# Typology and Representative Paradigms of Water Deficient Regions in Southern Europe

# Preface

Water deficiency in many regions in Southern Europe is increasingly becoming a major constraint for the economic welfare and sustainable regional development.

While in most European Countries there is no water deficit when the national long-term water balance is considered in many arid and semi-arid regions in Southern Europe there exists severe water shortage conditions. Moreover, the quality of both surface and groundwater resources is deteriorating due to the intensive use of agro-chemicals by the agricultural sector, inadequate urban waste water treatment and sea water intrusion due to overexploitation of aquifers.

A key step in analysing water deficient regions is the formulation of a typology that describes the entire range of circumstances in terms of water resources availability, water supply options, water policy options as well as institutional and socio-economic constraints.

In order to determine the issues faced in managing water resources in arid and semi-arid regions, a detailed definition was sought of the current conditions in water deficient regions in terms of water resources, water supply, use patterns, water management practices and policies.

The development of a typology is aimed at gaining a better understanding of the characteristics of the natural and man-made environment of the regions thereby depicting factors that affect the formulation and operational efficiency of an integrated water resources management approach.

The response to water shortage conditions and the forces that drive the decision-making processes in the regions is analysed by forming groups of regions that share similar approaches to water management *(paradigms)*.
This volume on developing strategies for managing and regulating water supply and demand in water deficient regions, is based on a thorough investigation of fifteen regions in the Mediterranean and is organised on the following manner:

The first Chapter outlines the criteria on which the selection of representative regions is based on and is aimed at highlighting the main characteristics of those regions. Chapter 2 introduces a methodological framework for analysing the regions in terms of natural conditions as well as the human environment that allows for identifying commonalities and gaps between water deficient regions. The various responses to water deficit conditions in terms of water policies and alternative water management options are discussed in Chapter 3. Detailed information on the fifteen regions, a summary of circumstances, the matrices of circumstances as well as the DPSIR Indicators for the regions are presented in Chapter 4.

For the collection and provision of data, the efforts of the following institutions are gratefully acknowledged: National Technical University of Athens (Greece), ProGeA Srl (Italy), INSULA (Spain), Porto University (Portugal), Water Development Department and AEOLIKI (Cyprus) and the Hebrew University of Jerusalem (Israel).

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# Chapter 1 Selecting the Regions

## Introduction

It was important to select a suitable range of regions in terms of water deficiency, in order to ensure that the analysis outcomes can eventually apply to as wide a range of water deficient areas as possible, to emphasise the regionality of water shortages, and to study those particular areas by way of characteristic case studies. There can be great differences among various regions even within a country (e.g. in terms of available resources and precipitation), so the selection of the appropriate regions was of great importance.

For that purpose, a total of **fifteen regions** in **six countries** (Cyprus, Greece, Israel, Italy, Portugal and Spain) were selected for which the range of circumstances was determined. These regions were selected based on the following criteria, or their combinations:

- The existence of Natural Aridity in the areas,
- The existence of Water Shortages on a permanent or seasonal basis due to natural or man-made reasons, or the recurrence of drought and/or flood cycles,
- The insufficient efforts of water resources management in the areas,
- The lack of proper administrative or institutional framework for the effective water resources management,
- The socio-economic conditions in the areas that affect the management of water resources.

In order to determine the existing conditions in the fifteen regions in terms of water resources and supply, use patterns, water management practices and policy-making functions, regional reports and matrices of circumstances were developed. Detailed regional data is given in Chapter 4. In this section, a brief description is provided for the areas analysed. The selected regions are depicted in Figure 1.


***Figure 1 Selected Regions***

In Greece:

- Attica prefecture that hosts over forty percent of the total population in Greece concentrated in the Capital city and the surrounding areas, with limited natural resources and haphazard development.
- Thessaly region, where large plains are intensively cultivated, requiring great quantities of irrigation water, due mainly to the crops selection.
- Cyclades, a complex of islands in the central Aegean Sea, which attract large numbers of tourists in the summer months, in a fragile area with limited natural resilience.

In Italy:

- Emilia Romagna, which hosts several large cities, has significant agricultural activities and also attracts a great number of tourists, leading to conflicts between the users over water allocation, environmental degradation and water resources overexploitation.
- Belice Basin, an area with intensive agriculture, where low rainfall as well as the inadequate infrastructure and the lack of even water distribution, does not allow full irrigation.

In Israel:

- Tel Aviv, an area with large population and significant industrial activity.
- Arava, which hosts mainly rural scattered population that is occupied with agriculture.

In Cyprus:

- Akrotiri, which hosts the urban area of Limassol and also significant cultivated plains.
- Germasogeia, an area with both agricultural and tourist activities, where water resources system is the most intensively exploited in Cyprus.
- Kokkinochoria, where tourist resorts have been developed and high efficiency irrigation is used.

In Spain:

- Canary Islands, a region that is made up by a group of volcanic islands, where the existence of intensive agriculture characterised by high water consumption, the very rapid rise of population and the spectacular development of mass tourism create serious conflicts and risks with regard to water availability.
- Doñana, which includes one of the most important wetlands of Europe, the Doñana National Park, but at the same time its surroundings host a large population.

Finally, in Portugal:

- Sado, an area where irrigation, industry and power generation demands are all of great significance.
- Guadiana, where irrigation demand and the poor water quality create deficit problems.
- Ribeiras do Algarve, a region that attracts a large number of tourists, especially in the dry semester and where there is also a lot of pressure due to irrigation water uses.

The natural characteristics as well as the human environment of the fifteen regions are briefly described in the following subsection of this chapter.

## Greece

For the process of selection of regions, the aridity and socio-economic characteristics of the Greek regions were investigated. Three particular regions emerged as the most arid:

- Attica,
- Thessaly, and
- The Aegean islands and the southern part of Crete.

The selection of these candidate regions was based on the water deficiency and aridity of the area, as mentioned above, but also on its social and economic characteristics. Each one of these three regions suffers water deficits for a different reason, which makes them good candidates for study:

Attica, the area that hosts over half of the country's population in the Capital city and the surrounding areas, suffers water deficits because of the permanent population size, which is too big for the available local water resources to cover. Water for the supply of the capital city originates mostly in other Water Regions, as the underground aquifers of Attica – not adequate since ancient times – are overall polluted and eutrophic. The water deficit in this case is permanent and caused by increased domestic demand.

The Thessaly plains are intensively cultivated, requiring large amounts of irrigation water. As has already been mentioned, large amounts of water are used for irrigation in Thessaly that could be drastically reduced by the introduction of more efficient irrigation networks and a more organised approach to the selection of crops. The water deficit in this case is seasonal, and caused by demand for irrigation.

The Cyclades islands attract large numbers of tourists in the summer months, which steeply increase the water demand to the point that it cannot be covered by the existing infrastructure and water resources. During the summer months, water demand reaches its peak both for irrigation, and for domestic supply; in some islands the summer peak may reach up to thirty times the permanent population, while water resources are very limited. The water deficit in this case is seasonal, and caused by an influx of tourist population, while there are severe conflicts with use of water for irrigation purposes.

## Italy

Of the Italian Regions examined, the following two emerged as potential candidates for investigation:

Emilia Romagna is one of the largest Italian regions, which hosts several large cities on the plain part, whereas on the mountainous part is thinly populated. The main economic activities are gathered on the plain. Except the urban and industrial development, it has significant agricultural activity. The region also attracts great number of tourists. These parallel activities lead to conflicts between the users over water allocation, environmental degradation and water resources overexploitation.

Belice Basin is located on the island of Sicily. It is an area with intensive agriculture, where low rainfall as well as the inadequate infrastructure and the lack of even water distribution create water shortage problems. Agriculture is the main sector that is affected by this shortage as irrigation demands are not fully covered.

## Israel

The Israeli National Water Carrier (NWC) connects all major sources of freshwater into a single network which serves most of the regions of the country. Thus, in principal, the management of water resources and the design of water policies can treat most of the country as a single economic entity. The region of Tel Aviv is an example of a region which served by the national water system. It is very important and interesting region for a few reasons. In terms of population it is the largest in the country with 30% of total population and it has 16,000 ha of irrigated land. Thus its water economy is characterised by (high) domestic and industrial water consumption as well as consumption of agricultural water. The region's large population creates the potential for large supply of recycled water for agricultural use as well as for rivers rehabilitation. Since the cultivated land in the region is overlying the coastal aquifer, the environmental consequences of irrigation with recycled effluents should receive a special attention. The climate in the region is semi-arid (Mediterranean climate) with annual precipitation of 450 mm. The Arava region is one of the very few regions in the country that is not connected to the national water system, and receives its water only from local system. The climate in the region is arid with very law precipitation (up to only 10 mm per year) and aridity index of 0.65.

In contrast to the region of Tel Aviv, it is sparsely populated and includes only one small tourist city (Eilat) and many rural villages. Currently, the city of Eilat is the only municipality in Israel that its water consumption is supplied via desalination of sea water (from the Red Sea). Water for the villages are supplied via local small ground water aquifers, some of them are saline. In addition, recycled effluent for irrigation is obtained from Eilat and the agricultural settlements. In contrast to the situation in Tel Aviv's region, land prices in the

Arava region are low and there is no demand for additional urbanisation in the expense of agricultural land.

## Cyprus

The selection of the three candidate regions in Cyprus was made based on the basis of water scarcity/ shortage or deficiency and aridity of the area, as mentioned above, but also on its social and economic characteristics and the complexity of the water system. Each one of these three regions suffers water deficits for a different reason, which makes them good candidates for study. These are:

- ❖ The Akrotiri aquifer area:

This was the most dynamic aquifer in the island with the annual recharge being about 32 $Mm^3$ and the extraction amounting to 10 to 15 $Mm^3$. The balance was being lost to the sea and the nearby Salt Lake through the subsurface. The completion of the Kouris dam of 115 $Mm^3$ capacity, in 1987 changed the hydrologic regime and cut off the main source of replenishment through infiltration within the Kouris riverbed. Presently the estimated annual recharge from local rainfall and return flow from irrigation is of the order of 6 to 8 $Mm^3$ while the extraction remains near the pre dam-construction levels. A major part of the balancing replenishment is made up by artificial groundwater recharge through releases from surface reservoirs into ponds and the dry streambed.

The groundwater levels are presently below mean sea level throughout most of the area of the aquifer. Sea intrusion has propagated up to 2 km and an important part of the aquifer has been rendered useless. The reduction of replenishment (leaching effect) and the increased agricultural activity using surface water from the Kouris dam has caused a trend of nitrate and other elements built up in the groundwater. The drop of the groundwater levels also affects the Salt Lake and marshland in the southern part of this area, which is of unique environmental importance. At the eastern fringe of the area lies Limassol the second largest city in Cyprus with a population of 100,000.

Until recently a large part of the domestic water supply of this city relied upon groundwater from this aquifer. At present, a number of communities as well as the British Bases still pump groundwater for their needs. The local demand for the irrigation of the citrus orchards and seasonal crops relies on surface water from Kouris dam, Polemidhia dam and Germasogeia dam, local groundwater, groundwater from within the Limassol city (high in nitrates) and tertiary treated effluent from the Limassol sewage treatment plant. Currently a sea water desalination plant is planned to start operating by 2004 and a major artificial recharge project using the tertiary treated effluent (up to 6 $Mm^3$) is being set up through recharge ponds and re-pumping for irrigation purposes.

The aquifer has excellent information for more than 30 years. It has quite a complicated water resources management system and serious management problems to address such as environmental, quality, quantity, social and economic. This area has permanent water shortage problems and it presents a unique situation for integrated management application.

- ❖ The Germasogeia aquifer:

The Germasogeia catchment is in the southern coast of Cyprus. It is about 141 square kilometres up to the Germasogeia dam, which is of 13.1 million cubic meters capacity. The average annual runoff is about 20 million cubic meters. A major part of the catchment is covered by natural forest but considerable agricultural activity is present in riparian land.

Downstream the dam a riverbed aquifer develops. This aquifer that is 5 km east of Limassol town has a length of 5.5 km and an average width of about 350 m. with an active storage of fresh water of the order of 3.5 $Mm^3$ increasing to 5.0 $Mm^3$ at high water table.

This small aquifer has been relied upon to meet the major portion of the increasing demand for the water supply of the town of Limassol and the neighbouring villages that have high seasonal water demand due to tourism.

The complete cut-off of the natural replenishment by the construction of the dam and the proximity to the sea, coupled with the increasing extraction from the aquifer, requires a co-ordinated programme of releases from the dam for artificial recharge to cope with the extraction. With such action the sea intrusion is controlled and at the same time an efficient use of the scarce water resources is made.

The catchment area has extensive hydro-meteorological, geological and hydrogeological data as well sufficient surface and groundwater quality data. It constitutes an excellent case study for conjunctive use of surface and groundwater and for evaluating drought conditions and their repercussion to the hydrologic regime and the socio-economic environment of the area.

- The Kokkinochoria aquifer:

The Kokkinochoria area is in the South-eastern part of the island, the coastal area of which has developed to an important tourist location. It is one of the most dynamic agricultural regions in the country with high-income farmers. The aquifer is made up of Miocene and Plio-Pleistocene sediments gravel, sand, silts and calcareous matrix and blocks of reef limestone. It has an areal extent of 170 $km^2$. The replenishment of about 12 to14 $Mm^3$ per year was exceeded for many years by an annual extraction of 25 $Mm^3$. The aquifer after 35 years of extensive development and mining presently holds some 10 to 15 % of its original reserves. This has resulted to excessive drawdown of the water levels, reduction in yield per well and sea intrusion.

At present, some 2500 boreholes are in operation irrigating about 6000 hectares of mainly seasonal crops, potatoes being the main crop with an estimated annual extraction of 10 $Mm^3$. The yield of these boreholes being very low at present, 1 to 7 $m^3$/h, is supplemented by surface water imported to the area by the Southern Conveyor project. Under normal years some 17 $Mm^3$ per year are envisaged to be transferred in the area from the Kouris dam, some 70 km to the west. In the last 10 years though due to a prolonged drought the quantity of water imported to the area annually has been less than 5 $Mm^3$.

With a drop of the water-table averaging to 1.5 m/y for the last 30 years, the water-table in many areas especially near the coast is located down to 40 to 50 m below mean sea level. The thickest and most productive part of the aquifer, being within 3 km from the coast has practically been sea-intruded and rendered useless.

The water deficiency problems of this area need to be addressed and alternative sources of supply, water demand management practices, change of cropping pattern and other similar issues need to be considered.

# Spain

Among the areas and regions affected by water resource deficiency, which fall within the arid and semiarid areas scope, two spaces have been selected, in view of their representative social, environmental and economic features.

- The Canary Islands. This region is made up by a group of volcanic islands with a land total area of 7,000 $km^2$ and a total population of 1,781,366 inhabitants (2001, INE). A large situation variability of water behaviour exists in the different islands. A large part of the archipelago's lands is subjected to drought conditions where disarrangements between resource availability and evolution of consumption progressively increase. The existence of intensive agriculture characterised by a high water consumption, the very rapid rise of population and the spectacular development of mass tourism create serious conflicts and risks with regard to water availability. Resorting to sea-water desalination, that was at a first beginning suggested as a complement and a security system to face supplying problems, is progressively turning to be the basis for water supply in the most arid islands.

- Doñana, region and connected hydrographic basins. The wide region of Doñana and its surroundings represents at present an authentic paradigm as regards water resource management, planning and assignment. It hosts the most important wetland of Europe, the Doñana National Park (Ramsar and World Heritage site), but at the same time its surroundings host a population of more than 100,000 inhabitants, whose activities (fundamentally recently introduced agriculture) progressively clashes with the requirements needed to maintain the seasonal water levels for the wetland conservation. The programme Doñana 2005 and the Sustainable Development Plans of the Doñana surroundings try to face the dilemma between conservation and development in a framework of water scarcity and progressive alteration of water tables in an area where quality of water, both for human consumption and for the conservation of basic ecosystems, is a serious problem.

## Portugal

According to Thornthwaite's aridity index in the river basins, three regions may be considered: a first one, north of Tejo, which can be considered humid, as precipitation exceeds evapotranspiration; a second one, sub-humid, in Douro's interior, and in some areas south of Tejo; and, a third one, arid, in Guadiana's basin, part of Sado's basin and Algarve region, where the ratio between precipitation and evapotranspiration is less than 0.5.

The basins that are currently facing water scarcity problems, with the hydric balance not enabling to guarantee water supply for different sector uses, monthly and annually, are the ones located in the arid and sub-humid regions. That figure refers some of those basins coastal areas as having not been covered by the evaluation study. Nevertheless, that doesn't mean that those areas have no problems; on the contrary, those problems may be enhanced by that littoral position, not only because the population and/or industry is mainly located there as also due to tourism (mainly in Algarve regions).

Thus the three regions selected to be candidate regions are Sado, Guadiana and Ribeiras do Algarve basins. The main reasons for these three River Basins' water scarcity current situation are:

- In the case of Sado, the main problems are related with the demands of water for irrigation (due to which Sado is the Portuguese river basin with the biggest storage capacity compared to annual mean flow) and for industry (mainly Sines' industry on the coast), and also with the demands of water for energy consumption (mainly due to cooling in thermo-electric power plants).
- As to Guadiana's, the water deficit is due to the demands of water for irrigation, to the poor quality of the water available for the various uses and to Spanish flow regularisation on summer/driest periods.
- In the case of Ribeiras do Algarve, because all the region attracts a large number of tourists, especially in the dry semester and there is also a lot of pressure due to irrigation water uses. The increase in the water demand in the summer period leads to the point that the demand cannot be covered by existing infrastructure and water storage, although currently there is already an inter basin water transfer from Guadiana's basin (for irrigation and domestic water supply uses).

# Chapter 2 Typologies

## Introduction

The formulation of a Typology of the characteristics of water deficient regions involves developing a common analysis framework in terms of the natural conditions and the human environment in the regions analysed. This will allow the highlighting of the commonalities and gaps among representative regions and watersheds in Southern Europe. Finally, it will depict the factors that affect the outlining and operational efficiency of water resources management approaches. The objectives of this chapter are:

- To present representative water deficient regions in Southern Europe ,
- To illustrate the commonalities, similarities, differences and gaps among them, and
- To develop a classification scheme and through the analysis of the selected regions to formulate a typology of regions in terms of Drivers and Pressures leading to water deficiency, and Responses to these.

***Table 1 Definitions of Terms***

| Term | Definition |
|---|---|
| Paradigm | The word Paradigm describes a school of thought on prioritising during the selection of Policy Options, for the Management of Water Resources. The Dominant Paradigm is the current school of thought for each region; the shifting paradigm is an alternative prioritising of policy options, and respective actions, aiming at achieving Integrated Water Resources Management, which is slowly becoming a necessity due to the increasing challenges of managing the water resources, particularly in water deficient regions, in a sustainable way. |
| Strategy | The set of actions / sequence of responses to existing and emerging conditions, that is suited / available aiming at the fulfilment of a selected goal (in the case of the project the goal is that of Integrated Water Resources Management). |
| Guidelines | A set of (relatively generalised) instructions that analyse a strategy into actions required set within a time framework. |
| Protocol of Implementation | A set of step-by-step analytical instructions that need to be taken in order to effect a specific task in the framework of a strategy. |
| Case Study | The application of a Paradigm on a selected Region. |
| Scenario | Developments which can not be directly influenced by the Decision Maker such as Weather, Market Prices. |

Fifteen regions have been selected which were analysed as to their specific characteristics. The Typology attempts to develop a classification scheme to form **Types** of regions that share similar characteristics and properties and finally to select **representative cases of each Type** in the subsequent stage of Paradigm formulation.

## The methodological approach

The methodology followed for the formulation of Typologies was structured in three major steps:

- **Step 1: Selection of the Sample of Regions.** The selection criteria have been described in the previous chapter.
- **Step 2: Data selection and collection.** The data selection and collection involved four distinct stages:
    - The selection of a set of indices. This is an important stage, as it influences ultimately the quality of analysis; it is described in section 2 of this chapter.
    - The data collection stage,
    - The data verification stage, and
    - The conflict resolution stage, where discrepancies and conflicts were resolved.
- **Step 3: Data Analysis.** The analysis of data was also performed in 4 stages:

- The first stage involved the determination of the range of circumstances. The data for all regions was examined and the gaps and commonalities among regions, as well as the data ranges, presented in section 4 of this chapter.
- Secondly, a classification scheme was developed, described in detail later in this chapter, which could be used to assess the data obtained. The classification was effected in three separate approaches, based on the:
  - Natural conditions (Drivers) and the
  - Human Pressures (Pressures) that result into the conditions of water deficiency, as well as
  - The Responses to these conditions.
- Thirdly, for the analysis of the quantitative data for the Human Pressures classification approach, an appropriate statistical analysis methodology was selected based on the multivariate methods of cluster and factor analysis.
- Finally, the distinguishing parameters in each classification approach were identified, and then used to form a synthesis of regional types.

*In search of Indices and Typologies*

All classification schemes are based on selected indices that are used to accurately describe the classification subjects' characteristics. In the past, different types of indices have been proposed to describe and assess the state of water resources, water management and the sustainability of management schemes in water deficient regions. A brief description of such indices and classification schemes follows.

*Climatic and natural conditions classification*

During the length of efforts to classify regions on the basis of water resources, attempts have been made to produce classifications based on the natural conditions alone, which were mostly based on climatic criteria. This limitation on natural conditions however means that these classifications, although still very widely used, and despite their usefulness for assessing certain aspects of the water deficiency issues, are not suitable for presenting the **full extent** of issues surrounding water deficiency. Three of the most significant approaches are presented, the aridity index, the Köppen climate classification, and the global Ecoregions.

**1. Köppen System of climate classification**

A widely used classification of world climates, based on the annual and monthly averages of temperature and precipitation, on which Thornthwaite's system that follows was also based. The original Köppen classification system has been revised several times, modified and refined from its initial form. Köppen related the distribution and type of native vegetation to the various climates, in a scheme that employs five major climatic types. Each type is designated by a capital letter, A, B, C, D and E. Each group contains subregions that describe special regional characteristics, such as seasonal changes in temperature and precipitation.

Köppen's system has been criticised on two accounts; firstly, its boundaries do not correspond to the natural boundaries of each climatic zone, and secondly, it implies that there is a sharp boundary between climatic zones, when in reality there is a gradual transition.

**2. Aridity index based on Thornthwaite**

There are variations over the definition of aridity and the boundaries of arid regions. Aridity is usually taken as a situation in which rainfall is less than half the value of potential evapotranspiration. This methodology was developed by Thornthwaite and adopted for the determination of areas susceptible to desertification, those with arid, semi-arid and dry sub-humid climates. This index is defined as the ratio between the amount of rainfall and potential evapotranspiration, that is, the maximum water loss that is possible through evaporation and transpiration, determining the categories Hyperarid, Arid, Semi-Arid, Dry Sub-humid and Moist Sub-humid. This index can be used to express limited water resources in a region.

***Table 2 Classification by Aridity Index***

| Type | Aridity Index |
|---|---|
| Hyper-arid | <0.03 |
| Arid | 0.03– 0.20 |
| Semi-arid | 0.21-0.51 |
| Dry sub-humid | 0.51-0.65 |
| Moist sub-humid | >0.65 |

Thornthwaite developed a classification system for climates, utilising temperature and precipitation measurements, and relating natural vegetation to climate. Using the precipitation to evapotranspiration index, the Thornthwaite system defines five major humidity regions and their characteristic vegetation: rain forest, forest, grassland, steppe, and desert.

To better describe the moisture available for plants, Thornthwaite proposed a new classification system that emphasised the concept of *potential evapotranspiration*, which is the amount of moisture that would be lost from the soil and vegetation if the moisture were available. Thornthwaite incorporated potential evapotranspiration into a moisture index that depends essentially on the differences between precipitation and potential evapotranspiration. The index is high in moist climates and negative in arid climates. An index of 0 marks the boundary between wet and dry climates.

Particularly for droughts most risk assessment efforts are using drought indices in order to provide reference points for drought duration, severity and time of occurrence. Palmer (1965) presented an index that may be used in drought analysis as well as in providing information about drought characteristics. This index is a function of runoff, evaporation, moisture recharge, and carryover of moisture from previous precipitation events. The Palmer index is widely and successfully used in the United States, however it should be applied with caution in other geographical locals.

### 3. Classification by Ecoregions[1]

Environmental issues are better addressed in the context of areas defined by natural features rather than by man-made boundaries. Growing awareness that the natural resources of an area do not exist in isolation, but instead they interact, has led to delineating and managing ecosystems rather than individual resources. Ecosystems of different size occur on many geographic scales, smaller ones embedded in the larger systems. Any large portion of the earth's surface over which the ecosystems have characteristics in common is called an ecoregion.

Although ecoregions can be defined climatically, they can be better defined by combining and rearranging the climatic types to maximise correspondence with major plant formations. Through this process, **Bailey** (1998) mapped the earth into zones he called ecoregion provinces. He recognised eighty-six subdivisions, which he grouped into fifteen divisions, and then further simplified this classification of ecosystems by grouping the divisions into four large regions called domains. He recognised four such subdivisions: polar, with no warm season; humid temperate, rainy with mild to severe winters; humid tropical, rainy with no winters, and finally dry, which is defined on the basis of moisture alone and transects the other three, otherwise humid domains.

A brief description of these domains, after Bailey:

- ❖ In the very high latitudes lies the polar domain, differentiated on the basis of ice formation and plant development into icecap, tundra, and subarctic taiga divisions.

[1] Bailey, RG. 1998: Ecoregions: The Ecosystem Geography of Oceans and Continents. New York, Springer-Verlag

- ❖ In the mid latitudes is the humid temperate domain of mid-latitude forests, differentiated on the basis of rainfall (steppe vs. desert) and winter temperature (cold vs. warm) into tropical/subtropical steppe, tropical/subtropical desert, temperate steppe, and temperate desert.
- ❖ In the low latitudes lie the humid tropical domain, differentiated on the basis of rainfall seasonality into savanna and rainforest divisions.

Each of these subdivisions is associated with a particular climate type, vegetation and soil structure.

*Classification based on Human Pressures*

Following the classification efforts based on natural conditions alone, which do not offer a full picture of the processes, attempts were also made at forming classification schemes that assess the human impacts on the system. These approaches assess the interaction of man with the environment, to produce measures that can be used on different geographic scales, from the local to the national level. The development of these approaches is a key step towards Integrated Water Resources Management. Two of the leading approaches in Europe are presented here, of the Mediterranean Blue Plan, and the 2000 EU Water Framework Directive.

**4. Plan Bleu Indicators**

These indices broadly measure the pressures exerted on the resource by man. They indicate a rough probability of pressures on water, not taking into account the water demand of the natural environment or the variability of resources and demand in time and in space. Although they do not reveal all aspects of water shortages, they provide an initial threshold estimate beyond which chronic water shortages may appear.

- ❖ **The Resources to population index**[2]: Measured in $m^3$ per capita, the index is the ratio of the average total resources (or flow) measured in $hm^3$/year, divided by the population of the region at a given time, measured in millions of inhabitants. The index expresses a measure of the sufficiency of the resources for the population.
- ❖ **The Exploitation Index of Renewable Resources**. The index, expressed as a percentage, measures the relative pressure of annual production on conventional renewable natural fresh water resources. It is the sum of the volumes of annual conventional renewable natural fresh water production for all uses, including losses during conveyance, referring to a specific year, divided by the volume of average annual flows of renewable natural water resources. Also,
- ❖ **The Consumption index of Resources**. Expressed as a percentage, it is the ratio of the annual final consumption divided by the mean annual flow of resource.

The exploitation index expresses the water quantities withdrawn, the consumption index measures the quantities consumed in a percentage of the theoretical total of renewable water resources. According to the Plan Bleu Report[3], indices equal to or greater than 25% are signs of local and circumstantial tensions in quantity and quality. Above 50% they point to more frequent and more regional circumstantial shortages. Towards 100% and especially if above, they indicate generalised structural shortages. In particular the increasing final consumption index illustrates the increasing scarcity of water availability.

**5. The Water Framework Directive Approach**

The Water Framework Directive established a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater. The WFD classification

[2] Plan d'Action pour la Méditerranée, Observatoire du Sahara et du Sahel, 1996: Les Indicateurs de l'Economie de l'Eau, Ressources et Utilisations, Document de réflexion

[3] Mediterranean Commission on Sustainable Development (MCSD), 2000: Indicators for the sustainable development in the Mediterranean region

methodology approaches water resources from an environmental perspective, and determines different levels of classification of water bodies, from the microlevel determination of chemical and biological indicators, to the determination of the quality status of entire bodies, to establishing macroscale ecoregions.

This Directive, under Article 8 which establishes "Monitoring of surface water status, groundwater status and protected areas" proposes a comprehensive set of indicators for assessing the quality of waters, as well as a series of standards and measures for the protection and improvement of the quality of waters. These measures, a brief description of which follows, are described in Annex V of the directive. The status of water bodies is determined, based on these indicators, to be improved or maintained accordingly.

Regarding Groundwater, the quantitative and chemical status of the resource is monitored. The parameter for the classification of quantitative status is the groundwater level regime. The core parameters for the determination of groundwater chemical status are:

- oxygen content,
- pH value,
- conductivity,
- nitrate,
- ammonium.

The quality elements for the classification of ecological status of Rivers, Lakes, Transitional waters, Coastal waters, and Artificial and heavily modified surface water bodies involve monitoring of:

- parameters indicative of biological quality elements,
- parameters indicative of hydromorphological quality elements,
- parameters indicative of all general physico-chemical quality elements:
    - Thermal conditions,
    - Oxygenation conditions,
    - Salinity,
    - Acidification status,
    - Nutrient conditions,
    - Transparency, and
    - Tidal regime for the transitional and coastal waters.
- priority list pollutants, and
- other pollutants discharged in significant quantities.

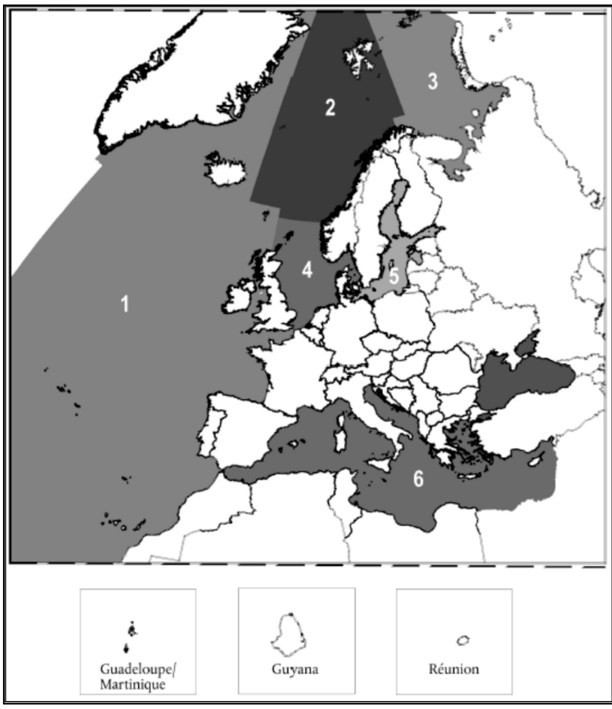
Article 6 of the WFD establishes a "Register of protected areas", which according to Annex IV of the directive include:

- areas designated for the abstraction of water intended for human consumption,
- areas designated for the protection of economically significant aquatic species,
- bodies of water designated as recreational waters, including areas designated as bathing waters,
- nutrient-sensitive areas, including areas designated as vulnerable zones,
- 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.

Finally, in Annex XI the WFD also presents a set of ecoregions in the European Union, for rivers and lakes, and for transitional and coastal waters. Figure 2 presents the WFD Ecoregions for rivers and lakes:

1. Iberic-Macaronesian region
2. Pyrenees
3. Italy, Corsica and Malta
4. Alps
5. Dinaric western Balkan
6. Hellenic western Balkan
7. Eastern Balkan
8. Western highlands
9. Central highlands
10. The Carpathians
11. Hungarian lowlands
12. Pontic province
13. Western plains
14. Central plains
15. Baltic province
16. Eastern plains
17. Ireland and Northern Ireland
18. Great Britain
19. Iceland
20. Borealic uplands
21. Tundra
22. Fenno-Scandian shield
23. Taiga
24. The Caucasus
25. Caspic depression


***Figure 2 WFD Ecoregions for rivers and lakes***




1. Atlantic Ocean
2. Norwegian Sea
3. Barents Sea
4. North Sea
5. Baltic Sea
6. Mediterranean Sea

***Figure 3 WFD Ecoregions for transitional waters and coastal waters***

Figure 3 presents the Ecoregions for transitional waters and coastal waters:

*The Responses approach*

The methodology used in this document followed up on the previous classification efforts and attempted to establish an analysis framework that would include the climatic and human pressures data. These approaches have in common the fact that they are descriptive of the **Characteristics of Water Deficiency** (Figure 4), in other words, they describe the existing situation in terms of the Natural and Human pressures applied. In this regard, various concepts have been used to exemplify a prevailing confusion among terms which signify "dry environments" or water deficiencies. There are four different terms that are important for some initial separation among types of water deficiencies (Vlachos, E.C., 1982; Karavitis, C.A., 1999): -aridity is referred to as a permanent natural condition;- drought may be understood as a temporary climatic phenomenon;- water shortage is associated mainly with small areas of water deficiencies;- desertification is principally a man-made phenomenon altering the ecological regime. It has been suggested that all the above terms and definitions associated with dryness may be considered as a part of a larger process named: xerasia (Vlachos, E.C., 1982).

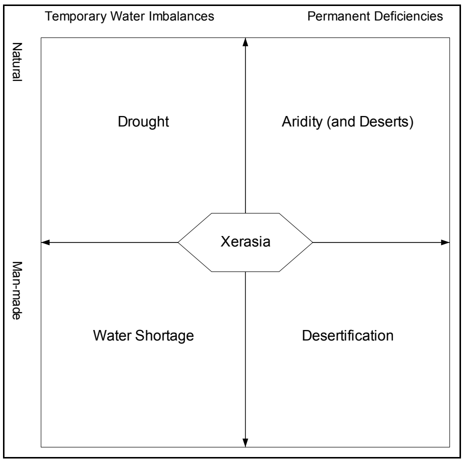



***Figure 4 Water deficiency characteristics (Vlachos, E.C., 1982).***

These approaches however do not present the full set of circumstances that apply in Water Deficient regions, as there is yet another important distinguishing factor that differs among regions. Therefore a third methodological step was introduced into the classification scheme, incorporating the **Responses** to the existing conditions. This allows for a more dynamic approach of the conditions that apply in each region.

*A proposal for a framework of Indices*

A classification scheme for water deficient regions would have to be based on indices related to water quality, quantity and management; a matrix of indices was used for quantifying and assessing all aspects of water management in the regions analysed. Detailed information on the matrices is given in Chapter 4.

A comprehensive water resources management plan may be centred around descriptive and performance indices. Descriptive indices present the existing conditions, the context of a water resources elements or issues in relation to the principal characteristics (time, geographical local, etc.) through which such elements may be expressed. Thus a first group of descriptive indices may present the water resources natural conditions and the corresponding existing regional context. A second group of descriptive indices may delineate the human induced conditions in the water resources system. Such a group reflects mainly the economic and social development of a region. Finally a third group is concentrated mainly on performance indices. Usually they assess the existing, the current water resources system status (real), with the ideal or desired status (target). Thus, it has to be underlined that such indices are monitoring and representing the results of policy responses generated from the overall water resources management structure.

In this regard, the selected approach attempts to combine the following indices descriptive of the natural conditions and regional context, with indices describing the human environment in relation to the water resources, including institutional and economic indices, and finally water policy, administrative and management status at a given time.

***Table 3 Indices and assessments for water resources management***

| Group I | Group II | Group III |
|---|---|---|
| Regional Context<br>Climate<br>Topography<br>Vegetation<br>Soils<br>Demography<br><br>Water availability<br>Precipitation<br>Surface runoff<br>Groundwater<br>Water storage<br>Reuse and recycling<br><br>Water quality<br>Geological formations<br>Effluent type<br>Pollution<br>Conservation<br><br>Water Supply<br>Surface water<br>Groundwater<br>Supply system<br>Distribution | Water use<br>Urban consumption<br>Agricultural consumption<br>Industrial consumption<br>Water Deficits<br><br>Water demand<br>Projections<br>Urban<br>Agricultural<br>Industrial<br>Water Budget<br>Efficiency of<br>water use<br>water supply<br><br>Pricing system<br>Equity<br>Economic efficiency<br>Revenue sufficiency<br>Resource conservation<br><br>Social capacity building<br>Stakeholders integration<br>Public Participation<br>Public integration<br>Conflict resolution<br>Training | Water Resources Management<br>Social and Legal aspects<br>Organisational framework<br>Planning environment<br>Political environment<br>Time horizon<br><br>Water Policy<br>National policy<br>Regional policy<br>Water resources<br>use goals<br>protection goals<br>conservation goals<br>Economic issues |

### *The Matrix of Indices*

The matrix that was developed follows; these indices were researched for each of the Regions selected, collecting relevant data to be used for classification.

**A. Indices relating to the Natural conditions and infrastructure (the physical environment)**

*1. Regional Context:*
- Climate type - according to the Köppen classification (Qualitative Index),
- Aridity index - by the Penman-Monteith calculation (Quantitative Index), and
- Permanent population (Quantitative Index).

*2. Water availability:*
- Total water resources / availability – an estimate of the total resources in the area, and, if known, the amount available for use (Quantitative Index), and
- Trans-boundary water (Quantitative Index) (Percentage).

*3. Water quality:*
- Quality of surface water (Qualitative Index),
- Quality of groundwater (Qualitative Index), and
- Quality of coastal water (Qualitative Index).

*4. Water Supply:*
- Percentage of supply coming from:
    - Groundwater,

    - Surface water,
    - Desalination, Recycling – includes all water obtained through purification,
    - Importing – includes all water that is used in the region but is transported from other regions.
- Network coverage (Percentage):
    - Domestic,
    - Irrigation, and
    - Sewerage.

**B. Indices relating to the Economic and Social system (the human environment),**

*1. Water use:*

- Water consumption by category (Percentage):
    - Domestic,
    - Tourism, and
    - Irrigation,
    - Industrial and energy production.
- Resources to population index- calculated as RP = Total Resources/population (Quantitative Index).

*2. Water demand:*

- Water Demand trends- if the water demand in the area is increasing, decreasing or is stable (Qualitative Index),
- Consumption index- calculated as CI = Water consumed/Total Water Resources (Percentage), and
- Exploitation index- calculated as EI = Water distributed/Stable Water Resources (Quantitative Index).

*3. Pricing system:*

- Average household budget for domestic water –the percentage of the average household income used to pay for the domestic supply of water,
- Average household budget for agricultural water –the percentage of the average household income of farmers used to pay for irrigation water,
- Average household income – the average in the region (Quantitative Index),
- Cost recovery– estimate of the degree of recovery of the costs of water provision (Qualitative Index), and
- Price elasticity – the change in demand, when there is a change in price, defined as the change in demand divided by the change in price (Qualitative Index).

*4. Social capacity building:*

- Public participation in decisions - the degree of public participation in decisions involving water management (Qualitative Index), and
- Public education on water conservation issues - the degree of education of the public regarding water conservation (Qualitative Index).

**C. Indices relating to the Decision Making process (the management processes)**

*1. Water Resources Management:*

- Water ownership – is water private or state-owned (Qualitative Index),
- Decision making level– at what lever are decisions made regarding the allocation and the management of resources to uses:
    - Water supply for each sector (Qualitative Index),
    - Water resources allocation for each sector (Qualitative Index).

*2. Water Policy:*

- Local economy basis – what are the main economic activities in the area (Qualitative Index),

❖ Development priorities – what are the development priorities for the region (Qualitative Index).

*Overview of regional characteristics*

This section presents the Regional characteristics, as those have been analysed in the Matrix of Circumstances. Regarding the data collected in the Matrices for each Region, a categorisation by index category is attempted; Indices relating to the natural conditions and infrastructure, Indices relating to the Economic and Social system, and Indices related to the Decision Making Process

*Natural conditions and infrastructure*

Figure 5 shows the Permanent Population of the 15 Regions Selected; there is a wide variety of regions in that respect, ranging from populations under 100,000 inhabitants to over 3 million.

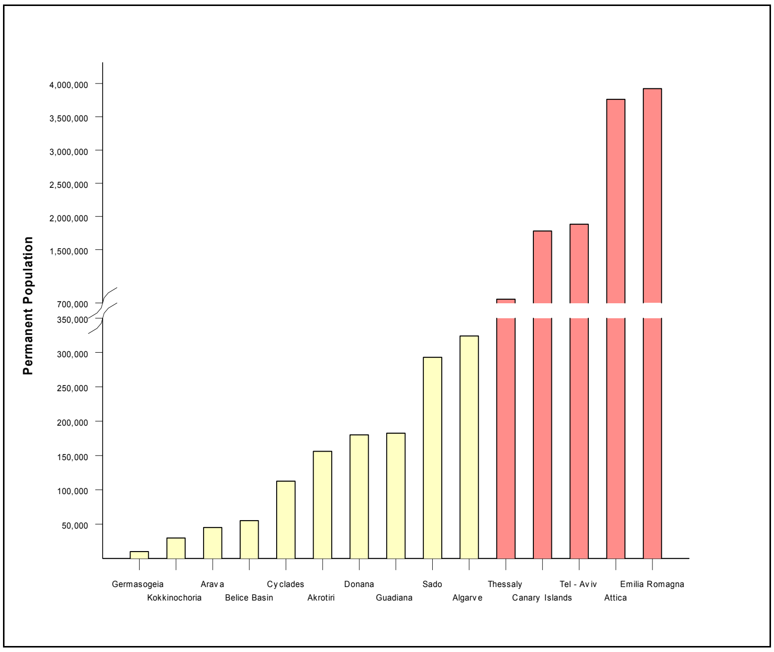



***Figure 5 Permanent population***

Table 4 presents the occurrence of water transfer in the Regions (inter-basin or trans-boundary); of the 15 regions, only in two, Emilia-Romagna and Doñana, there is no water transfer. Figure 6 presents Thornthwaite's Aridity index and the Water Resources in each of the fifteen regions.

***Table 4 Occurrence of trans-boundary or inter-basin water transfer***

| Yes | No |
|---|---|
| Attica | Emilia-Romagna |
| Cyclades | Doñana |
| Guadiana | |
| Kokkinochoria | |
| Arava | |
| Belice Basin | |
| Akrotiri | |
| Germasogeia | |
| Tel Aviv | |
| Sado | |
| Algarve | |
| Thessaly | |
| Canary Islands | |

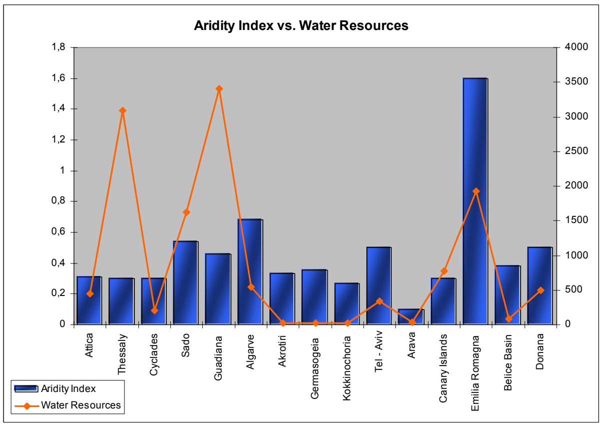



***Figure 6 Aridity index and total water resources in the 15 regions***

Figure 7 presents the sources of water supply in each region. The 15 Regions can be divided into three major groups:

- ❖ those that utilise importing as the primary means of obtaining water (which includes only two Regions, Attica and Kokkinochoria),
- ❖ those that utilise mostly Surface water, and
- ❖ those that utilise mostly Groundwater.

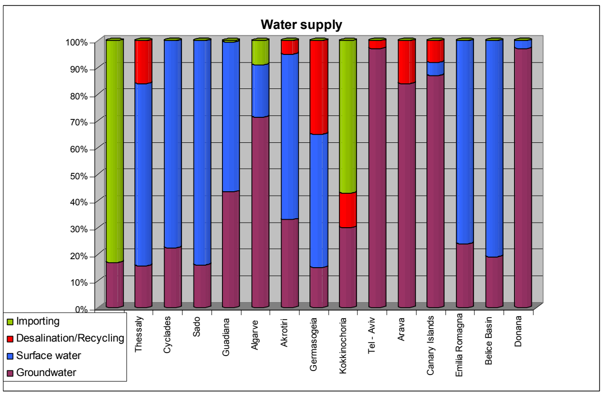



***Figure 7 Sources of water supply***

## *Economic and Social system*

Figure 8 presents the water consumption by sectors. Despite the importance of tourism in many of the Regions analysed, the Domestic sector, which includes Tourism consumption, is only the dominant water use in Attica and Tel Aviv, while in the majority of regions Irrigation is by far the most water-demanding use, with the exception of Sado and Emilia-Romagna where industrial usage of water exceeds the other uses.

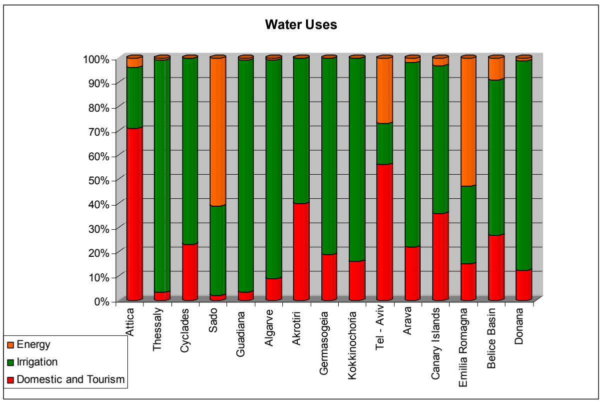



*Figure 8 Dominant water uses in the 15 Regions*

In Table 5 the water demand trends are presented for the 15 Regions, most of which show increasing trends. The exception to that is Attica, where the trend is towards a decrease in water consumption, and Thessaly, Arava and Emilia-Romagna where the water demand appears to have stabilised.

*Table 5 Water Demand trends*

| Trend | Regions |
|---|---|
| Increasing | Cyclades<br>Sado<br>Guadiana<br>Algarve<br>Akrotiri<br>Germasogeia<br>Kokkinochoria<br>Tel Aviv<br>Canary Islands<br>Belice Basin<br>Doñana |
| Stable | Thessaly<br>Arava<br>Emilia Romagna |
| Decreasing | Attica |

Figure 9 presents the Consumption and Exploitation indices in the 15 regions. With the exception of Thessaly and Guadiana, the Consumption index in all the other areas is over the threshold of 50%, whereas the Exploitation index ranges from low levels in Guadiana, the Cyclades and Thessaly to 100% and over.

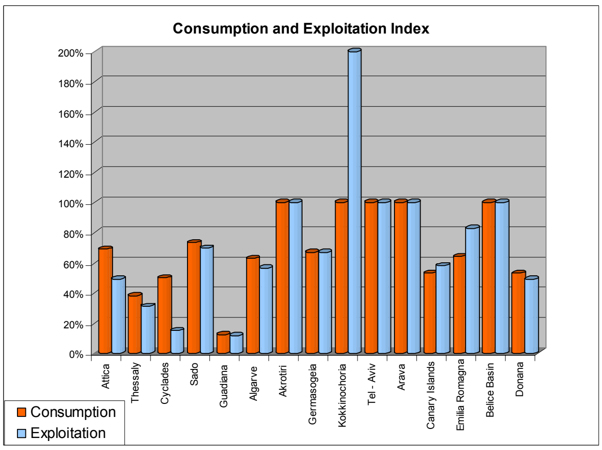



*Figure 9 Consumption and Exploitation Indices*

Table 6 and Table 7 present the economic aspect of the water sector. Cost recovery is low in Thessaly and the Cyclades in Greece, in the three Cypriot and the three Portuguese regions; it is considered average in the Spanish Regions, and good in the Italian and Israeli Regions as well as in Attica. Regarding price elasticity, in none of the regions has it been characterised good, it appears to be fair only in Attica and Arava, and poor in all three Cyprus Regions and Doñana. Figure 10 presents the average income in each of the 15 regions.

***Table 6 Cost recovery***

| Level | Regions |
|---|---|
| Good | Attica<br>Emilia Romagna<br>Belice Basin<br>Tel Aviv<br>Arava |
| Average | Canary Islands<br>Doñana |
| Poor | Thessaly<br>Cyclades<br>Sado<br>Guadiana<br>Algarve<br>Akrotiri<br>Germasogeia<br>Kokkinochoria |

***Table 7 Price Elasticity***

| Level | Regions |
|---|---|
| Fair | Attica<br>Arava |
| Average | Thessaly<br>Cyclades<br>Sado<br>Guadiana<br>Algarve<br>Tel Aviv<br>Canary Islands<br>Emilia Romagna<br>Belice Basin |
| Poor | Akrotiri<br>Germasogeia<br>Kokkinochoria<br>Doñana |

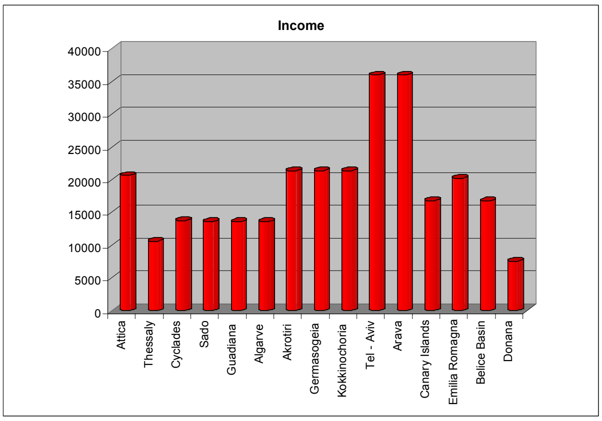



***Figure 10 Average Income***

Public Participation in Decisions and Public Education in Water Conservation Issues, as shown in Table 8 and Table 9, are both poor in the three Portuguese regions, the Canary Islands and Belice Basin, both average for Emilia-Romagna, and both above average in the two Israeli and the three Cypriot regions. In Doñana, although education is average, the participation is good, whereas participation in all three Greek regions is poor, even though education is good in Attica and of average level in Thessaly and the Cyclades.

***Table 8 Public Participation in Decisions***

| Level | Regions |
|---|---|
| Good | Tel Aviv<br>Arava<br>Doñana |
| Fair | Akrotiri<br>Germasogeia<br>Kokkinochoria |
| Average | Emilia Romagna |
| Poor | Attica<br>Thessaly<br>Cyclades<br>Sado<br>Guadiana<br>Algarve<br>Canary Islands<br>Belice Basin |

***Table 9 Public Education in Water Conservation Issues***

| Level | Regions |
|---|---|
| Fair | Attica<br>Akrotiri<br>Germasogeia<br>Kokkinochoria<br>Tel Aviv<br>Arava |
| Average | Thessaly<br>Cyclades<br>Emilia Romagna<br>Doñana |
| Poor | Sado<br>Guadiana<br>Algarve<br>Canary Islands<br>Belice Basin |

### *Decision-Making process*

In Table 10 there are two distinct groups of regions, according to the partial privatization or not of water as a resource. In Greece, Israel and Italy, water is state-owned; in Cyprus, Spain and Portugal, there is private ownership of the resource.

***Table 10 Water ownership***

| Ownership | Regions |
|---|---|
| State | Attica<br>Thessaly<br>Cyclades<br>Tel Aviv<br>Arava<br>Emilia Romagna<br>Belice Basin |
| Public / Partly Private | Akrotiri<br>Germasogeia<br>Kokkinochoria<br>Sado<br>Guadiana<br>Algarve<br>Canary Islands<br>Doñana |

In Table 11 the level of decision making regarding the water supply, and the resource allocation among the different sectors is shown. The water supply is delivered on a National level in the Cypriot and Israeli Regions as well as in Attica, and on a local or regional level in the other regions. The allocation of resources however is effected on a National level in Greece, Cyprus, Portugal and in Tel-Aviv, and is regional in Italy, Spain and Arava.

***Table 11 Decision-Making level***

| Sectoral Water Supply | | Sectoral Water Resources Allocation | |
|---|---|---|---|
| Level | Regions | Level | Regions |
| National | Attica<br>Akrotiri<br>Germasogeia<br>Kokkinochoria<br>Tel Aviv<br>Arava | Regional / Local | Emilia Romagna<br>Belice Basin<br>Arava<br>Canary Islands<br>Doñana |
| Regional / Local | Thessaly<br>Belice Basin<br>Cyclades<br>Sado<br>Guadiana<br>Algarve<br>Canary Islands<br>Doñana<br>Emilia Romagna | National | Attica<br>Thessaly<br>Cyclades<br>Sado<br>Guadiana<br>Algarve<br>Akrotiri<br>Germasogeia<br>Kokkinochoria<br>Tel Aviv |

Table 12 and Table 13, finally, present the current major economic sectors, as well as the development priorities for each Region.

***Table 12 Local Economy basis***

| Sector | Regions |
|---|---|
| Primary Sector | Thessaly<br>Arava |
| Tertiary Sector | Attica<br>Cyclades<br>Algarve<br>Canary Islands<br>Tel Aviv |
| Primary / Secondary | Sado |
| Primary / Tertiary | Guadiana<br>Akrotiri<br>Germasogeia<br>Kokkinochoria<br>Emilia Romagna<br>Belice Basin<br>Doñana |

*Table 13 Development Priorities*

| Priority | Regions |
|---|---|
| Urban Growth | Attica |
| Agriculture | Thessaly<br>Sado<br>Guadiana |
| Tourism | Cyclades<br>Canary Islands |
| Tourism / Agriculture | Algarve<br>Akrotiri<br>Germasogeia<br>Kokkinochoria<br>Belice Basin<br>Doñana |
| Supply Enhancement<br>Demand Management | Tel Aviv<br>Arava<br>Emilia Romagna |

# Classification

*The approach in developing Typologies*

Aridity and Water deficiency are central concepts in the development of Water Resources Management Plans and Strategies. These conditions in Southern European – Mediterranean areas are due mostly to the arid or semi-arid conditions. The water stress may be a permanent feature of an area or a temporary, isolated occurrence; it may be year-long, or seasonal through the summer months.

The level of variability among such regions indicates that a systematic approach should be taken towards forming a classification scheme, or Typology, that will allow the formation of groups of regions that share similar characteristics. In order to analyse the Typology, it will first be necessary to clarify the categories that are selected. The DPSIR (Driving-Forces–Pressure–State–Impact–Response) Indicators, adapted by J. Walmsley[4] (Figure 11) provide a useful framework for the formulation of a classification scheme.

[4] Framework for measuring sustainable development in catchment systems, Environmental Management, Vol. 29. No2. 2002

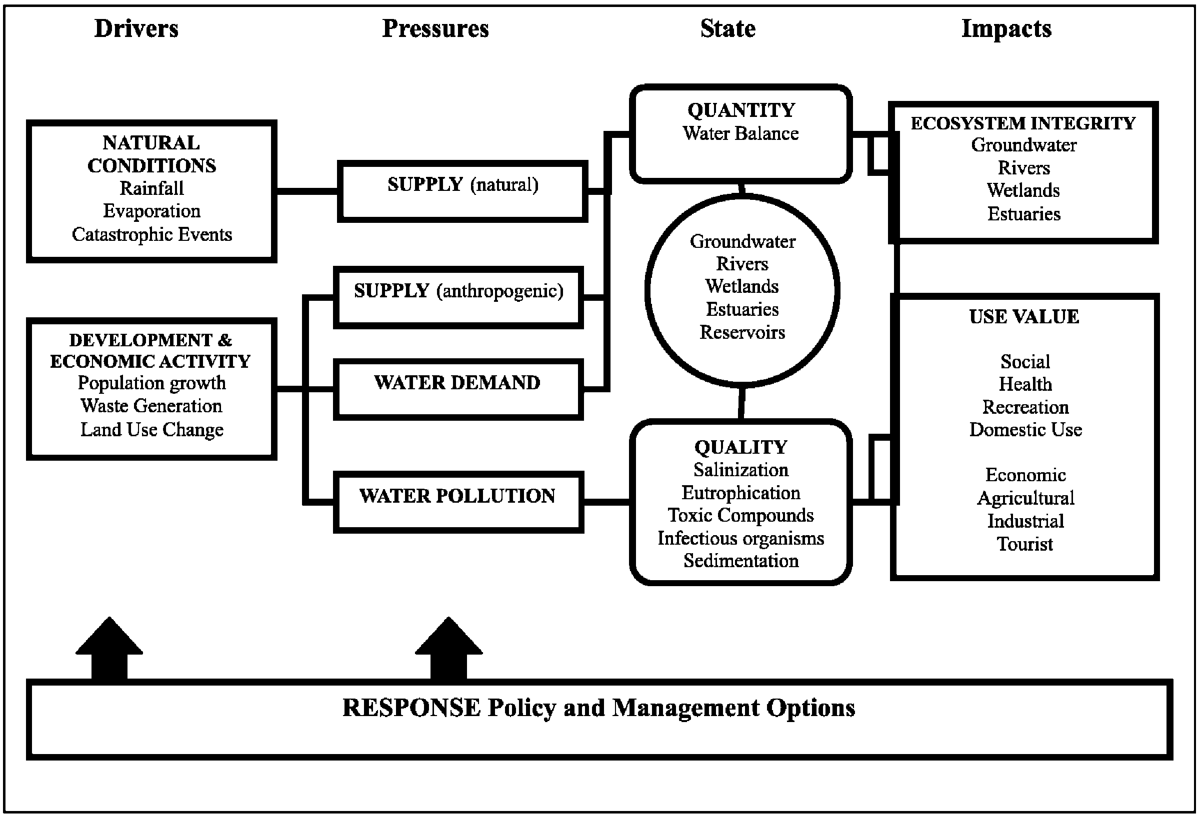



***Figure 11 Schematisation of the DPSIR framework***

*The DPSIR Indicators approach*

The DPSIR (Drivers – Pressures – State – Impacts – Responses) concept can be used as a basis for a framework to identify and develop indicators for Integrated Water Resources Management on a regional scale. The DPSIR framework identifies cause – effect relationships and allows for the separation of categories of issues and provides flexibility for usage and analysis. In this section the main elements of the DPSIR approach are defined, while in the next sections, an effort is made to identify the main elements of the DPSIR framework for the regions analysed.

The DPSIR categories are defined as follows:

- ❖ Driving force indicators reflect pressures exerted by natural phenomena and anthropogenic activities that, in general, cannot be easily manipulated but provide essential information to understand the regional context.
- ❖ Pressure indicators reflect the pressures exerted on water resources and the water use groups of a region, as a result of the driving forces.
- ❖ State indicators assess the current status of water resource.
- ❖ Impact indicators assess the effect that a pressure has on the state of user groups and resources
- ❖ Responses relate to the social response via policies, laws, measures etc.

These indicators are relevant to the formulation of water resources management Paradigms, mainly through analysis of the **responses** selected to adapt to drivers, relieve pressures, face states and mitigate impacts under conditions of water deficiency. The differences in responses between regions suggest the presence of different schools of thought with regard to water management. The Dominant Paradigms of each region are therefore reflected through these responses, as they have evolved over time under the specific conditions of each region and each distinct country.

In the next table the indicators and their importance/relevance are presented according to J. Walmsley (2002). This classification scheme has been followed to form a DPSIR Matrix for the selected regions

***Table 14. Indicators in DPSIR framework***

| Category | Indicator | Importance/relevance |
|---|---|---|
| Driving forces | Population density | A high or growing population can threaten the sustainability of water resources, particularly in arid catchments where freshwater resources are limited. |
| | Urbanisation | The number of people living in urban and rural environments has an impact on the infrastructure requirements, as well as waste management and pollution potential. |
| | Proportion of households earning less than US$1000 per annum | Household earnings is an internationally accepted indicator of poverty. If a household is earning less than US$1000 per annum, it suggests that the household is barely subsisting and lower order needs are the prime concern. |
| | Gross geographic product per capita | Growth in the production of goods and services is a basic determinant of how the economy fares, as well as the level of development in a catchment. It measures income growth, and is an important indicator of consumption patters and the use of renewable resources. |
| Pressures | Catchment population as a proportion of the maximum sustainable population | There is a certain minimum amount of water required for development, which can be expressed on a per capita basis (1000 $m^3$/yr). If there is not enough water for the size of the population, development will not be possible and subsistence will predominate. |
| | Population without access to piped water on site | Because of past imbalances, not all South Africans have access to water on site. This has implications for the control of water consumption in the catchment, as well as for future infrastructure development. |
| | Population without access to toilet facilities | Not all people have access to adequate sanitation facilities. This has implications for waste disposal and pollution potential in the catchment, as well as future infrastructure development. |
| | Anthropogenic supply as a proportion of total available | In arid regions, there is a reliance in many catchments on importation of water from other catchments, or even downstream in the same catchment. If a catchment is too heavily reliant on water importation, the development of the catchment cannot be considered sustainable. |
| | Reserve as a proportion of mean annual runoff | The WFD has legislated that a reserve shall be established for each catchment.<br>It consists of social requirements for essential use (minimum of 25 litres/day) and environmental requirements for the maintenance of the ecosystem. The higher the reserve requirement, the less water is available for development. |
| | Total liquid waste discharged as a proportion of supply | Liquid waste generation depends on industrial and agricultural processes as well as the population size. The more liquid waste that is discharged into the system, the more pressure is exerted on the system to maintain itself. |
| | Wastewater treated as a proportion of water care works' capacity | If the capacity of wastewater treatment plant is inadequate, this could provide a serious pollution threat to the resource. |
| State | Total water available per capita | This is an internationally accepted basic indicator for water availability. It can be used at a catchment level and further split sectorally. |
| | Demand as a proportion of supply | This indicator is the core indicator of water balance. If demand is nearing supply, action with regard to water resource development is required. In many catchments, demand has exceeded supply and augmentation is required. |
| | Proportion of groundwater utilised | In certain areas in the country, groundwater is a significant supply of water for domestic and agricultural use. If the demand for groundwater is higher than the safe yield, then groundwater usage will not be sustainable. |
| | Proportion of boreholes contaminated | Groundwater supplies are particularly important in the more arid areas of the country. Good water quality is essential to regional development. |

| Category | Indicator | Importance/relevance |
|---|---|---|
| State | Reservoir water quality | Reservoirs are a reflection of what is occurring in the catchment. Particular water quality problems that pertain to arid region catchments include salinisation, eutrophication, microbiological contamination, toxic compounds and sedimentation. If receiving water quality objectives have been set, these can be compared to the ambient water quality. |
| | Water quality at the downstream point | The downstream point is an indicator of the sum of all activities in the catchment. This indicator will complement water quality in reservoirs to provide an accurate picture of problem areas. |
| | Reservoir capacity as a percentage of total water available | Arid regions are prone to periodic droughts and floods. River regulation in the form of reservoirs mitigates against these catastrophic events, and this indicator shows the capacity for doing so. It could also be viewed as an indicator of the condition of the natural resource, where a highly regulated system would be viewed negatively. |
| | Riparian zone with development | The riparian zone is the interface between freshwater and land systems. In the past, riparian land rights of landowners in some regions have led to extensive degradation of the riparian zones of rivers, and irreparable damage to river ecosystems. |
| Impacts | Biodiversity of wetland birds | Wetlands are some of the most endangered ecosystems. The diversity of wetland birds, which require functioning wetland systems for their survival, is a good indication of the quality of wetlands in a catchment. |
| | Fish assemblage integrity index (FAII) | Fish, being relatively long-lived and mobile, are good indicators of long-term influences on rivers. The number of species, the size classes and health of fish give a good indication of river health. |
| | Riparian vegetation index (RVI) | Healthy riparian zones maintain channel form and serve as filters for light nutrients and sediments. The status of riparian vegetation, including removal, cultivation, construction, inundation, erosion, sedimentation, and alien vegetation, gives an indication of the deviation from the natural, unmodified riparian conditions. |
| | Index of habitat integrity (IHI) | Habitat availability and diversity are major determinants of aquatic community structure. The IHI is useful in assessing the impact of major disturbances on river reaches, including water abstraction, flow regulation, and bed and channel modification. |
| | Recreational index for raw water | Poor water quality in catchments has related health risks. One of the important uses of water is for full- and partial-contact recreation. If water is too polluted for recreation, it will also be unacceptable for domestic use for informal settlements. It also has implications for access. |
| | State of satisfaction of catchment population | Public opinion often influences the behaviour of people. The level of co-operation of the community in water resource management and conservation depends, along with other factors, on their satisfaction with water management in their area. |
| | Cost of water treatment | Water treatment costs rise with decreasing water quality. One of the major influences on water management decisions is the economic benefit of an action. If the cost of treating water exceeds the cost of pollution prevention activities, then pollution prevention will become the primary management thrust in a catchment. |
| Responses | Number of active hydrological monitoring stations per 100 $km^2$ | Continual monitoring of water resources is important for immediate management. Rainfall is irregular over many catchments, and constant surveillance is needed on the amount of water available in the catchment. |
| | Number of water quality monitoring points per 100 $km^2$ | Water quality information is important in the continual evaluation of pollution in a system and can be used as a warning system for spills. |
| | Level of forum establishment in the catchment | Water forums have been established, or are being established, in many catchments in South Africa with the objective of allowing participative management in the catchment. They are viewed as essential to the successful establishment of CMAs. One of their primary roles is the establishment of receiving water quality objectives. |

| Category | Indicator | Importance/relevance |
|---|---|---|
| Responses | Establishment of catchment management agency | The WFD requires that CMAs are set up for all the major catchments, within a reasonable time. If a CMA has been established, management in that area will be catchment specific. |
| | Completion of catchment management plan | The WFD requires that each CMA develop a catchment management strategy for each catchment. The strategies must be in harmony with the national water strategy and should set the principles for allocating water taking into account the protection, use, development, conservation, management, and control of water resources in the catchment. |

*The clustering analysis*

Cluster analysis is an analytical technique that can be used to develop meaningful groups of cases. The objective of cluster analysis is to classify a sample of cases into a small number of mutually exclusive groups based on the similarities among the cases. There are no a priori assumptions or hypotheses, and the groups are not pre-defined. Instead, cluster analysis techniques attempt to identify interdependencies among a number of variables without treating any of them as dependent or independent. Furthermore, cluster analysis is only descriptive and has no inference properties.

There exist a lot of algorithms used for forming clusters. In the present work the hierarchical procedure based on an agglomerative method was followed. The purpose of the agglomerative methods is to join together cases into successively larger clusters, using some measure of similarity or distance. Each case starts out as its own cluster and in subsequent steps the two closest clusters (or cases) are combined into a new aggregate cluster, thus reducing the number of cluster by one in each step. Eventually, all cases are grouped into one large cluster. Agglomerative methods differ by the formula used to measure distance or similarity between cases and the rule used to determine when two clusters are sufficiently similar to be linked together (agglomerative or linkage rule).

The Euclidean distance measure was used to compute the similarities between cases. It simply is the square of the geometric distance in the multidimensional space. This method has the advantage that the distance between any two cases is not affected by the addition of new cases to the analysis, which may be outliers.

The Ward's method was used as a linkage rule. This method uses an analysis of variance approach to evaluate the distance between clusters. It attempts to minimise the sum of squares of any two clusters that can be formed at each step/ In general, this method is regarded as very efficient, however, it is biased toward the production of clusters with approximately the same number of cases.

*A classification based on Drivers*

The term "Aridity" is used for regions that are generally, or at least periodically, dry. It can be both an ecological fact of nature, measurable and objective, and a human derived condition. In Southern Europe water deficiency originating from aridity is becoming a major constraint for the economic welfare and sustainable regional development. On the other hand, regions that may not conventionally be classified as "Arid" that are relatively rich on water resources can be water deficient, due to mismanagement of the resource. The **Drivers** that can lead to a State of water deficiency can therefore vary, so the nature of the water deficiency is one factor that needs to be determined.

The main characteristics of these Southern European regions are the high spatial and temporal imbalances of water demand and supply, seasonal water uses that strive for inadequate water resources and poor institutional water management. Therefore, the other characteristic that requires determination is the timescale of the water deficiency. Figure 12 presents an attempt to classify the 15 regions according to the Water Deficiency Characteristics of each region within a grid, separating them into four types, based on the duration of the deficiency and its cause:

- Type 1, Temporary, natural-induced water deficit.
- Type 2, Temporary human induced water deficit, which is the type where most cases are falling in.
- Type 3, Permanent natural water deficiency, and finally
- Type 4, Permanent human induced water deficiency.

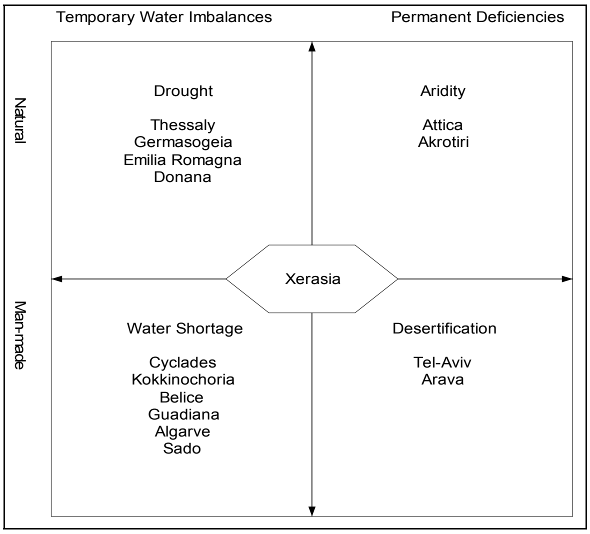



***Figure 12 Typology of regions selected (adapted from Vlachos E.C., 1982)***

*A classification based on Pressures*

*Classification according to water supply sources*

A combined approach based on the multivariate methods of cluster and factor analysis was followed, in order to classify the 15 regions into a small number of meaningful groups on the basis of the water supply sources utilised in each region. The analysis was based on the four quantitative indices representing the percentage of water supply coming from **groundwater**, **surface water**, **desalination – recycling** and **importing**.

Figure 13 presents the profiles of all regions on the three variables representing the sources of water supply. This diagram can be used for a preliminary screening for outliers. As can been seen from, there is no obvious outlier that has all extremely high or low values.

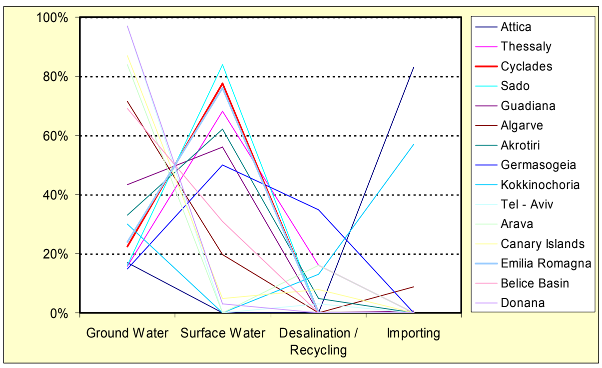



***Figure 13 Profile diagram for all regions***

Figure 14 displays the dendrogram of the hierarchical cluster analysis, calculated using the Ward's agglomerative procedure and squared Euclidean distance as the distance measure. It is clear that three main clusters are formed:

- **Cluster 1** includes only two regions (Attica and Kokkinochoria).
- **Cluster 2** includes six regions (Algarve, Belice Basin, Tel-Aviv, Doñana, Arava and Canary Islands)
- **Cluster 3** includes seven regions (Thessaly, Cyclades, Emilia Romagna, Sado, Guadiana, Akrotiri and Germasogeia).

Information essential to the interpretation of results is provided in Figure 15. For each cluster, the mean of each of the four clustering variables is plotted along with the mean of all regions. The following conclusions can be conducted by examining the patterns of the three cluster profiles:

- Cluster 1 is characterised by high values in **importing water** and low values in ground and surface water.
- Cluster 2 is characterised by high values in **ground water** and low values in surface and importing water.
- Cluster 3 is characterised by high values in **surface water** and low values in ground and importing water.
- All clusters have similar values of desalination-recycling water.

These conclusions are summarised in Table 14.

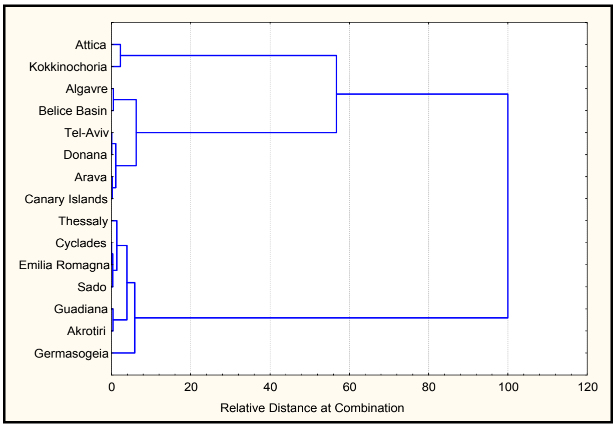



***Figure 14 Dendrogram obtained for classification according to water supply sources***

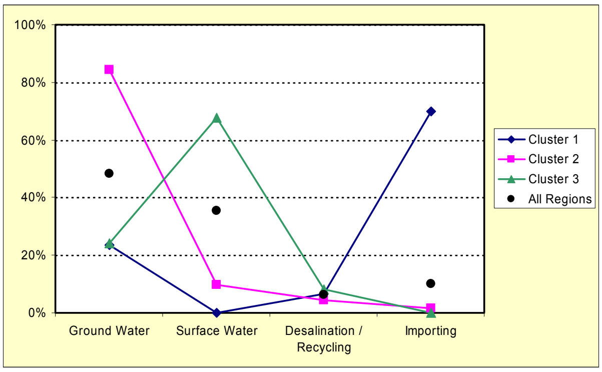



***Figure 15 Profile diagram for all clusters on the water supply sources***

*Table 15 Clustering by water supply sources*

| Cluster | Regions | Major Source |
|---|---|---|
| 1 | Attica<br>Kokkinochoria | Importing |
| 2 | Algarve<br>Tel Aviv<br>Arava<br>Canary Islands<br>Belice Basin<br>Doñana | Groundwater |
| 3 | Thessaly<br>Cyclades<br>Sado<br>Guadiana<br>Akrotiri<br>Germasogeia<br>Emilia Romagna | Surface Water |

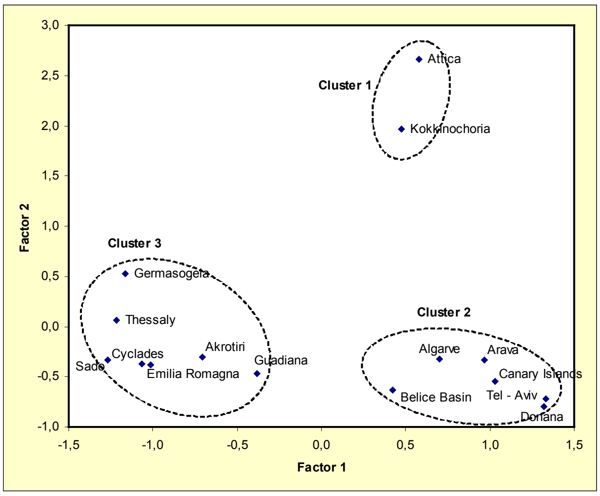



***Figure 16 Plot of regions on the first two axes extracted by principal components analysis***

In order to graphically illustrate the clustering of regions, a principal component analysis on the data matrix consisting of the above four quantitative indices was performed. Figure 16 shows a plot of 15 regions on the first two axes extracted by the analysis. The percent variance accounted for by the two principal factors (Factor 1 and Factor 2) is 75%. The separation of regions into the three groups, as resulted by the cluster analysis, is very clear.

### *Classification according to sectoral water consumption*

The same cluster and factor analysis approach was followed, in order to classify the 15 regions according to the water consumption by sector. The analysis was based on the three quantitative indices representing the percentage of water consumption in Domestic-Tourism sector, Irrigation and industry-energy production.

Figure 17 presents the profiles for all regions on the three indices representing the sectoral water consumption. Again, there is no obvious outlier that has all extremely high or low values.

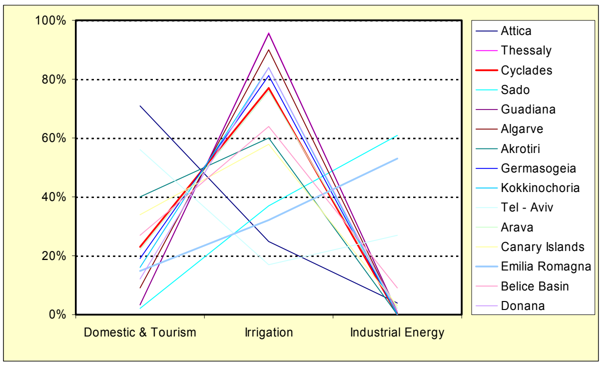



***Figure 17 Profile diagram for all regions***

Figure 18 displays the dendrogram of the hierarchical cluster analysis, calculated using the Ward's agglomerative procedure and squared Euclidean distance as the distance measure. It is clear that four main clusters are formed:

- ❖ **Cluster 1** includes two regions (Attica and Tel-Aviv).
- ❖ **Cluster 2** includes two regions (Sado and Emilia Romagna).
- ❖ **Cluster 3** includes eight regions (Thessaly, Cyclades, Guadiana, Algarve, Germasogeia, Kokkinochoria, Arava and Doñana).
- ❖ **Cluster 4** includes three regions (Akrotiri, Canary Islands and Belice Basin).

Information essential to the interpretation of results is provided in Figure 19. For each cluster, the mean of each of the three clustering variables is plotted along with the mean of all regions. The following conclusions can be conducted by examining the patterns of the three cluster profiles:

- ❖ Cluster 1 is characterised by high values in **domestic** and **tourism** consumption and low values in irrigation consumption.
- ❖ Cluster 2 is characterised by high values in **industrial** and **energy** consumption and low values in the other two sectors.
- ❖ Cluster 3 is characterised by values near the all-regions mean values for all sectors.
- ❖ Cluster 4 is characterised by high values in **irrigation** consumption and low values in domestic-tourism consumption.
- ❖ Irrigation is by far the most water-demanding use, with the exception of the regions of the first and second clusters.

These conclusions are summarised in Table 15.

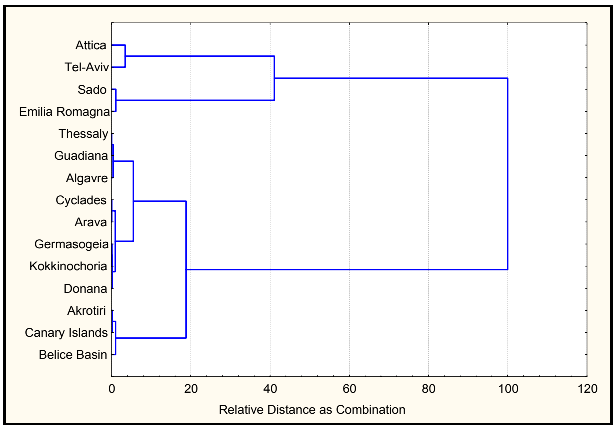



***Figure 18 Dendrogram obtained for classification according to the sectoral water consumption***

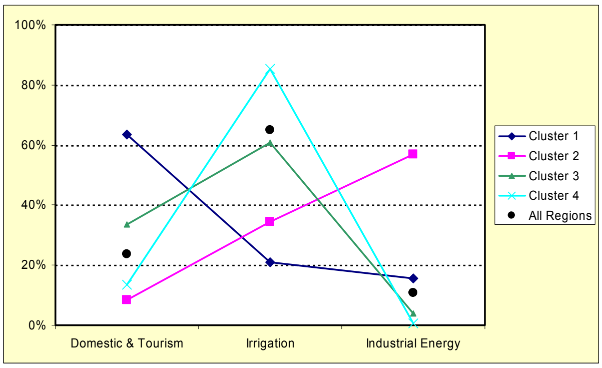



***Figure 19 Profile diagram for all clusters on the sectoral water consumption***

***Table 16 Clustering by sectoral water consumption***

| Cluster | Regions | Major Sector |
|---|---|---|
| 1 | Sado<br>Emilia Romagna | Industry / Power Generation |
| 2 | Attica<br>Tel Aviv | Domestic and Tourism |
| 3 | Thessaly<br>Cyclades<br>Guadiana<br>Algarve<br>Germasogeia<br>Kokkinochoria<br>Arava<br>Doñana | All sectors |
| 4 | Akrotiri<br>Canary Islands<br>Belice Basin | Irrigation |

In order to graphically illustrate the clustering of regions, a principal component analysis on the data matrix consisting of the above three quantitative indices was performed. Figure 20 shows a plot of 15 regions on the first two axes extracted by the analysis. The percent variance accounted for by the two principal factors (Factor 1 and Factor 2) is 99%. The separation of regions into the four groups, as resulted by the cluster analysis, is very clear.

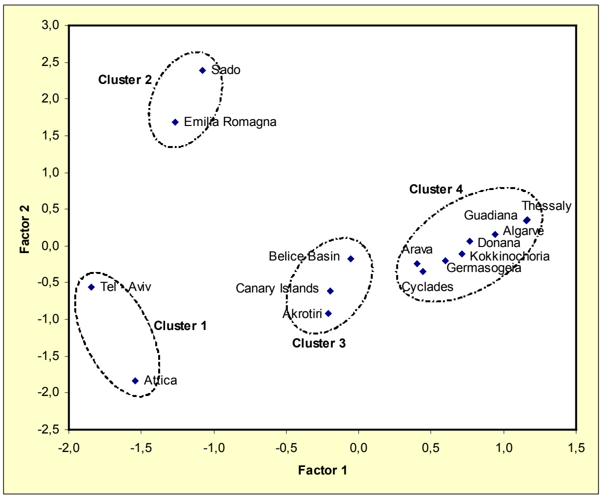



***Figure 20 Plot of regions on the first two axes extracted by principal components analysis***

## *A classification based on Responses to the Drivers and Pressures*

The term "Responses" in the context of the DPSIR framework applies mostly to long-term management actions. These generally aim at adjusting or mitigating the pressures and impacts caused by the human environment, but are rarely able to make an impact on the driving forces. These actions form parts of different Policy Options (Table 17).

The regions can therefore be classified according to the actions selected within each policy option (see Tables 18 to 21 that follow). It is also possible to see the policy options selected in each region.

***Table 17 Responses to water deficiency – Policy Options and Actions***

| Policy options | Actions |
|---|---|
| Supply Enhancement | Exploitation of unconventional/untapped resources<br>Exploitation of existing resources<br>Water production<br>Importing |
| Demand Management | Quotas<br>Irrigation improvements<br>Conservation measures<br>Recycling<br>Improve infrastructure<br>Water Reuse<br>Raw material substitution and process changes |
| Social – Developmental Policy | Change in agricultural practices<br>Change in regional development policy |
| Institutional Policies and other | Institutional Capacity Building<br>Economic Policies<br>Environmental Policies |

Regarding Supply Enhancement actions, it is obvious that all regions do utilise such actions. Also, it should be noted that Water Production as an action is only utilised in four out of the 15 regions.

***Table 18 Responses involving supply enhancement***

| Type | Response | Regions |
|---|---|---|
| I | Water transfers | Attica<br>Cyclades<br>Thessaly<br>Belice<br>Tel Aviv<br>Kokkinochoria<br>Sado<br>Algarve<br>Canary Islands |
| II | Exploiting existing resources | Cyclades<br>Thessaly<br>Germasogeia<br>Emilia-Romagna<br>Belice<br>Sado<br>Guadiana<br>Doñana |
| III | Water production | Cyclades<br>Tel Aviv<br>Arava<br>Akrotiri |

Similarly, for Demand Management options, it is obvious that only two of the regions use Quotas as a tool for demand management, whereas none of the three Greek Regions or the Canary Islands applies such actions.

*Table 19 Responses involving Demand management*

| Type | Response | Regions |
|---|---|---|
| I | Irrigation improvements | Emilia-Romagna<br>Belice<br>Sado<br>Guadiana<br>Algarve<br>Doñana |
| II | Quotas | Akrotiri<br>Germasogeia |
| III | Water reuse | Kokkinochoria<br>Tel Aviv<br>Arava<br>Emilia-Romagna<br>Belice<br>Sado<br>Algarve |

Few of the Regions analysed utilise Social and Developmental policies in water resources management. Of those, only in Germasogeia is there the option of a change in the Regional Developmental Policy. Agricultural practices changes are only employed in the other two Cypriot Regions, in Emilia-Romagna, Arava and Doñana.

*Table 20 Responses involving social and developmental policies*

| Type | Response | Regions |
|---|---|---|
| I | Change in regional development policy | Germasogeia |
| II | Change in agricultural practices | Emilia-Romagna<br>Arava<br>Akrotiri<br>Kokkinochoria<br>Doñana |

Finally, Institutional Policies are not used in the Cyclades, Belice and the Canary Islands, whereas all other Regions, with the exception of Doñana, utilise Economic policy actions.

*Table 21 Responses involving Institutional policies*

| Type | Response | Regions |
|---|---|---|
| I | Economic Policies | Attica<br>Thessaly<br>Emilia-Romagna<br>Tel Aviv<br>Arava<br>Akrotiri<br>Germasogeia<br>Kokkinochoria<br>Sado<br>Guadiana<br>Algarve |
| II | Environmental Policy | Thessaly<br>Tel Aviv<br>Germasogeia<br>Akrotiri<br>Kokkinochoria<br>Doñana<br>Emilia-Romagna |
| III | Institutional Capacity Building | Kokkinochoria<br>Doñana |

### *Conclusions - a proposal for Paradigm building*

The present research effort aims in ultimately developing and evaluating strategies and guidelines for an integrated water resources management that takes into account:

- economic,
- technical,
- social,

- institutional/political and
- **environmental** implications.

This is attempted through the determination of the distinguishing parameters that affect water deficiency and their interactions; the evaluation and formulation of strategies suited for water deficient regions will be attempted through the understanding of these processes.

To that effect, the approach for the formulation of the Typology of the regions, indices and indicators were analysed that address those specific issues; taking into account:

- The nature of the water deficiency,
- The water supply sources,
- The population, as they interact with, and shape, the natural environment,
- The economic activities in the area, and how they relate to water consumption,
- The social conditions in the area, and
- The current management of the water sector and the resource.

The ultimate aims of the formulation of this Typology approach can be summarised as follows:

- To enhance the understanding of the range of circumstances that occur in the analysed regions,
- To enhance the understanding of differences in types of water scarcity that are faced in different regions,
- To highlight the critical variables of vulnerability of the surrounding environments that affect water availability and water management,
- To develop a classification scheme of types of scarcity and responses using critical variables and important interrelationships of these variables, and
- To generate a typology of regions, in order to reduce the excessive number of individual cases and allow for generalising across meaningful categories.

In the aim to develop policies more sensitive to those particular ecosystems, an issue that is of major importance is the creation of **conflicts** among uses under the conditions of water scarcity. The nature of these conflicts is shaped by the interactions of economic activities of the area; these directly influence the **allocation** of water among uses, which at the present state is determined by each country's water policy.

Furthermore such conflicts contrast an existing or "real" management framework in the various areas with a proposed "ideal" or more comprehensive management approaches. The "ideal" may also be considered as the new "paradigm" for changing circumstances in a complex, demanding and fast evolving social and economic environment. By comparing the "ideal" with the real water resources management situation, it may be deduced that in all the cases the existing framework should deviate from the ideal one. Such a divergence may question the efficiency and effectiveness of the existing applied policy actions. Thus, the primary task of a holistic water resources management policy would be to bridge the gap between the ideal and the real conditions. Policy options should concentrate on minimising such a gap before it becomes chasmic through time Therefore, while the above arguments summarise, more or less, the character of water resources management policy options, such options may focus on the following:- towards the development of an <u>water resources policy</u> with a long-range time horizon for complex spatial and organisational systems such as the presented ones; -and the <u>application</u> of effective <u>water resources management schemes</u> as a result of the above action.

More specifically, the formulation of policies for the integrated management of water resources should take into account the **opportunity costs** incurred by the water deficit to each use, and produce rationalistic allocation alternatives that minimise those costs.

Under this light, the social and economic conditions that occur in the regions analysed become increasingly important, as it is those that will shape the conflicts that will invariably arise under shortage conditions.

In a synthesis of the classification approaches followed, three main types within the 15 regions can be distinguished based on Social and Economic criteria, summarised in Table 22 that follows. These three types concentrate the few characteristics that appear to be consistent throughout similar Regions.

***Table 22 Generalised Typology of Regions***

| Type | Distinguishing Characteristic | Description | Representative Regions |
|---|---|---|---|
| I | Predominantly Urban | Regions including metropolitan/large urban centres.<br>Main economic activities largely belong in the tertiary sector, although secondary sector activities are also present.<br>Water deficiency is either:<br>permanent, due to insufficiency of resources for the existing population, or seasonal due to meteorological / hydrological fluctuations.<br>Some price elasticity in water supply. | Attica<br>Tel-Aviv<br>Emilia -Romagna |
| II | Predominantly Tourist | Regions dependent on tourism, with small to medium sized urban centres and large seasonal population fluctuation.<br>Dependence on agriculture as well but the main source of income is tourist activities.<br>Seasonal water deficiency as a result of the population fluctuations due to the tourist industry's peak in the summer months.<br>Price elasticity is variable, depending on the local conditions. | Cyclades<br>Canary Islands<br>Algarve<br>Akrotiri<br>Doñana |
| III | Predominantly Agricultural | Regions dependent on agriculture, with small to medium sized urban centres and limited population fluctuation.<br>Dependence on secondary and tertiary sector activities is often limited compared to agriculture, which is the main source of income.<br>Usually seasonal water deficiency as a result of increased crop requirements of water in the summer time.<br>Price elasticity is variable, depending on the local conditions. | Germasogeia<br>Kokkinochoria<br>Arava<br>Belice Basin<br>Sado<br>Guadiana<br>Thessaly |

# Chapter 3 Paradigms

## Introduction

Water resources management policies around the world have used alternative paradigms and approaches. The pattern of development varied in different countries, but general trends are discernible. The traditional planning approaches that dominated showed a reliance on physical solutions, major new constructions and large-scale water transfers from one region to the other.

Today, the planning and decision processes begin to explore efficiency improvements, implement options for managing demand, and reallocating water among users to reduce projected gaps and meet future needs. The European Water Framework Directive has stressed the necessity of an integrated water management approach, for improving and maintaining environmental quality, using tools such as full recovery of the costs incurred in water supply, including environmental costs.

The term “Paradigm” has been used to describe a set of assumptions about reality held in common by a group of people. Philosophers have discussed its true meaning for many years. To ensure the understanding of the word “Paradigm”, a terminology definition is presented along with some of a Paradigm’s characteristics.

In the literature, “Paradigm” means a pattern or a model. It may be defined as *a set of rules and regulations (procedures, standards or routines) that:*

- *establishes boundaries, namely gives the edges or the borders, and*
- *provides solutions to problem-solving within those boundaries.*

*A paradigm is formed through a set of procedures. It is a sign of maturity in the development of the solution to any given problem. Before its formation there is a continual competition between various views that represent incommensurable ways of seeing the world. The laws, theories, applications and instrumentations that are used form the Paradigm* (Kuhn, 1970).

Paradigms filter incoming experience, and affect judgement and decision-making by influencing one’s perceptions. This “set of rules”, can have a positive or negative effect; it can focus attention to important information and enhance the perception of a problem, but it can also blind one to “alternative” and unexplored under the old paradigm solutions (paradigm effect). Paradigms can be challenged on a regular basis in order to identify potentially better ideas that exist outside the old paradigms (paradigm flexibility). On the contrary, believing that the only way to solve problems is the existing paradigms, can lead to the rejection of a new and different way of solutions, because it does not fit the rules that have already been followed and successfully used (paradigm paralysis).

When someone has used a certain Paradigm, it is difficult to change it, even though it is evident that the change is beneficial. One is seduced by success (paradigm paradox). On the other hand, there are practitioners of old paradigms who choose to change to a new one early in its development, even though there are no proofs for its success (paradigm pioneers). When the established Paradigm fails to provide effective solutions to emerging problems, a Shifting Paradigm usually occurs, which is a revolutionary new way of thinking about old problems.

In order to describe the Dominant Paradigm, one can utilise the indicators already determined in the DSPIR approach, which describe the processes taking place under different sets of conditions. The responses to the state of the water resources, the pressures applied to them and the impacts those pressures have can be used to define the current paradigm in managing the water resources. The DPSIR Indicators of each region are presented Chapter 4, and after the definition of these parameters, the Set of Paradigms applicable to each region, and a description of the Dominant Paradigms follow.

*Paradigms in Water Resources Management*

In Water Resources Management, the word **Paradigm** describes a school of thought on prioritising Policy Options for the Management of Water Resources. The formulation of a Paradigm is a difficult and complicated procedure as it reflects the conflicts between the established scientific and technological approach and the political and social opinions and demands. In order to define the range of and collect concepts that describe structural (dams, pipes) and human (administration, financial management) parameters of a water system, one must understand the technical, social, financial, cultural and environmental issues of the Paradigm.

The understanding of the existing policy options and actions that have been followed in order to manage water resources and their theoretical background, leads to identification of some basic and distinguished Paradigms of Water Resources Management for each region. Therefore, a dominant Paradigm for each region is the existing, traditional way of "how things have always been done".

Each Paradigm refers to the:

- geographical entities and their grouping regarding physical and human criteria,
- driving forces like population or economic activity trends,
- physical parameters of the available water resources (state, uses, effects),
- planning and measures regarding the available resources.

The first point offers the *Case Studies* for the Paradigm, the second and third point introduce the *analytical methodology* and the *qualitative and quantitative elements*, whereas the fourth point provides the *axiological, theoretical and practical socio-economical and political background*.

The twentieth century water development paradigm was based mainly on finding new sources of supply to meet new demand. The construction of massive engineering projects for flood control, water supply, hydropower and irrigation besides having undeniable benefits, it also has costs that are not purely economic, such as ecosystem degradation and water resources contamination. As these impacts become more obvious, the approach of water resources development starts to change. A *Shifting Water Paradigm* forms, which emphasises on incorporating ecological values into water policy. The shifting paradigm is an alternative prioritising of policy options, and respective actions, aiming at achieving Integrated Water Resources Management, particularly in water deficient regions, in a sustainable way.

This shift towards a new Paradigm is what is currently being effected in Europe through the Water Framework Directive. The WFD has introduced a new model of water management and planning, which has been prepared in order to accomplish a more effective governance of water in the environment. The directive enforces new structures and behaviours that aim to accomplish Integrated Water Resources Management and maintain or improve the environmental integrity of aquatic systems. The current, Dominant Paradigms will therefore need to shift, as the passage of enforcement deadlines continues, in order to accommodate the legislative aspects of the WFD.

Table 23 presents elements regarding practices that were used as dominant paradigm and those that can be used as shifting paradigm[5].

[5] Source: A New Paradigm for Water Management, N. Grigg

*Table 23. Elements of Water Management Paradigms*

| Paradigm Practice | | Dominant | Shifting |
|---|---|---|---|
| Governance | Authority | Command and Control, little regulation or participation | Distributed authority, co-ordinated approach, more regulation, more stakeholder involvement |
| | Regulatory structure | Weak regulations | Stronger regulations |
| | Centralization | Centralized | Decentralised |
| | Process | Simpler, more authoritarian decision-making | Searching for new processes for co-ordination and conflict resolution |
| | Ownership | Mostly public ownership | More flexible approach, more privatisation |
| Co-ordination | Geographic | Little basin or area-wide co-ordination | Watershed and area-wide approaches |
| | Competing uses | Priority uses such as irrigation dominated | More complete consideration of competing uses, including environmental |
| | Purposes | Fewer purposes | More purposes |
| | Values | Focus on economic goals | Balances values with appropriate consideration of social and environmental values to go along with economic and political |
| | Stakeholders | Less involvement of units of government and stakeholders | Consideration of views of wide range of stakeholders |
| | Disciplines | Engineering dominance | Multi-disciplinary |
| Technical | Hydrologic | Focus on yield of hydraulic structures and systems | Focus on natural systems and sustainability |
| | Administrative | Simpler command-and-control administrative systems with less regulation and participation | Dynamic process adapting to changing conditions |
| | Legal | Water law focused on allocation with less emphasis on environmental issues | Extensive bodies of statutory, administrative, and case law |
| | Engineering | Focus on structural solutions | Consideration of wider ranges of options to include non-structural and management strategies as well as structures |
| | Planning and assessment | Focused on economic issues | Extensive use of sophisticated planning tools to identify and assess alternatives throughout the planning and decision cycles |
| | Economic | Traditional benefit-cost analysis | Identifies full range of economic water needs and economic tools for use as incentives |
| | Ecological | Not very evident in water management | Identifies and considers full range of ecological water needs |
| Information Technology | | Centralised control of limited information | Distributed control of much information on real-time basis |
| Financial | Fairness and equity | Not very sensitive to social issues | Considers social aspects of financial resources to provide appropriate solutions |
| | Feasibility | Less stress on ability-to-pay | Advances affordable options |
| | Subsidies | More subsidies | More market-based |
| Education and Ethics | Continued improvement | Not evident in old paradigms | Enhances water quality and quantity |
| | Stewardship | Weakly valued | Added emphasis on stewardship of water resources |
| | Sustainability | Not in old paradigms directly | Managed on sustainable use basis |
| | Contributions to society | Less emphasis on contributions to society | Fosters public health, safety, and community good will |
| | Capacity-building | Little attention to capacity-building | More attention to capacity-building |

# Dominant Paradigms in Greece

Attica

The development priorities for the capital city and the surrounding areas include mostly the development of infrastructure in order to meet the needs of the growing population. Regarding water management, the main issues in this region are pollution prevention and mitigation, and the management of water demand. The response to water shortages in the region has been basin transfer from richer water regions, which is a very expensive and non-viable way of covering the demand. Attempts towards demand management have been made through conservation campaigns and pricing control. It is therefore apparent that for the Region of Attica, the Dominant Paradigm is Supply Enhancement, followed by Demand Management.

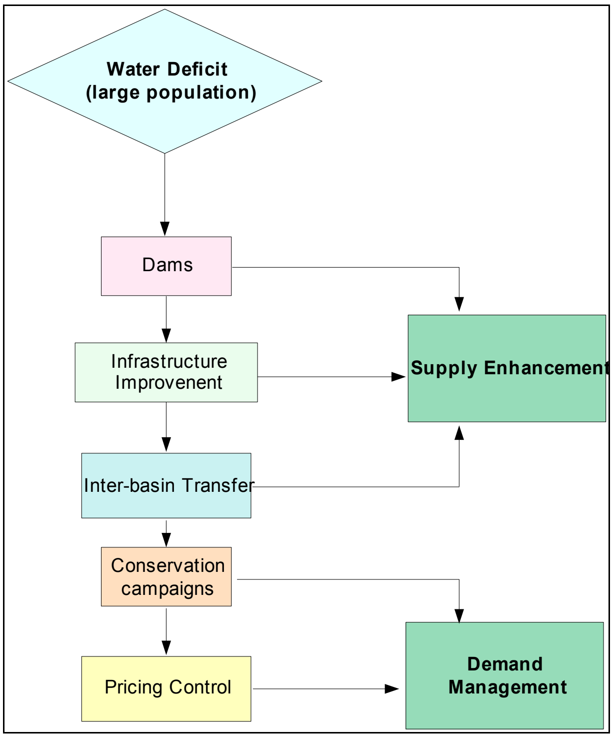



*Figure 21 Attica Dominant Paradigm*

Thessaly

Priorities for the region include the resolution of the conflicts that arise, the reallocation of water resources among uses that will allow for tourist development and the modernisation of the antiquated agricultural practices. Current practices have severe disadvantages like overuse of water and the pollution of aquifers and surface water resources with agrochemicals, as well as the overexploitation of the local aquifers. There is a planned inter-basin transfer of large quantities of water (600hm$^3$/y) from neighbouring regions, which however has already caused significant disputes. The Dominant Paradigm for this region is Supply Enhancement, followed by Environmental Policy.

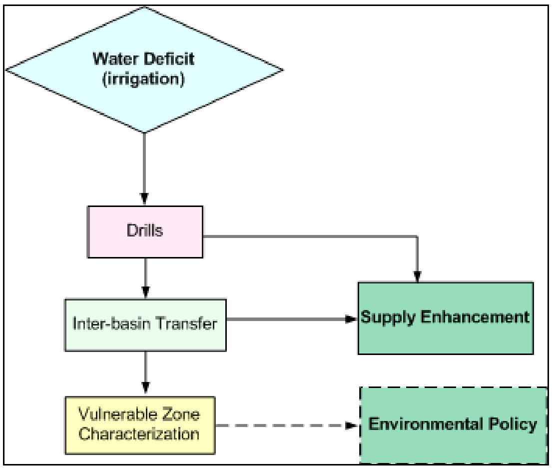



*Figure 22 Thessaly Dominant Paradigm*

Cyclades

The infrastructure of the islands is insufficient to cover the needs of the seasonal and in some cases even the permanent population, while at the same time the local resources are sparse and the increased demand is met through water transfer from the mainland, construction of small surface reservoirs and technological solutions such as desalination. Thus, the Dominant Paradigm for the region is the enhancement of the local supply, the creation and maintenance of infrastructure capable of meeting the needs of the permanent and seasonal population, and the conservation of water.

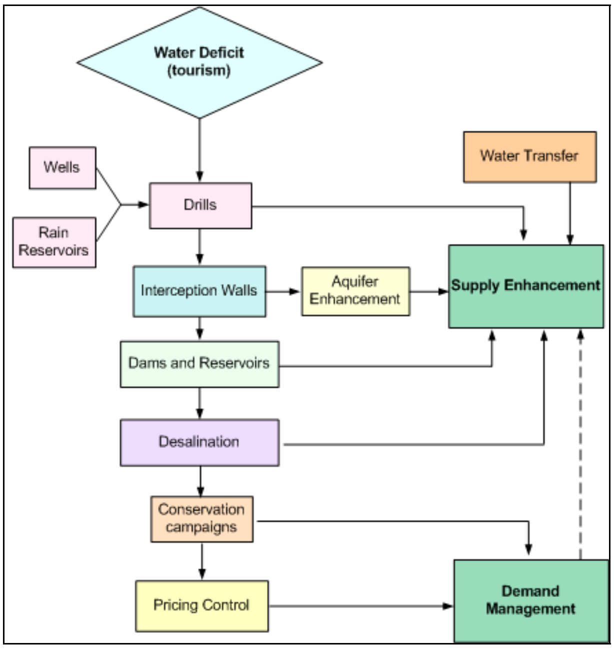



*Figure 23 Cyclades Dominant Paradigm*

## Dominant Paradigms in Italy

Emilia-Romagna

In Emilia-Romagna the Dominant Paradigm regards the protection and maintenance of Apennine's rivers and torrents. Therefore it involves the Demand Management option concerning the indirect solution of a shift from Apennine’s streams water use towards further exploitation of surface water from the Po River and his tributaries and increase of abstraction from aquifers, a water resource already overexploited.

Regarding eutrophication of the Po River basin fresh water and degradation of its ecosystem, the Dominant Paradigm focuses the attention on concentrations of nitrates and phosphorus of the water exiting the waste treatment plants which have to comply with standard values. If necessary, the building of new plants is considered. This solution aims to reduce the pollutant loads discharged in the Po River.

The Dominant Paradigm in the field of increased domestic and agricultural water demand and consumption, water losses along supply networks and decreased piezometric levels of aquifers, takes into account Supply Enhancement and Demand Management measures such as building of new supply and distribution networks, enhancement of existing reservoirs and pumping stations capacities, improvement of management efficiency of reservoirs and supply networks and use of more efficient irrigation techniques. The problem of over-exploitation of aquifers is partially solved by decreasing the abstractions and shifting towards surface water of river and reservoirs.

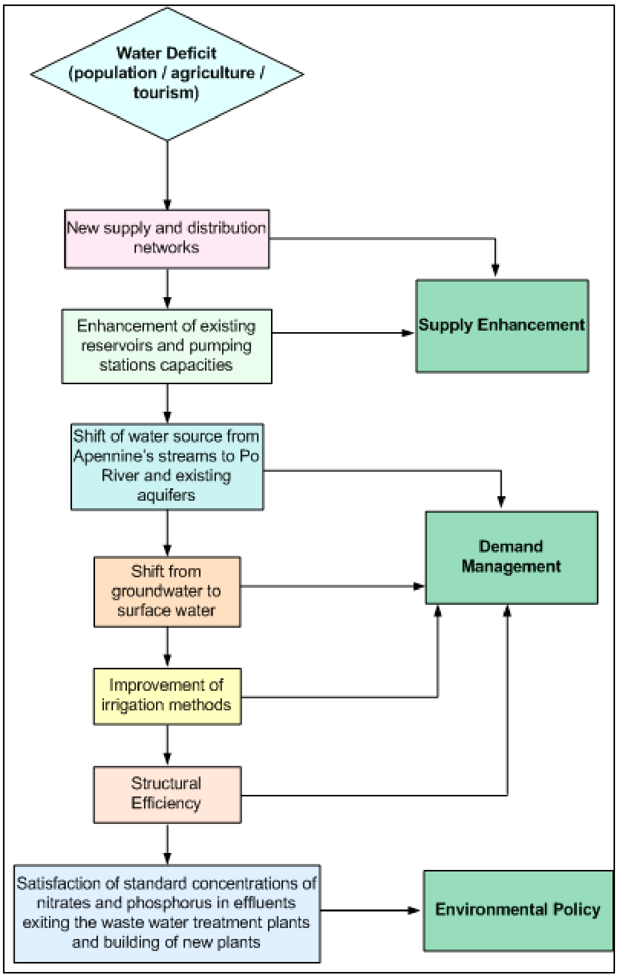



*Figure 24 Emilia-Romagna Dominant Paradigm*

Belice Basin-Sicily

The Dominant Paradigm regarding water deficit during the irrigation period involves the Supply Enhancement option mostly. It consists of transfers of water from neighbouring reservoirs and aqueducts, building of new proper connections, exploitation of unofficial wells and construction of further desalination units. Reservoirs feed water to agricultural sites mostly whilst unofficial wells and desalination plants feed municipalities. The social option is involved as well, addressing the change of water use of existing reservoirs from hydropower generation towards agriculture that has maximum priority.

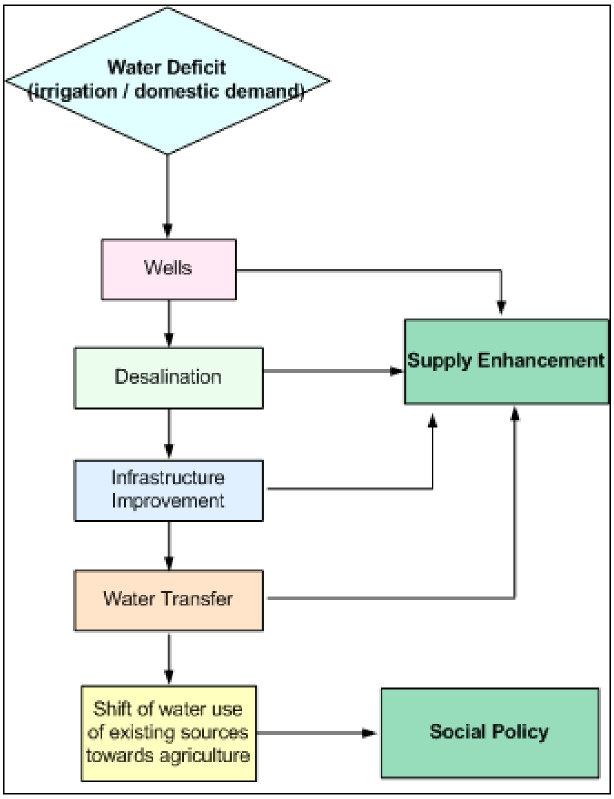



*Figure 25 Belice Basin Dominant Paradigm*

## Dominant Paradigms in Israel

Tel Aviv

The region is located in the coastal plain on the eastern shore of the Mediterranean Sea and it lies above the coastal aquifer. In terms of population, the Tel Aviv region is the largest in Israel with two million people, 30% of the total population. The region has 160,000 dunam (1 dunam = 0.10 hectares) of cultivated agricultural land, 5% of the total cultivated land in the country. The region's water economy is therefore characterised by relatively high domestic and industrial consumption, and relatively low agricultural consumption. About two third of the fresh water supplied to the region via the national water system operator by the national water company, Mekorot. The remaining third of the fresh water is provided by private producers from the coastal aquifer. In the future, this region is slated to receive a significant amount of the desalinated sea water.

Domestic consumption is similar to the national average (100 $m^3$ per capita per annum). This consumption is expected to increase by 20% with the development of metropolitan parks and the improvement in quality of life. The quality of the fresh water is good, with a salinity level of 150-250 mg chlorine per litre. In the future, the use of desalinated water will lead to an improvement in the water quality. The region's large population creates the potential for a large supply of recycled water for agriculture. In addition, high quality treated waste water can be used for irrigation of metropolitan parks and for rehabilitation of streams like the Yarkon River. The climate in the region is Mediterranean, semi-arid, with annual precipitation of 450 mm.

It is important to emphasise that in principal, the majority of the area of Israel (including the region of Tel Aviv) can be treated as a single geographic entity regarding the water economy for the following reasons:

- ❖ The National Water Carrier (NWC) connects all major sources of freshwater into a single network. Water can be transferred from one region to another, so that water from one aquifer may be used in a few geographical regions. In addition to the NWC which transfers water from the Sea of Galilee in the north to the centre and the south of the country (Negev), there are some additional major pipelines connecting various regions of the country.
- ❖ The Shafdan, a plant for the treatment of urban and industrial effluent of the greater Tel Aviv metropolitan area (which includes more than 30% of the country's population), is responsible for transferring recycled water to the southern region (Western and Northern Negev) for agricultural use. Two large additional networks convey recycled effluent from the Jerusalem metropolis to the Negev Plain and from the Haifa metropolis to the Western Jezreel Valley, respectively.
- ❖ Water prices by quality and sector (agricultural, industrial, and urban) are more or less uniform throughout the country.

The Israeli water economy is in the midst of a severe crisis whose main features are a shortage of fresh water and a steadily increasing deficit, poor and declining ground water quality (gradual salinisation) and pollution of most of the streams by untreated urban, industrial and agrochemical effluents. The commonly agreed-upon policy of maintaining a long term balance between the potential of available water and the utilisation of water resources could not meet consumer pressure, especially the pressure of the agricultural sector. The main quantitative expression of the crisis is a sharp decrease in the ability to pump groundwater without crossing predetermined red lines, where the agricultural sector bears the brunt of the necessary cuts. In the event of drought in the coming two to three years, the supply of water for domestic and industrial needs will also be in jeopardy.

Among many factors contributing to the water crisis are population growth and economic development, resulting in increased domestic and industrial consumption of freshwater. The transfer of freshwater to Jordan as required by the peace agreement and the over-pumping from the western mountain aquifer by the Palestinians both contribute to the crisis. Some decline in the natural renewal of water resources due to global climatic changes in the eastern Mediterranean region may result in a gradual decrease of the water potential. Additional crucial factors contributing to the crisis are inefficient institutional and administrative mechanisms for water allocation and control, and a poor decision-making culture (hydro-politics).

The Tel Aviv region is an integral part of the national water system and thus its current paradigm represents most of Israel's regions, which are connected to this system.

The Dominant Paradigm for the Tel Aviv region forms due to the facts that:

- ❖ There is no private ownership of water in Israel. By the Israeli Water Law of 1959 all water sources are publicly owned and their utilisation is controlled by the Water Commissioner. The allocation of water is administrative: the commissioner issues permits for production (extractions) to suppliers as well as allocations (quotas) for agricultural consumers.
- ❖ Prices of water delivered by the national company Mekorot are set by the government, and are determined in a procedure, which is open to political pressure (skilfully applied by the agricultural lobby). Viewing water prices not as an allocation instrument, but as a means to improve income distribution, water charges depend on the type of use: farmers pay the lowest prices, industry pays higher prices and households pay the highest. Within each sector prices do not depend on location; users

in all parts of the country face the same prices, regardless of the supply price of water. Private water suppliers are subject to quotas but can set prices independently.

The actual planning of water allocation made by the Water Commission follows several stages:

- ❖ Predicting annual water demand by sector and region (including, of course, that of Tel-Aviv), given the actual water prices,
- ❖ Determination of "red lines" for each of the major water sources and the implied total production permits of fresh water,
- ❖ The gap between aggregate demand and total supply of fresh water is bridged via investments in the water economy aimed at: (i) increasing the volume and flexibility of the within-region and between-regions conveyance systems of fresh water, (ii) development of additional (environmentally safe) water treatment plans, reservoirs and conveyance systems; (ii) improving the quality of fresh water as well as of the recycled effluents; and, in the longer run, (d) desalination of sea water.

The current management practices result in:

- ❖ Continuous pressure on the governmental budget to increase the share allocated to investments in the water economy and continuous pressure of the budget department of the Ministry of Finance to increase water prices, including the prices for agricultural use.
- ❖ The above pressure to raise prices is balanced by the agricultural lobby which is very influential in Israel. The main interest of the farmers is to receive as large as possible an allocation of fresh water at the lowest attainable price. The consequences of the success of the agricultural lobby have been over-utilisation of water for many years, hydrological deficits, the intrusion of seawater into the coastal aquifer, contamination of reservoirs, and the reduction of the carry-over capacity of the system. A major part of the hydrological crisis is also an environmental crisis, with continuous pollution of the rivers, aquifers and other natural resources. Serious ecological damage affecting unique natural resources and landscapes often results. These detrimental effects are among the major reasons for the current severe water crisis. Although still very influential, the agricultural lobby lost some of its political power in the last two decades.
- ❖ Additional conflict in the water economy exists between the agricultural and the urban sectors regarding the purification standards for disposal set for the cities by the government. Another conflict is over the allocation of the costs and the benefits associated with recycling between the generators of sewage (the municipalities) and the agricultural users. An additional conflict is the issue of assurance for the municipalities that the farmers will not reduce usage suddenly (due to an economic crisis for example) and leave the cities with treated water that cannot be disposed of.
- ❖ New and forthcoming partial privatisation of water supply is a potential source of conflict between the government-owned company, Mekorot, and private entrepreneurs on two issues: the control of the supply of newly developed water resources (mostly desalinated sea water and recycled wastewater) and the responsibility for the operation of the intra-cities water systems (currently operated by the cities themselves).

The current paradigm is the result of inefficient institutional and administrative mechanisms for water allocation and of a poor decision making culture (hydro-politics). The unsolved ongoing conflicts partially paralyse the water economy. This is especially true in a run of dry years (as in 1998-2001) in which many of the problems become more severe. The main quantitative expression of the current crisis is the severe reduction in the ability to produce freshwater from the aquifers (approximately 500MCM) without operating additional wastewater reclamation systems and desalination plants. The agricultural sector bears the brunt of the cuts (since the demand of the other sectors is rigid), and its allocation was recently reduced by about 40%.

To conclude, Israel (with the Tel Aviv region being a representative example of the situation associated with the national water system) is an example of a developed water economy experiencing a man-made water crisis. There has been neglect, much need for repairs, and attention must be paid to changing circumstances. A sustainable growth of the water sector requires a new paradigm. Fortunately, the fundamental structure of the sector is sound and the basis for reform exists.

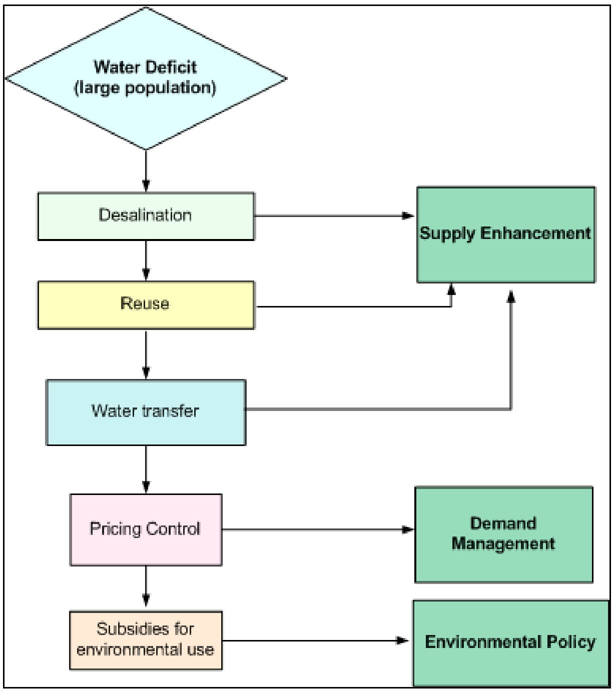



***Figure 26 Tel Aviv Dominant Paradigm***

Arava Region

The region is located at the south-eastern tip of Israel, between the Dead Sea and the Red Sea. The region is sparsely populated, based mainly on the tourist city of Eilat at the southern tip. The remaining population is scattered in rural villages. Land prices are low and there is no demand for additional urbanisation. Domestic consumption per capita in this region is particularly high, for two reasons; dry climatic conditions lead to heavy evaporation, and a greater demand for garden irrigation and drinking water. A large part of the population lives in rural settlements, where large amounts of water are needed for private and public gardens. Climatic conditions in the region: arid climate, very low precipitation (up to 10 mm rain per annum), aridity index 0.65. The climatic conditions favour intensive cultivation of vegetables, flowers and date palms. Some 40% of the greenhouses in Israel are located in this region.

The water supply system in the Arava is not part of the national water system. The region receives water from local sources only, via the national water company Mekorot. Drillings in the centre of the region (Faran drillings) yield water of reasonable quality - up to 350 mg chlorine per liter. Drillings in the southern Arava yield low-quality water of 600-1,100 mg chlorine per liter. It is important to note that the Red Sea is a unique coral reserve of great ecological value, and it is therefore essential that waste water be recycled for agriculture and not be disposed of in the sea.

The Dominant Paradigm for the Arava region forms due to the facts that:

- ❖ The prices for all the water supplied by Mekorot, fresh and saline, are determined within the national framework. Saline water is cheaper than fresh water, in accordance with the salinity level. The price for recycled water for agriculture covers the operational and the capital costs of Mekorot, after discounting state grants.
- ❖ The desalination plant of Red Sea water provides water for the local population in Eilat, the only city in the region.
- ❖ The utilisation of recycled waste water produced in Eilat for irrigation is insufficient and inefficient, due to lack of adequate storage facilities and conveyance systems as well as poor institutional structure. The potential to recycle wastewater produced in the rural villages is not utilised as well.

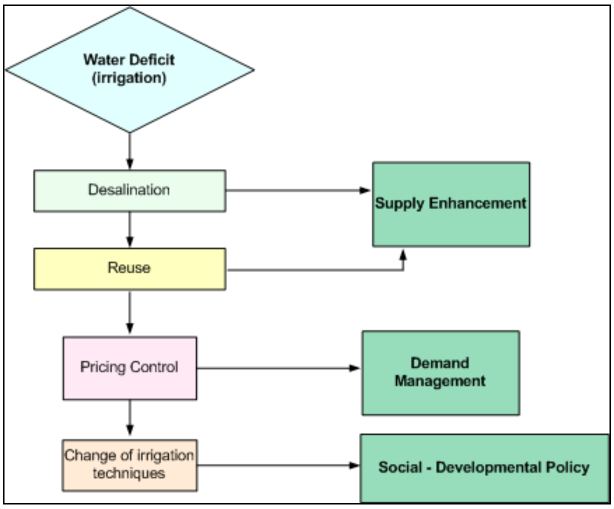



***Figure 27 Arava Dominant Paradigm***

The Arava region borders with Jordan. The water production balance – drillings and water production from the local aquifer – is affected by the peace treaty with Jordan.

# Dominant Paradigms in Cyprus

The Akrotiri area

The current strategy for ensuring adequate water supply for all uses, responding to the current conditions of water deficit, is based on a combination of a number of policy options including supply enhancement, demand management, social – developmental policies and institutional policies:

- ❖ Supply enhancement:
  - Efficient pumping control: The groundwater levels are observed monthly from a network of 150 since 1960, 85 to 100 of which are regularly sampled. The groundwater pumping is quite well monitored through water meters that are observed every month. About 90% of the annual extraction is metered and recorded at monthly intervals. The area is well surveyed and studied. A good database exists and numerous studies have been performed including groundwater modelling.
  - Water transfer from surface reservoirs: Until 1998 part of the irrigation requirements of the area were covered by water from the Germasogeia dam. Since that year the Germasogeia- Akrotiri pipe is used to transfer recycled water to the Germasogeia dam and as a consequence no water transfer is anymore possible from the Gerrmasogeia dam. Due to the water deficit problems, water is transferred from the Kouris dam (~ 6 $Mm^3$ in 2002).
  - Artificial recharge with water from surface reservoirs: Water from Kouris dam is

transferred to the area in order to recharge the aquifer at selected locations. This policy option depends on the available quantities of water in the dam (in 2002 2.6 $Mm^3$ were transferred, compared to only 42,000 $m^3$ during the drought period of 1998)

- Direct use of recycled water: Currently a major project using tertiary treated effluent (up to 6 million $m^3$) from the Limassol Central Sewerage Treatment Plant is in operation for irrigation purposes. The recycled water during the winter period is stored in Polemidia dam whilst during the summer period is used directly for irrigation.

- Exchange of pumping for domestic supply with desalinated water: A major desalination plant of 20,000-40,000 $m^3$/d capacity is planned for commissioning by 2004 to be built at the western part of the area. Surplus water that may arise from the operation of this plant will allow a better coverage of the agricultural demand and will also allow the built up of strategic reserves in the groundwater aquifer which are already to a very low level.

❖ Demand Management

- Application of special measures for water allocation (quotas): A quota system is applied for the allocation of government irrigation water in the Akrotiri area, on an annual basis and on the basis of the current groundwater conditions and the content in the surface reservoirs. The quota system in conjunction with penalty charges for over withdrawals contributes to the efficient use of the water. Under conditions of water scarcity, especially during droughts, priority and preference is given to covering a higher proportion of the domestic supply followed by greenhouse agriculture and permanent crops. Seasonal crops under these conditions are reduced dramatically.

- Application of special measures (water conservation law) which controls drilling and pumping on an annual basis requiring water metering (quotas): Special permits are issued on an annual basis governing the quantity of the water to be pumped. Preference is given to areas with problems of getting water from existing irrigation schemes.

- Water recycling (Limassol Central Sewerage Treatment Plant): Quantities of tertiary treated effluent (from the Limassol Central Sewerage Treatment Plant - LCSTP) are transferred at the Kouris river “Delta” area to recharge artificially the Akrotiri aquifer. It is expected that 5.25 $m^3$ of recycled water per year will be produced during the first stages of the operation of the LCSTP, and 10.6 $m^3$ per year at later stages.

❖ Social – Developmental Policy

- Implementation of Good Agricultural Practice Code regarding use of fertilisers and pesticides: The provisions of the Code of Good Agricultural Practice are applied through the Akrotiri area. The code includes: control of fertiliser use, use of improved irrigation systems and preparation of irrigation schedules, relocation (wherever is possible) of animal husbandry units, slurry collection, mechanical separation and land application of piggery waste, on-going farmer training programs, etc.

❖ Institutional Policies

- Implementation of block tariffs, seasonal prices and over-consumption penalties to domestic consumption: The Water Boards and the local Authorities and the area set progressive block tariffs, seasonal prices and over-consumption penalties to promote domestic water consumption efficiency and water conservation.

- Adjustment of water pricing to reflect true cost of irrigation water: contrary to the costs of domestic water that is almost full charged to customers, the price of irrigation water does cover neither the full financial nor the economic costs. The present tariff for the Akrotiri area is Cy £0.06/$m^3$ which is equivalent to 22.3% of the weighted average unit cost of water, although the Loan Agreements with the World Bank dictate that the price of the water should be at least 38% of the weighted average unit cost. As a result the WDD is examining the case to revise the prices upwards to reflect the true cost of the water. This will promote efficiency and water conservation measures contributing towards a sustainable water management alleviating the current water shortage problem. Such an approach complies also with the provisions of the new Water Framework Directive of EU, although it is well understood that its implementation will be very difficult.

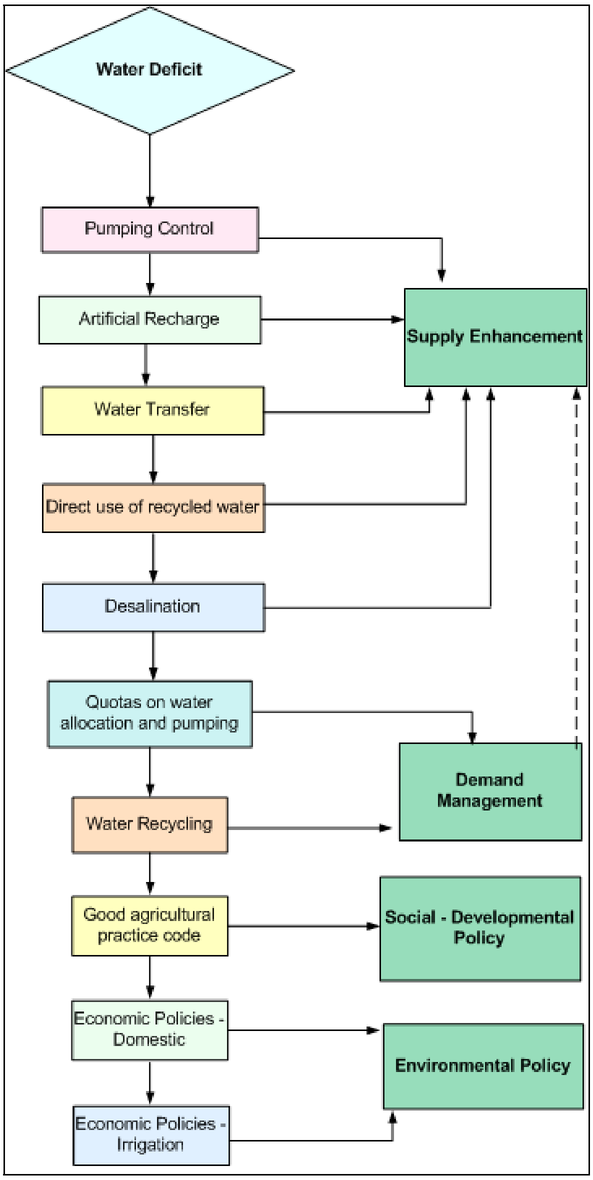



*Figure 28 Akrotiri Dominant Paradigm*

Germasogeia Area

The current strategy for ensuring adequate water supply for all uses, responding to the current conditions of water deficit, is based on a combination of a number of policy options including supply enhancement, social-developmental and institutional policies:

❖ Supply enhancement

- Co-ordinated program of releases from Germasogeia and Kouris dam for artificial aquifer recharge: The small Germasogeia riverbed aquifer has been turned into a natural treatment plant for domestic water supply without the need of complicated and expensive surface water treatment requiring chemicals, qualified technical and managerial personnel and the necessary civil engineering structures. Since the construction of the Germasogeia dam recharge of the aquifer depends on controlled releases from the dam and its spills and supplementary on releases from the Kouris dam (6.5 $Mm^3$ in 2002 compared to 2.3 $Mm^3$ in 1998).The complete cut-off of natural replenishment by the construction of the dam and the proximity to the sea, coupled with the increasing extraction from the aquifer made necessary the development of a co-ordinated program of releases from the dam for artificial recharge to cope with the extraction and minimise groundwater losses to the sea. With such action the sea intrusion is controlled and at the same time an efficient use of the scarce water resources is made. This conjunctive use of the surface and groundwater reservoirs enabled a dramatic increase in the extraction from this aquifer (more than three times its active storage capacity is being pumped annually) deferring the need for an expensive treatment plant for many years. Groundwater is pumped for the domestic water supply of the Limassol town, for the surrounding villages, and the tourist zone. This aquifer is the only source of domestic water supply of the local village communities and the tourist zone.

- Efficient pumping control: In the aquifer some 46 boreholes are monitored every 15 days and conductivity logs are kept for 10 boreholes for monitoring the sea/fresh water interface. The extraction from all wells and boreholes is monitored on a monthly basis by water meters. The releases for recharge are monitored on a daily basis. A good database exists and GIS as well as groundwater models exist for the area.

❖ Social – Developmental Policy

- Strict control of urbanisation within aquifer through Town Planning zoning and of domestic sewage management: A fast growing urbanisation within the aquifer area (the aquifer is crossed by the Limassol-Nicosia highway, by local important roads, the main SCP pipeline, the main pipeline and the irrigation network of the Germasogeia dam, the main pipelines of the Limassol-Amathus raw and treated sewage, the local sewage system, etc.) and tourist development are causing concern about the environmental conditions (mainly the possible deterioration of the quality of groundwater) of this highly susceptible aquifer. As a result the aquifer is considered as a high risk aquifer. A number of protection measures have been applied including: strict control on the planning zones of the area, Germasogeia Municipality was one of the first Municipalities to be connected to the Limassol Central Sewerage System.

- Reduction of pumping for the domestic supply and replacement with water from other sources: The WDD is examining alternative potable water sources for the areas within the aquifer, in order to reduce the pumping from it and use it for strategic planning.

- Increased monitoring of sea intrusion propagation and adjustment of artificial recharge regime accordingly: The hydrogeological regime and the water balance of the aquifer are "regulated" by controlled releases from the dam into the river valley and continuous monitoring of sea/fresh water interface (conductivity logs are kept for 10 boreholes.

- Development of protection areas around wells and well-fields: Due to the susceptible character of the aquifer, all the wells and boreholes in the Germasogeia aquifer are surrounded by a protection zone within which development is prohibited.

❖ Institutional Policies

- Implementation of block tariffs, seasonal prices and over-consumption penalties to domestic consumption: The Water Boards and the local Authorities and the area set progressive block tariffs, seasonal prices and over-consumption penalties to promote domestic water consumption efficiency and water conservation.

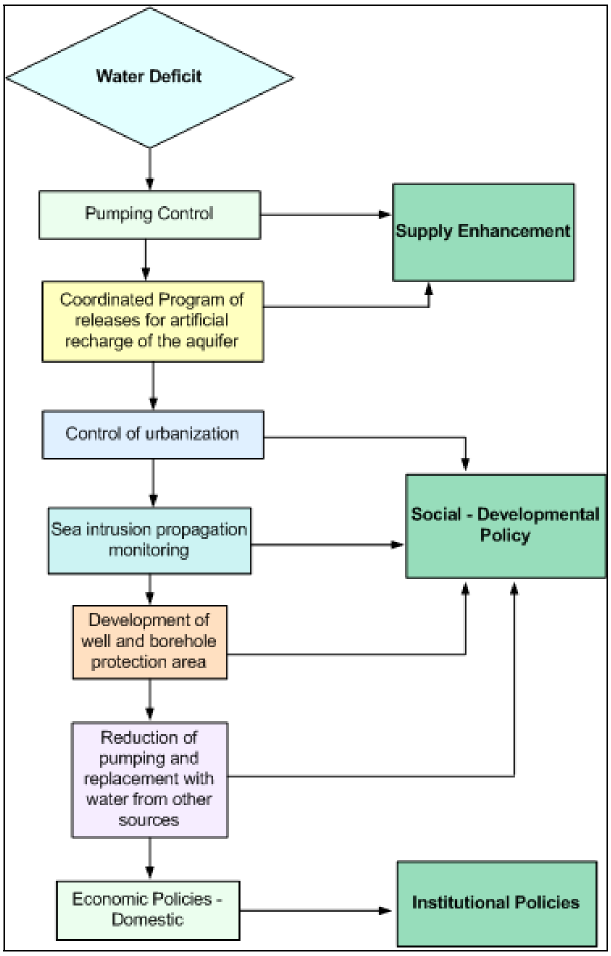



***Figure 29 Germasogeia Dominant Paradigm***

Kokkinochoria Region

The current strategy for ensuring adequate water supply for all uses, responding to the current conditions of water deficit, is based on a combination of a number of policy options including supply enhancement, social-developmental and institutional policies:

❖ Supply enhancement

- Inter-basin transfer: The past agricultural activity in the area has been maintained by importing water through the Southern Conveyor Project from the Kouris Dam some 70 km to the west. A total of an annual supply of 17 $Mm^3$ has been envisaged which together with the local safe yield of 8 $Mm^3$ allows the continuation of the agricultural activity in the area. However during the last four years (drought period) no more than 2 $Mm^3$ (annually) were transferred in the area to cover only the demand of the permanent plantations of the area.
- Exchange of pumping for domestic supply with desalinated water: Desalination is meeting most of the domestic water demand of the area. The area is served by the Dhekelia Desalination Plant. The Plant was established in 1997 with a capacity of 40,000 $m^3$/day.

❖ Demand Management

- Application of special measures for water allocation (quotas): A quota system is applied for the allocation of government irrigation water in the Kokkinichoria area, on an annual basis and on the basis of the current groundwater conditions and the content in the surface reservoirs. The quota contributes to the efficient use of the water. Under conditions of water scarcity, especially during droughts, priority and preference is given to covering a higher proportion of the domestic supply followed by greenhouse agriculture and permanent crops. Seasonal crops under these conditions are reduced dramatically.

- Alternative employment opportunities: A lot of the workforce shifted from agriculture to other employment associated with the locally thriving tourist industry.

❖ Social – Developmental Policies

- Implementation of Good Agricultural Practice Code to avoid excessive use of fertilizers: The provisions of the Code of Good Agricultural Practice are applied through the Kokkinochoria area. The code includes: control of fertilizer use, use of improved irrigation systems and preparation of irrigation schedules, on-going farmer training programs, etc.

- Change of cropping patterns: Due to the water deficiency problems in the area attempts to modify the existing cropping patterns shifting to winter (more rain-fed) potato are promoted. The Extension Services of the Department of Agriculture provide help to farmers in the modification of their cropping pattern while the Agricultural Research Institute provides the necessary scientific background in the process of introducing new profitable less water demanding crops.

❖ Institutional Policies

- Stricter enforcement of legislation: Thousands of illegal boreholes exist in the area. The associated uncontrolled over pumping lead in a dramatic depletion of the aquifer. As a result attempts for a stricter promotion of the legislation regarding the illegal boreholes are promoted.

- Adjustment of water pricing to reflect true cost of irrigation water: Contrary to the costs of domestic water that is almost full charged to customers, the price of irrigation water does cover neither the full financial nor the economic costs. The present tariff for the Kokkinochoria area is Cy £0.07 /$m^3$ which is equivalent to 26% of the weighted average unit cost of water, although the Loan Agreements with the World Bank dictate that the price of the water should be at least 38% of the weighted average unit cost. As a result the WDD is examining the case to revise the prices upwards to reflect the true cost of the water. This will promote efficiency and water conservation measures contributing towards a sustainable water management alleviating the current water shortage problem. Such an approach complies also with the provisions of the new Water Framework Directive of EU, although it is well understood that its implementation will be very difficult.

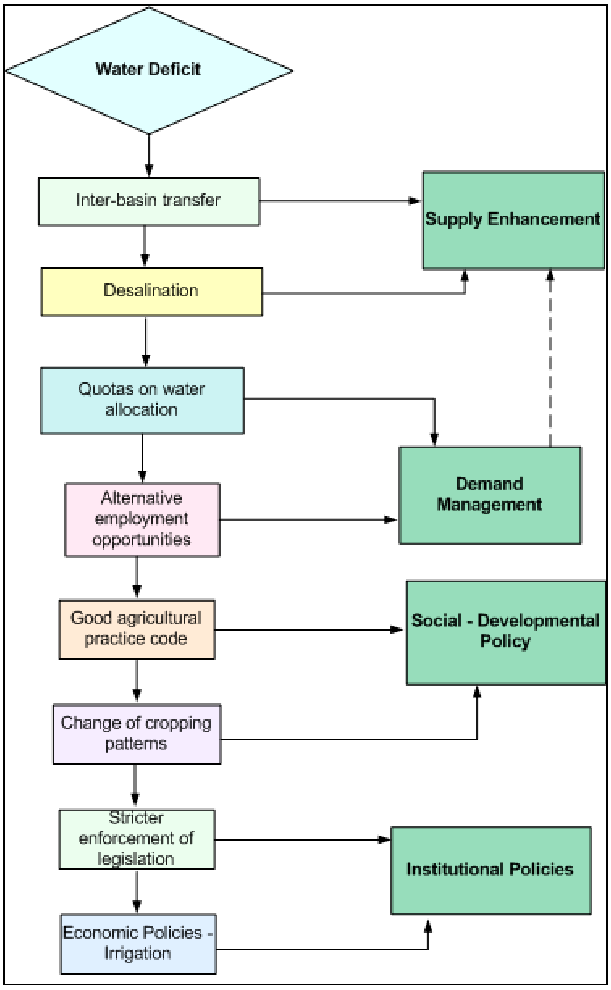



*Figure 30 Kokkinochoria Dominant Paradigm*

# Dominant Paradigms in Spain

Canary Islands

The Canary Islands face an uncontrolled growth of the population and the sector tourism. On the main islands (Tenerife and Gran Canaria), where the greatest part of population is concentrated, urban and tourist consumption dominate. In the minor islands of the archipelago with a strong tourist penetration, tourist water consumption is progressively approaching the urban one (in Fuerteventura, whereas in Lanzarote tourist water consumption is higher than urban consumption). Also, agricultural consumption is a priority on islands like La Palma and El Hierro, reaching the 80% of total consumption. The water demand has been exceeding for a long time the renewable resources available in several islands. The current responses described as follows lead to the formulation of the Dominant Paradigm for Canary Islands.

## Tenerife

The island of Tenerife represents an exemplary case with regard to the problems derived by progressive water scarcity and new difficulties of supply, due to very rapid rise in population accompanied by an arbitrary spatial distribution. This rise has been caused by the striking tourist growth that has been experienced in the last years (3,811,990 in 2001 - Source: ISTAC-Canary Islands Government).

On the island of Tenerife, there has been a significant exploitation of groundwater through wells and drills. Rain reservoirs were also used along with regulatory reservoirs. The construction of Desalination Plants followed, a practice on an increasing trend. Therefore Supply Enhancement is the dominant paradigm for this island, although there have been some actions towards Demand Management with water reuse and leakage control.

**Lanzarote**

Water availability has traditionally been very limited on the island of Lanzarote, characterized by extreme aridity. It is its low altitude, in fact, that does not allow the condensation of humidity that the trade winds supply to the higher islands of the Canary archipelago. The island could historically support a population slightly higher than the limit imposed by the lack of water thanks to the development of a surprising system of cultivation without water on volcanic sands that are able to collect humidity from the environment. To this we have to add a very complex water culture and the traditional saving systems. The island's opening to tourism started in the 1970s, and transformed the whole water system, driving the island to depend almost entirely on the production of desalinised water. In effect Lanzarote is the first European centre of large-scale water desalination deployment, having passed through all the technological stages (multi-stage flash, pressure steam and, finally, reverse osmosis).

The Dominant Paradigm for this island is again Supply Enhancement, but with the use of advanced technological methods, such as desalination and water reuse. On the island of Lanzarote, 97% of water supply is from desalination. Actions towards Demand Management have also been taken, like the establishment of tourist labels and eco-taxes and water campaigns.

**El Hierro**

Within the Canary archipelago, El Hierro has been among the islands where water scarcity and variability had the most dramatic repercussions. The lengthy droughts during 19th century lead to famine that decimated up to 30% of the population. For the same reason almost 40% of the population emigrated between 1930 and 1960. The island possesses a most valuable and particular water culture that includes amazing facts such as planting trees to capture the humidity contained in the fogs generated by trade winds, being each tree provided with an ingenious system for water collection at its base. El Hierro has been declared a Biosphere Reserve by UNESCO, to acknowledge not only its landscape and natural value but also for the importance of the exceptional water culture and the strategy for water production within the framework of the 100% RES project, since the island, after finalising this project will be the first island in the world to be entirely supplied from renewable energy sources.

Contrarily to Tenerife and Lanzarote, this island faces water deficit because of agricultural and domestic demand. Because of this difference, the Dominant Paradigm is Developmental Policy using water culture programs, substitution of crops, desalination with the use of renewable energy sources and new technologies on preserving water resources. Demand Management is also used additionally to the previous mentioned practices.

**La Palma**

The island of La Palma shows pronounced contrasts. The Northern and North-western part of the island are characterised by plenty of water, both surface and aquifers, while the South is an area extremely marked by recent volcanism. Massive development of agriculture for export (bananas), very high water-demanding, creates cases of local scarcity and overexploitation of some aquifers. Furthermore, new areas of tourist development, located in the South and the East, started to establish their water demand showing imbalance between areas and generating new transport demands.

On this island monitoring of water resources along with stakeholders involvement and the establishment of tourist environmental standards are the common acts regarding water resources management. Therefore, Institutional Policies form the Dominant Paradigm, reinforcing by Environmental Policy as well.

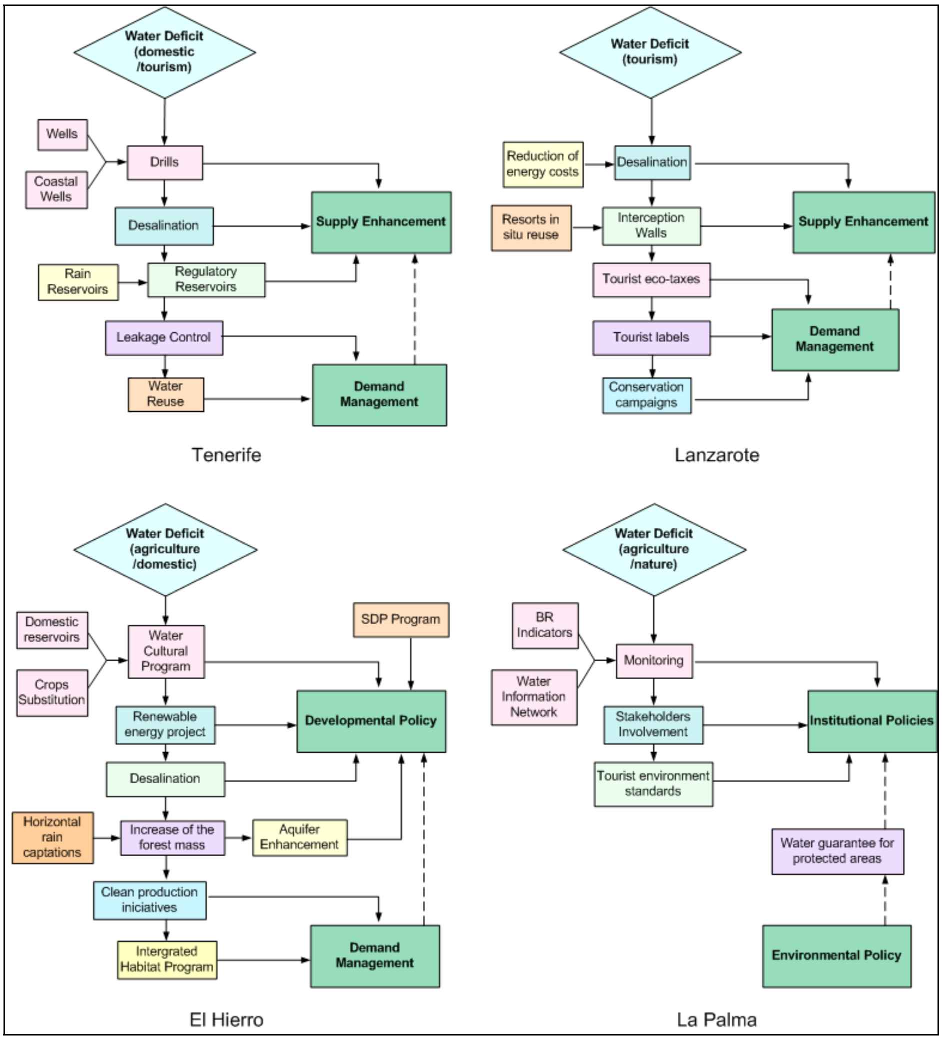



***Figure 31 Canary Islands Dominant Paradigm***

Doñana

Doñana is a typical case of commitment both to the conservation of the nature and the significant agricultural and domestic demand. It is a territory in which the most important European wetlands coexist, the National Park of Doñana that includes areas of rice fields, intensive crops and a considerable tourist activity, mainly concentrated on the coastline.

These multiple activities resulted in a change of the water regimes, followed by a serious overexploitation of groundwater and manipulation of superficial water systems, which have seriously endangered the preservation of the National Park of Doñana.

Another interesting fact is the hydrological characteristics of the area. It is divided into two domains:

- The coastal wetland. It is a plain area that combines periods of flood and drought. Its main sources of water are the rivers and tributaries and, in a smaller proportion, some few emergencies of underground water running through pipes.
- The rest of the territory is basically made up of sand. This is the area where water precipitation overload the water table (called water table 27). It holds most of the

water demanding activities.

The conflict between preservation and a balanced leverage of water resources in Doñana materialises with the solving and recognition of the following actions. These actions include reduction of groundwater exploitation, alternation of crops and tertiary treatment of sewage and have succeeded to maintain the aquifer level and the regeneration of the natural hydrological Systems. The Dominant Paradigm for this region is consequently the promotion of Environmental Policy.

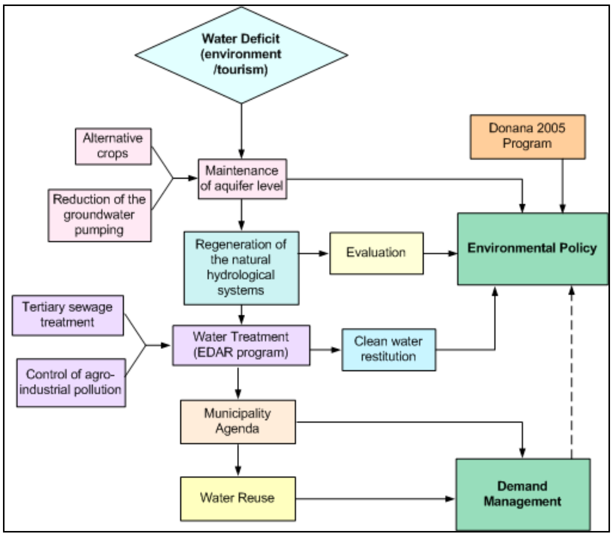



*Figure 32 Donana Dominant Paradigm*

## Dominant Paradigms in Portugal

The Regional Paradigms shall be framed on the current and foreseen national reality and policy options as well on its Dominant Paradigms and on the regional currently foreseen constraints and water policy strategic aims. That way, although the following analysis will refer only to the Syros paradigm components, it should be kept in mind that the referred main national specific policy options –“Transboundary Interdependence”, “EU and National Water Policy Integration” and “Land-use and Water Policy Integration”- shall also add to those. The three Portuguese chosen regions present specific realities that should be considered in the paradigm components definition.

Sado river basin

Sado is the Portuguese river basin with the biggest storage capacity when compared to annual mean flow. Up until now, the local economy was based in agriculture and industry. The Sado Basin concentrated an important part of the heavy industry, namely chemical industry. Nowadays this industry is stagnated and it is no more a region’s priority. Currently, the already chosen strategic option seems to focus (again) mostly on agricultural development. The Dominant Paradigm includes an improvement on management efficiency of reservoirs and supply networks, in order to increase water availability (Development Policy).

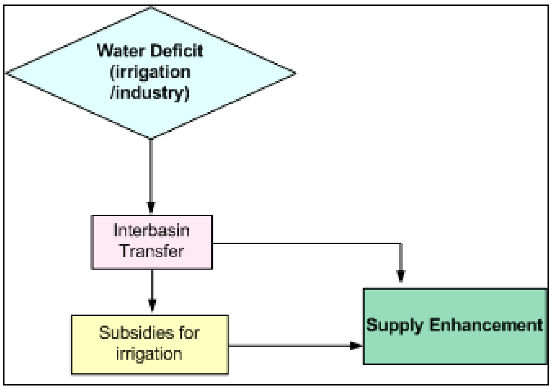



***Figure 33 Sado Dominant Paradigm***

Guadiana river basin

Guadiana is one of the regions that have lastly been more affected by droughts. The Guadiana basin, mostly because of the construction of Alqueva hydraulic plant, is on a transition phase. Until now, the large agriculture exploitations were on the basis of the local economy, and that is expected to stay unchanged on a mid-term development period. However, the low income existing in this region is still an important issue. That way, the huge increase on water storage capacity due to the construction of Alqueva hydraulic plant (Supply Enhancement / Social Policy) is an obvious major component of the Dominant Paradigm, but its medium and long-term effects cannot be determined and quantified.

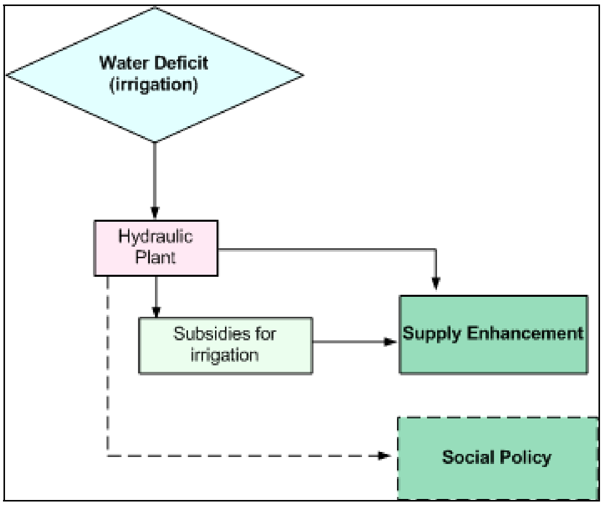



***Figure 34 Guadiana Dominant Paradigm***

Ribeiras do Algarve river basin

The Ribeiras do Algarve basin is the most important tourist destination in Portugal. This area attracts a large number of people, currently estimated as 5,000,000 tourists per year. The Ribeiras do Algarve basin suffers, mostly during the summer period, from the conflict of uses between urban needs and irrigation demands. Tourism is, and will remain, the development priority. Inter-basin water transfer and irrigation subsidies are the common used acts that form the Dominant Paradigm.

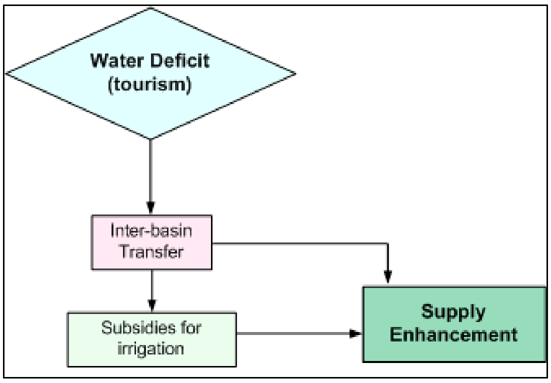



*Figure 35 Ribeiras do Algarve Dominant Paradigm*

# Chapter 4 Detailed Regional Data

## Greece

### *Attica*

#### *Regional Data*

The Water Region of Attica covers an area of 3,207 km$^2$. The region has several mountains (Parnitha, Kitheronas, Penteli, Imitos, Egaleo, Pateras) and plains on the coastal zone. The mean elevation is 115 m. It also includes a few islands, major ones being Egina, Salamis and the uninhabited Makronissos and a small part of Sterea Ellada (Voiotia) and Peloponnesus.

Attica borders Sterea Ellada to the north, Peloponnesus to the south, its eastern shoreline is on the south Evoikos Gulf and the Aegean and its western shoreline is on the Saronikos Gulf.

The two main rivers are Illissos and Kifissos, which in the urbanized areas have been transformed into covered stormwater conduits and drain into Saronikos Gulf. Their drainage basin covers 320 km$^2$. There are two small natural lakes, Vouliagmene and Koumoundourou. None of the drainage basins in Attica is larger than 600 km$^2$. The reservoir of Marathon, which is used for the water supply of the metropolitan Athens area, is located in the drainage basin of the Charadros River (185 km$^2$). The capacity of the reservoir is 41 hm$^3$.

***Table 24 Surface of the drainage basins in Attica***

| Drainage Basin | Surface (km$^2$) |
|---|---|
| Attica's Kiffisos River – Illissos River | 320 |
| Sarantapotamos River | 310 |
| Charadros River | 185 |

The climate is Mediterranean continental. The average temperature is 16 – 18°C. The average annual rain height is 400 mm, ranging from less than 400 mm in the south coastal areas, to 600 mm at the mainland and 1,000 mm on the mountains. Rain occurs 50 to 100 days per year. The precipitation is 1,698 hm$^3$/yr and the total runoff 259 hm$^3$/yr. Snowfall is very rare at the coastal areas but occurs on the mountains from October to April.

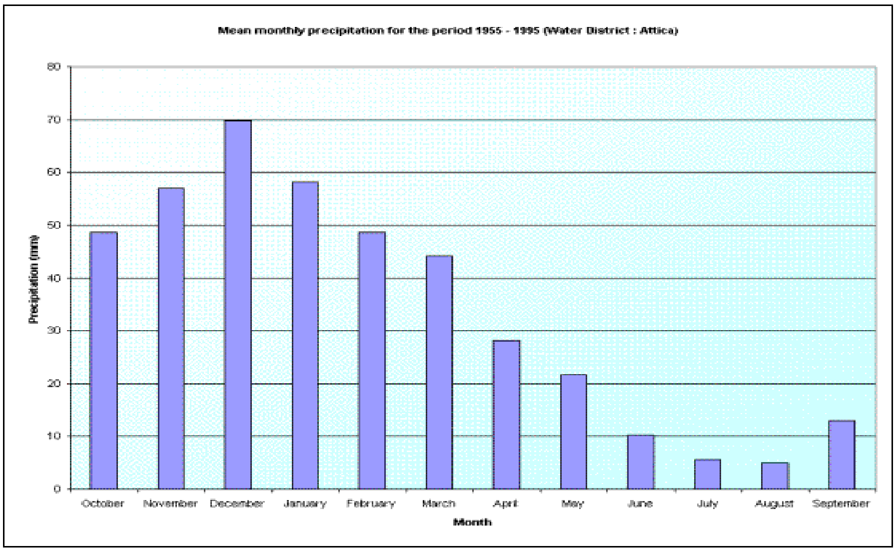



***Figure 36 Mean monthly precipitation for the period 1955-1995 in Attica***

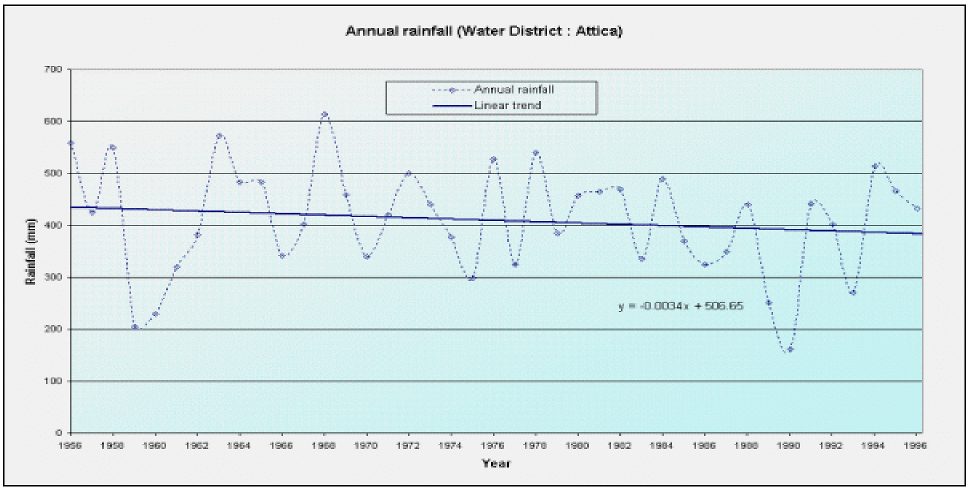



*Figure 37 Annual rainfall in Attica*

Permeable geological formations cover a significant amount of the total area. Karstic limestone formations cover the east and west part of the region. The total water availability is about 449 $hm^3$. This amount consists of 259 $hm^3$ surface water and 190 $hm^3$ potential groundwater. The groundwater can be found in the karstic and alluvial aquifers of the Region.

*Table 25 Hydrological Entities of Attica*

| Hydrological Entities | Surface ($km^2$) | Total Runoff ($hm^3/yr$) | Potential Groundwater ($hm^3/yr$) |
|---|---|---|---|
| Karstic entities in limestone formations | | | |
| South Parnitha – East Pateras - Egaleo | 510 | 157 | 120 |
| Kitheronas | 260 | 75 | 50 - 70 |
| Gerania | 250 | 42 | 20 |
| Penteli | 250 | 55 | 30 |
| Ymitos | 110 | 15 | 30 |
| Northeastern Parnitha | 300 | 95 | 60 |
| Total | | 439 | 250 - 270[6] |
| Alluvial aquifers | | | |
| Athens | 440 | 30 | 5 |
| Mesogeia | 820 | 50 | 15 |
| Megara | 260 | 15 | 3 |
| Loutraki | 320 | 20 | 4 |
| Total | | 115 | 27 |

[6] Northeastern Parnitha not included as it discharges in the Water Region of Eastern Sterea Ellada

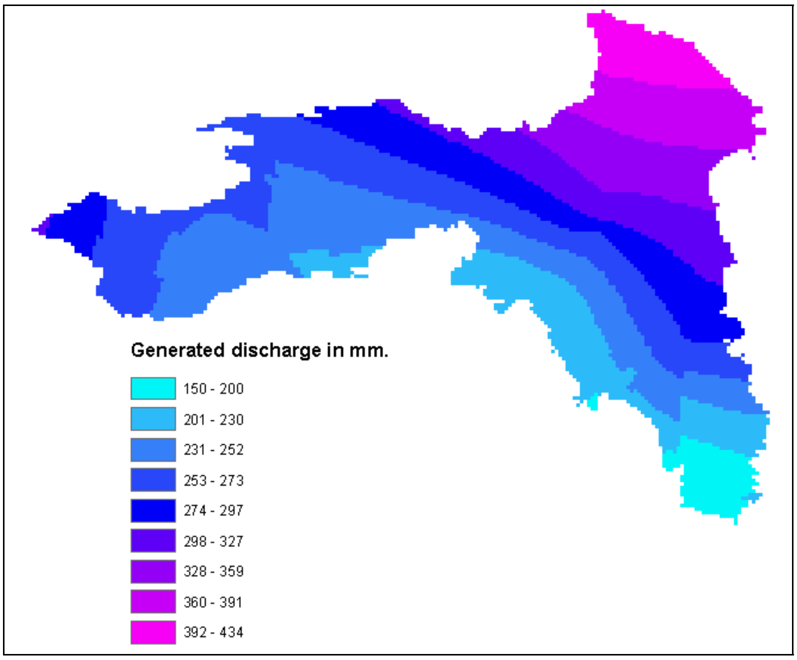



*Figure 38 Generated discharge in Attica*

There is no systematic monitoring of surface water quality in Attica, but as rivers are the recipients of unprocessed wastewater, they are generally in poor condition and their exploitation is unattainable. The treatment plant of Psytalleia treats 80-90% of the produced domestic wastewater. Many of the industries use the sewage system as well, but some others, through illegal connections, throw their waste directly into rivers and torrents or into the sea, which results the diminution of the quality of surface and ground water.

Results for ground water show that nitrates exceed the critical load for drinking water. In certain areas with significant industrial activity, high concentrations of heavy metals occur.

The main pollutant loads produced in Attica for the year 1996 were estimated as:

- BOD5: 120,000 ton/year,
- TSS: 420,000 ton/year,
- Total nitrogen: 20,000 ton/year, and
- Total phosphorus: 8,000 ton/year.

Attica has 3,761,810 inhabitants (2001). It includes the capital district, and small parts of Sterea Ellada and Peloponnesus Region. The main economic activities are commerce, industry, agriculture and tourism. The region produces 36% of the GNP, while the per capita product is €12,560, and the mean declared income per inhabitant was €6930 in 2000. The unemployment rate in the region is 10.4%. The total annual water demand is 408 $hm^3$, consisting of 289 $hm^3$ for domestic use, 101.5 $hm^3$ for agricultural use and 17.5 $hm^3$ for industrial use. The consumption index is estimated to be equal to 69% and the population to water resources index is equal to 4494. The exploitation index is 49%.

In order to satisfy the demand, a significant amount of water is imported from the Hydrological Department of West Sterea Ellada (Rivers Mornos and Evinos), and from the Hydrological Department of East Sterea Ellada (Lakes Iliki and Paralimni).

Desalination plants are used to cover industrial demand.

The supply of water and wastewater services is effected by EYDAP S.A., the biggest water company in Greece, and hence the cost recovery for water services in this region is good, and the pricing of water is done on the basis of the services provided and is not subject to political pressures. Attica is the only part of Greece where demand management through pricing control has been effective, in the drought periods in the 1990's. As a consequence, public education on water conservation issues is on average better than in most other regions of the country, although there is little to no public participation on water-related decisions. Decision making regarding water issues in Attica is effected on the national level, as the region is under the direct control of the Ministry of the Environment.

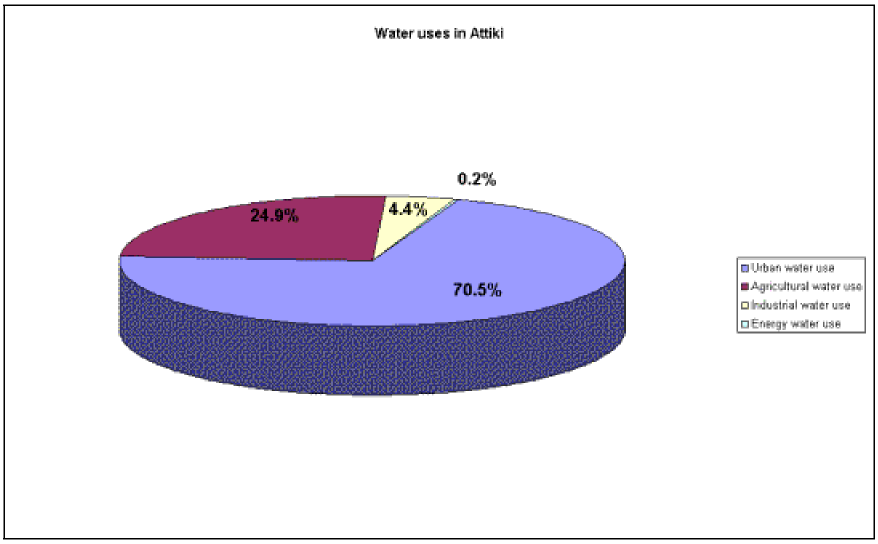



*Figure 39 Water uses in Attica*

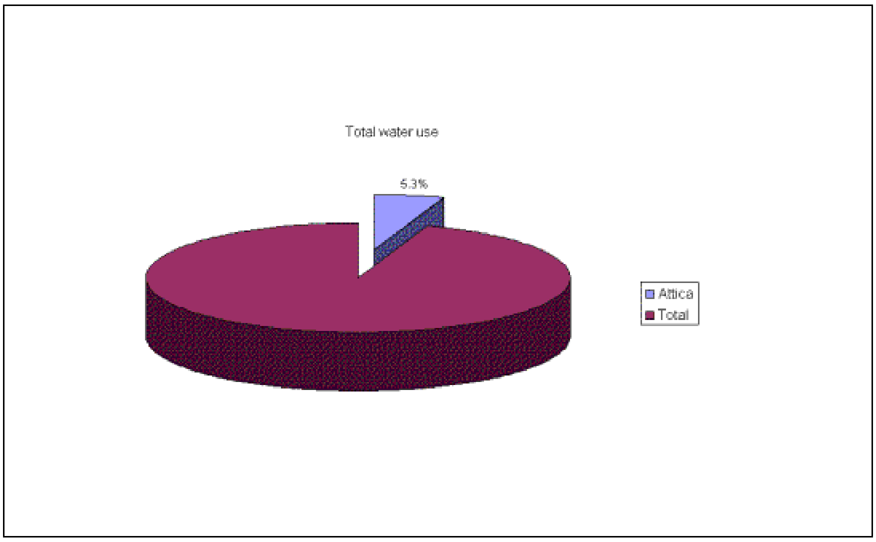



*Figure 40 Percentage of the total water use in Attica in proportion with the water use in the country*

## Matrix of Circumstances

***Table 26 Attica Matrix***

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Mediterranean |
| | | Aridity Index | 0.31- Semi-Arid |
| | | Permanent Population | 3,761,810 |
| | Water availability | Total Water Resources /Availability (hm$^3$) | 449 |
| | | Trans-boundary water | 388 |
| | Water quality | Quality of surface water | - |
| | | Quality of groundwater | Poor |
| | | Quality of coastal water | Fair - Poor |
| | Water Supply | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination, Recycling<br>Importing[7] | <br>17%<br>-<br>-<br>83% |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | <br>100%<br>-<br>90% |
| Economic and Social System | Water use | Water consumption by category:<br>Domestic<br>Tourism<br>Irrigation<br>Industrial and energy production | <br>71%<br>-<br>25%<br>4% |
| | | Population to resources index | 4494 |
| | Water demand | Water Demand trends | Decreasing |
| | | Consumption index | 69% |
| | | Exploitation index | 49% |
| | Pricing system | Average household budget for domestic water (pa) | €117 |
| | | Average household budget for agricultural water | |
| | | Average household income | € 20639 |
| | | Cost recovery | Good |
| | | Price elasticity | Fair |
| | Social capacity building | Public participation in decisions | Poor |
| | | Public education on water conservation issues | Fair |
| Decision Making Process | Water Resources Management | Water ownership | State |
| | | Decision making level (municipal, regional, national) regarding:<br>Water supply for each sector<br>Water resources allocation for each sector | <br><br>National<br>National |
| | Water Policy | Local economy basis | Tertiary sector |
| | | Development priorities | Urban growth |

## DPSIR Indicators

The special characteristic of Attica is that it includes the largest city of Greece and is inhabited by more than a third of the country's population. The area, from ancient times, suffered from severe water shortage problems.

❖ *Driving forces are the:*
- large population (population density is the highest in the country),
- land use change in order to accommodate the large population,
- periodic droughts which are a common phenomenon in the region,
- waste generation from industries and permanent population.

❖ *Drivers result to pressures which are exerted on natural and human environment. These are the:*

[7] Surface and ground water from other Water Regions

- pollution generation problem due to untreated effluent disposal,
- low water availability due to periodic droughts,
- very high water demand due to population size.

❖ *These result to a state of:*
- permanent water shortage,
- severe pollution problems for most aquifers and coastal waters of the region.

❖ *Impacts refer mostly to:*
- ecosystem degradation around the capital city and the surrounding areas,
- public health concerns.

❖ *The response for the high water demand, the reduced supply and the poor quality of local water resources has been:*
- inter basin transfer from other richer water regions,
- in order to accommodate the large population and the change of land use patterns, an extended network had to be developed,
- finally, in order to cope with the increasing water demand during the periodic droughts, information campaigns and pricing control were applied.

*Thessaly*

*Regional Data*

The fertile plain of Thessaly water region covers an area of 13,377 km$^2$ that occupies the central section of mainland Greece. It is surrounded by high mountain ranges with altitudes more than 2000 m (Pindus, Olympus, Pelion, Othrys, Ossa and Agrapha), encircling a low plain. The River Pinios, coming down from the western slopes of Pindus, cuts Thessaly in two, passes through the valley of Tempi and meets the sea. Thessaly borders Macedonia to the north, Sterea Ellada to the south, Epirus to the west, and its eastern shoreline is on the Aegean. It has the highest percentage of flat land in Greece and the mean elevation of the area is 285 m.

Among the mountains flows the Pinios River which drains into the Aegean, after passing through the Thessalic Tempi. The drainage basin of Pinios River is 9,500 km$^2$ and the main tributaries are the rivers Titarisios, Enipeas, Kalentzis, Litheos and Asmaki. Thessaly District consists also of two more hydrologic basins: the drainage basin of Lake Karla (1,050 km$^2$), rising at the eastern side of the District and Lake Plastira at the western side. Lake Plastira is a part of the watershed area of Achelloos River which belongs to the West Sterea Ellada Water Region.

***Table 27 Surface of the drainage basins in Thessaly***

| Drainage Basin | Surface (km$^2$) |
|---|---|
| Pinios River | 9,500 |
| Lake Karla | 1,050 |
| Other Basins | 2,812 |
| Total | 13,362 |

The climate is Mediterranean continental. Winters are cold, summers are hot, with a large temperature difference between the two seasons. The average temperature is 16-17°C. The average annual rain height is 700 mm, ranging from 400-600 mm at the central plains, to 600- to 1000 mm on the eastern part and over 1,200 mm on the mountains. Rain occurs 100-130 days per year. The precipitation is 10,426 hm$^3$/yr and the mean annual relative humidity is 67% - 72%. Snowfall is very frequent on the mountains.

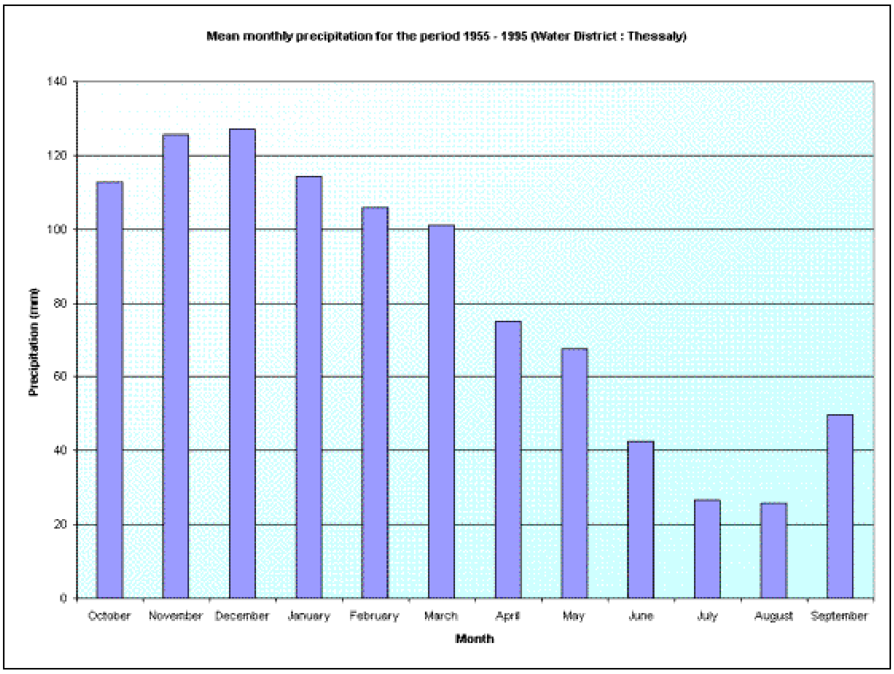



*Figure 41 Mean monthly precipitation for the period 1955-1995 in Thessaly*

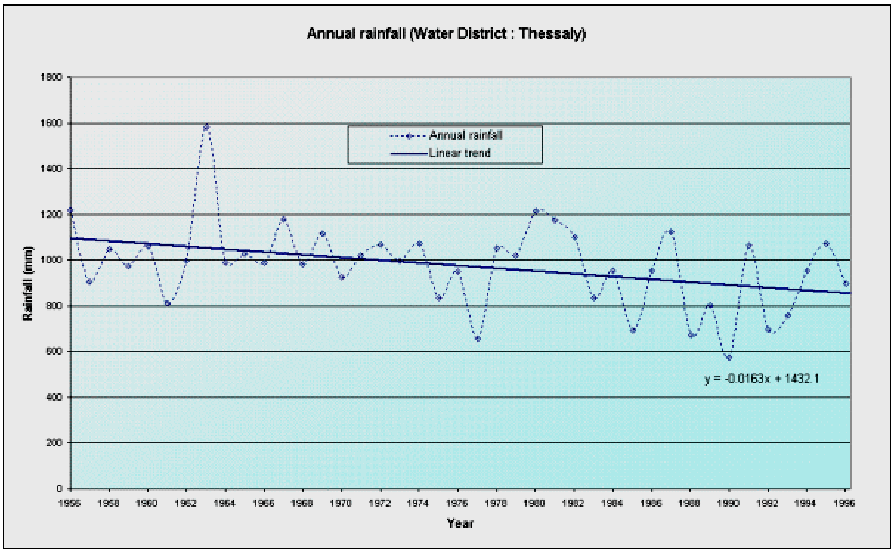



*Figure 42 Annual rainfall in Thessaly*

Impermeable geological structures cover 39.4% of the total area; karstic aquifers cover 16.2% and permeable structures which occur mainly on the plain cover 44.4%. The total water availability is about 3,094 $hm^3$. This amount consists of 2,558 $hm^3$ surface water and 506 $hm^3$ groundwater. The groundwater, which can be found in the karstic and alluvial aquifers of the District and the entire plain, consisting mainly of Neogene sediments, is fed from Pinios River and the tributaries, as well as from direct rainfall infiltration.

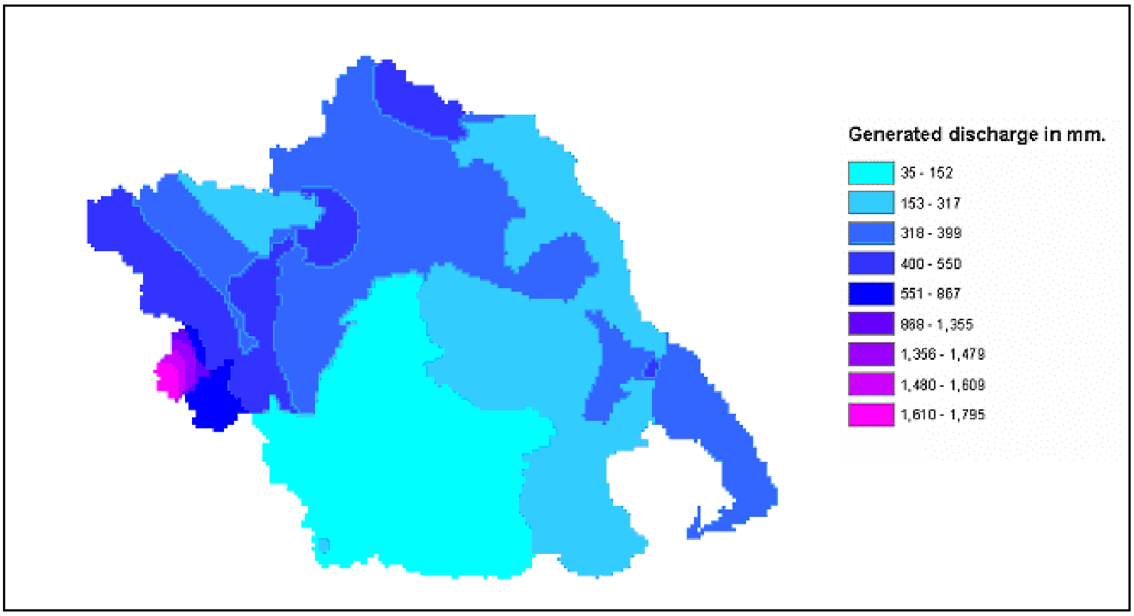



*Figure 43 Generated discharge in Thessaly*

According to monitoring results, surface water quality in Thessaly is generally in a good condition. The nitrites concentrations in a few sampling points exceed the limit values for drinking water, due to the cultivation carried out to serve agriculture in the specific areas of the drainage basin. In few of the sampling points, results for pesticides show elevated levels. Although urban waste loads in the water are significant, urban waste water treatment plants in the major cities of Thessaly ensure that the water quality remains good. The treatment plants constructed in all the major cities of the area are efficient enough and 45% of the population of the area (80% of the urban population) were connected to the public sewer network in 1998.

Results for ground water show that in many cases nitrates and in some cases ammonia exceed the critical load for drinking water. Because of this, the Thessaly plain is designated as a vulnerable zone (Joint Ministerial Decision 19652/1906/99), in order to take the appropriate measures for the protection of the area. The elevated nitrate and ammonia levels are attributed to agriculture and animal husbandry practices.

The main anthropogenic pressures observed in Thessaly are caused by loads coming from agricultural and breeding activities and from the urban wastewater. Non-point source loading from agriculture and animal husbandry in the area is significant. Cultivated areas are spread all over the plain areas and the land-application of all nitrogen-containing fertilizers enriches the watercourses causing significant pollution trends.

Pollution trends caused by industrial activities are not significant because of the limited industrial production. Pollution loads from industry are most abundant in Larissa and Volos where industrial units concentrate, and are particularly visible in the coastal waters of the region.

The main pollutant loads produced in Thessaly in 1996 were:

- BOD5: 51,740 ton/yr,
- TSS: 66,670 ton/yr,
- Total nitrogen: 37,920 ton/yr, and
- Total phosphorus: 3,750 ton/yr.

Thessaly has 753,848 inhabitants. The biggest cities in the area are Larissa and Volos (total population for both cities 300,000). The main economic activities are agriculture, industry and tourism. The region produces 6.3% of the GNP, while the per capita product is €10,950, and the mean declared income per inhabitant was €3550 in 2000. The unemployment rate in the region is 12.2%. Total annual water consumption is 1,171 $hm^3$, consisting of 65 $hm^3$ for domestic use, 1.060 $hm^3$ for agricultural use and 46 $hm^3$ for industrial use. The consumption index is estimated to be equal to 38% and the population to water resources index is equal to 204. The exploitation index is 31%.

Irrigated agricultural land occupies 1,894 $km^2$. Water shortage problems occur during the irrigation period, while in the winter floods occur in large areas. Other significant uses for the watercourse are for animal breeding and aquaculture.

The coastal zone in the area is a favourite destination for many tourists during the summer, and so water supply requirements increase during the summer tourist period. The annual water demands for domestic use and for tourism are about 53.7 $hm^3$, and the areas with the higher water supply requirements are the municipalities of Larissa and Volos.

Lake Plastira, with a storage capacity of 400 $hm^3$, is regulated for hydropower production. The installed hydropower capacity is 141 MW and the power plant produces a total of 250 GWh. Industrial activities are limited in the cities of Volos and Larissa, and they are related mainly to food processing, textile works and iron and steel production. As mentioned above, water demands for industry are not remarkable. Thessaly has a dense network of motorways and a harbour in Volos that serves the entire area.

Water supply in the region is not regulated by a single authority. The larger cities each have their own water and wastewater services providers, but there is a number of independent local services, where the services are mostly affected through the municipalities. Thus, the pricing of water is a subject of political pressures. Public education for water conservation is limited, and cost recovery is, on average, with the exception of the larger cities, poor.

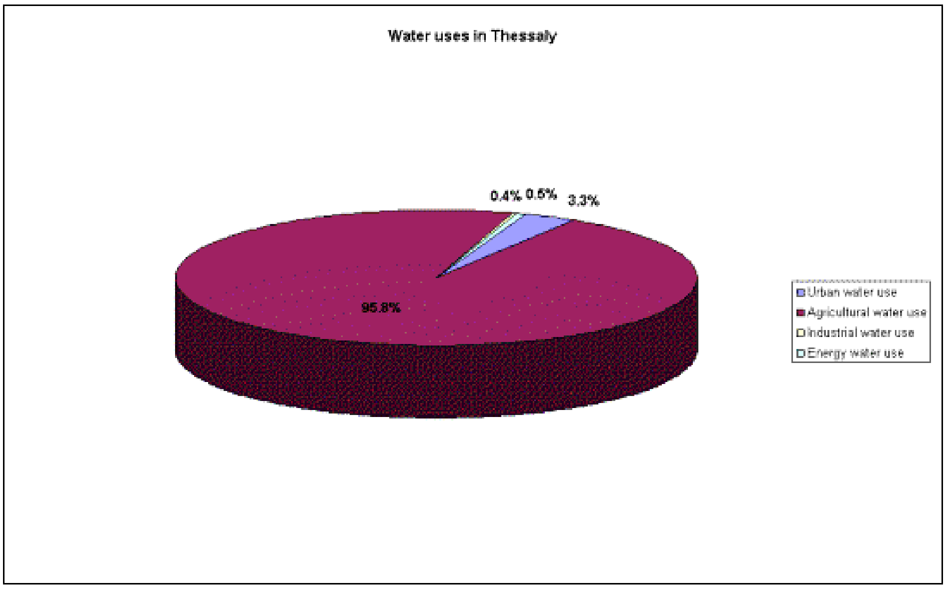



*Figure 44 Water uses in Thessaly*

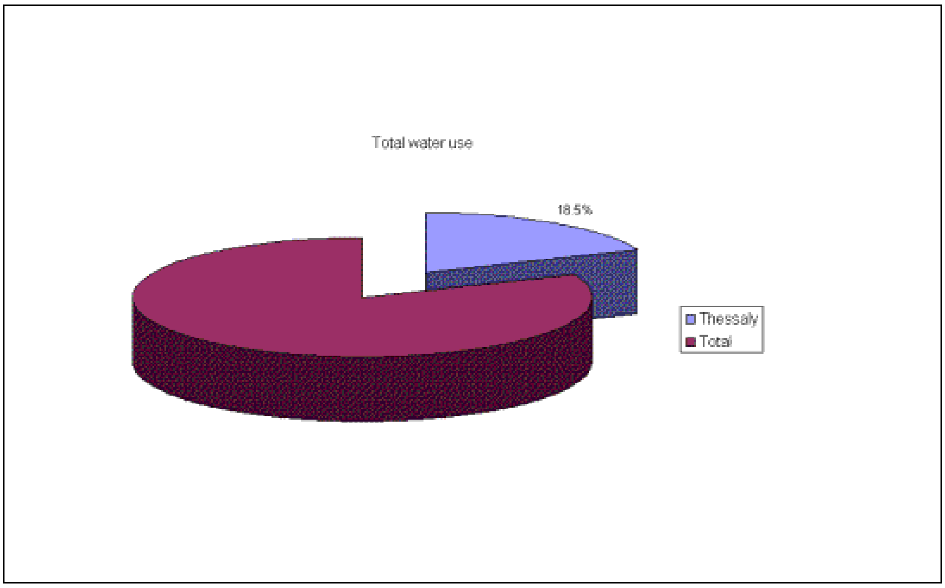



*Figure 45 Percentage of the total water use in Thessaly in proportion with the water use in the country*

## Matrix of Circumstances

**Table 28 Thessaly Matrix**

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Mediterranean Continental |
| | | Aridity Index | AI>=0.65 0.2<=AI<0.5 |
| | | Permanent Population | 753,848 |
| | Water availability | Total Water Resources /Availability ($hm^3$) | 3094 |
| | | Trans-boundary Water ($hm^3$) | |
| | Water quality | Quality of surface water | Good |
| | | Quality of groundwater | Average |
| | | Quality of coastal water | Poor |
| | Water Supply | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination, Recycling<br>Importing | <br>15.7%<br>68.3%<br>-<br>16.0% |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | <br><br><br>45% |
| Economic and Social System | Water use | Water consumption by category:<br>Domestic<br>Tourism<br>Irrigation<br>Industrial and energy production | <br>3.3%<br><br>95.8%<br>0.9% |
| | | Population to resources index | 204 |
| | Water demand | Water Demand trends | Stable |
| | | Consumption index | 38% |
| | | Exploitation index | 31% |
| | Pricing system | Average household budget for domestic water (pa) | € 149 |
| | | Average household budget for agricultural water | |
| | | Average household income | € 10582 |
| | | Cost recovery | Poor |
| | | Price elasticity | Poor |
| | Social capacity building | Public participation in decisions | Poor |
| | | Public education on water conservation issues | Average |
| Decision Making Process | Water Resources Management | Water ownership | State |
| | | Decision making level (municipal, regional, national) regarding:<br>Water supply for each sector<br>Water resources allocation for each sector | <br><br>Regional<br>National |
| | Water Policy | Local economy basis | Primary sector |
| | | Development priorities | Agriculture |

## DPSIR Indicators

Thessaly is a mainly agricultural region, and it includes two of the larger Greek cities. The region also has significant industrial activity, while the regional authorities are promoting the tourist development of the coastal areas. Despite the fact that the region is rich in water resources, there is a seasonal deficit during the irrigation period that leads to intense conflict between the two main water uses, irrigation and the urban water supply. This has caused considerable unrest and public dissatisfaction.

❖ *Driving forces in the region are the:*

- intensive agriculture,
- antiquated agricultural activities. The current irrigation practices and cultivations require vast amounts of water, thus producing a conflict with urban supply.

❖ ***Pressures** exerts on the:*

- natural water resources

- in addition, in spite of the fact that water availability is rather high, there is a surge of demand during the summer irrigation period,
- the problem with pollution of aquifers and surface water resources from agrochemicals is a severe pressure imposed on ecosystems.

❖ *The current state is the:*
- seasonal water deficit during the irrigation period,
- nitrates concentration for both surface and ground waters exceeds (in a few sampling points) the limit values for drinking water while results for pesticides also show elevated values.

❖ *Impacts from the seasonal deficit are:*
- significant economic pressures for the agricultural sector which result also to
- social discomfort with significant protests from the farmers during the irrigation period,
- environmental impacts can be very important. Pollution, eutrophication of the waters, and the severe decrease in flow during the times of maximum abstraction compromises the aquatic ecosystem integrity and the ecology of the surrounding areas.

❖ *The responses during water shortage periods are:*
- groundwater overexploitation,
- long – term solutions are interbasin transfer from neighbouring regions and for economic support, significant subsidies for irrigation water and agricultural products,
- finally, in an effort to prevent deterioration of ground and surface water quality, the Thessaly plain has been designated as a vulnerable zone in order to take the appropriate measures for the protection of the area.

### *Cyclades Islands*

#### *Regional Data*

The Water Region of Cyclades covers an area of 2,553 $km^2$. The region consists of 24 inhabited islands, and is characterised by the fragmentation in several smaller units with different climatological, hydrological and geomorphological parameters. The islands are semi-mountainous with plains and the mean elevation level is 160 m. There are no important rivers due to the small size of the islands, except for some torrential ones. Surface water is very limited on this area.

The climate in general is temperate Mediterranean but it varies on each island according to the geographical position, the size and the distance from the mainland. The average temperature is 16.5 – 19.5 °C. The average annual rain height is 379 mm for the central and southern islands (Naxos meteorological station) and 349 for the northern islands (Athens meteorological station). The precipitation is 902 $hm^3$/yr. The total estimated runoff is 156 $hm^3$/yr. The amount of evapotranspiration is estimated to be equal to 667 $hm^3$.

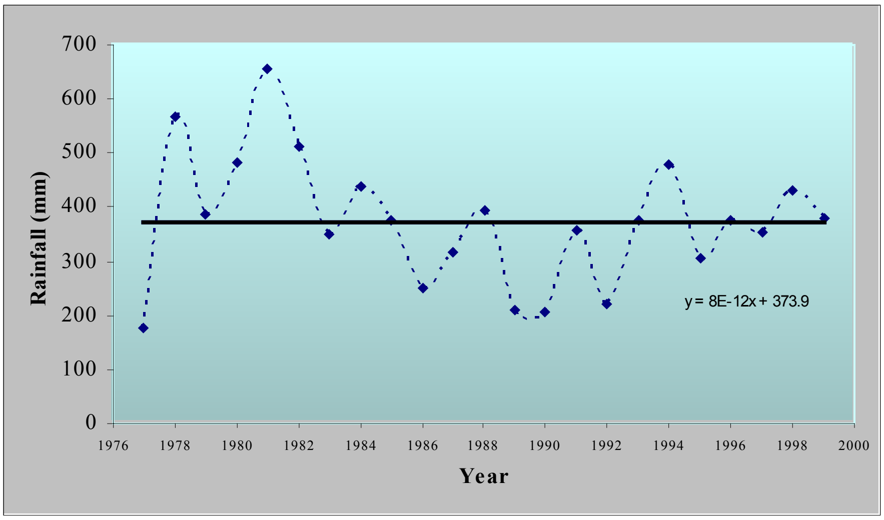



***Figure 46 Annual rainfall in Naxos Meteorological Station***

The geological formations that appear on the islands vary significantly. Metamorphic rocks cover large part of the complex. Limestone formations are very limited, whereas volcanic rocks appear on the islands Thira, Milos and Kimolos. The total water availability is about 212 $hm^3$. This amount consists of 156 $hm^3$ surface water and 55 $hm^3$ potential groundwater. The groundwater can be found in the karstic and grainy aquifers of the District. Due to the small size of the islands, springs are accordingly small and in many cases problems of brackish water occur.

There are no monitoring results for surface water quality in Cyclades. The most important sources of pollution are agriculture and animal husbandry and domestic wastewater. Similarly, results for groundwater quality are scarce as well. The underground aquifers are often subject to saline intrusion due to their overabstraction.

The main pollution loads produced in Aegean Islands in 1996 were:

- BOD5: 8,000 ton/year,
- TSS: 9,500 ton/year,
- Total nitrogen: 3,400 ton/year, and
- Total phosphorus: 500 ton/year.

The Cyclades have 112,615 inhabitants. The main economic activities are tourism and agriculture. The total annual water demand is 30.95 $hm^3$, consisting of 7.15 $hm^3$ for domestic use, 21.5 $hm^3$ for agricultural use and 2.3 $hm^3$ for animal husbandry. The region produces 1% of the GNP, while the per capita product is €12,330 and the mean declared income per inhabitant was €4600 in 2000. The unemployment rate in the region is 12%. The consumption index is estimated to be equal to 50% and the population to water resources index is equal to 531. The exploitation index is 15%.

***Table 29 Hydrological Data for the Cyclades Islands***

| Island | Surface ($km^2$) | Precipitation ($hm^3/yr$) | Evapotranspiration ($hm^3/yr$) | Total Runoff ($hm^3/yr$) | Groundwater ($hm^3/yr$) |
|---|---|---|---|---|---|
| Amorgos | 121 | 45.9 | 33.89 | 3.81 | 8.10 |
| Anafi | 38 | 14.4 | 10.66 | 3.64 | 0.10 |
| Andros | 380 | 144.0 | 104.75 | 25.05 | 2.80 |
| Antiparos | 35 | 13.3 | 9.77 | 2.43 | 1.00 |
| Folegandros | 32 | 12.1 | 8.88 | 1.62 | 1.50 |
| Ios | 108 | 40.9 | 30.27 | 10.39 | 0.24 |
| Kea | 131 | 49.6 | 36.10 | 9.50 | 0.10 |
| Kimolos | 36 | 13.6 | 10.06 | 2.24 | 1.30 |
| Kythnos | 99 | 37.5 | 27.25 | 7.15 | 0.10 |
| Milos | 151 | 57.2 | 42.33 | 12.47 | 2.40 |

| Island | Surface ($km^2$) | Precipitation ($hm^3/yr$) | Evapotranspiration ($hm^3/yr$) | Total Runoff ($hm^3/yr$) | Groundwater ($hm^3/yr$) |
|---|---|---|---|---|---|
| Mykonos | 85 | 32.2 | 23.83 | 8.12 | 0.25 |
| Naxos | 428 | 162.2 | 120.03 | 21.72 | 20.45 |
| Paros | 195 | 73.9 | 57.76 | 8.34 | 7.90 |
| Serifos | 73 | 27.7 | 20.50 | 7.10 | 0.10 |
| Sifnos | 73 | 27.7 | 20.50 | 3.00 | 4.20 |
| Sikinos | 41 | 15.5 | 11.47 | 3.23 | 0.80 |
| Syros | 84 | 31.8 | 23.53 | 7.47 | 0.80 |
| Thira | 76 | 28.8 | 21.31 | 5.69 | 1.80 |
| Tinos | 194 | 73.5 | 53.48 | 13.12 | 1.10 |

In some islands desalination plants are used to cover water demand and in some others water is transferred with tankers from other water sufficient regions. Several small dams and water tanks have already been constructed and are mainly used for irrigation purposes, while others have been planed and approved to be constructed in the near future.

Water supply in the region is not regulated by a single authority. The larger islands each have their own water and wastewater services providers, but there are a great number of independent local services, where the services are mostly effected through the municipalities. Thus, the pricing of water is a subject of political pressures. Public education for water conservation is limited, and cost recovery is overall poor.

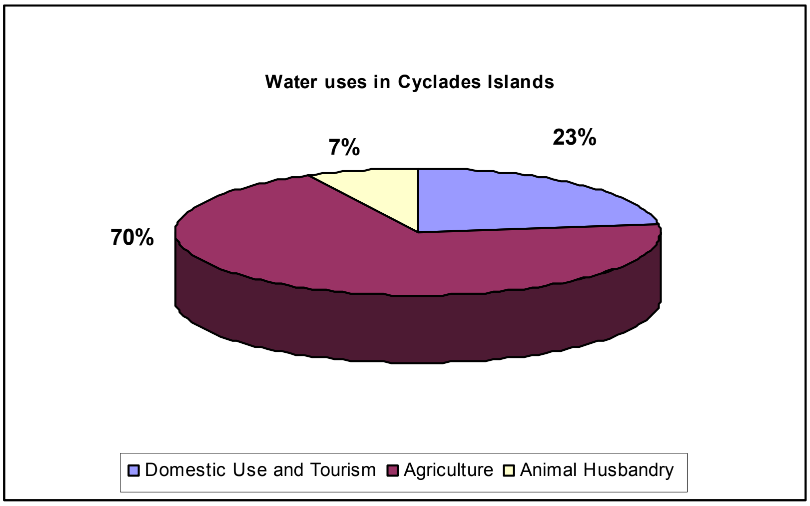



*Figure 47 Water uses in Cyclades Islands*

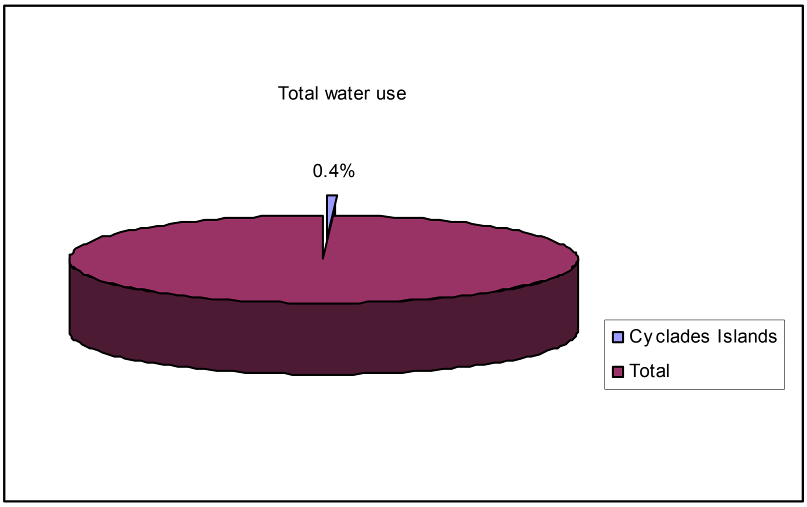



*Figure 48 Percentage of the total water use in Cyclades Islands in proportion with the water use in the country*

## Matrix of Circumstances

**Table 30 Cyclades Islands Matrix**

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Mediterranean Temperate |
| | | Aridity Index | 0.3- Semi-Arid |
| | | Permanent Population | 112,615 |
| | Water availability | Total Water Resources / Availability ($hm^3$) | 212 |
| | | Trans-boundary water | Yes |
| | Water quality | Quality of surface water | - |
| | | Quality of groundwater | Poor |
| | | Quality of coastal water | Good |
| | Water Supply | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination, Recycling<br>Importing | <br>22.5%<br>77.5%<br>Yes<br>Yes |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | |
| Economic and Social System | Water use | Water consumption by category:<br>Domestic<br>Tourism<br>Irrigation<br>Industrial and energy production | <br>9%<br>14%<br>77% |
| | | Population to resources index | 531 |
| | Water demand | Water Demand trends | Increasing |
| | | Consumption index | 50% |
| | | Exploitation index | 15% |
| | Pricing system | Average household budget for domestic water (pa) | € 231 |
| | | Average household budget for agricultural water | |
| | | Average household income | € 13730 |
| | | Cost recovery | Poor |
| | | Price elasticity | Poor |
| | Social capacity building | Public participation in decisions | Poor |
| | | Public education on water conservation issues | Average |
| Decision Making Process | Water Resources Management | Water ownership | State |
| | | Decision making level (municipal, regional, national) regarding:<br>Water supply for each sector<br>Water resources allocation for each sector | Municipal<br>National |
| | Water Policy | Local economy basis | Tertiary Sector |
| | | Development priorities | Tourism |

## DPSIR Indicators

The Cyclades Islands are currently among the most popular tourist destinations in Greece. The island economy is mostly based on tourism, while at the same time the geographical fragmentation of the region emphasizes the importance of the local agricultural production.

❖ *The driving forces are identified as the:*
- tourist development experienced during the last few years,
- aridity of the islands (average rainfall is very low). Limited precipitation results in very limited natural renewable water resources while tourist development and irrigation produce a surge of demand during the summer period.

❖ *The current state is a:*
- seasonal water deficit for domestic and irrigation sectors, leading to groundwater overexploitation in order to cope with the increasing demand,
- over- abstraction results to salinisation problems in most coastal aquifers.

❖ *As impacts, one could identify the:*

- poor quality of most aquifers,
- economic impacts from the seasonal water deficits for both tourism and agriculture,
- the deficit experienced results to social conflicts and unrest between the dynamic tourist sector and the traditional agricultural activities.

❖ *Short term responses are:*

- water transfer with ships from the mainland,
- in an effort to provide permanent solutions to the problem the local authorities and the government have tried to construct many small surface reservoirs and desalination units, in an effort to support the main economic activities (tourism and agriculture).

# Italy

## *Emilia-Romagna*

### *Regional Data*

Emilia-Romagna is one of the largest Italian regions (the sixth), linking the north with the centre of the country. Stretching as far as the Adriatic sea to the east, Emilia-Romagna borders with Veneto to the north-east, with Lombardia to the north and north-west, with Piemonte and Liguria to the west, with Tuscany to the south and with the Marche and the Republic of San Marino to the south-east, and there is close coincidence of administrative and physical boundaries, delineated by easily distinguishable natural features: the Po river to the north, the Apennine ridge separating the Po Valley slopes from the Tuscany-Marche to the south, and the Adriatic coast to the east.

The region is divided into two main portions: Romagna stays at the south-east with the provinces of Forlì-Cesena and Rimini while Emilia consists of the administrative provinces at the west and middle. Almost the half of the territory stays in the Pianura Padana plain, which the Via Emilia separates from the Apennine from the watershed, a series of nearly parallel ridges thrusts outwards towards the plain, progressively decreasing in height, sharply separated from the transverse river valleys. Beyond the extreme outlying hills lie the undulations of the stony upper plain, formed by the fusion of fluvial detritus, beyond which extends the wide fertile alluvial plain. Of the great swamps, which at one time characterised the lower Emilia and Romagna plain before systematic regulation of the waterways, remain only the Valleys of Comacchio and the stretches of water belonging to the Po Delta. Except for the Po River, which flows along the northern boundary of the region, all the water courses flow from the Apennine watershed, cutting parallel down hill before reaching the plain and flowing into the Po (Tidone, Trebbia, Nure, Arda, Taro, Parma, Enza, Secchia, Panaro), or directly into the Adriatic Sea (Reno, Lamone, Savio).

The climate of Emilia-Romagna has sub-continental characteristics, with cold winters and hot summers, moderated, however, by sea breezes along the Adriatic, while the temperatures are closely affected by altitude in the Apennine region. The rainfall is about 800 mm/year and the evapo-transpiration is around 500 mm.

With regards to population distribution, two zones are easily distinguished: the hills and mountains, thinly populated, and less suitable for economic exploitation, and the plains, characterised by an excellent communication network, the possibility of intensive farming and ideal conditions for industrial development.

***Table 31 Water Withdrawals in Emilia-Romagna in 2001 ($hm^3$)***

| | CIVIL MUN. | INDUSTRIES | AGRICULTURE | TOTAL |
|---|---|---|---|---|
| Ground Water | 279 | 169 | 212 | 660 |
| Surface Water | 205 | 52 | 997 | 1254 |
| Total | 484 | 221 | 1209 | 1914 |

The daily consumption of water for domestic uses at a regional level is estimated in 158 l/cap with a value of 150 l/(cap*day) for the western provinces and of a value over 160 l/(cap*day) for the eastern ones.

One of the problems in water resource supply regards the agricultural use. Part of the surface water used for field irrigation, about 260 $hm^3$, is currently uptaken from the Apennine's rivers and torrents but this amount is going to be dramatically reduced with the future application of the DVM, Minimum Vital Discharge. This water discharge has to be assured in order to reach and keep a certain environmental quality level of the fluvial ecosystem, in terms of river basin morphology, interactions with aquifers, water quality, hydrology. At the time being the Basin

Authority of the Po River is studying and testing some methods to compute the DVM and it is not so far to be applied. As a consequence, some hypothesis in the usage of water at the regional level have been made, revealing that the less water availability from hill and mountain basins, about 70 $hm^3$ per year, will be probably covered by further 30 $hm^3$ per year abstracted from the aquifers, a water resource already overexploited.

The greatest problems will concern the Emilia region, in particular the provinces of Parma and Piacenza where the use of Apennine basin water is greater.

The exploitation of the groundwater resources in Emilia-Romagna is presently not sustainable in that the yield produces a water deficit.

In general the aquifer is overexploited and this exacerbates the subsidence phenomenon and the intrusion of brackish and marine water along the coasts. The deficit in groundwater use represents the amount of water that exceeds the recharging capacity of the aquifer.

The shallow groundwater under Emilia-Romagna present extremely small deficits (fractions on $Mm^3$/year) as far as the abstraction of Ferrara, Forlì-Cesena and Rimini provinces is concerned, this also because the main water source in Romagna is given as surface water by the Ridracoli Reservoir managed by Consortium Romagna Acque. The deficit is limited to 1-2 $Mm^3$/year for the provinces of Ravenna and Modena and relevant for Bologna and Parma with 10-15 $Mm^3$/year. Total regional deficit in underground water at a annual level is about 30-35 $Mm^3$/year.

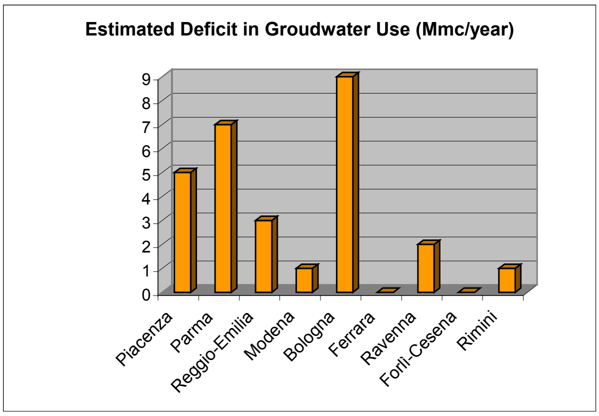



***Figure 49 Estimated Deficit in Groundwater Use in Emilia - Romagna***

Quality of water courses is pretty good at least for the stretches in the Apennine, where drinking use is usually possible without treatment. The use for irrigation is almost always permitted even if the stretches serving the provinces of Ferrara and Rimini have a relevant concentration of chlorides, so requiring a good drainage of the cultivated soil. Generally the river stretches in the plains present qualitative characteristics insufficient to direct drinking use and also to the aquatic life of plants and animals.

The main problem in groundwater quality consists in the presence of nitrates, mostly in the areas under alluvial cones where their concentration is greater than 50 mg/l, which is the limit for the drinking use. Therefore expensive treatment or mixing with water of better characteristics is needed.

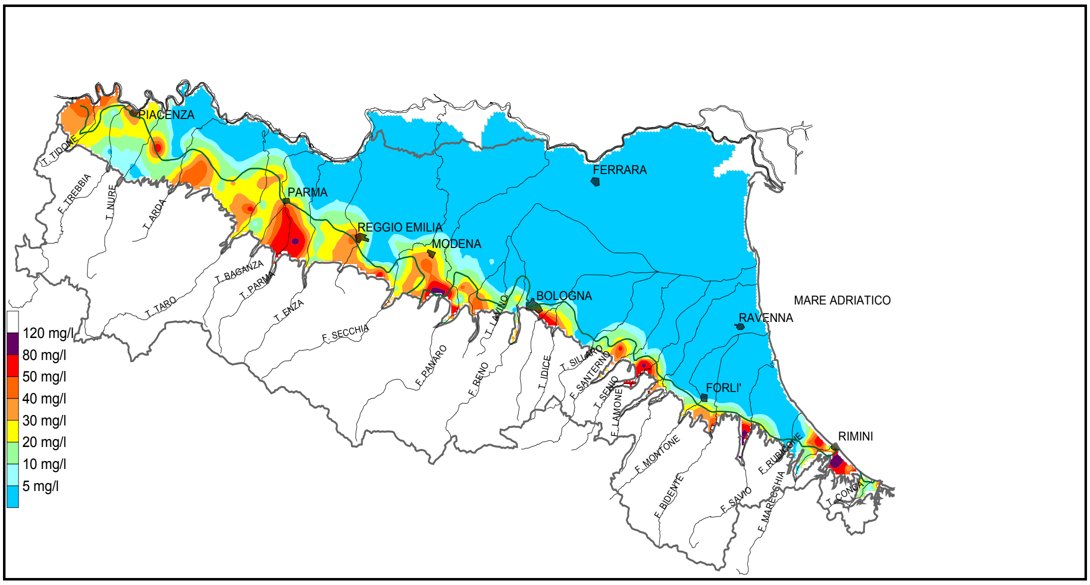



*Figure 50 Areal distribution of nitrates concentration in the aquifers of Pianura Padana in 2001*

However, the Groundwater Quality Status Index, which is used to study the antropogenic pollutant and natural chemical parameters distribution, shows that Emilia-Romagna groundwater belong to the "class 0" of the Index Range of values, denoting null or insignificant anthropical impact with medium-good natural hydro-chemical parameters.

*Table 32 Qualitative Chemical Classes of Groundwater*

| Class | Anthropical Impact | Natural Hydro-chemical parameters |
|---|---|---|
| 1 | Null or insignificant | Optimum |
| 2 | Small and sustainable over the long period | Good |
| 3 | Significant | Medium |
| 4 | Remarkable | Bad |
| 0 | Null or insignificant | Medium-Good |

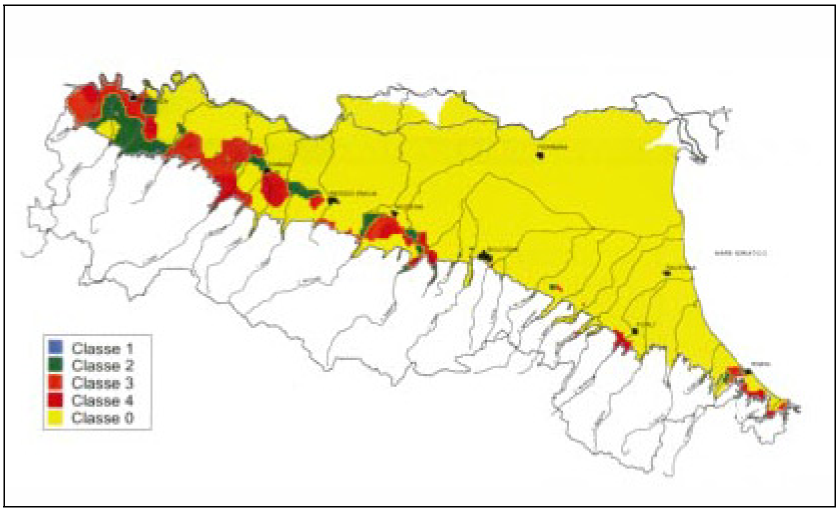



*Figure 51 Qualitative chemical Status of Emilia-Romagna groundwater in 1999*

As far as the coastal water quality is concerned, it can be given a "medium" rate. The eutrophication level denotes presence of nutrients and algal biomass associated to low transparent waters and suffering benthic life ecosystem. On the other hand, a study conducted in 1999 on the coastal zones says that bathing and swimming are allowed in the 99.7% of the controlled coasts so denoting a low presence of urban wasting pollutants.

The problem of eutrophication is not exclusive to the Adriatic coast but relevant to the entire Po River Basin, as declared by the European Commission within the Urban Waste Water

Treatment Directive 91/271/EEC. The commission gives two alternatives: a) to assure the standard concentration of nitrates and phosphorus of treated water in areas with more than 10000 equivalent habitants b) to reduce by the 75% the nitrates and phosphorus loads produced by the civil municipalities.

The role of agriculture in Emilia Romagna will be determinant as the regional and local authorities are studying plans to re-use the treated waste water in irrigation: this would have the two advantages of nullifying the drainage of treated waste water into the Po River and of reducing the withdrawals of water from aquifers.

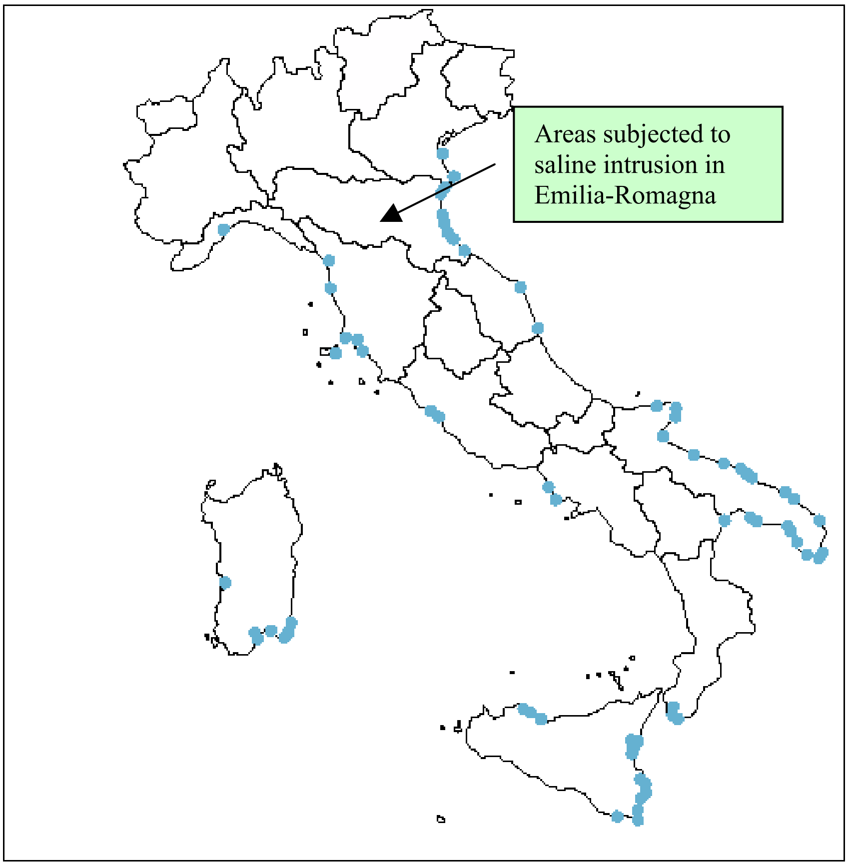



***Figure 52 Areas with saline intrusion phenomenon in Italy (source: Enea 1998)***

As regards the water price, it is established by the local authority with respect of general guidelines. In Bologna District for example, the water service is managed by the public firm Seabo and a typical household with civil consumption of 130 $m^3$/year can pay something like 132 Euro. The total cost of water per cubic metre considers a part for treatment service, about 0.276 euro/$m^3$, a part for water supply, 0.77 euro/$m^3$ (for annual consumes between 80 and 150 m3) and a part for the sewerage service, 0.096 euro/$m^3$.

Apart from Bologna and the other major urban centres, tourism in Emilia-Romagna is principally directed to the Adriatic coast, where from the Comacchio Valleys to the Marches boundary lie some thirty famous and busy seaside resorts. The beaches of Romagna such as Milano Marittima, Cervia, Cesenatico, Bellaria, Rimini, Riccione, Cattolica have, in fact, always attracted tourists from home and abroad.

*Table 33 Regional Tourist Presence in Emilia-Romagna in 2001*

| AREA | 2000 | 2001 | TREND% (2001-2000) | DIFF. |
|---|---|---|---|---|
| Adriatic Coast | 39.475.000 | 40.690.000 | +3,1% | +1.125.000 |
| Apennine | 2.812.000 | 2.835.000 | +0,8% | +23.000 |
| Cities | 3.403.000 | 3.480.000 | +2,3% | +77.000 |
| Watering places | 1.994.000 | 2.025.000 | +1,6% | +31.000 |
| Total | 47.684.000 | 49.030.000 | +2,8% | +1.346.000 |

*Table 34 Tourist Presence in Adriatic Coast in 2001*

| NATION | 2000 | 2001 | TREND% (2001-2000) | DIFF. |
|---|---|---|---|---|
| Italy | 31.642.000 | 32.480.000 | +2,6% | +838.000 |
| Germany | 3.505.000 | 3.724.000 | +6,2% | +219.000 |
| Switzerland | 662.000 | 687.000 | +3,8% | +25.000 |
| Austria | 316.000 | 333.000 | +5,4% | +17.000 |
| Others | 4.483.000 | 4.744.000 | +5,8% | +261.000 |
| Total | 39.475.000 | 40.690.000 | +3,1% | +1.215.000 |

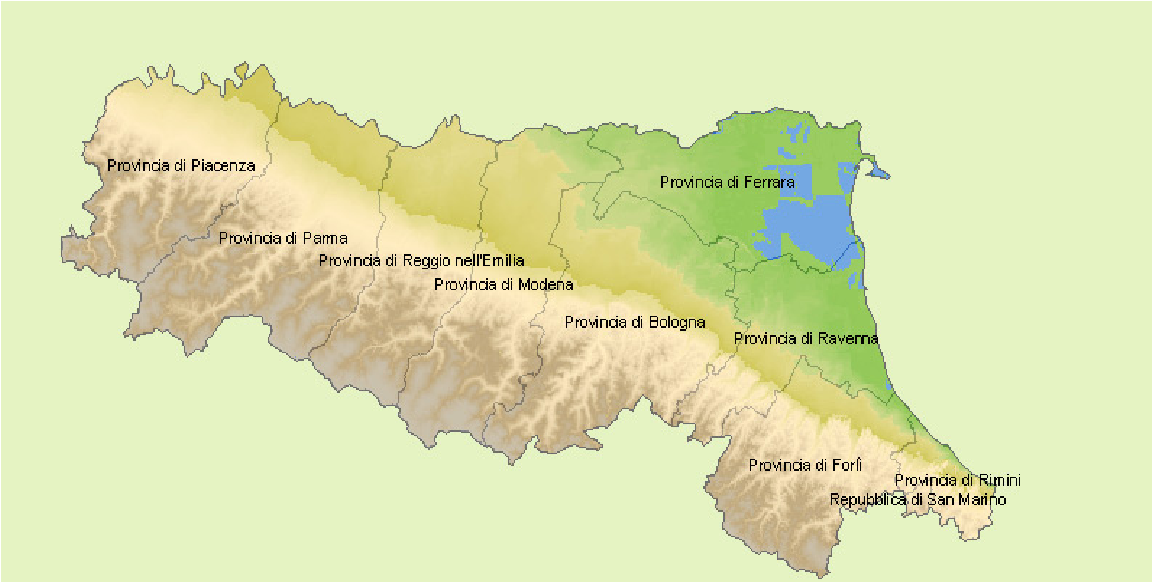



*Figure 53 Administrative Provinces' Division in Emilia-Romagna*

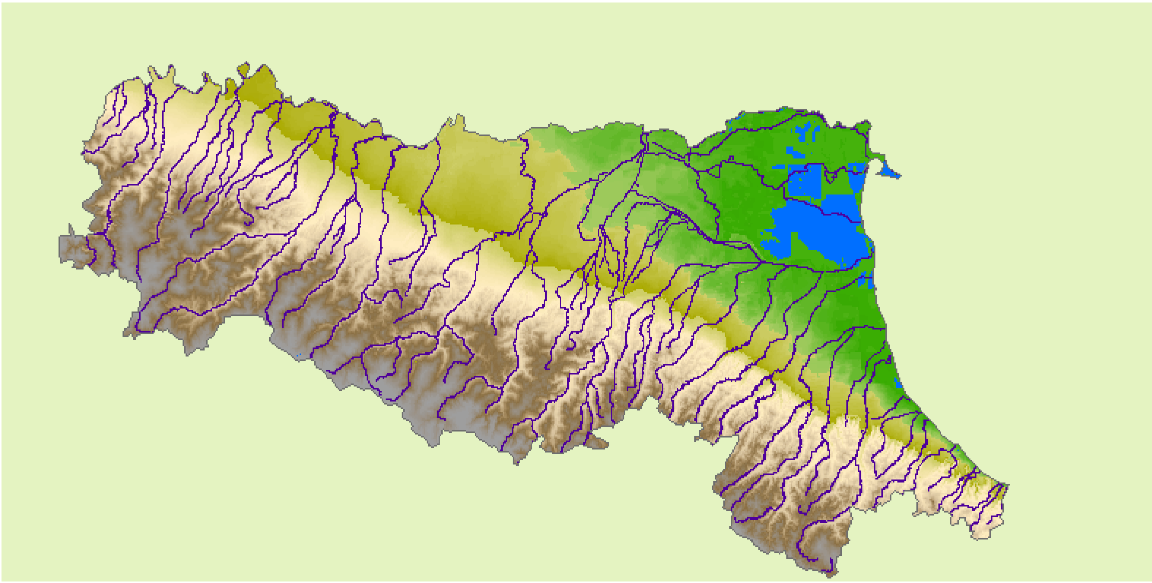


*Figure 54 The Rivers Network in Emilia-Romagna*

## Matrix of Circumstances

***Table 35 Emilia-Romagna Matrix***

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate type | Sub-Continental |
| | | Aridity index | 1.6 |
| | | Permanent population | 3,924,456 |
| | | Area | 22123 |
| | Water Availability | Total water resources / availability | 1925 |
| | | Trans-boundary water | 0 ( No ) |
| | Water quality | Quality of surface water | Medium |
| | | Quality of groundwater | Good |
| | | Quality of coastal water | Medium |
| | Water supply[8] | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination, recycling<br>Importing | <br>24 %<br>76 %<br>0 ( No )<br>0 ( No ) |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | <br>94.8 %<br>100 %<br>71 % |
| Economic and social system | Water use | Water consumption by category:<br>Domestic<br>Tourism<br>Irrigation<br>Industrial and energy production | <br>15 %<br>included in domestic<br>32 %<br>53 % |
| | | Resources to Population index | 720 |
| | Water demand | Water demand trends | Stable |
| | | Consumption index | 64 % |
| | | Exploitation index | 83 % |
| | Pricing system | Average household budget for domestic water (pa) | 0.65 % |
| | | Average household budget for agricultural water | 2.5 % |
| | | Average household income | 20228 |
| | | Cost recovery | Good |
| | | Price elasticity | Medium |
| | Social capacity building | Public participation in decisions | Average |
| | | Public education on water conservation issues | Average |
| Decision making process | Water resource management | Water ownership | Public |
| | | Decision making level regarding:<br>Water supply for each sector<br>Water resources allocation for each sector | <br>Regional –Municipal<br>Regional -Municipal |
| | Water policy | Local economy basis | Agriculture and Tertiary sector |
| | | Development priorities | Demand Management and Waste Water Re-Use |

## DPSIR Indicators

❖ *Driving Forces:*

- use of fertilisers and pesticides with nitrates,
- domestic and industrial production of nitrates and phosphorous loads,
- positive demographic trend,
- over-exploitation of groundwater,
- over-exploitation of water from Apennine's rivers and torrents,
- seasonal migration flows of resident people towards the Apennine and the Adriatic

[8] Water supply and water use computed from 1997-2000 data and power generation counts for 900 $Hm^3$

Coast during summertime plus tourists flows.

❖ *Pressures:*
- positive trend of domestic consumption,
- positive trend of agricultural consumption,
- positive trend of nitrates concentration in groundwater,
- salt intrusion in groundwater,
- negative trend of piezometric level of aquifers,
- seasonal peaks of water demand in the Apennine and the Adriatic Coast during summertime.

❖ *State:*
- increased domestic and agricultural water demand and consumption,
- high concentration of nitrates and salinity in groundwater,
- water losses along supply networks,
- decreased piezometric level of aquifers,
- eutrophication of the coastal water,
- eutrophication of the Po River basin fresh water.

❖ *Impacts:*
- groundwater use for domestic purposes could be compromised by high nitrates and salt concentrations,
- if the water discharge of the Apennine's rivers and torrents goes under the Minimum Vital Discharge, the fluvial ecosystem in terms of river basin morphology, interactions with aquifers, water quality, and hydrology could dramatically change,
- Po River basin ecosystem degradation.

❖ *Responses:*
- assure the Minimum Vital Discharge along Apennine's rivers and torrents,
- building of treatment plants for nitrates abatement and re-use of urban waste water for irrigation,
- change the water sources from groundwater to surface water by increasing the uptake from reservoirs and rivers,
- improvement of management efficiency of reservoirs and supply networks
- use of more efficient irrigation techniques,
- change the irrigation water source from the Apennine's rivers and torrents to treated waste water,
- selection of and priorities given to relevant cultivations,
- use of technologies for water re-use in industrial processes and related water price incentives,
- reduce heavily the load of nitrates and phosphorus produced by civil municipalities over the whole Po River Basin.

*Belice Basin – Sicily*

*Regional Data*

Sicily is the largest and most important island in the Mediterranean, and until the fourteenth century Sicily was the most important island in Europe. Though the Mediterranean is usually considered a single body of water, Sicily's shores are washed by two of its smaller seas: the Ionian and the Tyrrhenian. Most of the island's surface, covering more than 25,000 square kilometres, is mountainous and hilly, with some level coastal areas and a large plain near Catania. At 3342 meters, Mount Etna is the highest peak, and Europe's largest active volcano. A number of small islands located around Sicily are popular tourist resorts, the volcanic Aeolian (or Lipari) archipelago being the largest group.


***Figure 55 Sicily***

The extensive coastline ranges from rocky cliffs to sandy beaches, but Sicily also offers other fascinating natural sights such as Alcantara Gorge (near Taormina), various caverns (Carburangeli near Carini and others around Sicily and on the surrounding islands), and the grey mud flows formed by sporadic geysers that give Maccalube, near Aragona, its moonlike appearance.

While its mountains and coastline are Sicily's best known natural features, its low hills and flat valleys are quite scenic, too, though the rivers and streams that flow through them are usually dry by July.

The rivers are fast flowing with an irregular volume of water, flash flooding in winter and long periods of drought. The principal rivers are the Simeto (which channels the waters of the Dittaino, Gornalunga and Caltagirone), the Alcantara, Anapo, Cassibile and Tellaro, on the Ionian side; the Torto and San Leonardo, flowing into the Tyrrhenian Sea, and the Belice, Platani and Salso which empty into the Sicilian Sea.

The climate is in prevalence warm-temperate with annual mean temperatures of 14.5-16.9 °C and annual fluctuation of-15-17 °C.

The water availability is a very strategic element in the agricultural sector of Sicily, as the water scarcity have always been the main constraint to the agricultural development.

In Sicily region there are 11 Public Consortiums whose main tasks are the management of irrigation networks, the analysis of the water quality and the land reclamation.

The Consortiums have built the majority of the present catchment, supply and distribution systems all over Sicily. At the time being, the reality of irrigation water supplied by Private Consortiums or by the land owners themselves is very limited, there are just some areas in The Eastern Sicily. The private supply comes from the aquifers while the public consortiums take water from the artificial reservoirs and small lakes.


C. n° 1: TRAPANI
C. n° 2: PALERMO
C. n° 3: AGRIGENTO
C. n° 4: CALTANISSETTA
C. n° 5: GELA
C. n° 6: ENNA
C. n° 7: CALTAGIRONE
C. n° 8: RAGUSA
C. n° 9: CATANIA
C. n° 10: SIRACUSA
C. n° 11: MESSINA

*Figure 56 The Regions of Sicily*

The Sicily agriculture can count on 16 irrigation systems with a total length of 7000 km serving an area of 140000 ha. In spite of the rather full network coverage, the present really irrigated area is about the 50% of the potential equipped one and this is due to the effective lack of water: year 2001, for instance, has been so critical to agriculture that the entire water volume supplied for irrigation over the whole region, about 160 $hm^3$, has not been sufficient to cover the needs of The only Eastern Sicily. One of the reasons is the lower precipitation of the last few years and in particular of 2001 with about 200-250 mm less than the mean value of the past thirty years, but there are other remarkable factors among which the lack of a regular activity of maintenance both of the water distribution networks, where it would avoid pipe-bursts, and of the artificial reservoirs of which the region is rich, where it would help keeping the actual storage capacity near to the nominal value. There are also some reservoirs whose water is more than sufficient to cover the seasonal demand of the territory they serve, so they could give water to the neighbour poorer ones but unfortunately the necessary pipelines to connect them have never been built.

***Table 36 Available water volumes per single reservoir ($Mm^3$).***

| Reservoirs | Storage Capacity | Available volumes on 15/04/02 | Available volumes on 15/04/01 | Differential 2002-2001 | Var. 2002-2001 (%) |
|---|---|---|---|---|---|
| Rubino | 11,50 | 1,49 | 6,11 | -4,62 | -75,6 |
| Zafferana | 1,00 | 0,00 | 0,49 | -0,49 | -100,0 |
| Paceco | 15,00 | 4,10 | 5,03 | -0,93 | -18,5 |
| Trinità | 18,00 | 2,88 | 8,64 | -5,76 | -66,7 |
| Garcia (1) | 60,00 | 26,97 | 47,30 | -20,33 | -43,0 |
| Poma (2) | 68,00 | 7,69 | 38,47 | -30,78 | -80,0 |
| Rosamarina | 80,00 | 40,49 | 49,43 | -8,94 | -18,1 |
| Arancio | 38,80 | 10,70 | 21,13 | -10,43 | -49,4 |
| Prizzi | 9,20 | 3,02 | n.d. | n.d. | |
| Gorgo | 3,41 | 0,56 | 1,18 | -0,62 | -52,5 |
| Castello | 26,00 | 5,20 | 12,21 | -7,01 | -57,4 |

| Reservoirs | Storage Capacity | Available volumes on 15/04/02 | Available volumes on 15/04/01 | Differential 2002-2001 | Var. 2002-2001 (%) |
|---|---|---|---|---|---|
| San Giovanni | 16,30 | 5,71 | 9,31 | -3,60 | -38,7 |
| Comunelli | 8,00 | 0,00 | 1,20 | -1,20 | -100,0 |
| Disueri | 14,00 | 1,00 | 2,30 | -1,30 | -56,5 |
| Cimia | 11,30 | 0,40 | 4,20 | -3,80 | -90,5 |
| Biviere | 4,80 | 0,30 | 1,45 | -1,15 | -79,3 |
| Nicoletti | 19,30 | 5,96 | 10,03 | -4,07 | -40,6 |
| Pozzillo | 141,00 | 3,00 | n.d. | n.d. | |
| Ancipa (3) | 30,40 | | | | |
| Olivo | 10,00 | 1,69 | 3,63 | -1,94 | -53,4 |
| Don Sturzo | 110,00 | 8,20 | n.d. | n.d. | n.d. |
| Ragoleto | 20,00 | 1,60 | n.d. | n.d. | n.d. |
| Santa Rosalia | 20,70 | 13,38 | 20,01 | -6,63 | -33,1 |
| Lentini (4) | 127,00 | 32,00 | 37,00 | -5,00 | -13,5 |
| TOTAL | 863,71 | 176,34 | 279,12 | -102,78 | -36,8 |

## Sicily's precipitation

The wet season in 2002 proves to be even more crucial than in 2001. Water availability of Sicilian reservoirs is so decreased that even in case of rainfalls, problems can not be solved. According to the last INEA report on water emergency, the water quantity of Sicilian reservoirs has reduced by about 37% in comparison with that in the same period of the last year.

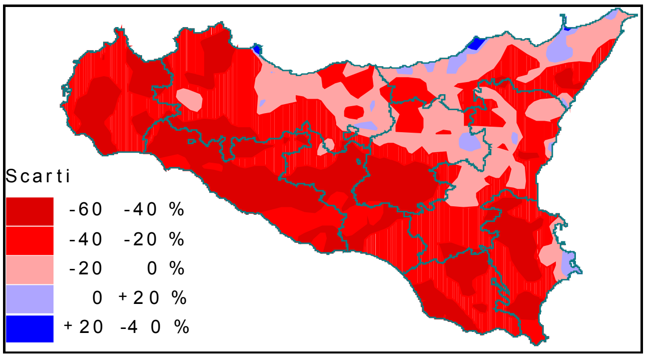



*Figure 57 Per cent deviations of rainfall rates during the period August 2001 – April 2002 from the mean rates of the same period of the past 30 years*

According to the data collected and processed by "Servizio Informativo Agrometeorologico Siciliano" (SIAS, i.e. Sicilian Agro-metereologic Information Center) the rainfall rates during the solar year 2001 have been considerably lower than the climatic mean rates of the last 30 years, the negative deviation being about 30 - 50% in the yearly average. This percentage has been higher in the middle-southern areas of the isle, with peaks of 50 - 70%. In general, the average negative deviation resulted to be about 150-250 mm in comparison with the climatic mean values. The most serious period came after summertime - which usually is a dry period in the areas with Mediterranean climate - and lasted up to the end of March. Later, more details on the recent period of drought will be given.

In the following paragraph we will show mapping calculations carried out focussing on the period August 2001-April 2002 in Sicily, by comparing the current rainfall rates with the climatic mean ones of the last thirty years (we always consider the "mean rainfall rates" as median rates, and even in this analysis we will consider them like that).

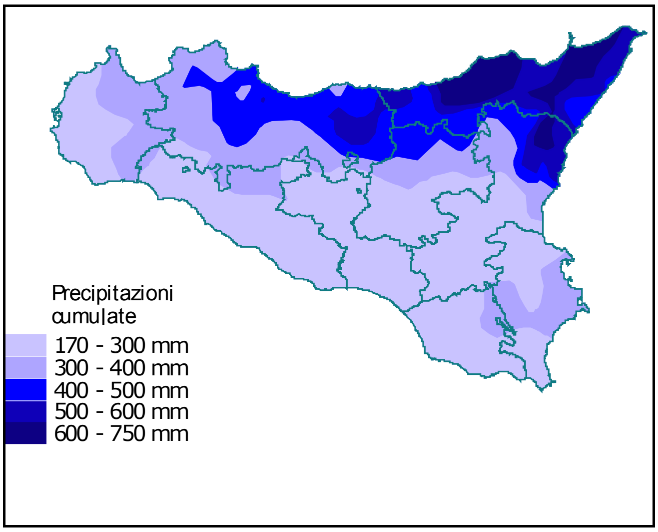



*Figure 58 Cumulated rainfall (August 2001 – April 2002)*

Comparisons have been made by per cent deviations, this being one of the possible ways to perform drought. By such a method the deviation (that is to say, the difference) between the current rainfall rates (meteorological data) and the reference rates (climate rates, that is to say, the mean rates of the last thirty years) are related to a value of 100. In other words, by considering 100 as the mean rainfall rate of a place, the difference in rainfall rate between the current period and the climate will be related to 100.

In the case of Sicily, our study starts with the data referred to August 2001, because in our climate from the month of August on, after the usual summer aridity, Autumn precipitation allow the storage capacity of water reservoirs to increase. Autumn rainfalls usually are among the most plentiful - and often "the" most plentiful - of the year.

Last year, 2001, it was not like that. In fact, in August in many areas the rainfall rate was higher than the mean one, but from September on the general situation has been very critical, particularly in many inland and south - west areas. But let's proceed methodically to more detailed considerations.

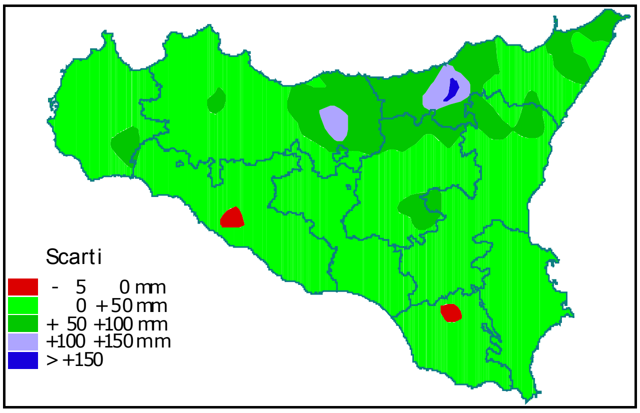



*Figure 59 Mean rainfall in May for the past 30 years*

The first map acts as a synthesis and shows the per cent deviations of rainfall rates during the period August - April. The map evidently shows that almost everywhere in the region the rainfall rate has strongly decreased, the overall situation being particularly crucial in north - west, south - east and middle - south areas.

The map is the result of the comparison between the map of the meteorological values concerning rainfalls during the period August 2001 - April 2002, and the map of climate values referred to the same period in the last 30 years (according to the above mentioned method).

In both mapping calculations the pluviometric deficit of the areas where the recent drought was most serious, can be quantified in about 200 - 250 mm, with peaks of 300 mm. It is to be considered that in many of these areas the rainfall rate of the same period is usually 400 - 500 mm, but this year it has drastically diminished to only 200 - 250 mm or less.

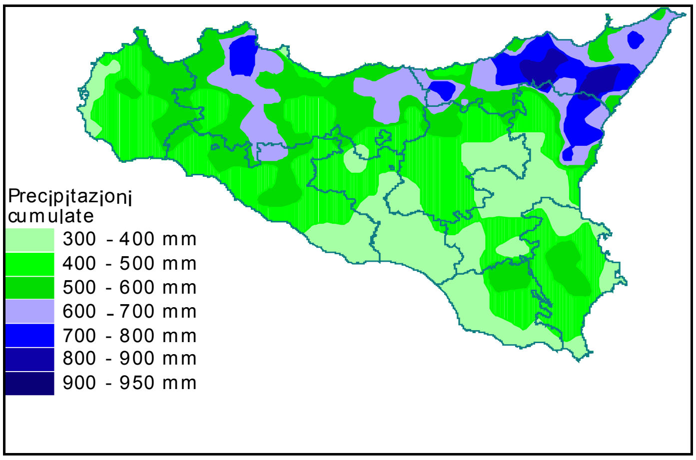



***Figure 60 Mean rainfall rates of the past 30 years (Cumulated values of period August 2001 – April 2002)***

Considering the monthly rainfall rate, data prove that in August it was higher than the average one, and that the rainfall shortage began from September on, worsening in the month of October, when the negative deviation has been as high as 100% - that is to say, there have been no rainfalls at all.

This situation has caused serious consequences, in particular to the zootechnic sector, that usually benefits a lot by rainfalls in September and October. In fact in that period, in Sicily forage species usually benefit their typical Autumn renewal.

Furthermore, rainfalls during November and December concentrated mainly in the northern area of the isle, the remaining area of the region keeping to suffer the current rainfall shortage. The crisis became even worse in the first three months of this year, from January on, and particularly in February and March, concentrating in the western and southern areas.

Luckily, the month of April has been definitely different, because almost everywhere in the isle rainfall rates resulted quite higher than the mean rates of the period, bringing some relief - even if just a little - to the very serious and evident water shortage.

Precipitation increased even more in May 2002, so that rainfalls rates were much higher than the average almost everywhere in the isle. In many cases rainfall rates were five times as high as the mean rates of the period.

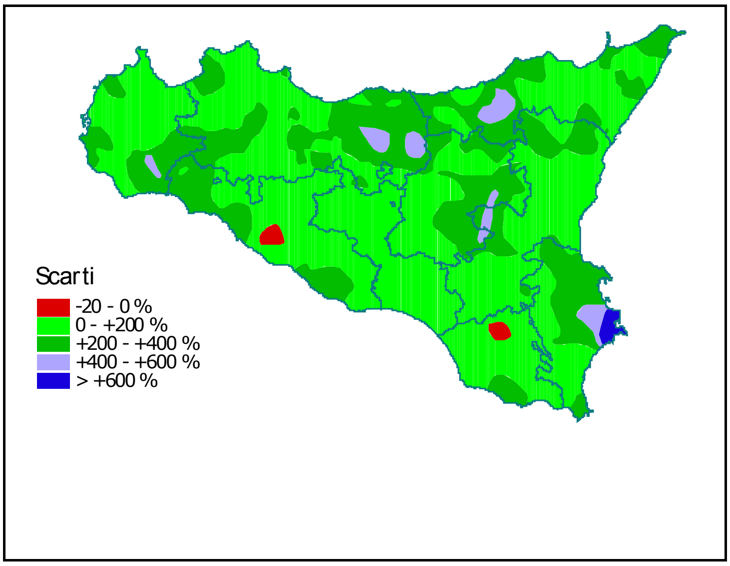



***Figure 61 Deviations of rainfall rates in May 2002 – April 2002 from the median rates of the past 30 years***

The increase of rainfall rate has helped improve the general situation of the region, above all the overall water supply, so like it happened in April, too. In agriculture, instead, together with positive effects, also some negative aspects are to be stressed out, above all those concerning the harvest of forage rich in hay, which in many cases has suffered the abundant and persisting rains, affecting the final quality of the product.

Furthermore, one of the most serious consequences of the rainfall deficit of last Spring - notwithstanding rains in April and May - was the big damage to cereal production, above all in inland and southern areas of the region, where strong reduction of the product quantity can already be calculated.

The Belice Basin is placed in the south-west of Sicily. It covers an area of about 967 $km^2$, in the administrative territory of Palermo, Trapani and Agrigento provinces. It borders with the Modione and Freddo River Basins at the west, with those of Jato and Oreto at the north and with those of Verdura and Carboj at the east. The Belice River is divided into three branches, the Right Branch, the Left Branch and the stretch after the confluence near the town of Poggioreale, each one defining a sub-basins. The Right Branch has a length of 55 km and comes from The Northern part of the Basin. His basin covers an area of 227 $km^2$. The Left Branch has a length of 57 km and comes from Mount Leardo and Mount Rocca Busambra and is supplied by torrents Fosso and Bicchinello. Some of his tributaries are Corleone River and the torrents of Batticano and Realbate. The sub-basin has an area of 407 $m^2$. After the confluence the river extends for 50 km up to the Sicily Canal.


***Figure 62 The Belice Basin***

In The Belice Basin there are many aquifers which are deeply exploited for irrigation and municipal supplies.

The mean daily precipitation and evapotranspiration are respectively about 1.256 mm and 3.23 mm, consequently the Aridity Index is 0.39 (semi-arid conditions).

The total water resource availability is 80 $hm^3$ of which 24.8 are groundwater. The water sources are the aquifers, 19% of supply, and Belice River together with artificial lakes, 81% of supply. Corleone city takes trans-boundary water from Prizzi Lake in the amount of 18 l/sec which corresponds to about 0.56 $hm^3$/year. About 21.9 $hm^3$/year are transferred towards near basins.

Groundwater is used mainly as drinking water for civil municipalities with the 45% of the total, while the 30% is used for irrigation and the 25% for industrial use.

Water consumed for irrigation is the 64% of the total, this reflects the fact that agriculture is at the basis of the local economy, while water consumed for domestic use, which includes the tourists' consumes, is about 27%, and the industrial and energy production one is 9%.

The water quality of the Belice River, of groundwater and of coastal water is good.

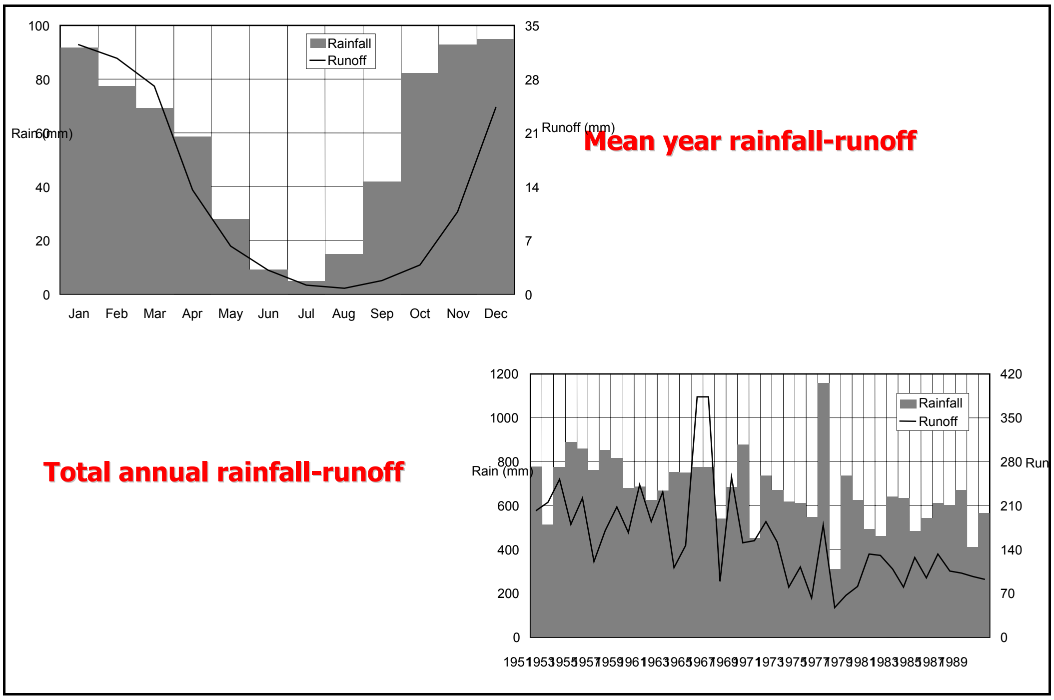



*Figure 63 Rainfall and runoff in the Belice Basin*

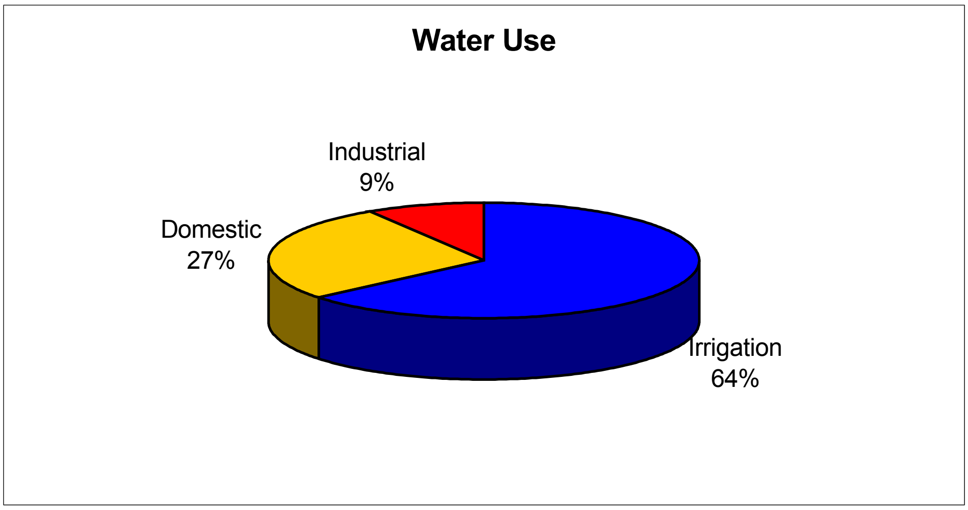



*Figure 64 Water Use*

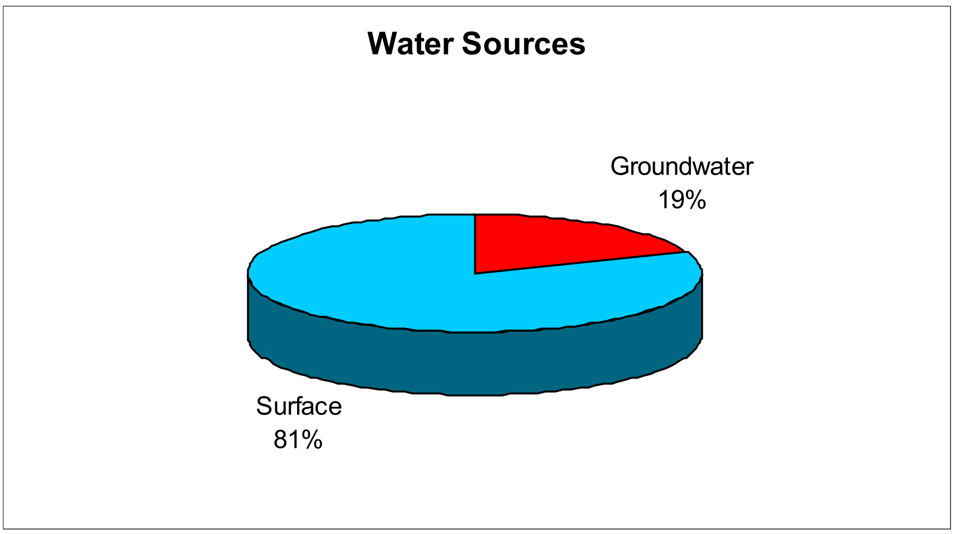



*Figure 65 Water Sources*

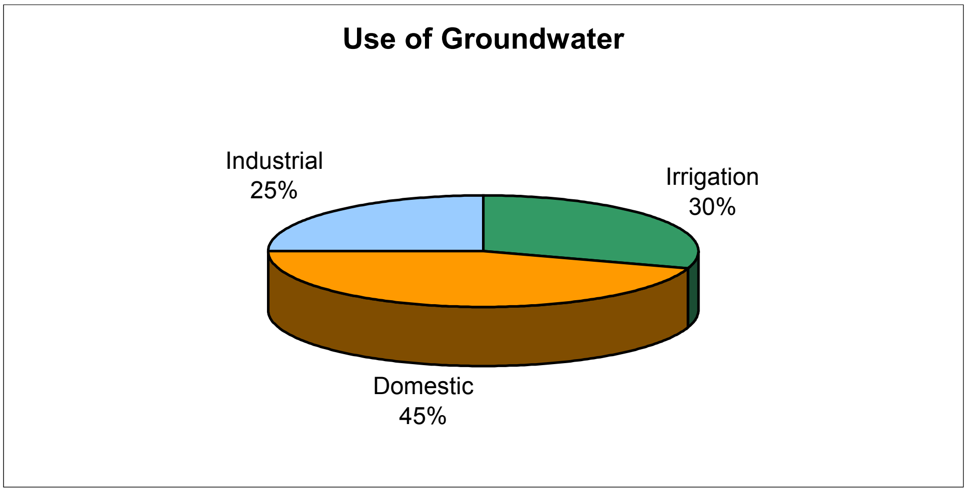



*Figure 66 Use of Groundwater*

The Belice Basin extends under the administrative competence of Consortium n°3 Agrigento. In his territory the lack of water for irrigation in 2001, mainly due to the lower precipitation, caused a heavy delay of the irrigation season from the usual and official starting month of April to the month of June. Besides, the fields' requirements of the entire region haven't been completely covered due to the uneven water availability conditions of the different water reservoirs and consequently some districts the irrigation season has terminated one month earlier.

Natural conditions are not the only problem affecting the fields water needs: in some districts the absence of the necessary activity of maintenance of the pipelines bringing water from the reservoirs has been the first cause of pipe bursts.

## Matrix of Circumstances

**Table 37 Belice Basin ( Sicily ) Matrix**

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate type | Warm-Temperate |
| | | Aridity index | 0.38 |
| | | Permanent population | 55329 |
| | | Area | 967 |
| | Water Availability | Total water resources / availability | 80 |
| | | Trans-boundary water | 0.56 |
| | Water quality | Quality of surface water | Good |
| | | Quality of groundwater | Good |
| | | Quality of coastal water | Good |
| | Water supply | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination, recycling<br>Importing | <br>19 %<br>81 %<br>0 (No)<br>0 (No) |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | <br>100 %<br>100 %<br>100 % |
| Economic and social system | Water use | Water consumption by category:<br>Domestic<br>Tourism<br>Irrigation<br>Industrial and energy production | <br>27 %<br>(inc. in Domestic)<br>64 %<br>9 % |
| | | Resources to Population index | 390 |
| | Water demand | Water demand trends | Increasing |
| | | Consumption index | 100 % |
| | | Exploitation index | 100 % |
| | Pricing system | Average household budget for domestic water (pa) | 0.47 % |
| | | Average household budget for agricultural water | 5 % |
| | | Average household income | 16740 |
| | | Cost recovery | Good |
| | | Price elasticity | Medium |
| | Social capacity building | Public participation in decisions | Bad |
| | | Public education on water conservation issues | Bad |
| Decision making process | Water resource management | Water ownership | National ( Public ) |
| | | Decision making level (municipal regional national) regarding:<br>Water supply for each sector<br>Water resources allocation for each sector | <br><br>Regional<br>Regional |
| | Water policy | Local economy basis | Agriculture, Tourism |
| | | Development priorities | Agriculture, Tourism |

## DPSIR Indicators

- Driving Forces:
  - reduced precipitation of the latest years: in particular year 2001 circa 200-250 mm lower than the mean value of the last thirty years,
  - absence of the necessary structural maintenance of artificial reservoirs and supply networks,
  - uneven distribution of available water all over the regional reservoirs,
  - population growth,
  - intensive agricultural activities,
  - pollutant loads generated from agricultural activities and domestic use of water.
- Pressures:
  - increased exploitation from aquifers,

- minimum storage levels in reservoirs,
- positive trend of agricultural water demand and consumption,
- positive trend of domestic consumption.

❖ State:
- actual irrigated area less than the total area equipped for irrigation,
- water losses along supply networks,
- increased domestic and agricultural water demand and consumptions,
- deficit in crop production.

❖ Impact:
- no recharge of the aquifers,
- the lack of water for irrigation damages the fruit and vegetables harvests with bad effects on the local agriculture-based economy. Tourism could be damaged too, as agriculture has water supply priorities.

❖ Response:
- increase the distribution system efficiency,
- re-use of treated waste water for agriculture,
- building of further small private lakes and their co-ordinated management with others water sources,
- use of efficient irrigation methods,
- facilitate within basin and inter-basin water transfers.

# Israel

*Tel Aviv*

*Regional Data*

The region is located in the coastal plain on the eastern shore of the Mediterranean Sea and it lies above the coastal aquifer. In terms of population, the Tel Aviv region is the largest in Israel with two million people, 30% of the total population (Table 39).[9] The region has 160,000 dunam of cultivated agricultural land, 5% of the total cultivated land in the country. The region's water economy is therefore characterised by relatively high domestic and industrial consumption, and relatively low agricultural consumption (see Tables 40 to Table 42 and Table 46).

Natural water sources in the area are:

- ❖ Supply from the national water system (via the national water network of the Mekorot company):
- ❖ Production from the coastal aquifer, above which the region lies
- ❖ Water supply from the Sea of Galilee via the National Water Carrier (NWC).

In addition, part of the fresh water is provided by private producers from the coastal aquifer (some 35% of the fresh water).

In the future, this region is slated to receive a significant amount of the desalinated sea water.

Aggregate supply is summarised in Table 46.

Domestic consumption is similar to the national average (100 $m^3$ per capita per annum). This consumption is expected to increase by 20% with the development of metropolitan parks and the improvement in quality of life.

The quality of the fresh water is good, with a salinity level of 150-250 mg chlorine per liter. In the future, the use of desalinated water will lead to an improvement in the water quality.

The region's large population creates the potential for a large supply of recycled water for agriculture. In addition, high quality treated waste water can be used for irrigation of metropolitan parks and for rehabilitation of streams like the Yarkon River (Table 44).

Climatic conditions in the region:

- ❖ Mediterranean climate, semi-arid.
- ❖ Annual precipitation 450 mm.
- ❖ Aridity index 0.05-0.2.

Water prices are determined within the national framework. Private producers are subjected to a production levy.

Land prices in this area are among the highest in the country. Therefore the region is subject to further urbanization and a reduction in agricultural area. Agriculture in this region has value as a public good in conserving open areas and "green lungs".

[9] Data in all tables refers to the year 2000

## Matrix of Circumstances

***Table 38 Tel-Aviv Matrix***

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Semiarid |
| | | Aridity Index | 0.05-0.2 |
| | | Permanent Population | 1,883,700 |
| | Water availability | Total Water Resources / Availability | 338 |
| | | Trans-boundary water | |
| | Water quality | Quality of surface water | - |
| | | Quality of groundwater | Good |
| | | Quality of coastal water | - |
| | Water Supply | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination<br>Recycling<br>Importing | <br>97%<br><br>0%<br>3%<br>0% |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | <br>100%<br>100%<br>100% |
| Economic and Social System | Water use | Water consumption by category:<br>Domestic<br>Irrigation<br>Industrial and energy production | <br>56%<br>17%<br>27% |
| | | Population to resources index | |
| | Water demand | Water Demand trends<br>Domestic<br>Industrial<br>Agriculture<br>Rivers | <br>Steadily increasing<br>Steadily increasing<br>Transfer to recycled water<br>Use of recycled water |
| | | Consumption index | Stable per-capita urban cons. |
| | | Exploitation index | 100% |
| | Pricing system | Average household budget for domestic water (pa) | $100 |
| | | Average household budget for agricultural water | |
| | | Average household income | |
| | | Cost recovery | |
| | | Price elasticity | Agriculture - somewhat elastic.<br>Urban and industrial - small. |
| | Social capacity building | Public participation in decisions | Very High |
| | | Public education | Fair |
| Decision Making Process | Water Resources Management | Water ownership | State |
| | | Decision making level (municipal, regional, national) regarding:<br>Water supply for each sector<br>Water resources allocation for each sector | <br><br>National<br>National |
| | Water Policy | Local economy basis | National |
| | | Development priorities | Recycling / Desalination |

## DPSIR Indicators

❖ Driving Forces:

- large population, approximately 2 million residents (most densely populated region in Israel),
- location: above coastal aquifer (as source for natural water) and proximity to Mediterranean Sea (potential for desalination),
- freshwater supply system connected to national system,
- large quantities of sewage water requiring treatment and disposal,

- potential for reuse of treated sewage water, either for the region itself or for southern region of Israel with transportation via central pipeline,
- present state of coastal aquifer: below "red lines", resulting in problems both with water quality and with rising salinity,
- crisis situation in national water supply system,
- instability of level of recharge of coastal aquifer (periodic droughts),
- high demand for water for public parks and for river rehabilitation,
- high value of land.

❖ Resulting pressures:
- large existing demands for water (domestic use, industrial and agricultural sectors, environmental needs),
- difficulties of national water system in supplying unsatisfied demands,
- conflicts regarding the use of reclaimed sewage water: within the region or in southern area of country,
- uncertainty regarding quantity of agriculture (and of its water use) in same region resulting from current trend to redirect land from agricultural to real estate uses,
- high cost of land for erection and maintenance of reservoir for treated sewage.

❖ Present state:
- massive cuts in water supply for agriculture, including drying of some lands (especially citrus orchards),
- rise in salinity of water for domestic and industrial use as a result of rise in salinity of water in coastal aquifer,
- drying out of rivers and danger to entire river ecosystem.

❖ Impacts:
- concern regarding fresh water shortages, including for domestic use,
- fear of irreversible damage to stream ecosystem,

❖ Responses:
- desalination of sea water in facilities along Mediterranean sea coast (increases water supply while decreasing average water salinity),
- desalination of water from saline wells (less expensive than desalination of sea water),
- high level treatment of sewage water and its use for river rehabilitation, for parks and agricultural irrigation,
- increased local use of treated sewage water and decreased transportation to southern area of country,
- pricing system adapted to water deficit,
- support (subsidies) for environmental uses of water,
- "import" of water from northern aquifer (Sea of Galillee), in limited quantities because of national shortage.

*Arava Region*

*Regional Data*

The region is located at the south-eastern tip of Israel, between the Dead Sea and the Red Sea.

The region is sparsely populated, based mainly on the tourist city of Eilat, at the southern tip. The remaining population is scattered in rural villages (Table 39).

Domestic consumption per capita in this region is particularly high (Table 40), for two reasons:

- ❖ Dry climatic conditions lead to heavy evaporation and a greater demand for garden irrigation and drinking water.
- ❖ A large part of the population lives in rural settlements, where large amounts of water are needed for private and public gardens.

Sources of fresh water in the region

- ❖ The Arava is not part of the national water system, but receives water from local sources only, via the national water company Mekorot:
- ❖ Drillings in the center of the region (Faran drillings) yield water of reasonable quality: up to 350 mg chlorine per liter.
- ❖ Drillings in the southern Arava yield low-quality water: 600-1,100 mg chlorine per liter.
- ❖ The desalination plant of Red Sea water provides water for the local population in Eilat.

In addition, waste water for agriculture is obtained from Eilat and the agricultural settlements. It is important to note that the Red Sea is a unique coral reserve of great ecological value, and it is therefore essential that waste water be recycled for agriculture and not be disposed of in the sea.

The prices for all the water supplied by Mekorot, fresh and saline, are determined within the national framework. Saline water is cheaper than fresh water, in accordance with the salinity level. The price for recycled water for agriculture covers the operational and the capital costs, after discounting state grants.

The water development plans for the region are mainly in the area of pooling and transferring waste water. In the more distant future there is a possibility that the desalination plant in Eilat will be enlarged.

Climatic conditions in the region:

- ❖ Arid climate, very low precipitation (up to 10 mm rain per annum).
- ❖ Aridity index 0.65.

The climatic conditions favor intensive cultivation of vegetables, flowers and date palms. Some 40% of the greenhouses in Israel are located in this region.

Some additional comments: This region borders with Jordan. The water production balance – drillings and water production from the local aquifer – is affected by the peace treaty with Jordan. Land prices are low and there is no demand for additional urbanisation.

***Table 39 Distribution of population by type of settlement***

| Type of Settlement | Tel - Aviv | | Arava | |
|---|---|---|---|---|
| | thousands | % | thousands | % |
| Metropolitan areas (Pop. exceeding 200,000) | 349 | 19 | - | 0 |
| Big cities (Pop. 100,000-200,000) | 887 | 47 | - | 0 |
| Mid-sized cities (Pop. 20,000-100,000) | 469 | 25 | 40 | 88 |
| Small towns and cities (Pop. 2,000-20,000) | 154 | 8 | - | 0 |
| Villages and communities | 25 | 1 | 5 | 12 |
| TOTAL | 1,884 | 100% | 45 | 100% |

*Table 40 Domestic Consumption (MCM/year)*

| Year | $m^3$ / capita | Consumption from National System | Consumption from Local System | Total Demand |
|---|---|---|---|---|
| Tel - Aviv | 100 | 75 | 113 | 188 |
| Arava | 200 | - | 9 | 9 |

*Table 41 Industrial Consumption (MCM/year)*

| | Freshwater Consumption from National System | Consumption from Local System | Total Demand | Saline Water | Recycled Water | Total |
|---|---|---|---|---|---|---|
| Tel - Aviv | 23 | 35 | 58 | 0 | 0 | 58 |
| Arava | 0 | 1 | 1 | 0 | 0 | 1 |

*Table 42 Agricultural Consumption (MCM/year) Sources*

| | | Tel - Aviv | Arava |
|---|---|---|---|
| National System | Fresh | 34 | - |
| | Recycled | 5 | - |
| | Saline | - | - |
| | Total | 39 | - |
| Local System | Fresh | 51 | 12 |
| | Recycled | - | 5 |
| | Saline | - | 14 |
| | Total | 51 | 31 |
| TOTAL | Fresh | 85 | 12 |
| | Recycled | 5 | 5 |
| | Saline | - | 14 |
| | TOTAL | 90 | 31 |

*Table 43 Environmental Consumption (MCM/year) Sources*

| | | Tel - Aviv | Arava |
|---|---|---|---|
| Local System | Fresh | | |
| | Recycled | 2 | |
| | Saline | | |
| | Total | 2 | |

*Table 44 Summary of Water Consumption by Water Type (MCM/year)*

| | | Tel - Aviv | Arava |
|---|---|---|---|
| National system | Fresh | 133 | - |
| | Recycled | 5 | - |
| | Saline | - | - |
| | Total | 138 | - |
| Local System | Fresh | 198 | 22 |
| | Recycled | - | 5 |
| | Saline | - | 14 |
| | Total | 198 | 41 |
| Total | Fresh | 331 | 22 |
| | Recycled | 5 | 5 |
| | Saline | - | 14 |
| | TOTAL | 336 | 41 |

*Table 45 Salinity Levels and Long-Term Average Recharge by Water Resource*

| Basin | Salination Level (mgchlorine/liter) | Average Annual-Recharge (MCM) |
|---|---|---|
| Coastal Aquifer – National System and Local Producers | - | 250 |
| Sea of Galilee Basin - National System | - | 180 |
| Arava – Local Sources | 400 | - |
| TOTAL | 400 | 222 |

*Table 46 General Water Balance (MCM/year) + estimates*

| | Arava | Tel - Aviv |
|---|---|---|
| Demand by sector: | | |
| Domestic | 9 | 188 |
| Industrial | 1 | 58 |
| Agricultural | 31 | 90 |
| Jordan & PA | - | - |
| Environment | - | 2 |
| Total | 41 | 338 |
| | | |
| Demand by water type: | | |
| Freshwater | 22 | 331 |
| Reclaimed | 5 | 7 |
| Saline | 14 | - |
| Total | 41 | 338 |
| | | |
| Supply: | | |
| Aquifers (including saline) | 27 | 333 |
| Desalination | 9 | - |
| Recycled | 5 | 5 |
| Total | 41 | 338 |

## Matrix of Circumstances

***Table 47 Arava Matrix***

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Hyperarid |
| | | Aridity Index | 0.5-0.65 |
| | | Permanent Population | 45,200 |
| | Water availability | Total Water Resources / Availability (MCM) | 41 |
| | | Trans-boundary water | |
| | Water quality | Quality of surface water | - |
| | | Quality of groundwater | Poor |
| | | Quality of coastal water | - |
| | Water Supply | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination<br>Recycling<br>Importing | <br>84%<br><br>0%<br>16%<br>0% |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | 100%<br>100%<br>100% |
| Economic and Social System | Water use | Water consumption by category:<br>Domestic<br>Irrigation<br>Industrial and energy production | 22%<br>76%<br>2% |
| | | Population to resources index | |
| | Water demand | Water Demand trends<br>Domestic<br>Industrial<br>Agriculture<br>Rivers | <br>Stable<br>Stable<br>Transfer to recycled water<br>- |
| | | Consumption index | Stable per-capita urban consumption |
| | | Exploitation index | 100% |
| | Pricing system | Average household budget for domestic water (pa) | $130 |
| | | Average household budget for agricultural water | |
| | | Average household income | |
| | | Cost recovery | |
| | | Price elasticity | Agricultural - somewhat elastic.<br>Urban and industrial - small. |
| | Social capacity building | Public participation in decisions | Very High |
| | | Public education | Fair |
| Decision Making Process | Water Resources Management | Water ownership | State |
| | | Decision making level (municipal, regional, national) regarding:<br>Water supply for each sector<br>Water resources allocation for each sector | <br><br>Local<br>Local |
| | Water Policy | Local economy basis | National |
| | | Development priorities | Recycling and Desalination |

## DPSIR Indicators

❖ Driving forces:

- independent water system, not connected to national water system,
- small and low-density population,
- single small city (Eilat) and agricultural villages,
- agricultural region, mostly for export: important center for greenhouse production of vegetables and flowers, also large areas of date orchards,

- City of Eilat located on Read Sea coast and in proximity to rare coral reef,
- some of water for agriculture from drilling with very high level of salinity,
- local aquifer shared by Israel and Kingdom of Jordan,
- desert region, extremely arid with no rain,
- high cost of water production in region, currently with subsidy for agriculture resulting in price lower than cost.

❖ Resulting Pressures:

- relatively stable water supply, independent of national water crisis,
- large urban demand for water reduces supply for agriculture,
- sewage water from Eilat must be recycled for agricultural use or there will be damage to coral reef both ecologically and in tourism,
- reduced profitability of agriculture resulting from exogenic factors such as: rise in water prices, difficulties in labour supply, lowered prices in export market.

❖ Present state:

- difficulty of agriculture (particularly date orchards) to adapt to water from different sources with varying levels of salinity,
- difficulty of agriculture in face of country's rising water prices, despite the fact that the Arava's water system is independent of the national water system,
- difficulty of agriculture to finance investments in reservoirs for reclaimed sewage water,
- sea water desalination facility constructed in Eilat,
- agreements in principle regarding division of water in aquifer shared with Kingdom of Jordan exist in peace treaty between the two countries,
- financial assistance for investments in reservoirs provided by government and other public organisations (Keren Kayemet L'Yisrael).

❖ Impacts:

- relatively stable and organised state.

❖ Responses (steps for further improvement of situation and to decrease difficulties):

- R&D activity regarding effects of irrigation with treated sewage water on greenhouse cultivation of dates and vegetables, particularly effects of salinity,
- adaptation of local irrigation systems to different sources of water,
- assurance of government assistance in reclaiming treated sewage water for agricultural use,
- revision of water price system to specific regional conditions of supply and demand.

# Cyprus

*Akrotiri*

*Regional Data*

The Akrotiri area covers the Akrotiri peninsula and it is the southernmost part of the island. It covers an area of 142 sq. km. Its eastern part is taken over by the urban area of Limassol with some 125000 inhabitants. There are 10 other village communities with a total population of 16000 within the same area that basically may be considered as suburbs to Limassol with their inhabitants commuting to the city and also working as farmers within the general area.

At the southern tip of the peninsula there is a major British military base with an airfield and an estimated force of the order of 15000 soldiers with their families. This is separated from the agricultural land and aquifer further to the north, by a Salt Lake and marshland that is of unique environmental importance.

The aquifer, the third largest in the island, essentially is a gently dipping coastal deltaic alluvial aquifer of a 40- $km^2$ extent. Its western half coincides with the alluvial fan deposits of the Kouris River that drains a catchment of 338 sq. km., whilst the Garyllis River draining a watershed of 100 sq.km takes up the eastern half. Groundwater is pumped through some 500 wells and boreholes mainly for irrigation (9 to 12 $Mm^3/y$) and for domestic purposes (1.5 to 3 $Mm^3/y$). About 90% of the annual extraction is metered and recorded at monthly intervals. Pumping permits are issued annually on the basis of the current groundwater conditions and the water content in the surface reservoirs.

The main source of the natural recharge of the aquifer, after the construction of Polemidia dam in 1965 on Garyllis river and the construction of the Kouris dam in 1987 on Kouris river changed dramatically. It now depends entirely on local rainfall of about 380 to 430 mm, return flow from imported water for irrigation and on artificial groundwater recharge.

Sea intrusion was originally confined at the eastern part but more recently, and after the construction of the Kouris dam of 115 $Mm^3$, a large part of the Kouris delta area has also been sea-intruded. Ongoing artificial groundwater recharge with water from the surface reservoirs, and planned with treated effluent, together with further control of pumping is expected to reverse the situation. Furthermore, with the reduction of the flashing effect of the annual recharge together with the increased agricultural activity, a gradual built up of nitrate and other elements has been noted in the groundwater of the area.

Presently the irrigation requirements of the area are met by local groundwater, tertiary treated effluent, surface water from the Kouris, Germasogeia and Polemidhia dams and from reclaimed groundwater pumped from within the Limassol urban area. The area irrigated at present is 2200 ha with a demand of 15 $Mm^3$, out of a planned area of 3775 ha. The Limassol domestic supply is mainly provided from the Kouris dam and partly from groundwater from the Germasogeia aquifer.

A major desalination plant of 20000$m^3$/d capacity is planned for commissioning by 2004 to be built at the western part of the area.

The aquifer is very well controlled. The groundwater levels are observed monthly from a network of 150 since 1960, 85 to 100 of which are regularly sampled. The groundwater pumping is quite well monitored through water meters that are observed every month. The area is well surveyed and studied. A good database exists and numerous studies have been performed including groundwater modeling.

Low rainfall and reduction of the surface reservoir water content resulted to diminished recharge, both natural and artificial, of the aquifer. This together with the continued extraction pattern of pre-dam construction has caused a serious drop of the groundwater levels (Figure 67, Figure 68 and Figure 69) and sea intrusion (Figure 70).

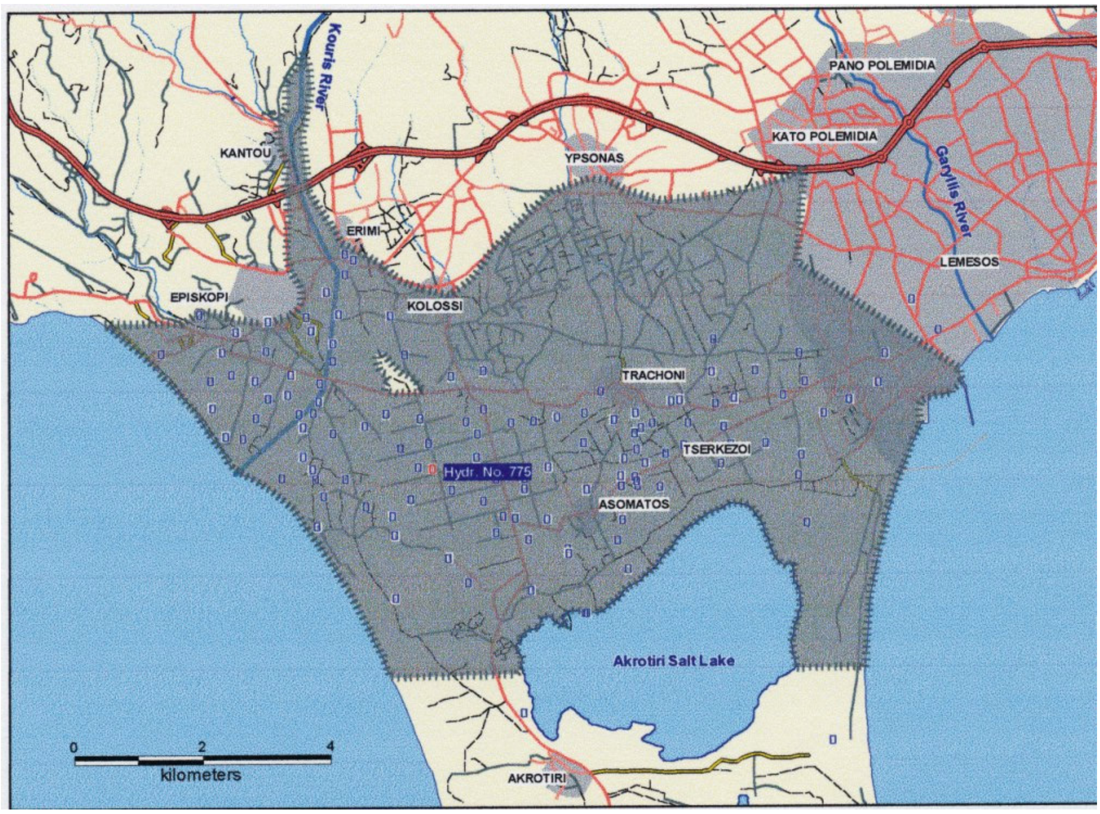



***Figure 67 Akrotiri Aquifer showing inhabited areas and well observation network***

The intensive use of fertilisers in agriculture together with the reduction of the flashing effect by natural recharge resulted to a nitrate built-up in the aquifer. The concentration of nitrate ion in the eastern part of the aquifer is in excess of 200 mg/l.

At the same time the diminished flows of Kouris River and the drop of groundwater levels are threatening the ecosystem of the marshlands and of the Salt Lake. Urbanisation at the eastern and northern parts of the aquifer and increased storm runoff from these areas presents also a problem to the Salt Lake being the lowland and the natural receiving area.

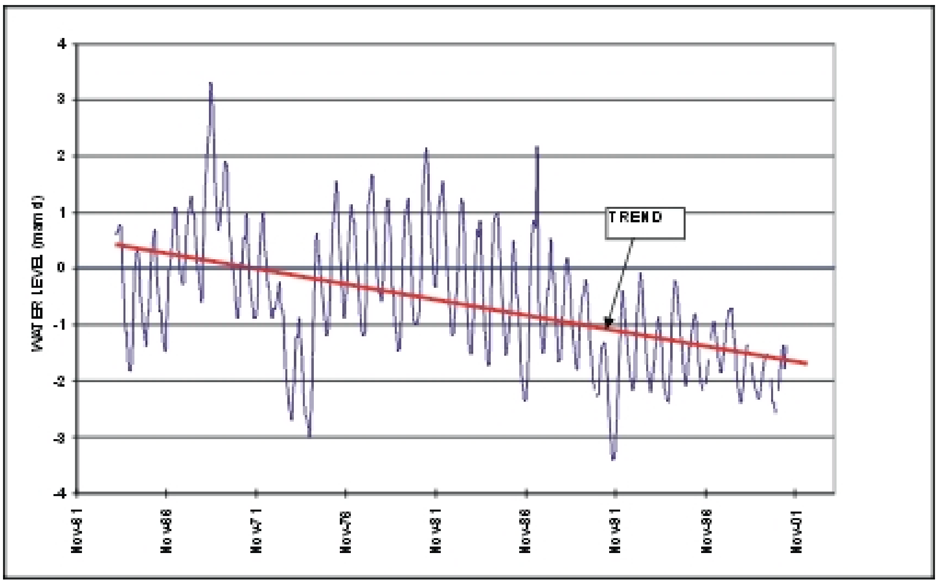



***Figure 68 Hydrograph of borehole Akrotiri 775 (Elev. 15.63 m amsl)***

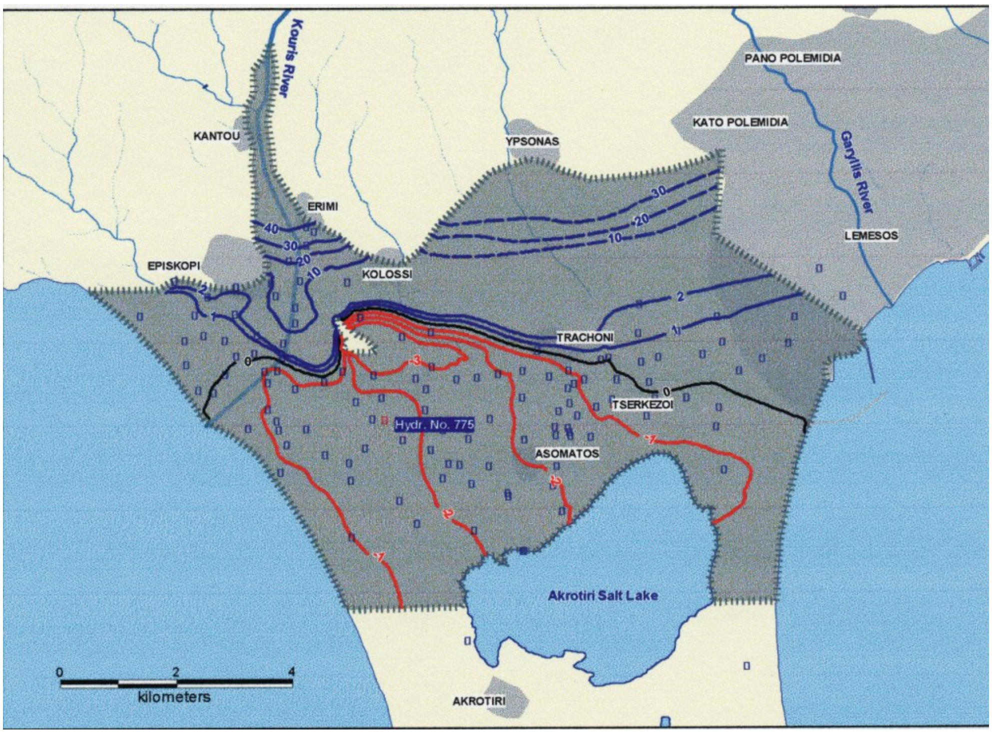



*Figure 69 Akrotiri Aquifer - Water Level (m amsl) Contour Map March 2001*

Anthropogenic intervention has changed dramatically the hydrologic regime in the area especially after the construction of the Kouris dam. The average water balance over the period of 1967/68 – 1976/77 compared to present conditions is shown on the Table below (All in $Mm^3/yr$).

***Table 48 Recharge***

| Kouris dam was constructed in 1987 | Rainfall | Riverbed Recharge | Subsurface Inflow | Sea intrusion | Return from irrigation | Return imported / Diversions | Artificial Recharge | Total | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| Before (1968-1978) | 5.9 | 15.4 | 4.2 | 0.7 | 4.5 | 3.5 | | 63 | Average rainfall 395 mm |
| At present | 4.2 | 0.5 | 0.2 | 3.0 | 1.1 | 0.7 | 3.3 | 31.0 | Average rainfall 380 mm |

***Table 49 Outflow***

| | Abstraction for irrigation and domestic | Evapotranspiration | Rising water | Sea/ Lake Outflow | Total |
|---|---|---|---|---|---|
| Before (1968-1978) | 14.5 | 2.5 | 2.2 | 16.0 | 46 |
| At present | 10.8 | 2.4 | 0.3 | 0.5 | 32.0 |

From the balance above one should note the very small quantity of groundwater that outflows from the system at present and which does not provide the required leaching effect, the reduction of rising water that affects the marshland, and the increase in sea intrusion quantities which although they are considered as part of the “recharge”, the resulting true balance is in effect negative and of the order of 4 $Mm^3$ per year.

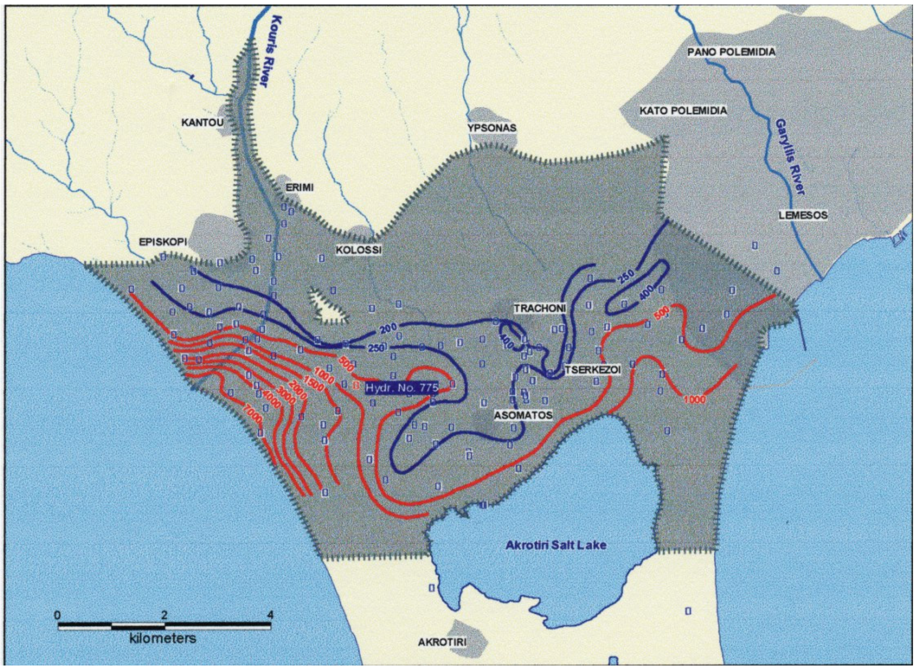



*Figure 70 Akrotiri Aquifer - Isochloride (ppm) Contour Map April 2001*

## *Matrix of Circumstances*

***Table 50 Akrotiri Area Matrix***

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Csa-Mediterranean |
| | | Aridity[10] Index | Semi-arid (0.330) |
| | | Permanent Population | 156000 |
| | Water availability | Total Water Resources /Availability | 30 $Mm^3$ |
| | | Trans-boundary water | - |
| | Water quality | Quality of surface water | Very Good |
| | | Quality of groundwater | Fair - Poor |
| | | Quality of coastal water | Good |
| | Water Supply | Percentage of supply coming from: | |
| | | Groundwater | 33% |
| | | Surface water | 62% |
| | | Desalination, Recycling | 5% |
| | | Importing | |
| | | Network coverage: | |
| | | Domestic | 100% |
| | | Irrigation | >85% |
| | | Sewerage | Apx. 75% |
| Economic and Social issues | Water use | Water consumption by category: | |
| | | Domestic | 30% |
| | | Tourism | 10% |
| | | Irrigation | 60% |
| | | Industrial and energy production | |
| | | Resources to population index | 192 $m^3$/c |
| | Water demand | Water Demand trends | Increasing |
| | | Consumption index | 100% Increasing |
| | | Exploitation index | 100% Increasing |
| | Pricing system | Average household budget for domestic water[11] | € 99.2/yr |
| | | Average household budget for agricultural water | €0.11/$m^3$ |
| | | Average household income[11] | €24207urban<br>€18488 rural |
| | | Cost recovery | Dom €0.58/$m^3$, Irr €0.11 |
| | | Price elasticity | Very small |
| | Social Capacity building | Public participation in decisions | Fair |
| | | Public education on water conservation issues | Fair |
| Decision Making Process | Water Resources Management | Water ownership | State- (partly private) |
| | | Decision making level regarding: Water supply for each sector | National |
| | | Water resources allocation for each sector | National |
| | Water Policy | Local economy basis | Agri/tertiary |
| | | Development priorities | Agri/tourism |

## *DPSIR Indicators*

The Akrotiri area was one of the most dynamic aquifers in the Island until 1987 when the Kouris dam was completed blocking the bulk of replenishment. The low topography, its large contact with the sea coast and Salt Lake and the continued pre-dam pumping pattern has resulted to serious problems to the aquifer. Citrus orchards and the supply for part of the domestic supply are threatened. The largest part of the area falls under the Sovereign British Base area which controls and limits tourist development. Agriculture is the main alternative left for the population in the area.

❖ The driving forces in the region were defined as the:
- inability to transfer water for irrigation with the Germasogeia – Akrotiri pipe after the use of the pipe to transfer recycled water to the Germasogeia dam,

[10] Aridity = 407/ (4.5x365x.0.75) 1961-1990
[11] Family Budget Survey 1996/97 Statistical Service of Republic of Cyprus

- reduction of the surface flows and of groundwater recharge (Kouris river) due to the construction of the Kouris dam,
- intensive use of fertilisers/reduction of flashing effect by natural recharge,
- urbanisation of the eastern and northern part of the aquifer,
- low local rainfall,
- over-exploitation of the groundwater,
- on-going water extraction pattern based on the pre-dam conditions,
- population growth,
- low topography – limitation on water storage capacity and immediate impact on groundwater levels by increased pumping,
- extensive contact with sea coast and Salt Lake,
- availability of expensive surface (dam) water and recycled water compared to relatively cheap groundwater,
- administrative control on development other than agriculture by Sovereign British Base Authorities,
- high proportion of permanent crops vs. seasonal crops,
- the area is under water conservation law (special measures) which controls drilling and pumping on an annual basis and requires water metering.

❖ The current state of aquifer and area currently is:

- reduced outflow from the groundwater system/inadequate leaching effect,
- high concentrations of salinity in groundwater,
- high nitrate built-up in the aquifer,
- increased demand (domestic, agriculture),
- groundwater levels below mean sea level throughout 80% of aquifer,
- all pumping and use of water monitored through water-meters – annual permits and water allocation.

❖ As impacts were identified the:

- deterioration of the quality of the water in the aquifer,
- role of area for providing domestic water supply is being diminished – plans for desalination plant to replace supply are under development,
- reduced income from agriculture due to cuts in water allocations,
- threats on the ecosystem of the marshlands and the Salt Lake,
- minor shift to less water consuming agriculture and other activities (Water Parks).

❖ The responses to the above are:

- more efficient pumping control,
- more effective water allocation with increased surface water and treated effluent component,
- on-going artificial recharge with water from the surface reservoir and the recycled water from the Limassol Central Sewerage Treatment Plant,

- exchange of pumping for domestic supply with desalinated water (by 2004) with plans under way,
- implementation of Good Agricultural Practice Code regarding use of fertilizers and pesticides,
- adjustment of water pricing to reflect true cost of irrigation water as a tool for water demand management.

### *Germasogeia*

#### *Regional Data*

The Germasogeia catchment is in the southern coast of Cyprus. It is about 141 square kilometres up to the Germasogeia dam of 13.1 million cubic meters capacity. Its average annual flow is about 20 million cubic meters. A major part of the catchment is covered by natural forest but considerable agricultural activity is present in riparian land. The annual and seasonal crops irrigated from the various sources of water are shown on Table 51 that follows.

***Table 51 Annually and Seasonally Irrigated Crops (in hectares and Mm$^3$)***

| Germasogeia Watershed (in relation to Dam) | RIVER | | SPRINGS | | WELLS/BH | | TOTAL | |
|---|---|---|---|---|---|---|---|---|
| | Area | Water Use | Area | Water Use | Area | Water Use | Area | Water Use |
| Upstream | 295 | 2.5 | 78 | 0.8 | 16 | 0.2 | 386 | 3.5 |
| Downstream | 304 | 3.0 | | | | | 304 | 3.0 |

There are 14 village communities within the watershed with a total permanent population of just over 10000 and water demand of 0.5 to 0.7 Mm$^3$ per year, of which 12 villages are upstream the dam with a population of about 4000. There is considerable tourist development at the coastal area with an estimated 0.5 million-guest nights and a water demand of 0.9 Mm$^3$ during the tourist season.

Downstream the dam a riverbed aquifer develops. This is a typical river alluvial aquifer.

This aquifer, which is 5 km east of Limassol town (Figure 71), has a length of 5.5 km and an average width of about 350 m. This phreatic aquifer consists of sandy gravels with low silt content except towards the coast where an increase of finer material is noted. The thickness in the deepest part varies from 35 meters near the dam to 50 meters near the coast. The permeability in the upstream part of the aquifer is as high as 300 m/d reducing to 100 near the Delta. The specific yield varies from 13 to 22%. The active storage of fresh water is of the order of 3.5 MCM increasing to 5.0 MCM at high water table.

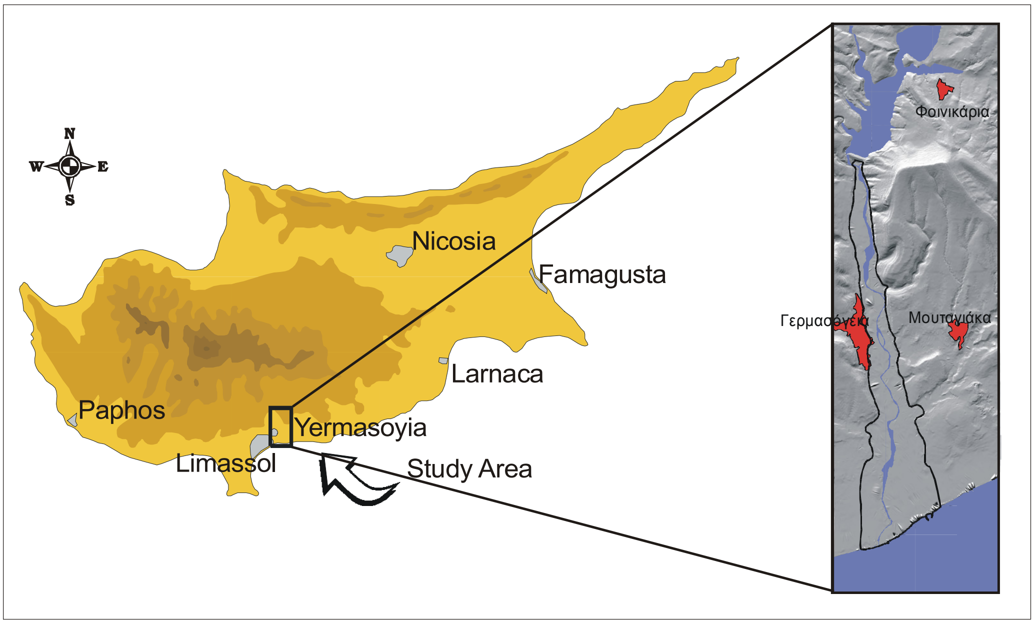



***Figure 71 Location of the Germasogeia watershed (the part downstream the dam)***

The small aquifer between the surface reservoir and up to 4 km downstream, before the development of the Delta area, has been relied upon to meet the major portion of the increasing demand for the water supply of the town of Limassol and neighbouring villages with high seasonal demand due to tourism.

Since the construction of the dam in 1968 the recharge of the aquifer depends on controlled releases from the dam and its spills. During the last ten years the dam spilled only twice, in 1993 and 1995.

The complete cut-off of natural replenishment by the construction of the dam and the proximity to the sea, coupled with the increasing extraction from the aquifer, requires a co-ordinated programme of releases from the dam for artificial recharge to cope with the extraction. With such action the sea intrusion is controlled and at the same time an efficient use of the scarce water resources is made.

The need for controlled releases from the dam to artificially recharge this aquifer through flooding in the active channel became a necessity by 1982 due to the increasing demand for domestic supply and the rather dry conditions experienced at the time. This conjunctive use of the surface and groundwater reservoirs enabled a dramatic increase in the extraction from this aquifer deferring the need for an expensive treatment plant for many years.

The extraction was doubled due to an equivalent increase of recharge. It is important to note that with the regulated releases of water and the resulting recharge the annual extraction in many years was about three times the active storage of the riverbed aquifer.

In the early days of the recharge, large quantities were released at irregular time intervals. Gradually, the daily release quantities were being reduced and the length of the period of release was increased.

Since 1986, the release is practically continuous and at such rates that the losses to the sea through the subsurface are minimal.

The rates of release are of the order of 15 to 25 000 $m^3$/d whilst the total groundwater inflow to the main well-field serving Limassol is in the range of 18 to 30 000 $m^3$/hr.

Chemically the groundwater is similar to that of the water in the surface reservoir. Bacteriological analyses from all the boreholes show that the 10 to 20 meters of unsaturated thickness of alluvial sediments provides an efficient protection to bacteriological pollution.

In the Delta area and near the coast the interface has remained practically stable showing that the recharge-extraction regulation has been of the correct order without excessive pumping or serious subsurface loss of fresh water to the sea.

In effect the small Germasogeia riverbed aquifer has been turned into a natural treatment plant for domestic water supply without the need of complicated and expensive surface water treatment requiring chemicals, qualified technical and managerial personnel and the necessary civil engineering structures. Surface water from the Germasogeia and Kouris dams is being released in the riverbed since 1982 for recharge of the aquifer. Groundwater is pumped for the domestic water supply of the Limassol town, for the surrounding villages, and the tourist zone. This aquifer is the only source of domestic water supply of the local village communities and the tourist zone.

The catchment area has extensive hydrometeorological, geological and hydrogeological data as well sufficient surface and groundwater quality data. It constitutes an excellent case study for evaluating drought conditions and their repercussions on the hydrologic regime and to the socio-economic environment of the area. In the aquifer area some 46 boreholes are monitored every 15 days and conductivity logs are kept for 10 boreholes for monitoring the sea/fresh water interface. The extraction from all wells and boreholes is monitored monthly my water-meters. The releases for recharge are monitored on a daily basis. A good database and GIS as well as groundwater models exist for the area.

The Germasogeia water resources system (surface reservoir and aquifer) is the most intensively exploited one in the island. In 1996 up to 9 $Mm^3$ of groundwater were extracted from this small aquifer, whose area is only 3 $km^2$ and its total fresh water capacity at average groundwater level conditions, is in the order of only 3.5 $Mm^3$.

A fast growing urbanization within the aquifer area and tourist development is causing concern about the environmental impact and possible deterioration of the quality of groundwater in this highly susceptible aquifer.

The hydrogeological regime and the water balance of the aquifer are "regulated" by controlled releases from the dam into the river valley. The main targets are:

- To cover water demand with groundwater of acceptable quality,
- To protect the aquifer from sea intrusion,
- To minimise groundwater losses to the sea and to
- Maximise the water availability through conjunctive use of surface and groundwater.

Some 23 boreholes operate in the aquifer today for domestic water supply. The yields of these boreholes vary from 50 to 200 $m^3$/hour. Annually, the average extraction is about 6 $Mm^3$, whilst the average artificial recharge is about 5 $Mm^3$.

The water balance of the aquifer is quite good and no problems of sea intrusion are faced provided there is ample water in the surface reservoir for recharge and the groundwater extraction is contained within the capabilities of the system.

The sustainable extraction under natural conditions i.e. with no artificial recharge of the aquifer is estimated to be of the order of 1.4 $Mm^3$/year based mainly on the leakages from the dam.

Figure 72 shows the location of the surface reservoir and the aquifer whilst Figure 73 shows a typical groundwater level fluctuation. The cycles of increased recharge or extraction are quite obvious on this hydrograph. Figure 74 shows the groundwater contours in the area, especially as these develop around the main well-fields and near the coast.

*Table 52 Recharge*

| Germasogeia dam (13Mm$^3$) was constructed in 1968 | Rainfall and Return from irrigation /domestic | Riverbed Recharge | Leakage from dam | Sea intrusion | Artificial Recharge | Total | Remarks |
|---|---|---|---|---|---|---|---|
| (1982– 1987) average rainfall 430 mm | 0.4 | 0.5 | 1.8 | 0.0 | 3.6 | 27 | By A. Christodoulides |
| (1991-2000) average rainfall 400 mm | 0.5 | | 1.0 | 0.1 | 5.1 | 8 | By A. Georgiou |

*Table 53 Outflow*

| | Abstraction for domestic | Sea Outflow | Total | Remarks |
|---|---|---|---|---|
| (1982– 1987) average rainfall 430 mm | 5.6 | 0.7 | 18 | By A. Christodoulides |
| (1991-2000) average rainfall 400 mm | 6.4 | 0.3 | 13 | By A. Georgiou |

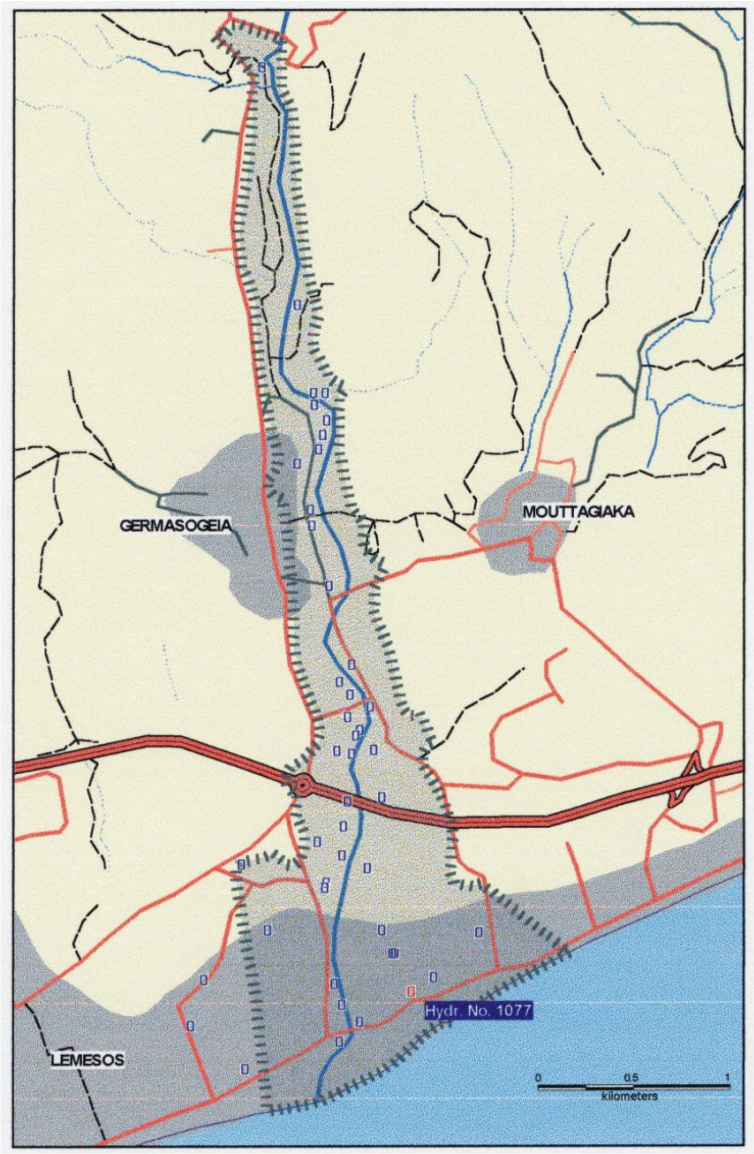



*Figure 72 Germasogeia Riverbed Aquifer - Location Map*

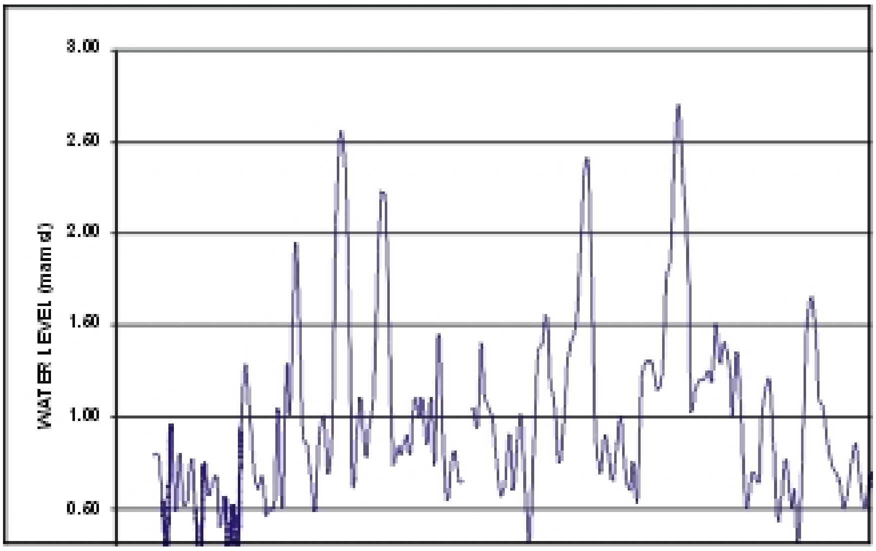



*Figure 73 Hydrograph of borehole Germasogeia 1077 (Elev. 4.98 m amsl)*

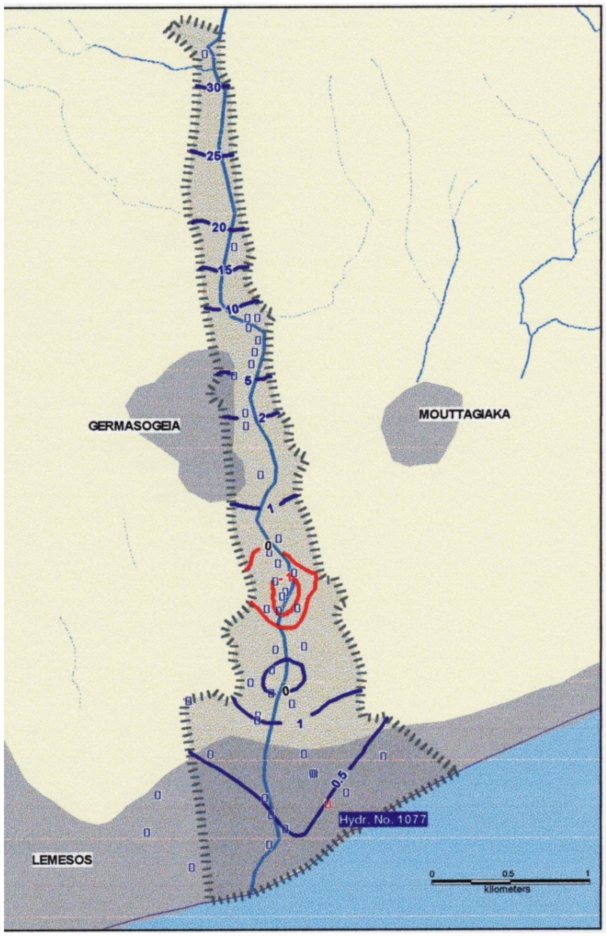



*Figure 74 Germasogeia Riverbed Aquifer Water Level (m amsl). Contour Map November 2001*

## Matrix of Circumstances

**Table 54 Germasogeia Area Matrix**

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Csa- Med/ean |
| | | Aridity[12] Index | Semi-arid (0.356) |
| | | Permanent Population | 10000 |
| | Water availability | Total Water Resources /Availability | 20/12 $Mm^3$ |
| | | Trans-boundary water | - |
| | Water quality | Quality of surface water | Very Good |
| | | Quality of groundwater | Very Good |
| | | Quality of coastal water | Good |
| | Water Supply | Percentage of supply coming from: | |
| | | Groundwater | 15% |
| | | Surface water | 50% |
| | | Desalination, Recycling | 35% |
| | | Importing Exporting | |
| | | Network coverage: | |
| | | Domestic | 100% |
| | | Irrigation | >70% |
| | | Sewerage | Apx. 80% |
| Economic and Social issues | Water use | Water consumption by category: | |
| | | Domestic | 0.6 $Mm^3$ |
| | | Tourism | 0.9 $Mm^3$ |
| | | Irrigation | 6.5 $Mm^3$ |
| | | Industrial and energy production | |
| | | Resources to population index | 1200 $m^3$/c |
| | Water demand | Water Demand trends | Increasing |
| | | Consumption index | 67% increasing |
| | | Exploitation index | 67% Increasing |
| | Pricing system | Average household budget for domestic water[13] | € 99.2/yr |
| | | Average household budget for agricultural water | €0.11/$m^3$ depends on land |
| | | Average household income[13] | €24207urban<br>€18488 rural |
| | | Cost recovery | Dom €0.58/$m^3$<br>Irr €0.11 |
| | | Price elasticity | Very small |
| | Social Capacity building | Public participation in decisions | Fair |
| | | Public education on water conservation issues | Fair |
| Decision Making Process | Water Resources Management | Water ownership | State- (partly private) |
| | | Decision making level (municipal, regional, national) regarding:<br>Water supply for each sector | National |
| | | Water resources allocation for each sector | National |
| | Water Policy | Local economy basis | Agri/tertiary |
| | | Development priorities | Agri/tourism |

## DPSIR Indicators

The Germasogeia aquifer is a very small alluvial aquifer but of immense importance to the area since it has been used for more than 20 years as a natural treatment plant for the domestic supply of a large proportion of the needs of the neighbouring town of Limassol and it is the sole source of domestic supply for a number of village communities and the tourist development in their coastal area. More than three times its active storage capacity is being pumped annually by inducing water through releases from an upstream dam. Increased urbanisation threatens the quality of the water resources in this area.

❖ The driving forces in the region were defined as the:

[12] Aridity = 478/ (4.9x365x.0.75) 1961-1990
[13] Family Budget Survey 1996/97 Statistical Service of Republic of Cyprus

- complete cut-off of natural replenishment of the aquifer due to the construction of the Germasogeia dam,
- fast growing urbanisation within the aquifer area,
- rapid tourist development at the coastal area,
- increasing water demand for domestic supply which for the communities and tourist development in the area can only be met by pumping from this aquifer,
- the current state of aquifer and area currently is: Increased domestic demand (Limassol city, neighbouring villages),
- increased agricultural demand,
- regulation of the aquifer's water balance by controlled releases from the dam into the river valley,
- state of aquifer fully dependant on contents of Germasogeia Dam,
- high intensity of aquifer utilisation renders it liable to pollution – pumping is 3 times its active storage capacity made possible by artificial recharge,
- current quality and state is very good.

❖ As impacts were identified the:
- deterioration of the quality of the groundwater by urbanisation,
- occasional sea intrusion – controlled by increased artificial recharge,
- ground water for domestic purposes could be compromised by deteriorating water quality (salinisation, high nitrate concentrations, etc.),
- importance of aquifer and its protection limits the value of land for development – conflicts.

❖ The responses to the above are:
- development of protection areas around wells and well-fields,
- strict control of urbanisation within aquifer are needed through Town Planning zoning and of domestic sewage management,
- coordinated program of releases mainly from the Germasogeia dam but also from Kouris dam for artificial recharge of the aquifer to compensate for the water extraction,
- reduction of pumping for the domestic supply of Limassol and replacement with water from Kouris dam,
- increased monitoring of sea intrusion propagation and adjustment of artificial recharge regime accordingly,
- plans being considered to enable domestic supply from Kouris Water Supply Treatment Plant.

*Kokkinochoria*

*Regional Data*

The area includes five village communities and three municipalities with a total permanent population of 30000 and an annual water demand in excess of 1.7 $Mm^3$. Two areas near the coast (Paralimni and Agia Napa) have developed to a very attractive tourist resort with tourists exceeding 6 million-guest nights and a water demand of about 3 $Mm^3$.

The Kokkinochoria area being at the lee-side and far from the Troodos Mountains receives the lowest rainfall in the island, the long-term average being 330 mm per year. There is no stream crossing the area except during storm events in winter due to local storms.

The local aquifer has been overexploited since the early 1960s and the groundwater mined is in excess of 350 $Mm^3$. At present the groundwater reserves are only 15% of the original. Water levels in the aquifer within 2 km from the coast have dropped to 50 m below mean sea level.

The region is an early-potato producing area with most of the produce being exported to the UK and elsewhere. The past agricultural activity in the area has been maintained by importing water through the Southern Conveyor Project from the Kouris Dam some 70 km to the west. A total of an annual supply of 17 $Mm^3$ has been envisaged which together with the local safe yield of 8 $Mm^3$ would allow the continuation of the agricultural activity in the area. This has been accomplished, although the extended drought of the last decade did not allow the transfer of the quantities envisaged. This did not have devastating repercussions since a lot of the workforce shifted in the meantime from agriculture to other employment associated with the locally thriving tourist industry. Nonetheless, both the soils and farming experience in the area is a resource that should be exploited to its maximum and the conditions need to be established in the area to allow the continuation of potato production for the benefit of the economy of the island.

There exists good hydrogeological information for the area with some 164 wells being monitored for water levels since 1964 every three months (see Figures 75 and 76). Water quality surveys are carried out seasonally to check the propagation of the sea-intrusion (see Figure 77)

In the Table that follows an estimated water balance of the Kokkinochoria aquifer is presented for two periods: 1963-78 and for 1990 to present.

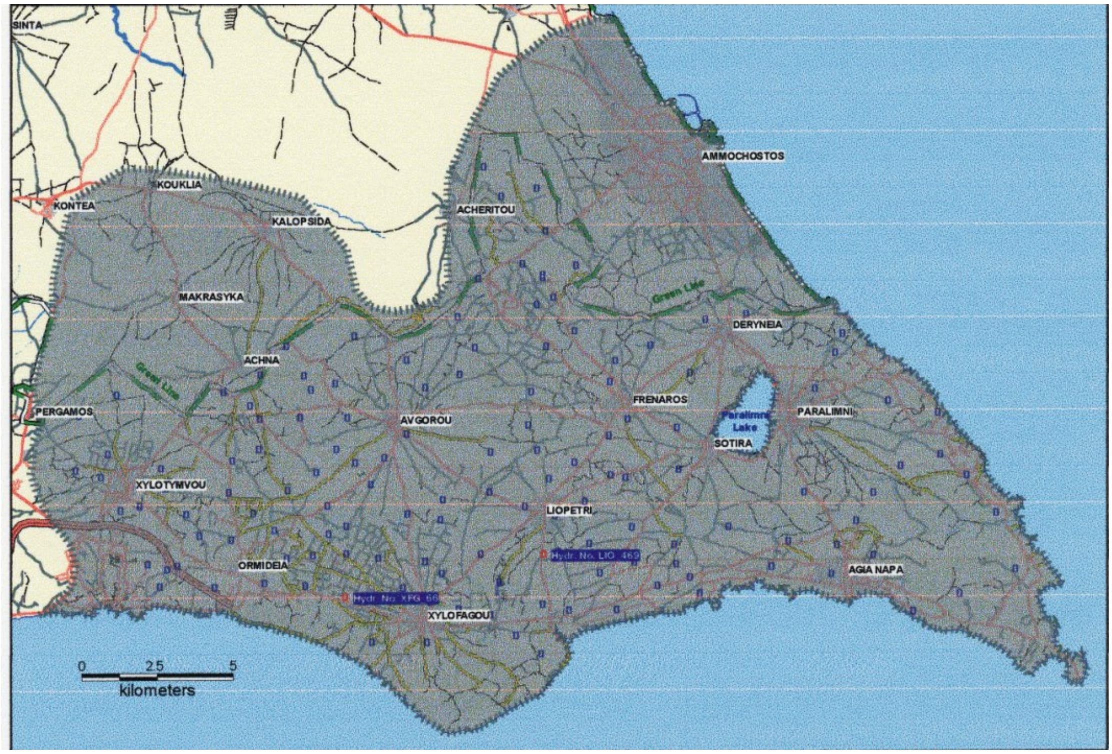



*Figure 75 The general area and the Kokkinochoria aquifer*

***Table 55 Recharge***

| Southern Conveyor Project completed in 1987 | Rainfall | Subsurface Inflow | Sea intrusion | Return from irrigation | Return imported / Diversions | Total | Remarks (aquifer area 172 sq. km) |
|---|---|---|---|---|---|---|---|
| 1963-1978 (SCP study – Iacovides) | 8.2 | 1.1 | 2.9 | 4.7 | | 16.9 | Average rainfall 330 mm |
| At present (FAO study – Georgiou) | 8 | 0.1 | 5.5 | 0.5 | 1.6 | 15.7 | Average rainfall 300 mm |

***Table 56 Outflow***

| | Abstraction for irrigation and domestic | Sea Outflow | Total | Balance |
|---|---|---|---|---|
| 1963-1978 (SCP study – Iacovides) | 27.1 | 0.4 | 27.5 | –10.6 |
| At present (FAO study – Georgiou) | 14.0 | 1.5 | 15.5 | + 0.2 *14 |

The most productive parts of the aquifer (Ormidhia, Xylophagou, Liopetri, Phrenaros), have been sea intruded and abandoned since the early 1980s. The less productive parts are already depleted with dramatically reduced borehole yield.

It is estimated that over 5000 boreholes operate in the area today. Yields of these boreholes have reduced from an average of 10 m³/hour in 1980 to 1 to 2 m³/hour in 2000. Boreholes with yields of 2-3 m³/day are still in operation. In effect the farmers are rapidly and inexorably drying out the aquifer. A rough estimate of the average annual extraction during the past 10 years is estimated to be around 12 to 14 Mm$^3$.

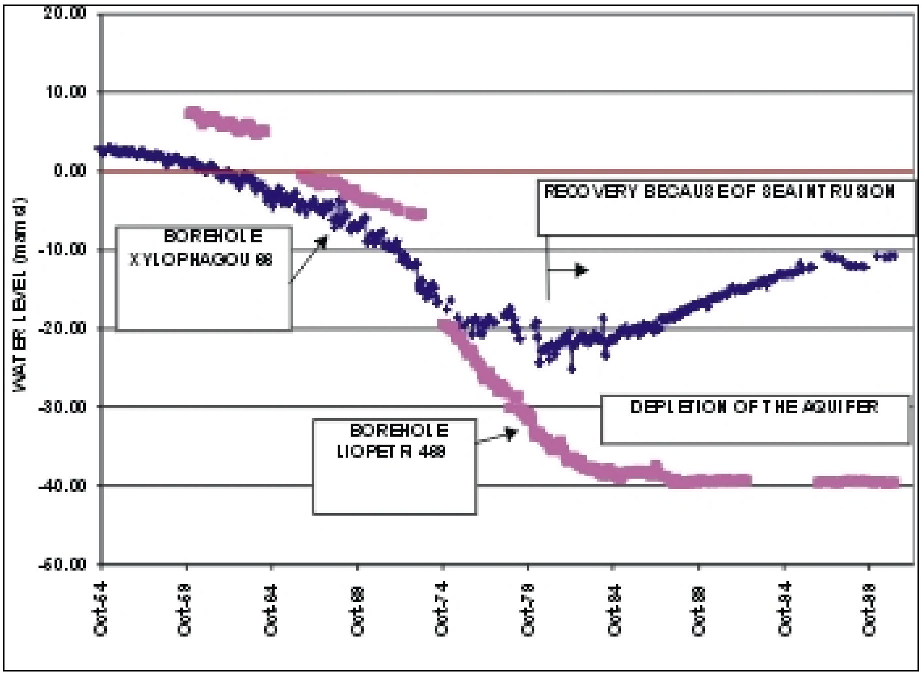



***Figure 76 Hydrograph of boreholes Xylophagou 66 and Liopetri 469 (Elev. 52.61 and 30.74m amsl)***

14 The annual balance would be – 5.3 Mm$^3$ if the sea intrusion is considered.
The recommended annual pumping from this aquifer is only 8 Mm$^3$

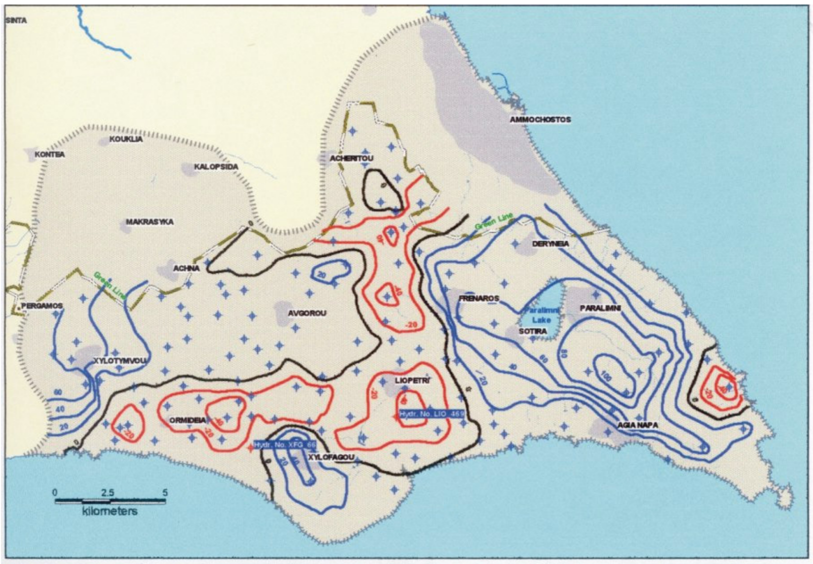



*Figure 77 Kokkinochoria Aquifer - Water Level (m amsl) Contour Map Sept. 2000*

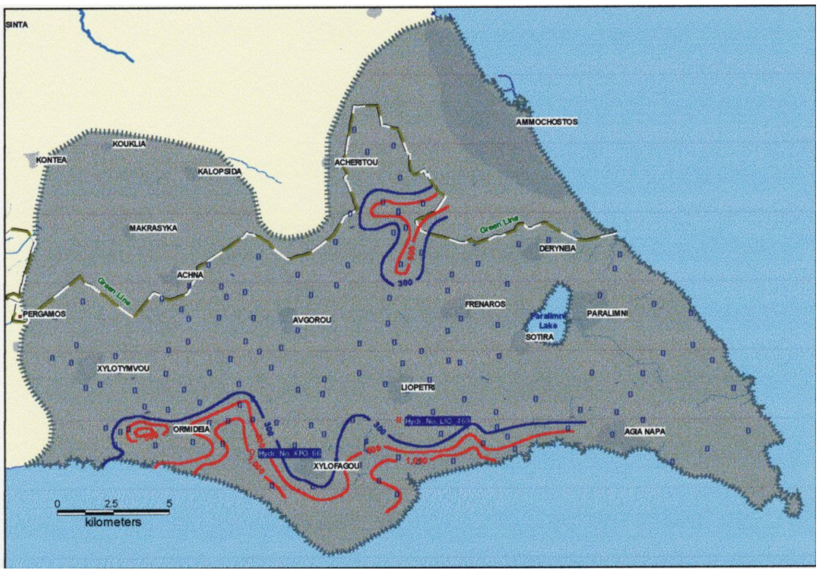



*Figure 78 Kokkinochoria Aquifer Isochloride contours (ppm) for June 1994 (after Georgiou)*

## Matrix of Circumstances

**Table 57 Kokkinochoria Area Matrix**

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Csa-Med/nean |
| | | Aridity[15] Index | Semi-arid (0.268) |
| | | Permanent Population | 30000 |
| | Water availability | Total Water Resources /Availability[16] | 30 $Mm^3$ ** |
| | | Trans-boundary water | - |
| | Water quality | Quality of surface water | Very Good |
| | | Quality of groundwater | fair |
| | | Quality of coastal water | Good |
| | Water Supply | Percentage of supply coming from: | |
| | | Groundwater | 30% |
| | | Surface water | - |
| | | Desalination, Recycling | 13% |
| | | Importing | 57% |
| | | Network coverage: | |
| | | Domestic | 100% |
| | | Irrigation | >85% |
| | | Sewerage | Apx. 70% |
| Economic and Social issues | Water use | Water consumption by category: | |
| | | Domestic | 6% |
| | | Tourism | 10% |
| | | Irrigation | 84% |
| | | Industrial and energy production | |
| | | Resources to population index[16] | 1000 $Mm^3$/c |
| | Water demand | Water Demand trends | Increasing |
| | | Consumption index | 100%Increasing |
| | | Exploitation index[17] | 300%Increasing |
| | Pricing system | Average household budget for domestic water[18] | € 99.2/yr |
| | | Average household budget for agricultural water | €0.11/$m^3$ depends on land |
| | | Average household income[18] | €24207urban €18488 rural |
| | | Cost recovery | Dom €0.58/$m^3$ Irr €0.11 |
| | | Price elasticity | Very small |
| | Social Capacity building | Public participation in decisions | Fair |
| | | Public education on water conservation issues | Fair |
| Decision Making Process | Water Resources Management | Water ownership | State- (partly private) |
| | | Decision making level regarding: Water supply for each sector | National |
| | | Water resources allocation for each sector | National |
| | Water Policy | Local economy basis | Agri/tertiary |
| | | Development priorities | Agri/tourism |

## DPSIR Indicators

The Kokkinochoria area is in the South-eastern part of the island, the coastal area of which has developed to an important tourist location. It is one of the most dynamic agricultural regions in the country with high-income farmers. This area has been the most productive region in the island in terms of value of agricultural produce, mainly potatoes, with well-developed export potentialities and practice. The high income of produce led to uncontrolled drilling and pumping for irrigation water mining the aquifer to exhaustion. Agricultural practices have been maintained to a large extent through inter-basin water transfers. Tourist development in the area has also allowed the employment of many farmers whilst desalination

[15] Aridity = ((350+318+330)/3)/ ((4.6+4.4+4.6)/3)x365x.0.75) .. 1961-1990
[16] Includes import by SCP (17$Mm^3$), local groundwater (9 $Mm^3$) and Desalination (4 $Mm^3$)
[17] Exploitation index = 300% since 30$Mm^3$ are used against 10$Mm^3$ locally available
[18] Family Budget Survey 1996/97 Statistical Service of Republic of Cyprus

development in the area has also allowed the employment of many farmers whilst desalination is meeting most of the domestic water demand. Climatic and soil conditions as well as quality of farmers make the continuation of this area as an agricultural region a high priority.

❖ The driving forces in the region were defined as the :
- the area receives the lowest rainfall in the island,
- absence of surface flows,
- excellent land resources with very good soils,
- soils and climate suitable for potato production with very long local tradition and export potential,
- intensive high income agricultural activities,
- very experienced farmers – mechanized farming and use of high efficiency irrigation systems,
- intensive tourist activities attracting labor force and taking up agricultural land at the coast.

❖ The current state of aquifer and area currently is:
- groundwater resources in the region are near exhaustion with the situation being almost irreparable,
- transfer of water, through the Southern Conveyor Project, from the Kouris Dam some 70 km to the west maintains long-term agricultural practice. This supply is subject to availability depending on weather conditions,
- increased demand (agricultural, domestic, tourist),
- domestic and tourist demand is being met mainly by sea water desalination.

❖ As impacts were identified the:
- loss of aquifer reserves,
- sea intrusion,
- reduction of well yield by 90% resulting to expensive groundwater if available,
- the lack of water for irrigation compromises the potato production with negative effects on the local as well as the country's economy.

❖ The responses to the above are:
- interbasin transfer of water through the Southern Conveyor from basins 70 km to the west,
- introduction of alternative sources of supply (through desalination for potable water and import of tertiary treated water for irrigation),
- new water demand management practices – alternative employment opportunities,
- change of cropping patterns – increased shift to winter (more rain-fed) potato crop,
- application of the Code of Good Agricultural Practice to avoid excessive use of fertilisers,
- stricter enforcement of legislation regarding well permits and illegal drilling,
- adjustment of water pricing to reflect true cost of irrigation water as a tool for water demand management.

# Spain

*Canary Islands*

*Regional Data*

Due to their geographic localisation, close to the Tropic of Cancer, the Canary Islands are under the influence of the trade winds, originated by the circulation of air masses around the anticyclone of Azores. Air-layering caused by trade-winds generates a characteristic layer of stratocumulus clouds on the northern coast of the higher islands, which occur between 500 m and 1,500 m. Humidity condensation in these areas involves a complementary water contribution, saving the western Canary Islands (higher than 500 m) from extreme aridity conditions.

In spite of that, the Canaries are poor in freshwater resources. The extent of their own freshwater resources, 177 $m^3$ per inhabitant per year, place them in the last place within the Spain classification by hydrographical river basins, and this number is very far from the national average of 1,389 $m^3$/pers./year. With a population near to 1.5 million inhabitants, the islands host every year more than 10 million tourists whose average daily water consumption is of 350 l/pers./day (Insular Hydrologic Plans). This increasingly pronounced difference between resource availability and consumption is one of the present-day most relevant characteristics of the archipelago. Rainfall in the Canary archipelago is very scarce (an average of 310 l/$m^2$/year) and irregular, both in time and space.

Topographic difficulties and permeability of the existing geologic materials lead to the exploitation of only a minimum share of the surface water resources. It is explanatory enough that the volume of water retained by the some 100 dams built to this end (41 $hm^3$/year), only reaches the 33% of their total capacity.

A relevant feature of underground water management is the fact that they are private property, a singularity in Spain. This market is subjected and regulated by the Canary Islands' Water Law (12/1990).

Another important feature that affects especially the Eastern islands is the progressive dependence from desalinated water, which is greatly increasing every year. An extreme case is the island of Lanzarote, where 97% of water supply is from desalination (the maximum security forecast of the system is 5.4 days). The progressive energy conception of water in the Canaries is reflected by the fact that in the year 2000 almost 15% of available power in the grid was directed to this aim.

Agricultural consumption is a priority on islands like La Palma and El Hierro, reaching the 80% of total consumption. On the main islands (Tenerife and Gran Canaria), where the greatest part of population is concentrated, urban and tourist consumption have greater protagonism. In the minor islands of the archipelago with a strong tourist penetration, tourist water consumption is progressively approaching the urban one (Lanzarote and Fuerteventura).

One of the most distinctive features of water consumption for agriculture refers to the generalised presence of intensive crops characterised by a high demand. Banana plantations – representative crop and main consumer of water in the Canary archipelago- are characterised by water demands around 11,350 and 14,850 $m^3$/ha/year. These crops receive subventions in the framework of the European Common Agricultural Policy and are important producers of landscapes that have progressively reached a crisis point, similarly to other productions, because of conflicts with tourist and urban water demand and the as a consequent rise in water price, since the private character o the canary water market.

The unforeseeable population growth of the last years causes strong uncertainty as regards water resource planning. In only five years the foreign population growth doubled the natural growth rate. A similar tendency is detected in the tourist sector, where the tourist lodging capacity has practically doubled itself in the period 1998-2001.

As regards sewerage, we also find important deficits, especially among the dense scattered settlements of the islands, which directly influence underground waters due to contamination of aquifers. Only the two main islands rely on acceptable grids although they also have significant deficiencies in specific settlements. The remaining ones have serious deficiencies regarding sewers or pour too large quantities of surface or underground wastewater.

With regard to water treatment, serious competency conflicts have also been detected in tuning and maintenance of the treatment systems that at present have a very low operational rate (close to 30%). Scattered treatment plants are a distinctive feature of the Canary situation. Price policy of treated water, public owned, is also characterised by its variability and inconsistence. In Tenerife, as an example, the price of treated water treated to a third stage is 0.36 €/m$^3$ while that treated to only a second stage is 0.31 €/m$^3$, while in Gran Canaria prices are around 0.12-0.15 €/m$^3$, clearly below cost.

Water quality for urban supply followed a descending curve in the last years. Following-up carried out by the different hydrological plans detects negative effects in the quality of underground waters, to which it must be added those derived from hydrogeologic situations that present specific aquifers characterised by a high fluor content.

Public management, especially the local one, faces serious difficulties for a sufficient and efficient implementation. Difficulties have to do with, from the one side, budget origin and destination, without forgetting financial collection; from the other side with the politic price of cost transfer to users, the progressive rise in price of the higher number of services required and, lastly, with the population to serve, characterised by a very high growth rate or by depopulation. All this has an influence on scale economies or diseconomies.

The studies: SPA-15, Canarias Agua 2000, Mac 21, advances of several Insular Hydrological Plans, Canary Islands Hydrological Plan, constitute the basic list of planning actions in the matter of water carried out in the Canary Islands in the last 25 years.

Within this context, the strategy of the Canary Islands Hydrological Plan is founded on the following principles:

- To promote a sustainable use of water resources on the basis of a medium-large term planning.
- To protect water ecosystems as an essential principle for a sustainable development.
- To guarantee a qualitatively and quantitatively appropriate water supply to achieve a sustainable development.
- To achieve the economic efficiency of water offer and use compatibly with social and environmental dimensions.
- Congruence between economic and environmental criteria and the design of an integrated management system, with a prudent use of regulatory and market processes.
- To advance in setting up innovatory and realistic policies on endowment and prices.
- To these criteria some considerations of the Infrastructure Director Plan within the section regarding water resources:
- To improve knowledge about natural resources, setting up an automatic control network within the whole region that allows the following-up of comparable data and the establishment of a sound basis to achieve and maintain a sustainable use of the public water domain.
- To protect quality and guarantee renovation of the different sources of production.
- To optimise the implementation of systems for non-conventional resource production.
- To intervene in sewerage and supply infrastructures.

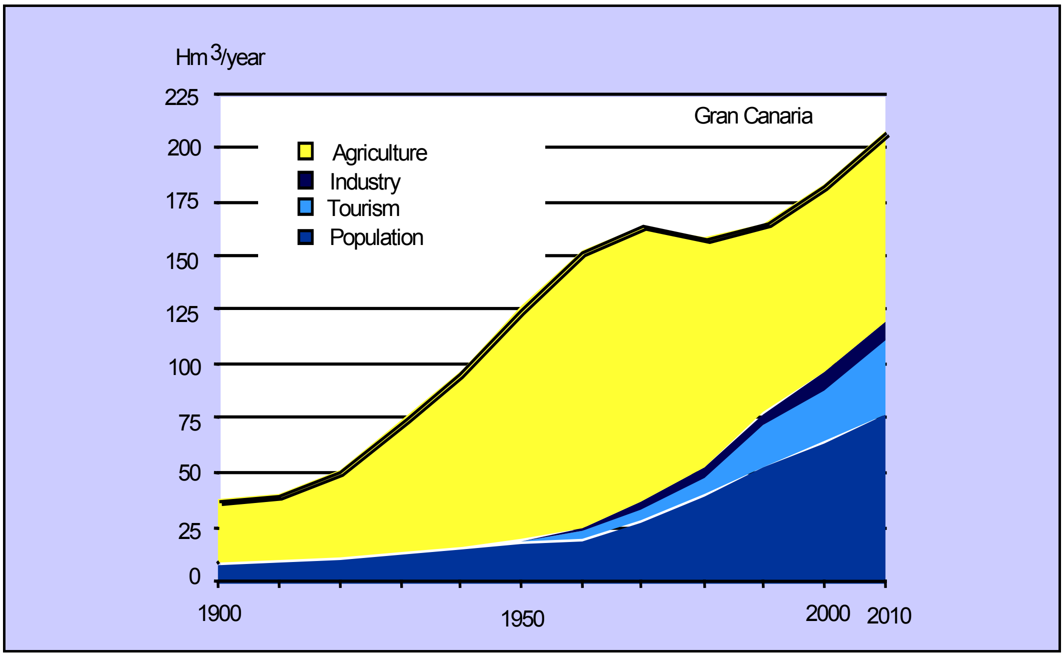



*Figure 79 Evolution of water demand (perspective – year 2000) Source: Canary Island Water Centre*

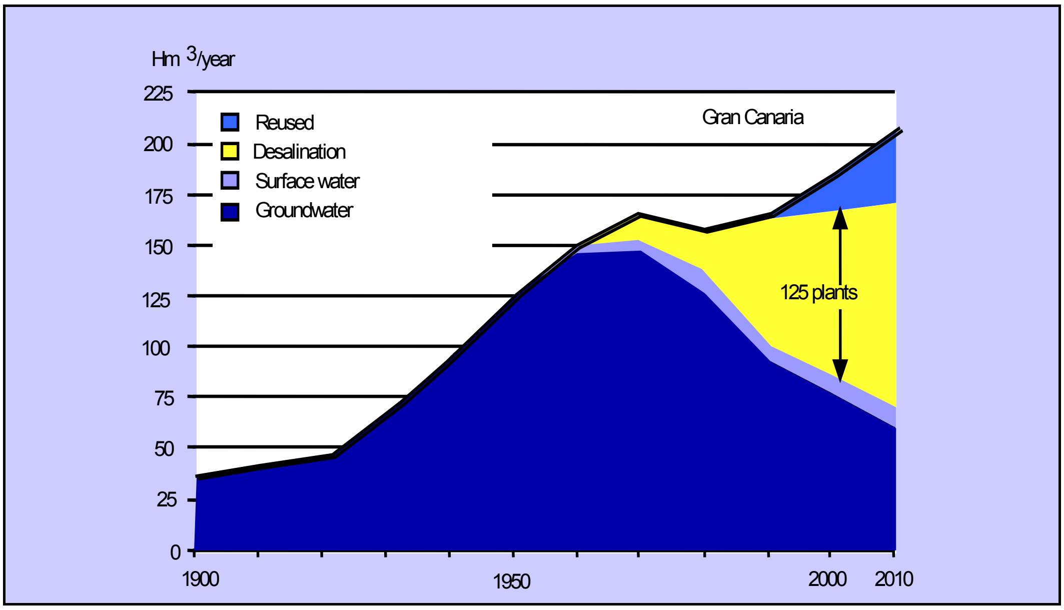



*Figure 80 Evolution of water production (year 2000 perspective) Source: Canary Island Water Centre*

*Table 58 Water Balance*

| Concept/Island | FUERTEVEN(1) | | LA GOMERA | | GRAN CANARIA | |
|---|---|---|---|---|---|---|
| | hm$^3$ | % | hm$^3$ | % | hm$^3$ | % |
| Precipitation | 16 | 100 | 140 | 100 | 466 | 100 |
| Evapotranspiration | s.d. | - | 69 | 49,3 | 304 | 65 |
| Surface water | 4 | 25 | 11 | 7,8 | 75 | 16 |
| Infiltration | 12 | 75 | 60 | 42,9 | 87 | 19 |

| Concept/Island | EL HIERRO | | LANZAROTE | | LA PALMA | | TENERIFE | |
|---|---|---|---|---|---|---|---|---|
| | hm$^3$ | % | hm$^3$ | % | hm$^3$ | % | hm$^3$ | % |
| Precipitation | 95,3 | 100 | 127 | 100 | 518 | 100 | 865 | 100 |
| Evapotranspiration | 69 | 72,4 | 122,2 | 96 | 238 | 46 | 606 | 70 |
| Surface water | 0,3 | 0,3 | 1,3 | 1 | 15 | 3 | 20 | 2 |
| Infiltration | 26 | 27,3 | 3,3 | 3 | 265 | 51 | 239 | 28 |

Sources: Advance of island hydrological plans. 1. Island Plan of Fuerteventura s.d.- without data available

*Table 59 Water Balance*

| | FUERTEVENT | | LA GOMERA | | GRAN CANARIA | |
|---|---|---|---|---|---|---|
| PRODUCTION | $hm^3$ | % | $hm^3$ | % | $hm^3$ | % |
| Surface water Small dams | 2,6 | 21,3 | 3,4 | 24,3 | 11 | 8,5 |
| Groundwater | 5,3 | 43,5 | 10,6 | 75,7 | 98 | 75,4 |
| Desalination | 4,3 | 35,2 | 0 | - | 21 | 16,1 |
| Re-use | - | - | 0 | - | 0 | - |
| TOTAL | 12,2 | 100 | 14 | 100 | 130 | 100 |

| | EL HIERRO | | LANZAROTE | | LA PALMA | | TENERIFE | |
|---|---|---|---|---|---|---|---|---|
| PRODUCTION | $hm^3$ | % | $hm^3$ | % | $hm^3$ | % | $hm^3$ | % |
| Surface water Small dams | - | - | 0,07 | 0,7 | 5 | 7 | 1 | 0,5 |
| Groundwater | 1,45 | 100 | 0,2 | 2,3 | 68 | 93 | 211 | 99,5 |
| Desalination | - | - | 9,6 | 97 | 0 | - | 0 | - |
| Re-use | - | - | s.d. | - | 0 | - | s.d. | - |
| TOTAL | 1,4 | 100 | 9,9 | 100 | 73 | 100 | 212 | 100 |

Sources: PPHH of La Palma, La Gomera and El Hierro. Hydrological Plans of Tenerife and Lanzarote;" Las Aguas del 2000" - and PIO Fuerteventura. s.d.- without data available

*Table 60 Water consumption by category*

| | FUERTEVENT. | | LA GOMERA | | GRAN CANARIA | |
|---|---|---|---|---|---|---|
| CONSUMPTION | $hm^3$ | % | $hm^3$ | % | $hm^3$ | % |
| Irrigation - Agriculture | 8,4 | 61,8 | 6,1 | 43,3 | 75 | 58 |
| Domestic and Services | 2,7 | 19,8 | 6 | 42,6 | 38 | 29 |
| Tourism | 2,5 | 18,4 | - | - | 15 | 11 |
| Industrial | - | - | 2 | 14,1 | 2 | 2 |
| Resources nonused | - | - | - | - | - | - |
| Distribution losses | - | - | - | - | - | - |
| TOTAL | 13,6 | 100 | 14,1 | 100 | 130 | 100 |

| | EL HIERRO | | LANZAROTE | | LA PALMA | | TENERIFE | |
|---|---|---|---|---|---|---|---|---|
| CONSUMPTION | $hm^3$ | % | $hm^3$ | % | $hm^3$ | % | $hm^3$ | % |
| Irrigation - Agriculture | 1,2 | 85,7 | 0,3 | 6 | 58 | 79,5 | 109,2 | 52,7 |
| Domestic and Services | 0,2 | 14,3 | 2,4 | 52 | 6 | 8,2 | 62,7 | 30,2 |
| Tourism | - | - | 1,4 | 31 | - | - | 14,1 | 6,8 |
| Industrial | 0 | - | 0,5 | 11 | 2 | 2,8 | 5,3 | 2,6 |
| Resources nonused | - | - | - | - | 6,9 | 9,5 | 4,5 | 2,2 |
| Distribution losses | - | - | - | - | - | - | 11,5 | 5,5 |
| TOTAL | 1,4 | 100 | 4,6 | 100 | 72,9 | 100 | 207,3 | 100 |

Sources: PHH La Palma, La Gomera, El Hierro, Tenerife and Lanzarote; "Las Aguas del 2000".

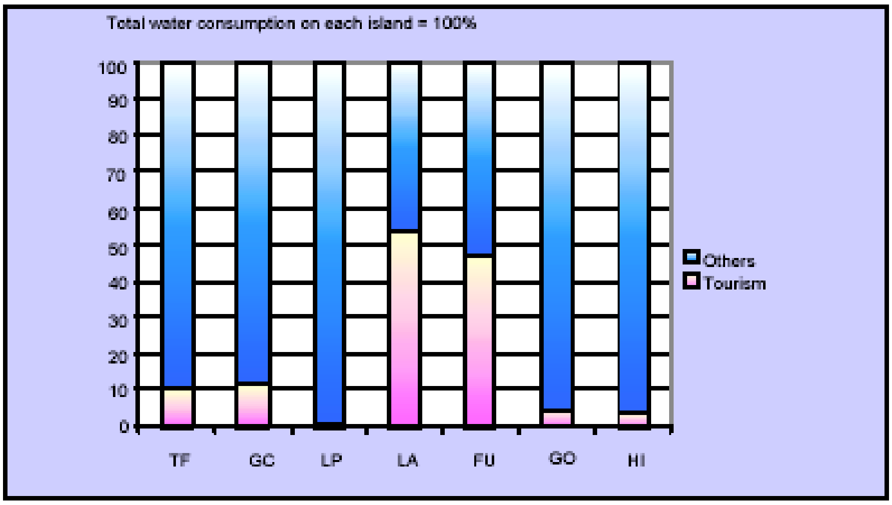



***Figure 81 Percentage water consumption of the tourist sector on each island. Source: Canary Island Water Centre***

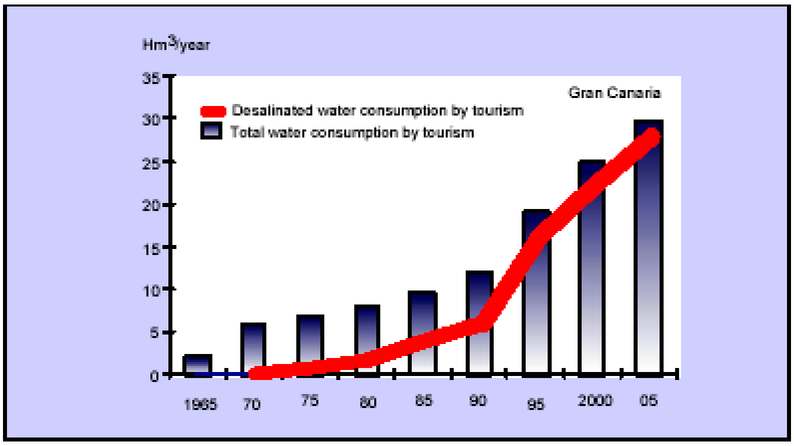



*Figure 82 Tourism water supply and desalination. Source: Canary Island Water Centre*

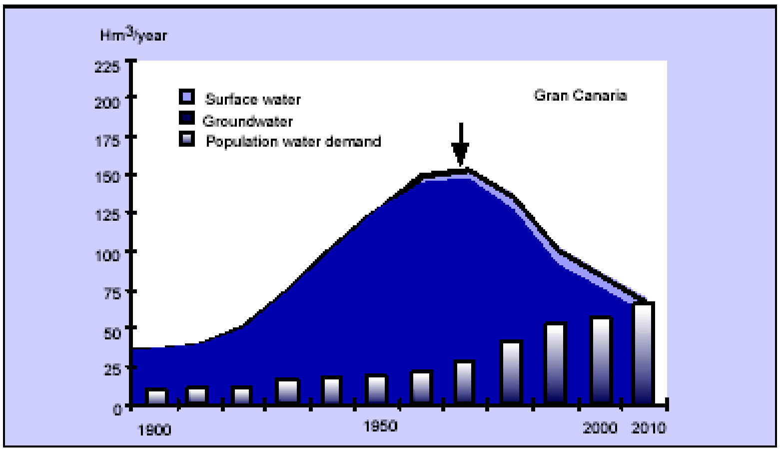



*Figure 83 Evolution of water production and population demand (perspective). The case of Gran Canaria. Source: Canary Island Water Centre*

*Table 61 Growth in tourist accommodation. 1986-1996. Canary Islands*

| Year | Tourists | Rooms |
|---|---|---|
| 1986 | 4,169,050 | 201,493 |
| 1987 | 5,068,242 | 251,067 |
| 1988 | 5,416,652 | 308,177 |
| 1989 | 5,352,205 | 343,559 |
| 1990 | 5,459,473 | 364,269 |
| 1991 | 6,136,990 | 375,995 |
| 1992 | 6,327,112 | 337,482 |
| 1993 | 7,551,065 | 337,975 |
| 1994 | 9,256,817 | 330,614 |
| 1995 | 9,693,086 | 324,124 |
| 1996 | 9,804,540 | 328,254 |

Source: White Paper on Canary Island Tourism. 1998

## *Matrix of Circumstances*

***Table 62 Canary Islands Matrix***

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Oceanic |
| | | Aridity Index | 0.2 < AI < 0.6 coastal and oriental islands |
| | | Permanent Population | 1781366 |
| | Water availability | Total Water Resources /Availability (hm3)<br>Groundwater<br>Surface water | <br>702<br>78 |
| | Water quality | Quality of surface water | Good |
| | | Quality of groundwater | Average |
| | | Quality of coastal water | Poor |
| | Water Supply | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination | <br>87%<br>5%<br>8% |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | <br>60%<br>85%<br>60% |
| Economic and Social System | Water use | Water consumption by category:<br>Agriculture<br>Domestic and services<br>Tourism (only accommodation)<br>Industrial<br>Non-used resources<br>Losses (internal network) | <br>58%<br>27%<br>7%<br>3%<br>2.5%<br>2.5% |
| | | Resources to population index | 438 |
| | Water demand | Water Demand trends | Variable - Increasing |
| | | Consumption index | 53% |
| | | Exploitation index | 58% |
| | Pricing system | Average household budget for domestic water (pa) | 356 € (Average price 1,55 $m^3$) |
| | | Average household budget for agricultural water | Variable |
| | | Average household income | 16800 € |
| | | Cost recovery | Average |
| | | Price elasticity | Average |
| | Social capacity building | Public participation in decisions | Poor |
| | | Public education on water conservation issues | Poor |
| Decision Making Process | Water Resources Management | Water ownership<br>Groundwater<br>Surface water | <br>Mostly private<br>Public and private |
| | | Decision making level regarding:<br>Water supply for each sector<br>Water resources allocation for each sector | <br><br>Regional - Local<br>Regional - Island |
| | Water Policy | Local economy basis | Tourism |
| | | Development priorities | Tourism |

## *DPSIR Indicators*

### Tenerife

❖ The driving forces are identified as the:

- increase in population density (307 inhabitants/km$^2$ in 1991 and 366 inhabitants/km$^2$ in 2001),
- high demand dispersion (both urban and tourist),

- exponential tourist growth,
- spatial changes of intensive agriculture characterised by high water demand.

❖ The current state is a:
- progressive depletion of water galleries exploiting the upper aquifers,
- groundwater over-exploitation by coastal wells, progressive salinisation,
- disproportionate growth of water supply infrastructures. Increase in maintenance costs.

❖ As for impacts, the following can be identified:
- progressive decline of water quality due to aquifer over-exploitation,
- increase of water prices and appearance of competition between rural-agricultural and urban-tourist activities. Rise of social conflicts to the detriment of the countryside,
- sewage problems due to house dispersion (aquifer pollution),
- loss of critical habitats (particularly in gullies).

❖ Short and medium term responses are:
- over-exploitation of aquifers,
- response by the administration for the establishment of a Plan of reservoirs that would allow the increase in surface runoff utilisation and agricultural supply by areas,
- progressive increase in desalination capacity, basically aimed to urban and tourist supply,
- re-use of treated effluents,
- creation of the Island Water Agency and Development of the Hydrological Plan.

Lanzarote

❖ The driving forces are identified as the:
- increase in population density (77 inhabitants/km$^2$ in 1991 and 122 inhabitants/km$^2$ in 2001),
- tourist growth (from 200 beds in 1970 to 60,000 in 2000),
- high increase in income and consumption.

❖ The current state is a:
- absolute dependence on desalinised water. Only 4% of water resources correspond to the exploitation of the very saline aquifers.

❖ As for impacts, the following can be identified:
- strong energy dependence and risk of running out of water.

❖ The responses are:
- steady increase in desalinised water production,
- start of water efficient use and saving strategies in the framework of the sustainable hotels strategy,
- progressive capacity of water re-use (especially in the hotel and gardening sectors),
- definition of a water strategy by the Biosphere Reserve Board,
- progressive increase of the wind-power installed entirely used for water production. Start of experiences based on RES-WATER variable inputs autonomous systems.

El Hierro

- The driving forces are identified as the:
  - increase in cultivated land area,
  - increase in population due to return of immigrants,
  - important increase in income and consumption.
- The current state is a:
  - limitation of agricultural activity due to water scarcity and need to guarantee supply to local population,
  - problems derived to quality of water for human consumption from wells and galleries, caused by the action of the volcanic materials where aquifers are located.
- As for impacts, the following can be identified:
  - extraction of water in very sensitive habitats (particularly in the last island's cloud forest redoubts),
  - high water treatment costs due to small scale of settlements, which obliges to develop integrated systems (anaerobic and aerobic treatment, ponds, algae).
- The responses are:
  - development of a water strategy in the framework of the island's Sustainable Development Plan,
  - development of a plan of reservoirs to establish systems for regulation and optimizing of water for agricultural use by hydrological areas,
  - doubling production of desalinised water. The entire water production will be powered by wind energy,
  - development of an ambitious Reforestation Plan that will allow the natural recharge of aquifers to the historic levels,
  - inclusion of minimum water consumption standards in the labels of the ecological products that support the island's Clean Production strategy,
  - recuperation, updating and modernisation of traditional systems for water collection in houses, including advanced saving systems and municipal housing standards,
  - development of surface runoff collection, including systems to collect water from the road network,
  - consideration of the water sector as an innovator, productive sector within the strategy of island development, favouring water SME's.

La Palma

- The driving forces are identified as the:
  - generalization of intensive crops,
  - population increase,
  - tourist growth in the Southern and Eastern areas.
- The current state is a:
  - water scarcity in specific areas and seasonal scarcity during irrigation periods,
  - resource imbalance between areas, adjusted with high-cost water transfers.
- As for impacts, the following can be identified:

- extraction of water in very sensitive habitats particularly affecting riverbed vegetation,
- infrastructural impacts derived from new water transfers,
- scarce development of the sewerage network due to population dispersion and decline of the aquifers water quality.

❖ The responses are:

- development of the Hydrologic Plan and strengthening of the "Consejo de Aguas" (Water Council),
- sustainable Tourist Destination strategy that includes water management dimension as a priority factor,
- energy deployment program (mini-hydraulic) oriented to compensate water transport costs within the island imbalance,
- development of a water-monitoring network in the framework of the island's institutional sustainable development, supported by the development of municipal Agendas 21,

technological innovation in the irrigation systems.

*Doñana*

*Regional Data*

Doñana and its surroundings constitute a natural space featuring the widest variety of pressures regarding the use and assignment of water resources. As a territory in which the most important European wetlands coexist, the National Park of Doñana includes areas of rice fields, intensive crops and a considerable tourist activity, mainly concentrated on the coastline.

Doñana could be considered to be an excellent laboratory for studying the management of water resources, a place where all the preservation and development strategies applied during the last decades share the difficulties of managing water resources.

Regarding the policies of preservation and management of water resources, the plans have entirely focused on the National Park of Doñana. With an area of more than 50 thousand hectares, Doñana is one of the world's most emblematic coastal wetlands. Apart from being a Ramsar site and a Special Protection Area for birds, the National Park of Doñana was declared a Biosphere Reserve in 1980, and was inscribed on the World Heritage List in 1994. The Biosphere Reserve includes a buffer zone of 26 thousand hectares, summing a total of 77,260 hectares. Doñana belongs to the small group of coastal wetlands within the three categories, together with San San-Pond Sak (Panama), Palawan (Philippines), Danube Delta (Romania-Ukraine), Ichkeul (Tunisia) and Everglades (USA).

Around this sanctuary of the European biodiversity is the Natural Park of Doñana and its Surroundings, located in the municipalities of Almonte, Hinojos, Lucena del Puerto, Moguer and Palos de la Frontera (province of Huelva), Sanlúcar de Barrameda (province of Cádiz), Puebla del Río, Aznalcázar, Villafranco del Guadalquivir and Villamanrique de la Condesa (province of Seville). This extended list is representative to the administrative and territorial complexity of the area.

The territory occupied by Doñana's basins, which also includes the National and Natural Parks, holds over 180,000 permanent inhabitants. The figures indicate a considerable increment compared to the 128,000 inhabitants registered in 1981. More than 60% of the employment is concentrated on the agricultural sector, and another 25% is devoted to the service sector, which is mainly focused on tourism.

The agricultural development in the area arrives at a later stage due to its hard conditions: the XIX century witnessed a series of failed efforts oriented to drying the salt marsh. By the end of the 1920's, the area devotes itself to massive rice crops, which nowadays occupy over 35,000 ha, thus becoming a factor of pressure for the National Park.

After this episode, in the 1970's, the FAO generates a report that results in the creation of a Plan for Agricultural Development in Almonte-Marismas (decree 1194/71), driven by a development-oriented mentality that resolves to declare it an Area of National Interest. This is the consolidation of 45,960 ha of crops; 30,000 of which correspond to irrigated land. This strategy is based on recognising the existence of an important water table in the area. Nowadays, the useful surface for irrigation sums up to approximately 14,000 ha.

Regarding the agricultural exploitation, we must highlight de importance of the strawberry trees, which occupy some 2500 ha, and constitutes a very concentrated source of employment. The exploitation of groundwater does not directly affect the water supply of the National Park, although it does affect the quality of underground waters, which sometimes feature nitrate concentrations of more than 50 mg/l.

The tourist activity, mainly concentrated on the area of Malascañas, located at the border of the National Park, is also a factor of pressure for water resources, especially during times of drought. Matalascañas offers a tourism capacity of 63,233 people, with a high level of concentration during the high season.

All these episodes resulted in an alteration of the water regimes, followed by a serious overexploitation of groundwater and manipulation of superficial water systems, which have seriously endangered the preservation of the National Park of Doñana.

This has lead to a progressive recognition of the fact that the preservation of the National Park is not only an obligation brought about by the need to preserve this important natural sanctuary, but also of the fact that Doñana is a patrimonial value which cannot be dissociated from the future economy of the area. This concern has resulted in the implementation of several strategies oriented to the sustainable management of water resources. In this sense, we must highlight the International Experts Commission's Report about the Development of Strategies for the Sustainable Development of Doñana in 1992. This report has inspired many of the principles for the alternative management of water resources during the last years.

But in 1998, Doñana faces one of its worst moments due to the breaking of a pyrite pond belonging to a mining exploitation, that caused the flooding of more than 2600 ha with high metal content muds. Although the muds did not reach the park itself, this accident caused red alert within all administrations and the whole society. After an impressive deployment of technical and human resources, the muds could be removed avoiding an ecological catastrophe with unforeseeable consequences.

What at the beginning appeared to be one more regrettable accident due to lack of planning and foresight in natural areas management turned to be the start of one of the most important wetland regeneration initiatives ever carried out in the whole planet. In reply to this situation, the big water regeneration programme named "Doñana 2005" was started, supported by the Spanish Ministry of Environment, whose immediate environmental actions were funded with some 140 million €. It is a project whose objectives are a lot more ambitious than providing the mere solution of the problems caused by the accident. It is also complemented by another important action called "the Green corridor of Doñana", supported by the "Junta de Andalucía" that will be carried out within the buffer zone.

**Hydrological characteristics**

The area is divided into two domains:

The salt marsh. Is a very plain area that combines periods of flood and drought. Its main sources of water are the rivers and tributaries and, in a smaller proportion, some few emergencies of underground water running through pipes.

The rest of the territory is basically made up of sand. This is the area where water precipitations overload the water table (called water table 27). It holds most of the water demanding activities.

On the overall system, the role and the alteration of underground waters is one of the fundamental problems for the management of this resource in the area. As in many other groundwater, overload is one the factors where estimations are more subject to error. The figures range from 50 to over 200 mm/year.

**The Challenges**

The conflict between preservation and a balanced leverage of water resources in Doñana materialises with the solving and recognition of the following aspects:

The overexploitation of groundwater is seriously affecting natural areas of vital importance. The effects of overexploiting the underground waters in the ecosystems seem to be put off with the years. Nowadays, a great portion of the water table under the salt marsh has fallen from a 1-meter level over the ground to a 2-meter fall under its own level.

Overexploitation is starting to allow the entrance of the salty waters contained in the sediments of the salt marsh, with a considerable impact on the quality of waters.

The massive usage of fertilisers in the main agricultural activities has a devastating effect on the quality of the waters.

The organic contribution due to domestic tributaries also adds to the problem, since the network of cleansing stations is still to be completed.

The agricultural and industrial residues, especially the vegetable waters derived from olive manipulation, results in scattered episodes of contamination in large brooks.

The original water system of the salt marsh is deeply altered. For many years, a series of corrective actions have tried to balance the complex system of the salt marsh. A considerable part of the Doñana Programme 2005 is oriented to regenerating the hydrological systems for the basic functions of the salt marsh and its compatibilization with human needs.

## Matrix of Circumstances

***Table 63 Donana Matrix***

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Mediterranean |
| | | Aridity Index | 0,4<AI<0.65 |
| | | Permanent Population | 180000 |
| | Water availability | Total Water Resources /Availability (hm3)<br>Groundwater<br><br>Surface water | <br>Min: 155 $hm^3$/year<br>Max: 425 $hm^3$/year<br>Min: 32 $hm^3$/year<br>Max: 78 $hm^3$/year |
| | Water quality | Quality of surface water | Average |
| | | Quality of groundwater | Average |
| | | Quality of coastal water | Average |
| | Water Supply | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination | <br>97%<br>3%<br>0% |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | <br>95%<br>95%<br>60% |
| Economic and Social System | Water use | Water consumption by category:<br>Agriculture<br>Domestic and services<br>Tourism (only accommodation)<br>Industrial<br>Non-used resources<br>Losses (internal network) | <br>84%<br>4%<br>8%<br>1%<br>3%<br>30% |
| | | Resources to population index | |
| | Water demand | Water Demand trends | Variable - Increasing |
| | | Consumption index | 53% |
| | | Exploitation index | Max: 49% |
| | Pricing system | Average household budget for domestic water (pa) | 50 € |
| | | Average household budget for agricultural water | 8114 € |
| | | Average household income | 7.535 € |
| | | Cost recovery | Average |
| | | Price elasticity | Fix |
| | Social capacity building | Public participation in decisions | High |
| | | Public education on water conservation issues | Average |
| Decision Making Process | Water Resources Management | Water ownership<br>Groundwater<br>Surface water | <br>Public and private<br>Public |
| | | Decision making level (municipal, regional, national) regarding:<br>Water supply for each sector<br>Water resources allocation for each sector | <br><br>Regional - Local<br>Basin |
| | Water Policy | Local economy basis | Agriculture<br>Tourism |
| | | Development priorities | Intensive Agriculture<br>Tourism |

## DPSIR Indicators

❖ Driving forces in the region are the:
- excessive surface of intensive agricultural cultivation,
- excessive surface of antiquated agricultural activities (rice),
- high level of concentration of tourist demand.

❖ Pressures exerts on the:
- natural water resources,

- the demand exceeds in many areas the limit of for the conservation of the wetlands,
- in several areas the capacity recharge of groundwater exceeds (average 49% extraction in shortage period),
- massive water derivation in shortage periods for the irrigated land,
- the problem with pollution of aquifers and surface water resources from agrochemicals and agro-industry is a severe pressure imposed on ecosystems,
- low percentage of treated waters (5%).

❖ The current state is the:
- overexploitation of groundwater is seriously affecting natural areas of vital importance,
- seasonal water deficit during the irrigation period,
- excess of superficial water derivation,
- nitrates concentration for both surface and ground waters exceeds (in a few sampling points) the limit values for drinking water while results for pesticides also show elevated values. Unacceptable values for the wetlands conservation,
- permanent conflict between the farmers and the environmentalists.

❖ Impacts are:
- loss of wetlands. Loss of biodiversity,
- extension of the dry period,
- groundwater overexploitation,
- environmental impacts can be very important. Pollution, eutrophication of the waters, compromises the aquatic ecosystem integrity and the ecology of the wetland areas,
- economic impacts from the seasonal water deficits for both tourism and agriculture.

❖ The response are:
- to increase the water monitoring network,
- diminution of the irrigated areas of rice with groundwater,
- changes of intensive cultures, greater diversification,
- increase of treated waters,
- regeneration of the natural hydrological systems (Doñana 2005 Project),
- development of the plans of sustainable use of the water by each basin,
- information campaigns.

# Portugal

*Sado*

*Regional Data*

Sado's river basin has an area of 8,295 $km^2$ and its population is 292,960 inhabitants (1998), with a population density of about 35 inhabitants per $km^2$, a low value when compared to Portugal Continental territory value of 110 inhabitants per $km^2$. The region is mostly plain, except to some low mountains, with an overall average altitude of 127 m. In fact, the altitudes range from 50 m to 200 m in most of the area, with a maximum basin altitude of 501 m. Most of the area presents tertiary and quaternary deposits with formations mainly composed by limestone and sedimentary rocks.

The climate is Mediterranean temperate, with rainy winters and dry summers. The average temperature is of 16 ºC, and in the summer peak months (July and August), it varies from 19 ºC in the coastal areas to 24 ºC in the interior. In the coldest month (January) it varies from 9 ºC in the interior to 12 ºC in the coastal areas. The average annual sunshine duration is about 2900 hours. The average annual precipitation is 622 mm, ranging from less than 600 mm in the coastal areas to more than 900 mm on the mountains. About 78% of the precipitation is concentrated in the dry semester (between October and March) and occurs 75-100 days per year in the coastal areas and 50-75 days per year in the rest of the basin. As to potential evapotranspiration its yearly average is 1145 mm and it increases in the dry semester. Figure 84 presents the mean monthly precipitation and potential evapotranspiration in Sado's basin. The total runoff is 972 $hm^3$/year.

Sado has a storage capacity of 771 $hm^3$ which makes it the Portuguese river basin with the biggest storage capacity when compared to annual mean flow, and that reflects irrigation availability needs. The overall availability is currently, in average, of 1714 $hm^3$/year, consisting of 918 $hm^3$ of surface water (716 $hm^3$/year in dry years) and 796 $hm^3$ of exploitable groundwater. However there will be a big increase in the availability of surface water due to the foreseen inter basin water transfer of about 450 $hm^3$/year from Guadiana's basin when Alqueva new multi-purpose hydraulic plant (still in construction) will be operating.

Surface waters are considered inadequate to the various uses, according to the national legislation, due to its poor quality, with pollutants loads exceeding the recommended values. In terms of groundwater, in the monitored aquifers the quality is good. As to coastal waters the quality is also good, with the exception of one or two polluted spots.

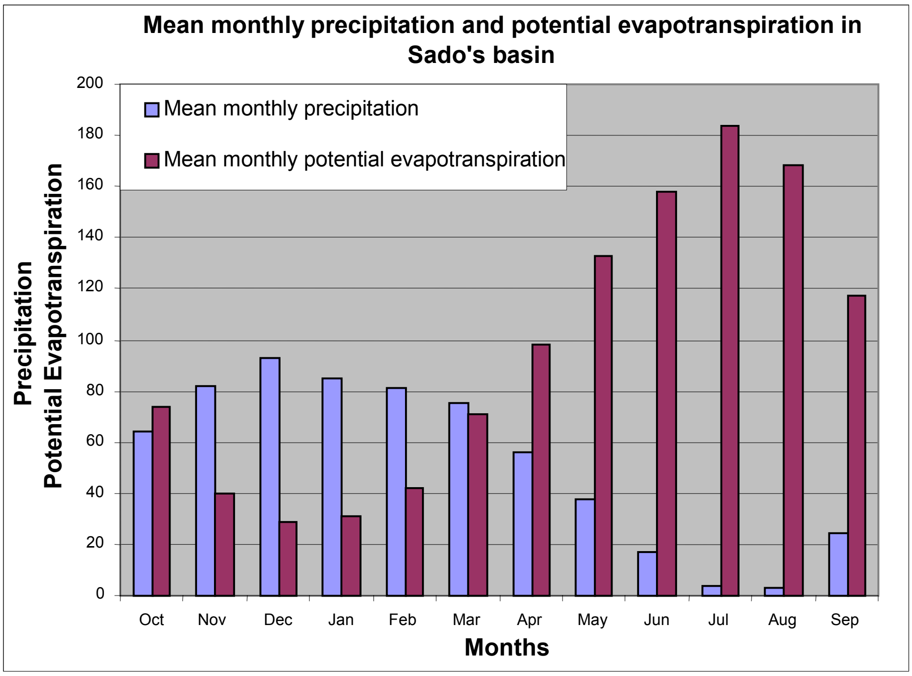



*Figure 84 Mean monthly precipitation and potential evapotranspiration in Sado's basin*

Industry, animal husbandry and non-point source loading from agriculture are the responsible for the majority of the pollutant loads verified in Sado. The main pollutant loads produced in Sado´s basin in 1998 were estimated as:

- BOD5 = 22461 ton/year
- TSS = 45281 ton/year
- COD = 42807 ton/year
- Total nitrogen = 3926 ton/year
- Total phosphorus = 2505 ton/year

The percentage of population served with water supply is currently of 97%, higher than the value correspondent to wastewater drainage (87%), with only 56% benefiting of treatment facilities. Urban water supply overall losses are currently high (average of 20%), and there is a low overall efficiency in agriculture water use (about 60%). The total annual water consumption is 1,195 $hm^3$ (600 $hm^3$ returning back to the hydric environment), distributed as follows: 672 $hm^3$ of water are used in energy production to the cooling in thermo-electric power plants, 441 $hm^3$ in agriculture, 58 $hm^3$ in industry (mainly Sines' industry on the coast), and about 24 $hm^3$ in domestic uses, with the water uses in tourism less than 1 $hm^3$. The percentage distribution of water uses per sector can be seen in Figure 85, whereas the percentage of the total water use in Sado's basin in proportion with the water use in Portugal Continental territory can be seen in Figure 86.

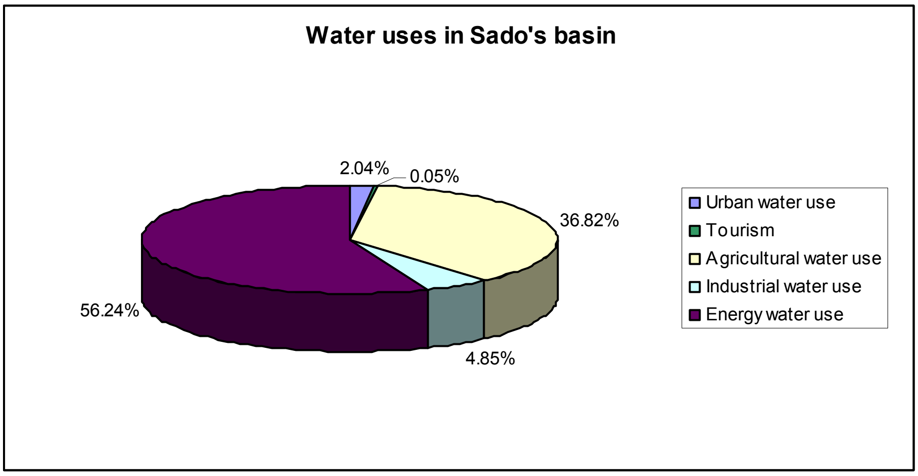



***Figure 85 Water uses in Sado's basin***

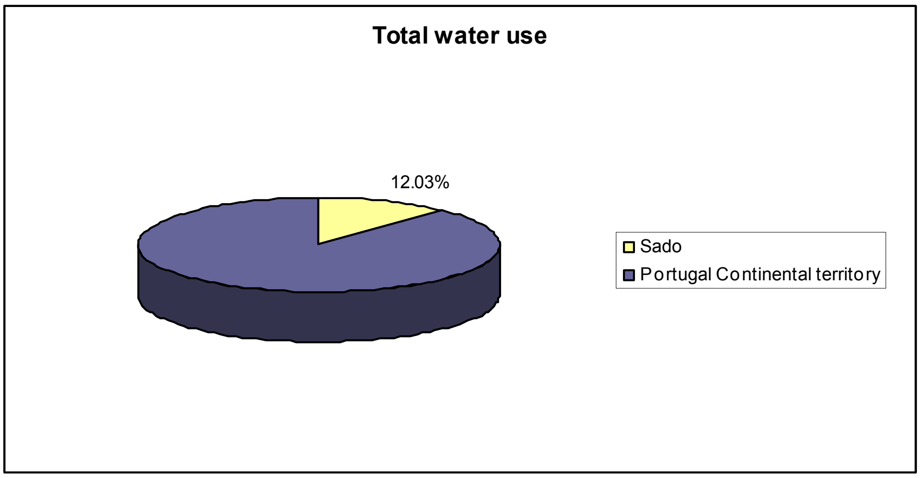



***Figure 86 Percentage of the total water use in Sado's basin in proportion with the water use in Portugal Continental territory***

The average household income in 2000 was 13562 €/year, with only 0.75% of this value allocated to domestic water supply, which indicates a low water pricing (0,57 €/$m^3$) and a low urban water sector cost recovery (37%). This situation is much aggravated in agricultural sector, with prices very low (0,06 €/$m^3$) and strongly subsidised.

There is no inter-municipal primary urban water supply system covering the basin. The (secondary) water supply distribution networks are mostly 100% (except one system, partly owned by Águas de Portugal group) of full municipal responsibility, and similar situation is due to wastewater drainage and treatment systems. Thus the pricing of water is mostly a political issue and not currently aiming cost recovery.

## Matrix of Circumstances

***Table 64.Sado matrix***

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Cs: Mediterranean Temperate |
| | | Aridity Index | AI =0.54 Dry Sub-humid |
| | | Permanent Population | 292,960 |
| | Water availability | Total Water Resources/ Availability (hm3) | 1768 /1714 |
| | | Trans-boundary water | No |
| | | Inter-basin water transfer | Yes ( -2 $hm^3$ ([19]) -10 $hm^3$ ([20]) ) |
| | Water quality | Quality of surface water | Poor |
| | | Quality of groundwater | Good |
| | | Quality of coastal water | Good |
| | Water Supply | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination, Recycling<br>Importing | <br>16%<br>84%<br>-<br>- |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | <br>97%<br>72%<br>87% |
| Economic and Social System | Water use | Water consumption by category: (hm3)<br>Domestic<br>Tourism<br>Irrigation<br>Industrial and energy production | <br>24.3<br>0.6<br>441<br>730.1 |
| | | Resources to population index | 6035 |
| | Water demand | Water Demand trends | Increasing |
| | | Consumption index | 68% |
| | | Exploitation index | 70% |
| | Pricing system | Average household budget for domestic water | 0.75% |
| | | Average household budget for agricultural water | 0,06 €/$m^3$ |
| | | Average household income | 13562 €/year |
| | | Cost recovery | Low (37%) |
| | | Price elasticity | Very small |
| | Social capacity building | Public participation in decisions | Poor |
| | | Public education on water conservation issues | Poor |
| Decision Making Process | Water Resources Management | Water ownership | Public (partly private) |
| | | Decision making level regarding:<br>Water supply for each sector | <br>National/Municipal |
| | | Water resources allocation for each sector | National |
| | Water Policy | Local economy basis | Agriculture and industry |
| | | Development priorities | Agriculture |

## DPSIR Indicators

❖ As driving forces one could identify the:

- irregular temporal precipitation distribution (about 78% concentrated in the humid semester),
- important thermo electric energy production,
- intensive and antiquated agricultural activities, with low efficiency in agriculture water use,
- waste generation from agricultural and industrial activities.

[19] Transferred to Guadiana's basin
[20] Transferred to Rib. Costa Alentejo basin

- ❖ The current state is a:
  - current and short-term water shortage (on dry years), aggravated in the summer months, during the irrigation period,
  - significant urban water supply and irrigation losses,
  - water quality inadequate to the various uses.
- ❖ The impacts are identified as the:
  - surface water pollution and the decrease in flow during summer time leading to ecosystem degradation,
  - economic impacts due to water deficits for agriculture.
- ❖ Short-term responses are:
  - important inter basin water transfer (450 $hm^3$/year) from Guadiana's basin when Alqueva new multi-purpose hydraulic plant will be operating,
  - significant subsidies for irrigation water.

*Guadiana*[21]

*Regional Data*

Guadiana's river basin covers an area of 11,601 $km^2$ and its population is 182,580 inhabitants (1998), with a population density of about 16 inhabitants per $km^2$, almost the lowest value for all Portuguese river basins. The average altitude is 237 m, most of the region with altitudes that range from 100 m to 400 m, with a southern mountain chain (making the division between Alentejo and Algarve) where the maximum altitude occurs (1027 m). The slopes are mainly of 0% to 5% with 5% to 30% in the mountains. Most of the area presents formations mainly composed by metamorphic, eruptive and sedimentary rocks, with 2/3 of the basin composed by schistones.

The climate is temperate, with rainy winters and hot and dry summers. The average temperature is of 16 ºC, and in the summer peak months (July and August) it varies from 23 - 26ºC. In the coldest month (January) it varies from 8 ºC in the north of the basin to 11 ºC in the (south) coastal areas. In this river basin temperature reaches maxims of 41 to 44 ºC. The average annual sunshine duration is 2829 hours, with an average: maximum for July (370 hours) and minimum for December (147 hours). The average annual precipitation is 568 mm, spatially ranging from a minimum of 350 mm to little more than 1000 mm. Precipitation occurs 50-80 days per year and, in volume, more than 80% of it is concentrated in the dry semester (between October and March). As to potential evapotranspiration, the averaged yearly value is 1242 mm and it increases in the dry semester. Figure 87 presents the mean monthly precipitation and potential evapotranspiration in Portuguese Guadiana's basin territory. The total runoff due to that part of the basin is 1,887 $hm^3$/year, whereas in Spain the annual mean flow is 5,470 $hm^3$/year.

[21] All the referred data concerns, with exception if expressly referred, to the Portuguese river basin territory and internal resources

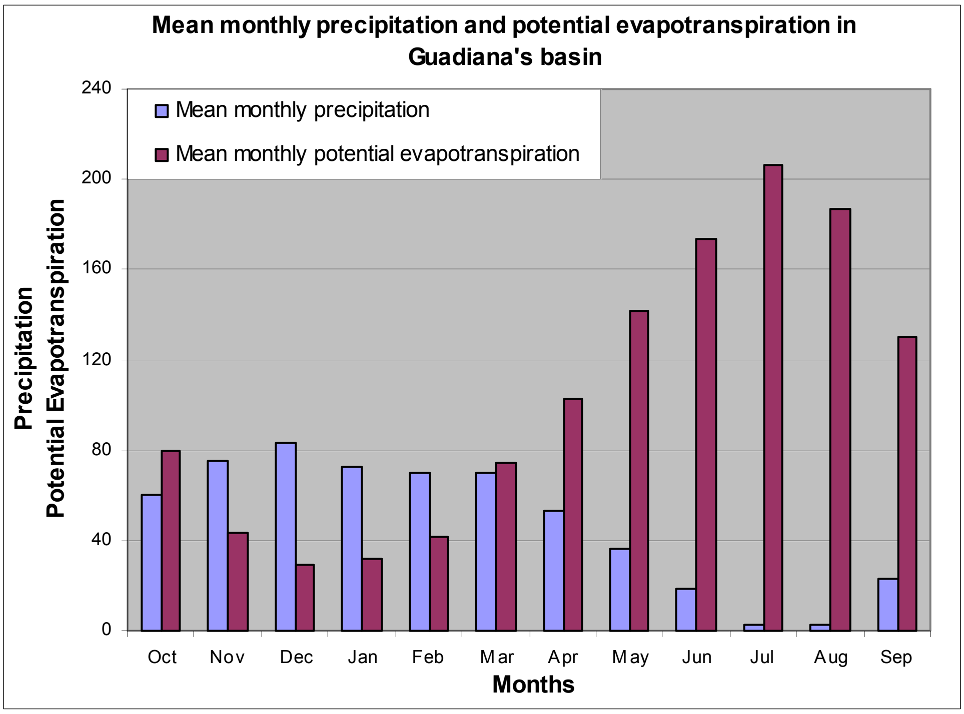



***Figure 87 Mean monthly precipitation and potential evapotranspiration in Guadiana's basin***

Portuguese Guadiana's water storage capacity is of 460 hm$^3$, but this figure will be highly increased due to Alqueva new multi-purpose hydraulic plant (still in construction), which will account for a (useful) storage capacity of 3,150 hm$^3$. Although currently a 30 hm$^3$ inter basin water transfer from this basin to Algarve occurs, Alqueva's storage capacity will enable a foreseen big inter basin water transfer of about 700 hm$^3$, mainly to Algarve (for irrigation and for public water supply, in support of tourism water needs) and also to Sado's basin (for domestic and industrial water supply).

In terms of water availability, in average, it is currently of 3585 hm$^3$/year, consisting of 3156 hm$^3$ of surface water (1476 hm$^3$/year in dry years) and 429 hm$^3$ of exploitable groundwater. It must be emphasised that Guadiana's basin is one of the regions of Portugal that has lastly been most affected by droughts, namely in the beginning of last decade (90-95), when periods with no affluences from Spain did occur. This way, the "resources to population index" was evaluated on a dual way, i.e., considering "total resources" as the natural mean flow (i) of all basin or (ii) of only the Portuguese basin area. On a similar way, this has been reflected also on the consumption index, with values of (i) 5% and (ii) 18%, respectively. Nevertheless, although those values are currently not high, it should be stressed that even if only the referred 700 hm$^3$ inter-basin transfer (to Sado and Ribeiras do Algarve) is taken into account, those values would increase to values of (i) 14% and of (ii) 49%, correspondent to the two different referred "total resources" definition.

Surface waters are considered inadequate to the various uses, according to the national legislation, due to its poor quality as they are the receptors of the pollution caused mostly by Spain and also by national agriculture. The same can be applied to some aquifers, with groundwater presenting parameters like magnesium, sodium and nitrates exceeding the maximum acceptable values for drinking water. As to coastal waters the quality is good.

The main pollutant loads produced in Guadiana´s basin in 1998 were estimated as:

- ❖ BOD5 = 17389 ton/year
- ❖ TSS = 17849 ton/year
- ❖ COD = 26250 ton/year
- ❖ Total nitrogen = 6425 ton/year
- ❖ Total phosphorus = 2194 ton/year

The percentage of population served with water supply is currently of 84% and a similar percentage (83%) applies to wastewater drainage, but only 67% benefit from treatment facilities. There is a low overall efficiency in agriculture water use (about 60%). The total annual water consumption is 419 $hm^3$ (with about 98 $hm^3$ returning back to the hydric environment), with the following distribution: about 400 $hm^3$ of water are used in agriculture, 14.5 $hm^3$ in domestic uses, 3.3 $hm^3$ in industry, and in tourism about 1.4 $hm^3$. The percentage distribution of water uses per sector can be seen Figure 88, whereas the percentage of the total water use in Guadiana's basin in proportion with the water use in Portugal Continental territory can be seen in Figure 89. Again it should be stressed that water demands are expected to increase due to Alqueva new multi-purpose hydraulic plant in construction, namely on agriculture, due to the development of the currently predicted new irrigation areas.

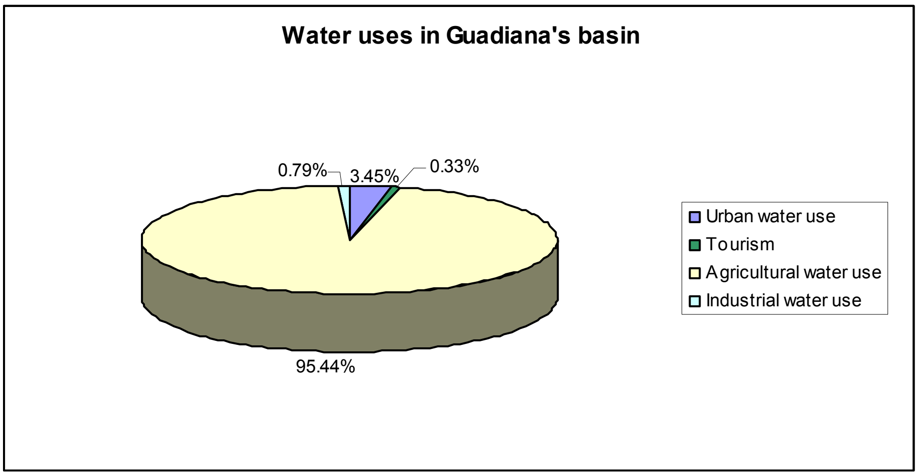



***Figure 88 Water uses in Guadiana's basin***

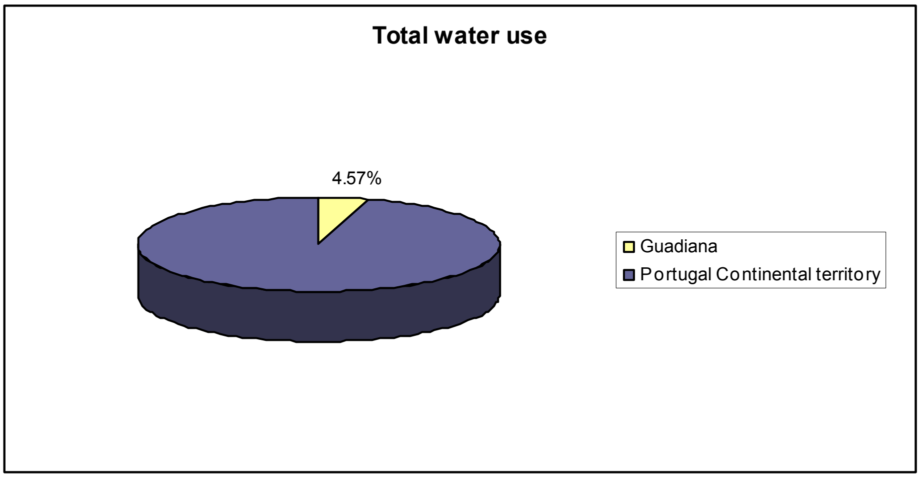



***Figure 89 Percentage of the total water use in Guadiana's basin in proportion with the water use in Portugal Continental territory***

The average household income in 2000 was 13562 €/year, with only 0.89% of this value allocated to domestic water supply, which indicates the low water pricing (0,70 €/$m^3$), although much higher than for irrigation water (0,06 €/$m^3$), which is strongly subsidised, as already referred. The cost recovery is correspondingly low (23% in the urban water sector).

Agriculture is (even if indirectly) the most important economic activity in the region, with the viticulture sector assuming high importance and contributing to the increase of the tertiary sector in the region.

There is a recent inter-municipal urban (main) water supply and wastewater drainage and treatment systems' company (Águas de Portugal group) that only "covers" the northern part of the basin. Thus the pricing of water is mostly (still) a political issue and not currently aiming cost recovery.

*Matrix of Circumstances*

***Table 65 Guadiana matrix***

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Csa (Temperate) |
| | | Aridity Index | AI =0.46 Semi- Arid |
| | | Permanent Population | 182,580 |
| | Water availability | Total Water Resources/ Availability (hm3) | 7800 (2300)([22])/ 3585 |
| | | Trans-boundary water | 5500 |
| | | Inter-basin water transfer | Yes ( 2 $hm^3$ ([23])<br>-30 hm3 ([24]) ) |
| | Water quality | Quality of surface water | Poor |
| | | Quality of groundwater | Poor |
| | | Quality of coastal water | Good |
| | Water Supply | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination, Recycling<br>Importing | <br>55.5%<br>56%<br>-<br>0.5% |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | <br>84%<br>76%<br>83% |
| Economic and Social System | Water use | Water consumption by category: (hm3)<br>Domestic<br>Tourism<br>Irrigation<br>Industrial and energy production | <br>14.0<br>1.37<br>400<br>3.3 |
| | | Resources to population index | 42720 (12600)([25]) |
| | Water demand | Water Demand trends | Increasing |
| | | Consumption index | 5.4% (18,2%)[25] |
| | | Exploitation index | 12% |
| | Pricing system | Average household budget for domestic water | 0.89% |
| | | Average household budget for agricultural water | 0,06 €/$m^3$ |
| | | Average household income | 13562 €/year |
| | | Cost recovery | Low (23%) |
| | | Price elasticity | Very small |
| | Social capacity building | Public participation in decisions | Poor |
| | | Public education on water conservation issues | Poor |
| Decision Making Process | Water Resources Management | Water ownership | Public (partly private) |
| | | Decision making level regarding:<br>Water supply for each sector | <br>National/Municipal |
| | | Water resources allocation for each sector | National |
| | Water Policy | Local economy basis | Agriculture/Tertiary sector |
| | | Development priorities | Agriculture |

*DPSIR Indicators*

- ❖ The driving forces can be identified as the:
  - Spanish flow regularisation,
  - irregular temporal precipitation distribution (more than 80% concentrated in the humid semester),

[22] Internal resources
[23] Imported from Sado's basin
[24] Transferred to Ribeiras do Algarve basin
[25] Considering "Total Resources" as "Internal Resources"

- intensive and antiquated agricultural activities, with low efficiency in agriculture water use,
- waste generation from agricultural and industrial activities.

❖ The actual state can be defined by the:

- current water shortage, aggravated in the summer months during the irrigation period,
- high urban water supply and irrigation losses,
- groundwater overexploitation due to water deficits,
- surface and groundwater pollution.

❖ As impacts one could emphasise on the:

- low flow (or even no flow, on dry years) on bordering stretches,
- surface and groundwater pollution leading to ecosystem degradation,
- economic impacts due to water deficits for agriculture.

❖ Short-term responses can be:

- Alqueva new multi-purpose hydraulic plant (with a very large reservoir (useful water storage capacity of 3150 $hm^3$) foreseen to provide a solution to the water deficit problem,
- significant subsidies for irrigation water.

*Ribeiras do Algarve*

*Regional Data*

Ribeiras do Algarve river basin covers an area of 3,837 $km^2$ and its population is 324,100 inhabitants (1998), with a population density of about 84 inhabitants per $km^2$, a value still smaller than the average for Portugal Continental territory (110 inhabitants per $km^2$) but the greatest among all southern (of Tejo) river basins, namely Sado and Guadiana. The region is mostly plain, with altitudes ranging from 0 to 100 m, and only a few spots above these values. Most of the area presents formations mainly composed by volcanic rocks (especially basalts).

The climate is Mediterranean temperate, characterised by rainy winters and dry summers. The average temperature is 18 ºC. The average annual sunshine duration is maximum along the south coastal areas (3180 hours). The average annual precipitation is 840 mm, occurring 50-75 days per year in almost all the region. As to potential evapotranspiration its yearly average is 1229 mm and it increases in the dry semester. Figure 90 presents the mean monthly precipitation and potential evapotranspiration in Ribeiras do Algarve basin. The total runoff is 348 $hm^3$/year.

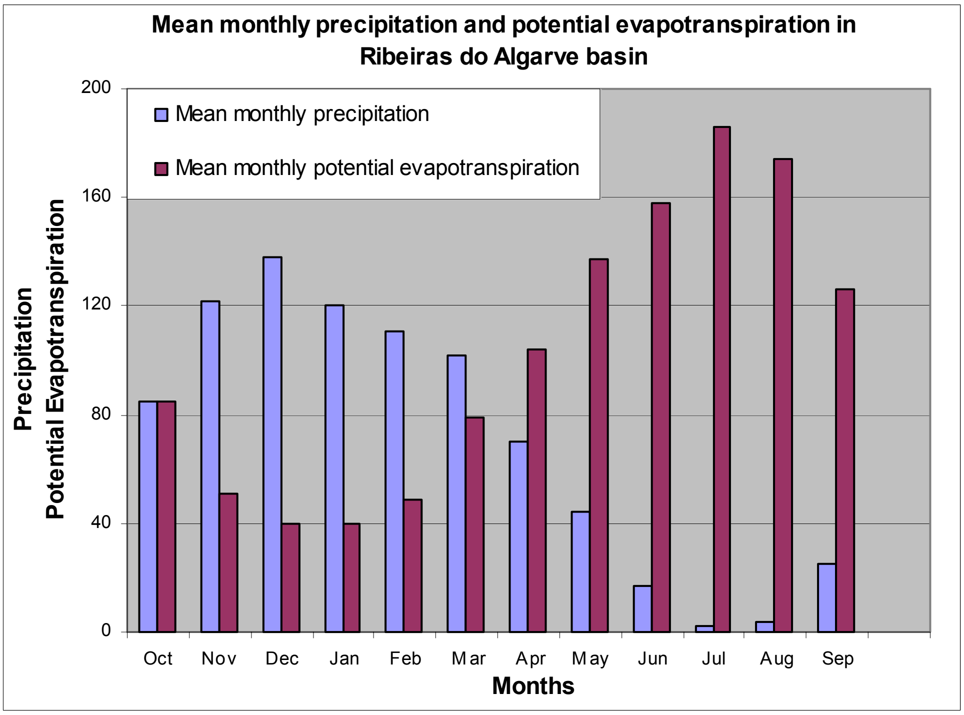



*Figure 90 Mean monthly precipitation and potential evapotranspiration in Ribeiras do Algarve basin*

The overall water availability is currently, in average year, of 599 $hm^3$/year, consisting of 327 $hm^3$ of surface water (160 $hm^3$/year in dry years) and 272 $hm^3$ of exploitable ground water. Algarve's storage capacity is small (about 63 $hm^3$).

Surface water presents quality problems, as rivers have almost no flow in dry period and receive the pollution caused by urban areas and agriculture. Dam storage reservoirs assume a high importance in water supply due to that fact, but also some quality problems occur on it, especially in the summer. The same can be applied to groundwater with parameters like calcium, sodium, chlorides and nitrates exceeding the maximum acceptable values for drinking water and irrigation water. As to coastal waters the quality is good, with the exception of one or two polluted spots.

The main pollutant loads are mostly generated by urban wastewater, animal husbandry and non-point source loading from agriculture. The loads produced in Ribeiras do Algarve basin in 1998 were estimated as:

- BOD5 = 11678 ton/year,
- TSS = 17492 ton/year,
- COD = 12091 ton/year,
- Total nitrogen = 2140 ton/year, and
- Total phosphorus = 980 ton/year.

The percentage of population served with water supply is currently of 82%, higher than the value correspondent to wastewater drainage (73%), with only 72% benefiting of treatment facilities. Urban water supply overall losses are currently high (with an average of 37%) and there is a low overall efficiency in agriculture water use (about 60%). The total annual water consumption is 340 $hm^3$ (about 95 $hm^3$ returning back to the hydric environment), distributed as follows: 305 $hm^3$ of water are used in agriculture, 21.8 $hm^3$ in domestic uses, 11 $hm^3$ in tourism, and in industry about 2.4 $hm^3$. The percentage distribution of water uses per sector can be seen in Figure 91, whereas the percentage of the total water use in Ribeiras do Algarve basin in proportion with the water use in Portugal Continental territory can be seen Figure 92.

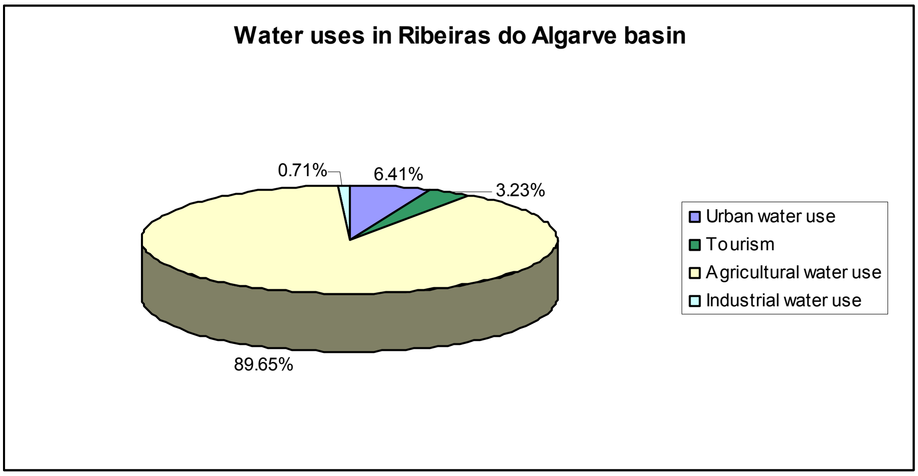



***Figure 91 Water uses in Ribeiras do Algarve basin***

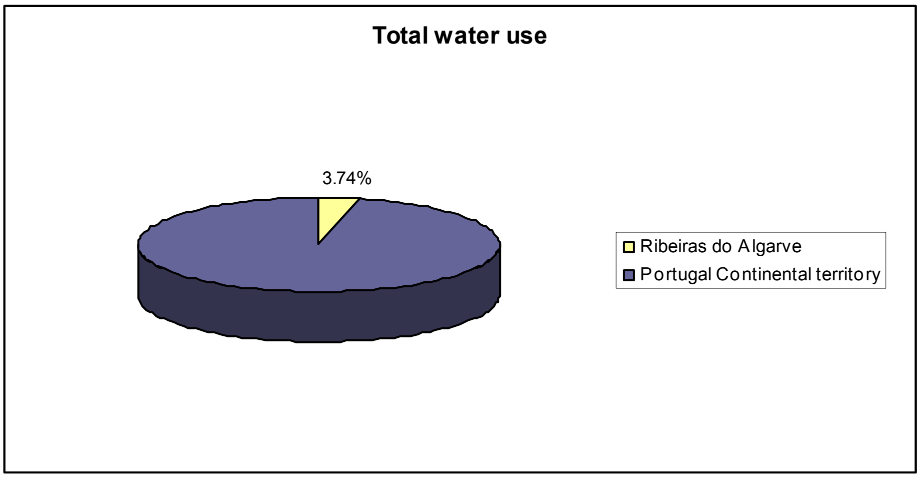



***Figure 92 Percentage of the total water use in Ribeiras do Algarve basin in proportion with the water use in Portugal Continental territory***

Water shortage occurs in the summer period, when the demands of water are higher, once this is an area that attracts a large number of tourists (currently estimated as 780,000, more than twice the permanent population) and also with strong needs of water for irrigation. Thus the conflict of uses of water between the two sectors.

The average household income in 2000 was 13573 €/year, with only 0.90% of this value allocated to domestic water supply, which indicates a low water pricing (0,68 €/$m^3$), although much higher than for irrigation water (0,07 €/$m^3$), which is strongly subsidised as already referred. The cost recovery is correspondingly low (40% in the urban sector).

There are two inter-municipal urban water supply, wastewater drainage and treatment systems covering most of the region, both under a company (Águas de Portugal group) which is the responsible for the "primary system" overall management. The secondary (domestic) water supply and wastewater drainage systems are of municipal responsibility. Thus the pricing of water is (still) a political issue and not currently aiming cost recovery.

## Matrix of Circumstances

**Table 66 Ribeiras do Algarve matrix**

| | | | |
|---|---|---|---|
| Natural conditions and infrastructure | Regional Context | Climate Type | Cs: Mediterranean Temperate |
| | | Aridity Index | AI =0.68 |
| | | Permanent Population | 324,100 |
| | Water availability | Total Water Resources/ Availability (hm3) | 620/599 |
| | | Trans-boundary water | No |
| | | Inter-basin water transfer | Yes (30 $hm^3$) ([26]) |
| | Water quality | Quality of surface water | Poor |
| | | Quality of groundwater | Poor |
| | | Quality of coastal water | Good |
| | Water Supply | Percentage of supply coming from:<br>Groundwater<br>Surface water<br>Desalination, Recycling<br>Importing | <br>71.5%<br>19.7%<br>-<br>8.8% |
| | | Network coverage:<br>Domestic<br>Irrigation<br>Sewerage | <br>82%<br>77%<br>73% |
| Economic and Social System | Water use | Water consumption by category: (hm3)<br>Domestic<br>Tourism<br>Irrigation<br>Industrial and energy production | <br>21.8<br>10.9<br>305<br>2.4 |
| | | Resources to population index | 1912 |
| | Water demand | Water Demand trends | Increasing |
| | | Consumption index | 55% |
| | | Exploitation index | 57% |
| | Pricing system | Average household budget for domestic water | 0.90% |
| | | Average household budget for agricultural water | 0,07 €/$m^3$ |
| | | Average household income | 13573 €/year |
| | | Cost recovery | Low (40%) |
| | | Price elasticity | Very small |
| | Social capacity building | Public participation in decisions | Poor |
| | | Public education on water conservation issues | Poor |
| Decision Making Process | Water Resources Management | Water ownership | Public (partly private) |
| | | Decision making level regarding:<br>Water supply for each sector | <br>National/Municipal |
| | | Water resources allocation for each sector | National |
| | Water Policy | Local economy basis | Tourism |
| | | Development priorities | Tourism and Agriculture |

## DPSIR Indicators

- As driving forces one could identify the:
  - irregular temporal precipitation distribution (more than 80% concentrated in the humid semester),
  - tourist development,
  - intensive and antiquated agricultural activities,
  - waste generation from both urban (permanent population and tourists) and agricultural sectors.
- The current state is a:

[26] Imported from Guadiana's basin

- current and long-term foreseen water shortage, aggravated in the summer months during the irrigation period,
- high urban water supply and irrigation losses,
- surface and groundwater pollution,
- salinisation in most coastal aquifers (due to over-abstraction),
- reservoir water eutrophication.

❖ The impacts could be identified as the:

- surface and groundwater pollution and the decrease in flow (even no flow, on certain cases) during summer time, leading to ecosystem degradation,
- economic impacts due to water deficits for both tourism and agriculture,
- inadequate land use and water infrastructure.

❖ Short-term responses are:

- current and foreseen (plus 250 $hm^3$/year on a short-term) inter basin water transfer from Guadiana's basin,
- significant subsidies for irrigation water.

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