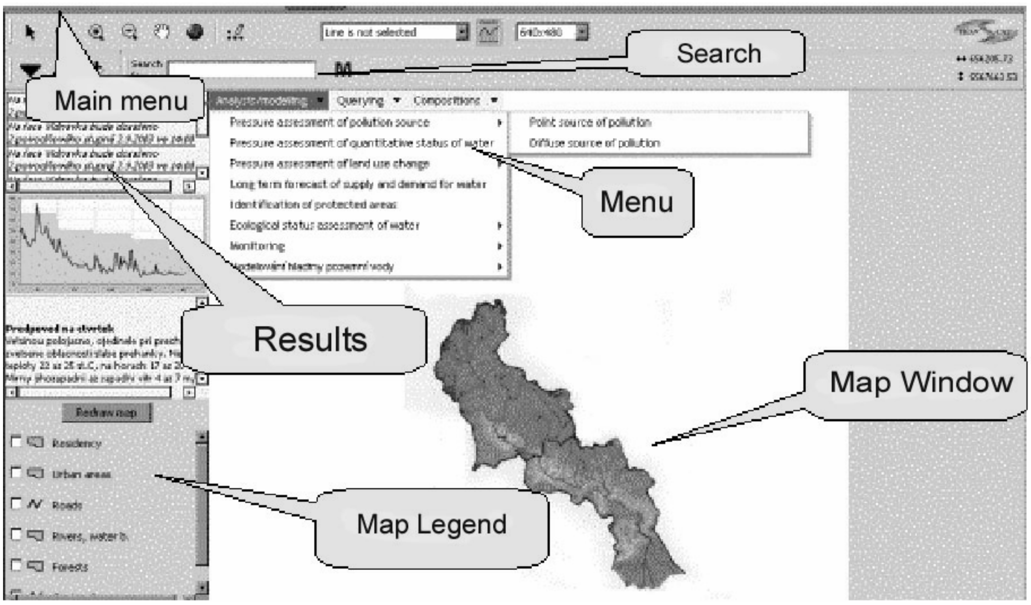

Figure 4: TRANSCAT DSS

Moreover, the project enhances public participation and cross-border co-operation through a series of Greek-Bulgarian meetings that took place the last two years. Participation of the stakeholders is constant since the beginning of the project and the developed DSS is reflecting their needs and requirements. Their answers in questionnaires set the basis for the selection of the DSS's functions that will be applicable in each Pilot Area. The following graph shows the main problems of Nestos area as indicated by the local authorities and stakeholders. These provide the directions on how TRANSCAT DSS will be formed for the Greek-Bulgarian reference area.

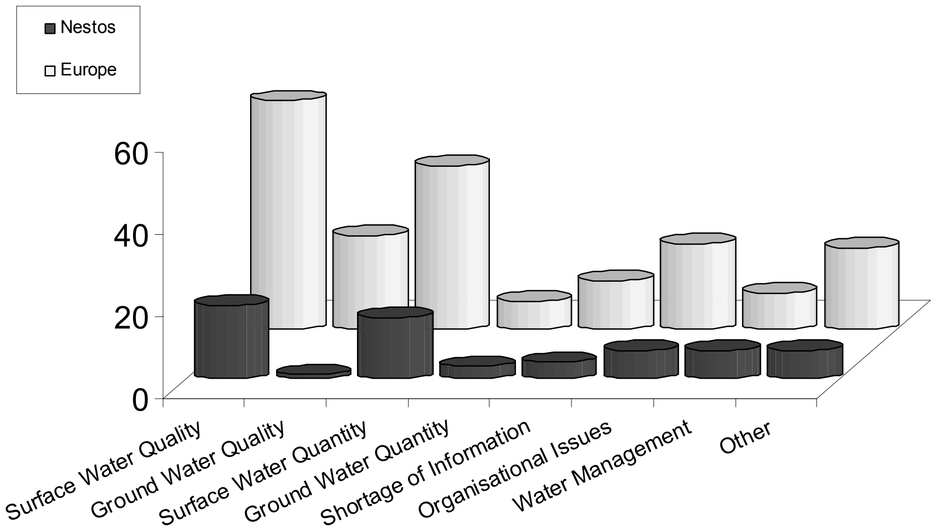

Figure 5: The main problems of Nestos/Mesta cathcment

The novelty of TRANSCAT project lies on the fact that the developed DSS will be widely applicable as it is being formed taking into account representative European catchments. Hence, the DSS will be able to incorporate diverse situations while promoting public participation in water management. In the same time, TRANSCAT follows the European guidelines and cooperates with other European projects of the same framework. The methods used in the project refer to recent evolutions in the decision making sector. The web application of the DSS will ensure the participation of local authorities and the public information while offering the necessary protection of the data.

The completion of the DSS is expected in 2006 and it is anticipated to comprise a useful tool towards the water resources management of transboundary catchments.

5. CONCLUSIONS

Transboundary water resources of North Greece constitute a major asset for the country and introduce high uncertainty for the country's imported water due to the lack of efficient transboundary agreements.

The WFD could act as a guideline for international co-operation.as it promotes the management of transboundary watercourses among EU and non EU countries . It requires the establishment of common management plans at the river basin level whereas the bilateral agreements signed so far between Greece and its neighbor countries do not contain similar provisions and none of the joint body established so far has the competence to undertake this responsibility. The issue of common planning and management is of great importance in effective transboundary co-operation. Since almost all of the neighbor countries are in an era of transition, it is a great opportunity for Greece as an EU full member state to proceed to agreements for the benefit of all.

The two European projects described play a major role in the development of the area as they offer a common scientific language, common schemes, the support of local authorities and the introduction of new methodologies. What is needed in practice is the political will for the promotion of "Hydrodiplomacy" in order to strengthen the mutual trust and to achieve welfare and ecological stability of the transboundary water resources.

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The Cyprus experience in planning Water Resources Management: Past and Future

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ABSTRACT

Cyprus, an arid to semi-arid island, has practically developed all its conventional water resources and ranks high in terms of surface reservoir capacity per capita. At the same time it has overexploited all its aquifer systems and in the last few years has brought non conventional water resources into stream such as desalination and reuse of treated effluents. The faltering agriculture is still the main user but at the same time the growing tourist sector and the rising living standards continuously press for more water. Water scarcity continues to lurk and creates anxiety. An anthology of the wealth of gained experience in the planning and managing water resources is presented showing that water scarcity is so much a supply challenge as much as it is good governance and a water allocation challenge.

1. INTRODUCTION

An attempt for a technically insightful presentation of the Cyprus experience in planning water resource management is a difficult task and many of the intricacies of the subject may be left out. Furthermore, many concepts and issues presented may at least be controversial and even stepping on toes. In my small capacity as water resources specialist I was involved throughout the most important period of the water development planning and implementation in the island (1966 to 2002) and I have my share for whatever went wrong. It is easy to criticize after the effect. The main thing one has to bear in mind is that the enthusiasm for developing the water resources of the island and help the economy, possibly overshadowed other considerations such as environment, repercussions on water resources by development, changes in agricultural practice, changes in political conditions affecting exports or imports, sectoral changes such as tourism versus agriculture and many others.

In the short life of the Cyprus Republic since 1960, the water issue has many a times been quoted as the second biggest problem of the island after the political problem. True to this, the water sector has received the largest part of government investment for development. As a result, Cyprus can today claim to be among the first in dam capacity per capita, among the first in its aquifers utilization and among the most advanced in terms of evaluation of its available water resources, an advanced user of water efficient irrigation systems, and with a populace that is well aware of its water problems. Very frequently Cyprus is quoted as an example of a success story for water development and management. How correct this impression is and what are the realities and the problems associated with it will be the subject of this presentation.

By the early 1990s practically all the major dams and inter-basin water infrastructure were completed and yet by the late 1990s the island faced one of the most serious shortages of water. Water stored in dams was at its lowest, as low as 5 to 10%, the aquifers were at their maximum depletion and seriously threatened by an advancing sea water intrusion, and water was rationed both to domestic supply and agriculture, with the latter seriously facing survival.

Has the water crisis of the late 1990s been created more by bad planning and management than by nature? Is the apparent lack of adequate water a real problem or one created by poor planning or by overextended use of available water resources?

Should we have concentrated our policies more on managing demand, changes in legal, economic and other institutional aspects rather than on costly new construction projects? Subsidizing water for irrigation in a country where water is scarce by nature does not help the situation but then what will happen to the small farmer? How will the island look if irrigated agriculture is abandoned? How do we cope with the growing tourism demand and its competition with the agricultural sector on water and other resources? How will the implementation of the European Water Framework Directive help in the improved management of the island's water resources and what implications and repercussions will it have on the Cypriot farmer and other water users, on the decision makers and planners and on the water resource managers in general?

These are questions that will be attempted to be addressed.

The premise of this presentation revolves around two basic positions:

a) That "the human right to water is indispensable for leading a life in human dignity" and,

b) That "water scarcity is so much a supply challenge as much as it is a good governance and water allocation challenge".

2. THE PAST

Some 60 years ago irrigation was based on the seasonal flows of the streams. In the plains, mules or donkeys were turning chains of buckets drawing water from shallow wells. In the mountains, where the flow in streams was lasting much longer, water was being diverted by canals for flooding the fields on the basis of intricate water rights dating back to the ottoman rule. Chains-of-wells, a system similar to the Persian kanats were extensively used to prolong the availability of water from streams for water supply and irrigation. These were subterranean tunnels dug in the riverbed which then following a gradient they would discharge water at far distances to the surface.

Soon after, windmills made their appearance and by the thousands dotted the landscape in the plains. These were followed by pumps and drilling machines which opened the way for deeper aquifer exploitation. The registered number of boreholes is in excess of 50000 throughout the island. In the late 40s and the 50s the Government was carrying out all the drilling, and private boreholes were heavily subsidized. Private drillers appeared in the late 50s and with them illegal drilling started to become a serious problem. The first indications of groundwater mining and sea intrusion started appearing.

Water scarcity was the norm and the irrigated agriculture was confined only in areas of shallow water tables or near streams flowing for only part of the year and in fact during winter and spring. Modern irrigated agriculture under these conditions could not be practiced and domestic supply for the major urban centers was not secured or sufficient.

3. THE DAMS

To alleviate water scarcity strangling the national economy, Cyprus, since the 1960s, embarked in a program to increase water supply by constructing dams and conveyance infrastructure under the motto “Not a drop of water to the sea”.

Since 1960, the freshwater storage capacity was increased 50 times from 6 million m^3 to 300 million m^3. Nowadays Cyprus ranks as one of the countries with the highest degree of dam development in the world. Water storage capacity in Cyprus is about twice the average annual runoff and a good degree of national water security was achieved in the face of unreliable rainfall.

Many of the larger dams have spilt water over their spillways only last year owing to their large capacity with respect to annual runoff and a persistent dry spell. While most river catchments are small, the construction of the Paphos and the Khrysokhou irrigation projects and especially the Southern Conveyor, with controlled connections to rural and urban user communities, enabled wide area water management.

The implementation of these water projects transformed the commanded land radically and lands that were never irrigated before found themselves with a hydrant valve and an access road. Land consolidation and modern irrigation systems were promoted, new plant varieties were introduced and modern agriculture had come to stay.

The vagaries of weather, changing market prices for produce and labor costs took a toll on the early enthusiasm of water development and use. At the same time tourism started expanding dramatically outpacing all other sectors of the economy and competing for labor and resources. Furthermore, with the increase of the standard of living and the expanding tourism and due to the extraordinarily prolonged drought of the 90s more of the available water resources were being primarily committed for drinking purposes rather than for agriculture. Commitments made for agriculture could not be fully met or continued.

Of all possible dams that engineering can construct in Cyprus, a large list taken from the more attractive opportunities has already been implemented. More dams are possible but carry a high price tag: the cost of water from new sources is higher than the cost of water that has already been developed.

4. THE NON CONVENTIONAL WATER RESOURCES

When the large water development projects were planned in the 1980s, desalination and reuse of treated waste water were thought to be required to come in stream after the 2010 time horizon. Nonetheless, these became part of the water policy as early as the mid 90s.

4.1 Desalination:

Aggravated water scarcity in the 1990’s and the deficient situation of water supply for domestic use, including the growing tourist sector, necessitated swift and decisive measures to ensure a stable and continued supply of good quality drinking water. This could only be done through seawater desalination.

Two desalination plants are presently in operation, one at Dhekelia built on 1997 at a daily production rate of 40000 cubic meters at 54 cents/m^3 (0,92 €) and the second at Larnaca airport since 2001, producing 51000 cubic meters per day at 41 cent/m^3 (0,7 €) . Both are under BOOT financial arrangement and they both use the Reverse Osmosis method.

The measure was successful in providing to the domestic sector, including the economically important tourist industry, a steady supply. However, considering that close to 70% of all water resources on Cyprus are used by agriculture, a sector that contributes only a minor part to national wealth and struggles with labor scarcity problems, a close scrutiny of water allocation policy appears to be in order. It is important, in setting policies, to consider the ways in which water can best contribute to national wealth.

The end of the drought by 2001 brought an end to the policy of providing desalinated water to all urban centers and the plans for plants at Limassol and Paphos were abandoned. Following the very wet winter of 2004 a decision has been made to buy out the Dhekelia plant, rehabilitate it with new technology and operate it on demand.

4.2 Water recycling:

A substantial amount of water is becoming available for reuse for agriculture and the urban and rural environment. Recycled domestic water is a growing resource in Cyprus. Policies need to strengthen its role in enhancing the urban and rural environment (green areas, parks, forestation), in backing up agricultural water needs and in recharging groundwater reserves. Policies should probably discourage using the boon of recycled water for expanding an already subsidized agriculture.

At present only about 3 million cubic meters of tertiary treated sewage effluent is used for agriculture and landscape irrigation. The crops irrigated with recycled water are citrus, olives, vines and fodders. It is estimated that by the year 2012 an amount of approximately 30 million m^3 of treated sewage effluent will be available for agriculture and landscape irrigation.

5. THE WATER MANAGEMENT

In the brief presentation made so far, the water development efforts made in the past 50 years and the agonizing and continuous effort in harnessing the water resources of the island and satisfying the ever growing thirst within a practically arid environment has been shown. Huge investments have been made to this end but nonetheless the water scarcity problem is far from being solved and an uninterrupted supply having been secured. Obviously, water scarcity is not only a supply challenge but also a good governance and water allocation challenge.

Water management in Cyprus has met difficulties owing to the inherited legal and institutional framework. Most of these problems have been on the discussion table in the past 40 years and many proposals and legislation formulations have been put forward for their rectification. The entry of Cyprus into the European Union gave a new impetus in solving these problems but to this moment no final decisions have been taken. Furthermore, new legislative measures harmonizing the Cyprus legislation to that of the EU may be complicating matters even more since there does not appear that these are accompanied by the required staffing to meet the new requirements.

Most of the problems arise from the fragmentation of jurisdiction in the planning, design, implementation and control of the water resources management. The Water Development Department of the Ministry of Agriculture, Natural Resources and Environment, is responsible at the executive level for water management at the technical level and to this effect the situation is very good. However, effective decision-making, implementation of works and enforcement is made difficult because legal and management responsibilities rest with the District Officers of the Ministry for the Interior. These difficulties lead to considerable delays in project authorization, implementation and effective overall water management. Through various laws, the District Officer is the controlling authority at the user level. The WDD and the Department of Agriculture assist the District Officer in an advisory capacity on technical matters. This is not a satisfactory arrangement because there is no single agency responsible. When there is a conflict of interest and purpose, the technical departments are unable to implement agricultural policy even though it should be a major criterion in irrigation works and to define domestic water supply allocation.

In the discussion that follows and within the limited length of this presentation some of the positive and negative points derived from the past experience in water management in the island are highlighted under the major headings of supply, governance and water allocation.

5.1 The Supply Challenge

The built water infrastructure has been the result of master-plans, extensive and comprehensive feasibility studies and sound workmanship. This infrastructure has been designed with a 2 to 3 year capacity under normal weather conditions and involves extensive inter-basin transfers which allow considerable flexibility in the water management in most of the areas of the island.

The experienced problems associated with this development were:

- The inclusion of far more new lands for irrigation and the creation of new demand that did not exist before in order to achieve economically sound projects.
- The exclusion of the dry weather conditions of 1931 -33 and 1970-73 on the assumption that the intervening 40-year sequence was sufficient for the evaluation of the hydrology and yield of the works. This was done for enabling larger areas to be included.
- Lobbying by farmers and political pressure promoted further this problem since land under irrigation results to a great increase (tenfold) to its value. Furthermore, lands commanded by a water project fell under “land consolidation” which enabled land development for resort housing with water availability and access roads.
- The comparatively high cost of surface water for irrigation, although subsidized, to the cost of groundwater (operation costs only), led to the over-exploitation of the aquifer systems in the island, the reduction of their yield, sea-intrusion and groundwater quality deterioration.
- Added to the above, was the decisive reduction of natural recharge to downstream aquifers due to the cut-off effected by the dams, the subsequent built up of nitrates, pesticides and other substances in the groundwater due to increased irrigation with water from the reservoirs and the absence of the flashing effect of

winter floods. The motto of the original planning strategy "not a drop to the sea" is at least today questionable on environmental grounds and on the fate to downstream aquifers and users.

- The cropping pattern within the commanded areas followed the market trends rather than what was envisaged at the planning stage, resulting to high water demanding crops such as bananas rather than table-grapes.
- One should have been more prudent in view of the arid to semi – arid nature of the climate of the island and the unavoidable recurrence of drought spells. The devastating results of the above were felt with the occurrence of the drought spell of 1990 onwards.
- On the other hand the lack of labor and the development of the tourist industry in certain areas did not allow the development of agriculture as planned and thus the use of the waterworks has been limited. The same effect was caused by reduced export prices of certain agricultural products (citrus, table-grapes) indicating that the market studies made during the feasibility studies were not exhaustive enough.
- The unforeseen increase in tourist development in certain areas (south-eastern Cyprus) created a water demand that could not be met by the available local resources or the built infrastructure. This was decisive in the decision for the first desalination plant.
- The domestic water tariff is way below the cost of desalinated water (CY£ 0.335 or 0.57€ as opposed to CY£ 0.62, or 1.0€ per m3). Besides recovering the cost, the water policy for this sector will have to consider disincentives to the use of drinking quality water in garden irrigation and to foster and encourage use of cheaper, lower quality water (groundwater, recycled water) for this purpose. Unaccounted water and losses in many domestic water distribution networks, mainly in rural areas, are quite high and considerable additional effort should be done to detect and replace defective pipes and to establish water awareness.
- The recycled water is a growing resource in Cyprus. Its acceptance for irrigation is far from certain as yet especially when there is alternative water available. Adjustment of pricing will encourage its use. Policies need to strengthen its role in enhancing the urban and rural environment (green areas, parks, forestation), agricultural water needs and in recharging groundwater reserves. Policies should discourage using the boon of recycled water for expanding an already subsidized agriculture. On the other hand, the recent lifting of subsidies on animal feed has raised their prices and consequently the demand for water for such produce has increased. The recycled water could be very well used for such crops.
- Seawater desalination has ensured a continued supply of good quality drinking water for domestic uses, including the economically important tourist industry. However, it represents a trend that leads the island's water security into dependence on oil imports for desalination.

5.2 The Governance

The problems that arise from the fragmentation of jurisdiction in the planning, design, implementation and control of the water resources management have already been mentioned. Efforts for creating a single Water Authority and the amalgamation of legislation have been under discussion in the past 40 years without a clear decision on the matter.

The staff within the government departments, and especially in the Water Development Department, that took part in the feasibility and implementation studies of the water infrastructure in the 1970s to 1990s with their accumulated expertise has retired without adequate replacement. Hiring of young personnel has been very limited with the result that hydrological surveys on available water resources and their use had to be curtailed making management decisions and operations much more difficult than before. The impetus gained during the planning and implementation stage has been lost for the management stage.

The implementation of the Water Framework Directive and other EU Directives with the added data and decision requirements with the present level of staff available becomes a very difficult task.

Environmental concerns during the 60s to 80s were sluggish and many waterworks did not take account seriously the effects of these structures to downstream users.

Similarly, public participation sessions and efforts with all stakeholders were minimal and this affected the degree and manner of involvement of farmers in the development of projects and to the adherence to cropping patterns and other particularities of the water projects.

Outsourcing of many of the State's water resources management activities has only recently started to be made. This has to expand to activities such as monitoring and data collection. Unfortunately, the practice of the last 50 years did not allow the development of private enterprises able to cope for such duties but this is something that needs to be developed gradually if the present policy of staffing in the government departments remains to present levels.

Groundwater management has failed to meet the expectations of maintaining sustainability and strategic reserves to help mitigate effects of drought spells. Groundwater supplied most of the water needed before the construction of surface dams and still provides some 50 percent of the demand. In general, all the aquifers are overexploited, some are depleted to 15 – 20 percent of their original reserves, coastal aquifers are sea-intruded to varying extents and their yield reduced. In the last 50 years the aquifers have been thoroughly studied, modeled, surveyed, and in some of them all the extraction is metered. Special legislation for their protection has been enacted and new drilling permits are issued after considerable scrutiny. Nonetheless, the aquifers have reached their present undesirable state. What caused this state of affairs? Some of the reasons are the following:

- Well permits are issued by the District Officer with the concurrence of the Water Development Department in the main aquifers and without, in the rest of the areas.
- Well permits are considered not on the basis of the existing water balance in the area but rather on the distance from an existing well, spring or domestic supply well. Social reasons, existing irrigation commitments and similar criteria are decisive on issuing a permit.
- Illegal drilling and illegal pumping do not carry sufficient penalties and the control is sluggish. Social aspects and political pressures make this problem quite difficult to deal with. As a result in certain areas the illegal wells may be 50% of

all wells. It is obvious that farmers do not necessarily subscribe to the principles of sustainability but rather to personal income.

5.3 The Water allocation

Considering that close to 70% of all water resources on Cyprus are used by agriculture, a sector that contributes only a minor part (less than 5%) to national wealth and struggles with labor scarcity problems and marketability of produce, a close scrutiny of water allocation policy appears to be in order. This may partly be achieved if the correct price for irrigation water is charged.

Water policy for the agricultural sector may consider a number of incentives and disincentives to conciliate water availability with demand and to ensure that adequate food security and rural targets are achieved in exchange for the substantial subsidy the sector is receiving. The matter is complicated by the traditional two-tiered nature of water rights: users of government owned water systems pay the established tariff, while owners of wells do not pay. Under such circumstances, an increase in water tariffs in the public systems is bound to encourage further overexploitation and mismanagement of groundwater. The concept of equity among farmers depending on surface water distribution to those on groundwater does not exist. Realizing a policy of uniform water rates over the island remains a difficult problem.

Citrus, which takes 32 % of all irrigation water, shows a low value-in-use of water and modest net benefits and invites to closer scrutiny in agricultural water policy.

Water use efficiency, in terms of water used per ton of crop, is reasonably good. However, use of water in the services and light industries sector bears a potential to generate more and better remunerated employment.

A review of water allocation criteria and tariffs should be in order.

6. THE FUTURE AND THE CHALLENGE IN IMPLEMENTING THE WATER FRAMEWORK DIRECTIVE

Being a small isolated island, the country needs to rely on its own water resources; the biggest challenge will be the compromise between conflicting and competing uses while at the same time protecting the resource and using it in a sustainable manner. Implementation of the recently enacted legislation that harmonizes Cyprus to the EU Directives, points to the direction that future water management should follow. Implementation though of this legislation and of the WFD faces major problems some of which are:

- Insufficient quantitative and qualitative data required for the initial crucial steps in implementing the Directive;
- Lack of a rationally organized national network for observation and collection of information as well as the lack of a unified database;
- Difficulties in the coordination among the responsible authorities and all the other involved agencies;
- Limitation in sufficient expertise and appropriate human potential and necessary technological means;

- The attitude of water users;
- High implementation cost;
- Fragmentation of responsibilities, jurisdiction and lack of a unified Water Authority.

7. CONCLUDING REMARKS

Cyprus has come a long way in developing its limited water resources. Nevertheless, the pressure on its water resources by the expanding tourism, the continued agricultural activity and the increasing standard of living coupled with arid to semi-arid climatic conditions and frequent dry spells, continues to increase. This calls for a continuous effort in improving both the management of existing water resources and for the development of whatever quantities can still economically be developed. Development of unconventional water resources such as reuse of treated effluent and seawater desalination are already well in line. Other options are water demand management, reallocation of supply to less water demanding crops, reduction of losses from networks and from irrigation systems.

Groundwater should be left to recover to a reasonable level so that this resource can help to mitigate future water shortages. It is relevant for the island's water security that the adverse trend in groundwater is checked and reversed.

In the context of this presentation, it has been shown that the water crisis is as much the creation of nature as it is of man. The water crisis has been aggravated by the greed of some and the indifference of many.

It is as much the result of shortcomings in human rules and regulations as much as nature's resources. Rather than change the institutions, legal framework and manage the demand, Government pursued a continuous effort to increase the supply for the local entities that have looked to government to solve their self-imposed crises. Politicians and bureaucrats have been only too willing to exploit the void and further compound the crises.

In the past, little attention was given to the value of water left flowing undisturbed in a natural stream bed, yet we all recognize the beauty of natural streams and rivers. With the construction of dams, the flow of water downstream is stopped and the riparian habitat is destroyed.

Conflict exists between urban users of water and older agricultural users. Tourism exerts a heavy pressure on water resources competing with all other sectors. If irrigated agriculture is to remain an important component of the economic and social structure, it is vital that both urban and agricultural users increase their efforts to conserve and reuse water.

A serious review is needed for the water policies, the water management set up, the water prices, the water demand, the water allocation matrix, the environmental ramifications of water use and the public participation in these efforts.

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Characterisation of Coupled Socio-Natural Systems

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ABSTRACT

The couplings between land use, water usage and management contexts during the last half-century in the Marina Baixa (Alicante) county are analyzed bearing in mind that for decades the county's main productive sectors have been tourism and agriculture. In order to demonstrate the different development strategies and changes in land use in the area, three municipalities in very close proximity yet with contrasting characteristics have been analyzed: Benidorm, Callosa d'en Sarrià and Guadalest. Forestry usage has declined in Callosa and Benidorm, in favour of agriculture and urban development respectively. Guadalest has witnessed an increase in vegetation cover due to the abandonment of farmland but there has also been a decrease in the mass of pinewoods due to forest fires. Tourism development in Benidorm has led to an increase in developed areas. The analysis of transitions between uses indicates that Guadalest is the municipality with the greatest stability and also that which suffers the lowest degradative transitions, while Callosa shares with Benidorm high percentages of degradative transitions. The management system and the governance process analysis revealed that there exists a definite link between degradative land-use change and unsustainable management.

1. INTRODUCTION

The identification and characterisation of co-dynamic processes between landscape, water usage, management system and governance is crucial to determine the causes of structural change in a socio-natural system of semi-arid Spain. Our hypothesis is that if co-dynamic processes cause structural change in socio-natural systems, then structural change could offer the key through which to identify the characteristics of both the type of resilience and adaptive capacity that maintains the long-term sustainability of a socio-natural system (Walker et al, 2002, see also Gunderson & Holling, 2002). In this study the characteristics of the type of resilience we are interested in locating provides a socio-natural system with the potential to adapt or reorganize in a desirable way following disturbance driven change (Gunderson & Holling, 2002) that is caused by significant and regular water transfers. Therefore, the ultimate challenge in this study is to locate the reciprocal co-dynamic processes that promote the type of structural change that increases the ecological, as well as the social resilience and adaptive capacity of the water using communities in the study area. The aim then is to analyse structural change in the natural as well as the social system and the nature of the reciprocal co-dynamic processes that promote both ecological and social adaptive capacity.

2. METHODS

The Marina Baixa catchment area, (MB, 671 km^2), located on the border between a semi-arid rainshadow climate and a dry climate, comprises a complex and varied topography characterised by dense land occupation where irrigated crops (medlars, citrus and other fruits) and dry crops (carobs, olives and almonds) predominate together with developed and industrial areas as well as an abrupt area of Mediterranean woodland. It is one of the nine counties that conform the province of Alicante and is one of the regions that has undergone the greatest socio-economic changes due to the fact that today it concentrates over 60% of the Valencian Community's tourist activity. In its turn, the Marina Baixa county comprises 18 municipalities. The main change attractors are coastal proximity (tourism) and water availability (irrigated crops).

In order to determine co-dynamic processes we identified the links between landscape structure, water usage system and governance process during recent period (1956-2000) in MB. The analysis of the physical change is focused on a) transitions patterns that are evaluated in terms of ecological sustainability and b) the identification of the key elements on management system dynamics, meanwhile c) the analysis of the governance process is focused on the dynamics of embedded and disembedded institutions concerned with water management.

Three different patterns of land cover and land use change, showing the different development strategies at work in the area are analysed in MB: Benidorm (51,873 inhabitants, 3,860 has), Callosa d'en Sarriá (7,057 inhabitants, 3,430 has) and Guadalest (180 inhabitants, 1,610 has). The first of the above is one of Europe's main coastal resorts. Guadalest, located inland has followed a development strategy completely different to that of Benidorm. It welcomes more than 2 million visitors per year who come to see the castle and its surroundings yet do not stay overnight. Callosa on the other hand is located between the above two municipalities and its strategy has been to develop the specialised irrigation cultivation of citrus fruit and medlars, a large part of the latter destined for export to EU markets.

Taking 1956, 1978 and 2000 land use and land cover maps obtained from aerial photography as our point of departure, the space-time dynamic of land use has been studied, considering 5 general categories of hydrological interest. The alterations that the changes have implied for the area's environmental quality are evaluated using transition matrices (Martens and Rotmans, 2002) where ecological complexity, environmental stability and the system's sustainability are all taken into account. We considered a set of subrogates of the ecological sustainability of the water management system: ecological complexity and stability; ecosystem services (Costanza et al. 1997) provided as steady environmental returns of natural capital.

Table 1.- Transition types: A, aggradative, D, degradative, S, stationary (no change) .

		2000				
		Urban	Dry Crops	Irrigation	Shrublands	Pine Woods
1956	Urban	S	A	A	A	A
	Dry Crops	D	S	D	A	A
	Irrigation	D	A	S	A	A
	Shrublands	D	D	D	S	A
	Pine Woods	D	D	D	D	S

A simple, non-spatially explicit, model analogous to the Markov chain transition method was generated for each combination of map pairs; 1956-1978, 1978-2000 and 1956-2000 (Dale et al., 2002). The transition's qualification criteria for ecological sustainability have taken into account the increase or reduction in indicators such as biomass, successional status, irreversibility of change or the potential to reverse a change, land fragmentation (MacGarigal and Marks, 1995), variations in water consumption, evaporation and evapotranspiration. This has enabled us to group together the transitions based on the processes that have occurred in the territory (succession, degradation, etc.) into aggradative (A) degradative (D) and no change (stationary, S) processes. In order to do this, the reduced land use categories have had to be considered giving possible 5 x 5 = 25 types of transition (see Table 1). Water balances of each land use category are calculated following Bellot et al., (1999, 2001) and Bonet et al. (in press).

3. RESULTS

The patterns of change have been very different in all of the municipalities even though the initial situations in all three cases were very similar. Forest land use, which includes the different types of natural cover (pinewoods, dense and clear shrublands and abandoned farmland), has decreased during the study period in both Callosa and Benidorm, in favour of agriculture and urban development use (caused by tourism) respectively. In Guadalest however the tendency has been towards an increase in all types of natural vegetation (20%), except for the pine woodlands which have decreased due to forest wildfires. As a result, the predominant plant cover is shrublands both with and without the presence of pine trees.

Regarding to the overall MB County, crops decreased from 43% to 23% of the territory during the study period, meanwhile forest land use increase from 56% to 68% due to land abandonment.

Since 1978 agriculture has been in steady decline in Guadalest (13%) and Benidorm (30%), while in contrast since the same year irrigation farming, especially under plastic has grown by 300%. Dry crop farming has fallen considerably in Callosa, somewhat less in Guadalest, and in Benidorm it has disappeared (Figure 1).

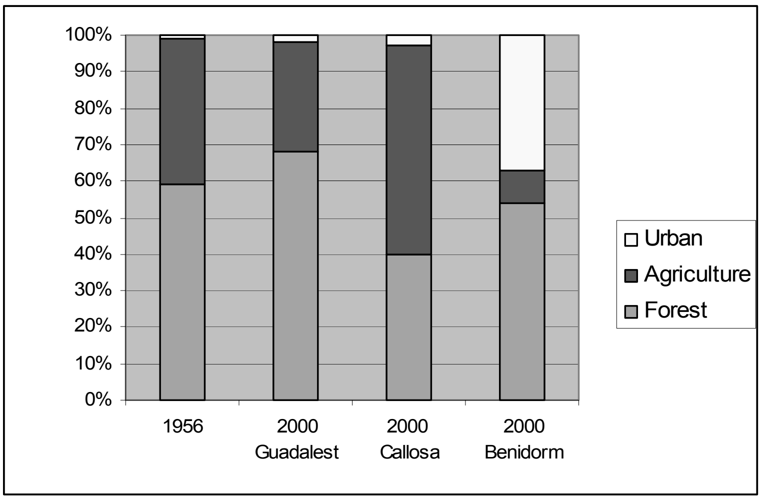

Figure 1.- Changes in land use area (%) in Benidorm, Guadalest and Callosa (MB). Agriculture includes irrigated and dry crops. Forest includes shrublands and pine woodlands. Proportions in 1956 are similar for all municipalities.

Associated urban use (settlements and infrastructure) reflects the degree of anthropisation of the territory, the use evolving differently in different municipalities (from 0.6 % to 6.4% for overall MB territory). There has been almost no change in Guadalest and Callosa since 1956 while Benidorm's initial urban area has increased fifty fold (Figure 1). Although this category occupies less land areas than forest and agricultural use, it is a new use with important consequences on the conservation of resources such as water. Its impact occurs in the last period with the appearance of industrial, commercial and above all recreational and leisure areas.

Infrastructure with which to move water has appeared in the territory, altering its natural character. In 1978 the dam to regulate the Guadalest rivers flow came into service. Although it maintained almost the same area of water it substituted an active natural system (ravines downstream the river disappears) for a controlled, passive system. The numbers of irrigation dams and swimming pools have increased during the last period in both Callosa and Benidorm, thus raising the risk of evaporation of waters that had previously been underground.

Applying the evaluation criteria to the transition matrix in the selected cases, the results show that Guadalest is the municipality with the greatest degree of stationary changes (55% of changes), and that which has the least degree of degradative changes (20%). Callosa and Benidorm share the same percentage of degradative change (>41%), while Callosa also presents the greatest degree of stationary changes. Finally, Benidorm has the largest number of transfers and is characterised by its low stationary changes and high level of degradation. However, it also has the highest percentage of aggradative transfers (29%), due to the abandonment of crop farming and afforestation (Figure 2).

With regard to water consumption, the main change in the water balance is to urban and recreational consumption, with high demand for water from outside the area (transfer) and water from reservoirs. Even though this link is significant, there is low return of water to the aquifer or to the system once it has been purified (Figures 3 and 4).

In environmental terms, Benidorm has lost all of its natural character since 50% of its territory is now occupied by urban development and infrastructure. The aquifer recharge using recovered water takes place in a polluted, salinated aquifer, such water not being suitable for human consumption. Therefore, the analysis of the real recharge of aquifers in the three municipalities and in total indicates that only Guadalest is still a source of this resource, while over time the roles of both Benidorm, in spite of its recycling measures, and especially Callosa, as sinks, increase.

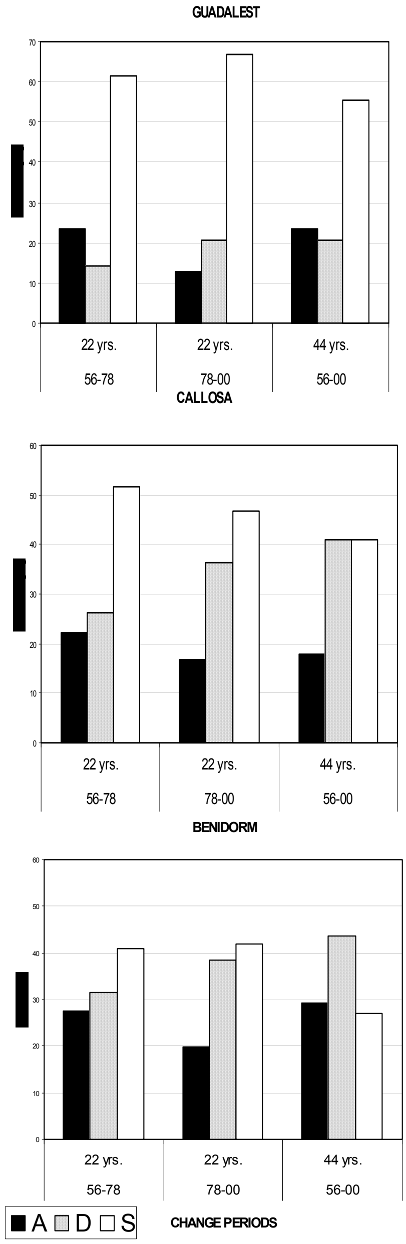

Figure 2- Types of transition: A, aggradative ; D, degradative and S, Stationary, over two 22-year periods (1956-1978; 1978-2000) as well as for the whole 44 years (1956-2000).

A global view of the situation in 1956 reflects a more rational use of the territory and greater sustainability in water consumption in that year. In 1956 Benidorm, Callosa and Guadalest had a similar composition (<1% urban, 39-43% agriculture and 56-59% forest), a situation that has been truncated in recent decades, transforming the landscape's traditional architecture, irreversibly degrading the environment and over-exploiting hydraulic resources. The lower presence of agriculture in Callosa and of tourism in Benidorm in the above period resulted in a water balance that was almost in equilibrium (a deficit of 0.9 Hm3). However, the increased complexity of water exploitation has been accompanied by greater rationalisation (Figures 3 and 4). On the other hand, it will be necessary to evaluate from an environmental point of view (biodiversity of species, ecosystems etc.) other negative and positive impacts in the area caused by the present-day surface circulation of larger volumes of water.

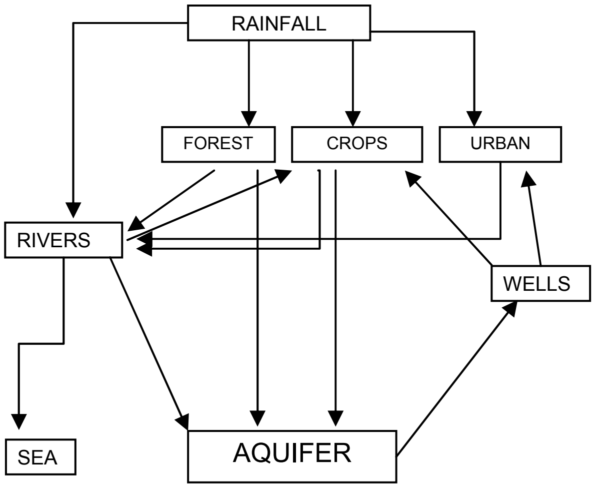

Figure 3.- Water use system during the 1950's in the Marina Baixa**.**

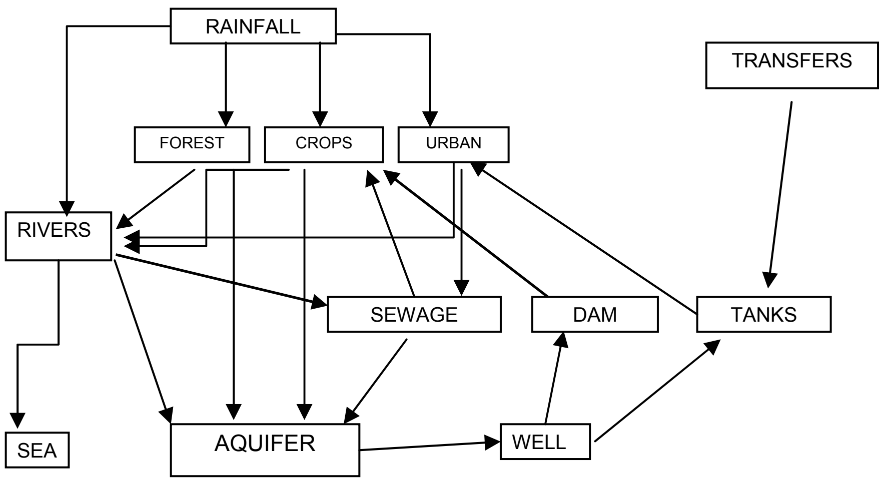

Figure 4. Water use system during in the year 2000, in the Marina Baixa

A gross water balance at county scale (Bonet et al., *in press*) indicates that natural inputs reach 355.49 Hm^3 $year^{-1}$ in the MB. The annual outputs produced by uncontrolled run-off to the sea and by evapotranspiration, are elevated to 14.71 and 257.58 Hm^3 $year^{-1}$, respectively. So, the balance is positive and, on an annual basis we can assume that water inputs to the county are sufficient to meet demand and provide an excess of 83.2 Hm^3 $year^{-1}$. However, the temporality of demands places the balance in disequilibrium, making other contributions necessary that are obtained from the aquifers or from transfers external to the system.

The hydrological model (Bonet et al., *in press*) reveals that the current annual deficit between availability and consumption is 10 Hm3.year-1. The consequence of water transfers on other ecological systems is evidenced in land use change over the time frame of the study that results in a high potential of reversibility that is proportionally more relevant in inland municipalities than in coastal municipalities when considering the MB County as a whole. Municipalities situated in more coastal locations exhibit high proportions of irreversibility of landscape change (i.e. changes from agriculture to urban

use). Unsustainable transformations of the landscape are related to the increase of urban and irrigation uses, thus indicating also an increase in the water demand.
The observed transitions in land use and water management system changes can be linked with governance context. MB because of its geographical location has a history of water deficiency. Local water-using communities have devised complex supply and demand management arrangements to accommodate this deficiency.

The water resource governance process in the MB is influenced by determinations made by disembedded institutions i.e. global water institutions, NGO's, the European Union parliamentary departments, the relevant state ministries, the relevant departments of the autonomous community and provincial governments.

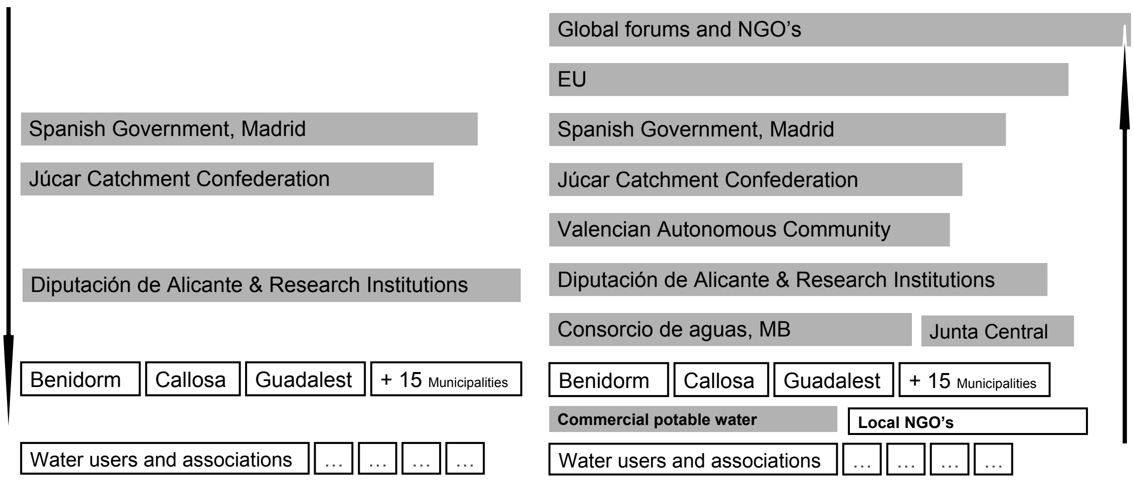

Figure 5. Embedded (clear) and disembedded (shadow) institutions concerned with water management during periods 1956-60 (left) and 1960-2000 (right) in Marina Baixa. Down arrow represents law and policy; Up arrow represents information and claims flux.

The Consorcio de Aguas de la Marina Baja (a consortium of MB coastal municipalities) is one of these complex management arrangements that emerged in 1977. Equally, the Junta Central del Usuarios del Alto y Medio Vinalopó, l'Alicanti y la Marina Baja (the central unit that will administer the proposed Júcar-Vinalopó water transfer) was ratified in 2002. Both of these institutions have emerged to respond to the ever increasing demand for water supply. The Junta Central and the Consorcio, because of their roles in the governance process, are also considered to be disembedded institutions. Together with the embedded institutions, there exist other types of embedded water user associations and local NGO's that complete the governance process. Accordingly, management responsibilities overlap in a relatively complicated hierarchical arrangement (Figure 5).

Institutions that we consider to be embedded function on at least two different layers; at community, municipal and local NGOs level. However, Comunidades de Regantes that extract and allocate water predominantly for irrigation and Ayuntamientos that source and allocate potable water appear to be the significant actors in the allocation process. Despite the apparent hierarchy of embedded and disembedded institutions, both institutional context and water resource legislation is such that these embedded institutions operate with a fair degree of autonomy that would seem imply that it is at this level that the capacity to adapt to changes in water supply and demand pattern changes could be detected. However, high volumes of this water are extracted and transferred in fairly complex inter-basin transfer arrangements (Figure 4).

4. CONCLUSIONS

Municipalities situated in more coastal positions showed high proportions of degradative transitions due to a higher degree of irreversibility of the transformations of the landscape (i.e. changes from agriculture to urban use). As a consequence of these degradative landscape changes, there is evidence of reciprocal co-dynamic processes in the physical characteristics of the water management system. Unsustainable transformations of the landscape are related to the increase of the urban and irrigation uses, thus indicating also an increase in the water demand.

It can be assumed that if there is evidence of resilience and adaptive capacity in the water governance process, it is most likely to be in the embedded institutions. These are the institutions that maintain constant and direct interaction with the resource. However, there are variations between the extensions of land that can legally be irrigated and actual irrigated areas. These variations come about as the result of either cyclical water scarcity or new clearances of land.

In terms of the effect of disembedded institutions it is difficult to neglect the emergence of the Consorcio in 1977, a municipal consortium whose sole task is to seek and administer water supply for the coastal municipalities where tourism development has been concentrated or the formation of the Junta Central that is to administer the proposed Júcar-Vinalopó water transfer, of which the MB is to receive $11.5Hm^3$. The emergence of these two institutions – whose sole task is to source and administer water supply – has established path dependence for the governance context of the MB.

In summary it would seem salient to assume that there exists a definite link between unsustainable and exponential land-use change in Benidorm and water transfers. On the other hand, the degradative trend change in Callosa, is based on the fact that it has its own water resources. The nature of the problem in this particular study is that the inter-basin and intra-basin water transfers (engineering resilience) that maintain the global stability of the hydrological system, could have ultimately locked out the type of desired co-dynamic processes and structural change that can lead to the creation and testing of alternative water sourcing and usage practices.

The result of which appears to have a negative impact on the social adaptive capacity of the human population in MB, to adapt to a new more sustainable culture. This lack of social adaptive capacity can potentially be traced to the structural change in the governance process. Moreover, the important role that these institutions assume in the water governance process, have resulted in a situation of path dependence for the water governance context. The trajectory of the water governance process is difficult to alter because the water management system is 'locked in' to a path that supports exponential land-use change that is promoted by water transfers that are currently administered by institutions that have emerged to fulfill this role (Eisenhuth, 2005).

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