Antonia A. Donta, Manfred A. Lange, Annett Herrmann (Eds.)

Water on Mediterranean Islands: Current conditions and prospects for sustainable management

ZUFO-Berichte
(ZUFO-Reports)

Published by
Centre for Environment Research (CER)
University of Muenster

Volume 5

ISSN 1611-4957
ISBN 3-9808840-7-4

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Project No EVK1-CT-2001-00092
Funded by the European Commission

Centre for Environmental Research, University of Muenster
ZUFO-Berichte, Band 5 (ZUFO-Reports, Volume 5)

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Layout: Annett Herrmann

Published by: Centre for Environmental Research (CER), University of Muenster,
Robert-Koch-Str. 40, D-48149 Münster
Email: zufo@uni-muenster.de, Internet: http://zufo.uni-muenster.de

Print: CCC Copy Center, Coerdestr. 44, D-48147 Münster

ISSN 1611-4957
ISBN 3-9808840-7-4

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Preface

Climate changes caused naturally and by human activities have a great impact on the water cycle which leads to extreme hydrologic situations: Given current research, both floods and droughts occur more frequently and at a raised magnitude. Furthermore where precipitation does not follow these extreme patterns, it at least shows geographically, annually and inter-annually an uneven distribution. Thus, water availability and severe management inconveniencies occur.

Though water on a global and European level and in its long term balance does not face overall shortages, Europe's south is confronted with a severe lack of water. The Mediterranean and particularly its islands are mostly affected due to their geographical isolation and thus their impossibility to draw on more distant or diverse aquifers. In addition, near-shore aquifers are threatened by seawater intrusion and their utilisation is thereby reduced. Thus Mediterranean islands rely solely upon their precipitation which is quite low and above all with great annual and inter-annual variations. Moreover this situation worsens during summer when conflicting demands and availability of water are imbalanced: While the average precipitation within this period is very low, the water demand is quite high. The water needs of the agricultural sector as the major user of water are very high and occur during the same period as the considerable water needs of the tourist sector. This makes water resources management on Mediterranean islands vastly challenging.

In the past, water resources management was largely moulded by technical solutions and engineering approaches. Nowadays, governance, institutional change, economic and social dimensions and allocation issues are equal or even more important than technical solutions alone to deal with this complex problem. In addition, the community reflects an increased environmental awareness and willingness to participate in decision making. Hence interdisciplinarity, i.e. a holistic approach involving and integrating natural and human sciences as well as a multi-stakeholder dialogue is greatly required. Moreover, lasting solutions for a sustainable water management can only be found through recommendations and regulations that are equally accepted by stakeholders and the population. Furthermore involving local stakeholderr, who possess the necessary expertise and experience on their particular needs, increases their approval and thus the implementation of these regulations.

The European project MEDIS realises the aforementioned holistic and interdisciplinary process on five European islands in the Mediterranean Basin i.e. Majorca, Corsica, Sicily, Crete and Cyprus. Its particular aim is to find solutions and derive the most appropriate recommendations for water management facing conflicting demands and varying hydrological, social and economic conditions in order to achieve and maintain a long-term protection of available water resources. For the realisation of the latter, scientific investigations of each island are required, hence this volume includes five chapters, devoted to a characterisation of each of the islands.

At this point, we would like to emphasize that the sole responsibility for the content of the island reports lies with the colleagues from each island team of the MEDIS project. We also want to emphasize that the data reported here represent the status as of April 2005 and that deviations from more recent data are thus unavoidable.

We would like to thank the European Commission for generous funding of MEDIS and Dr. Balabanis, the responsible officer in particular for his support and help during the project.

Antonia Alkistis Donta, Manfred A. Lange,

Münster, Germany, April 2005

Report on Majorca

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Abstract

Majorca is the main island of the Balearic archipelago located to the north-west of the Mediterranean. Majorca has an extension of 3,640km^2 with the maximum altitude of 1,443m corresponding to *Puig Major*. The permanent total population of Majorca is of 609,150 inhabitants (1996), which increases in summer due to tourism reaching a maximum of 1,013,713, resulting in an annual mean population of 819,523 inhabitants. Consequently, the main socio-economic aspect of the island is the seasonal variation of population: one quarter of the total population are seasonal residents. The Gross Domestic Product (GDP) of the island is 11,114million € (1996), 2.38% of the national GDP, and is divided into agriculture 1.5%, industry 6.6%, building construction 8.5% and services 83.4%. The Gross Domestic Product per capita is 17,682€.

The climate in Majorca is considered Mediterranean temperate with temperate humid winters and hot, dry summers. The yearly mean temperature is 17°C. The temperature lightly varies from the *Tramuntana* mountain range – where snow may be present during winter – to the warmer coastal regions.

The average annual precipitation is of 625mm (1400mm/yr in the *Tramuntana* range and 400mm/yr in the southern part of the Island). 60% of the annual precipitation falls between October and January. Available time-series of rainfall all over Majorca show an irregularity index of 1-2.5. Although the obtained value is not very high, the quantity of water is still very important, since aquifer recharge mainly occurs during rain years. The uneven spatial and temporal rainfall distribution, in combination with the varying total population leads to important changes in regional and seasonal water availability. Moreover, water demand from agriculture and tourism exacerbate the situation.

The total renewable water resources of Majorca account for 494Mm^3/yr, where 374Mm^3/yr correspond to groundwater and 120Mm^3/yr to surface water. Scarce water regulation plans have been developed and an important amount of surface water flows to the sea during rainfall events. Surface water and groundwater flowing to the sea has been estimated to be 124Mm^3. Around 20% of the total annual precipitation constitutes the groundwater recharge.

The potential water availability in the Island is 275.5Mm^3/yr (groundwater: 250Mm^3/yr; surface water: 7.2Mm^3/yr; treated waste-water: 18.3Mm^3/yr). Since 1999 the Palma bay desalination plant is in operation with a maximum production capacity of 23Mm^3/yr. Two extra smaller plants are located in western Majorca. Total production of desalinated water between 1999 and 2005 varied between 13 and 24Mm^3/yr.

Total water supply in Majorca is 246Mm^3/yr and estimated losses are 12.6Mm^3/yr. Therefore real water consumption is 233.4Mm^3/yr. Water consumption distribution for individual sectors is as follows: domestic water supply – including tourism – 36.7%, irrigation 61.05%, golf courses 1.3%, other (irrigation of parks and gardens) 0.7%,

industry 0.2%. The major water use in Majorca is for irrigation in agriculture with a 150.2Mm^3/yr water demand (61% of the total consumption). However, contribution of agriculture to the GPD of the island is 1.5%, while services, including tourism is 83.4%.

The demand for irrigation water is high, although only 10% of the cultivated land is under irrigation. Of 2,205km^2 of agricultural land, 195.18km^2 are irrigated with 150.2Mm^3/yr from groundwater and treated wastewater. The main crops of Majorca are cereals, fruit trees (apple, apricot, pear, peach), citrus trees (orange, mandarin, lemon), vegetables, potatoes (2nd harvest), forrage crops, pulses (bean, string bean, etc.), and industrial crops.

Municipalities are responsible to cover their urban water supply, which may be provided by municipal companies, public or private enterprises selected to from a call for tenders.

Majorca's geology is the consequence of the Alpine ranges development and its location in the centre of the western Mediterranean basin. The Balearic Islands constitute emerged enclaves of "Balearic Headland", the emerged prolongation of the Betic belt. According to the geology and landscape, Majorca is divided into three units: the *Tramuntana* range (northwest), the *Llevant* range (southeast) and the central plains.

The principal aquifers are developed in the tertiary and quaternary materials of the island plains: *Palma, Inca-Sa Pobla* and *Llucmajor-Campos*. In the upper range (*Sierra*s), the aquifers are constituted by calcareous formations with an important karstic development leading to the presence of important springs. Due to the geologic heterogeneity, hydraulic conductivity shows an important range of variation. Aquifers are generally unconfined, although facies changes and geological structures may impose confined or semi-confined conditions. Recharge due to direct infiltration from precipitation or surface water accounts for 330Mm^3/yr approximately.

Perennial streams do not exist and surface water is reduced to the presence of creeks, although sometimes they may show important flow rates during a short period of time. Water flow in creeks is only significant for long-lasting precipitation. The most important creeks are those that originate in the *Sierra Tramuntana* and the *Canyamel torrent* of the *Sierra de Llevant* with two reservoirs holding water for drinking water supply. These are located in the *Cúber* and *Gorch Blau* area with a capacity of 2.7 10^{3}m^3/yr and 13.5 10^{3}m^3/yr respectively. The *Dirección General de Recursos Hidraulics* (Hydraulic department of the autonomous region) is by law in charge of the water management of the island. Autonomous, national and European laws are applied.

The *Inca-Sa Pobla* aquifer, located in the central plains, has been selected as case study of the MEDIS project. It extends over an area of 360km^2 with a population that seasonally duplicates and shows important agricultural activity. The aquifer drains into a wetland (Natural Park of *S'Albufera*). The water demand is composed of drinking water supply, irrigation and environmental needs.

The most important problems of the island related to water are that of marine water intrusion, diffuse pollution from fertilisers, and possible groundwater overexploitation. The water management actions mainly concentrate on:

The improvement of treated wastewater reuse (for agriculture, artificial recharge of aquifers, recreational uses):

- interdiction of new wells construction,
- increasing public awareness on water use *and*
- construction of new desalination plants.

Chapter I: Overview of the island

1.1 Physical characteristics

1.1.1 Climate

The Majorca climate is typically Mediterranean, although variations exist due to the mountainous relief that determines an increase of aridity from North to South. Monthly average temperature varies between 11ºC in January and 24ºC in August. Precipitation mainly falls as rain; snow rarely occurs in the *Tramuntana* range. As a consequence of the island relief, there is a trend of precipitation decrease from North to South. So, in the *Tramuntana* range rainfall reaches up to 1400mm/yr, while in the southern part of the island, it hardly reaches 400mm/yr. Mean precipitation is 625mm/yr. The most important climatic characteristic is the seasonal distribution of precipitations: from October to January more than 60% of the annual precipitation occurs, with less than 10% occurring during the summer months. Figure 1 shows the mean distribution of precipitation in Majorca. According to data from the *Libro Blanco del Agua en España/White book of Water in Spain* (LBA, 2000), the mean annual potential evapotranspiration for Majorca varied between 800 and 1,000mm/yr for the periods 1940-1941 and 1995-1996 respectively. Potential evapotranspiration has been calculated with two different methods (Penman-Monteith and Hargraves) and data from three weather stations. For the period 1986-2003 the following results were obtained: 1,025mm/yr (Penman-Monteith) and 1,255mm/yr (Hargraves).

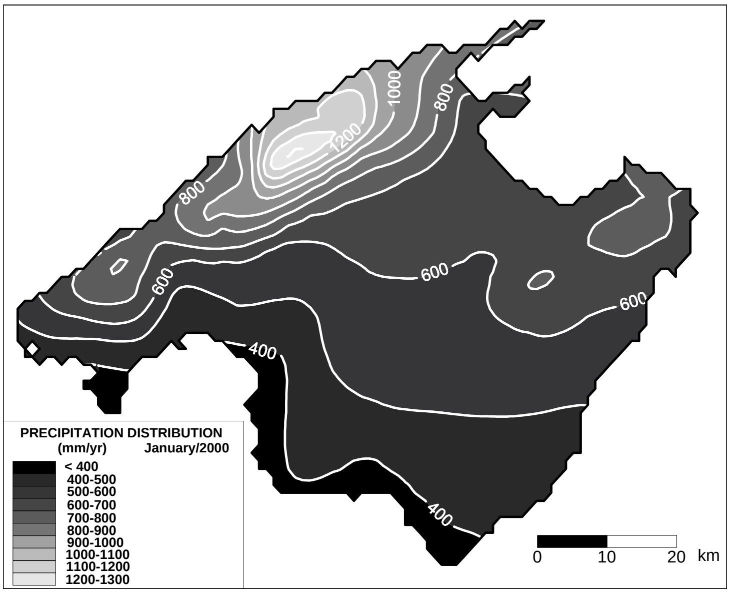

***Figure 1**: Distribution of precipitation on Majorca Island (modified from PHIB, 1999).*

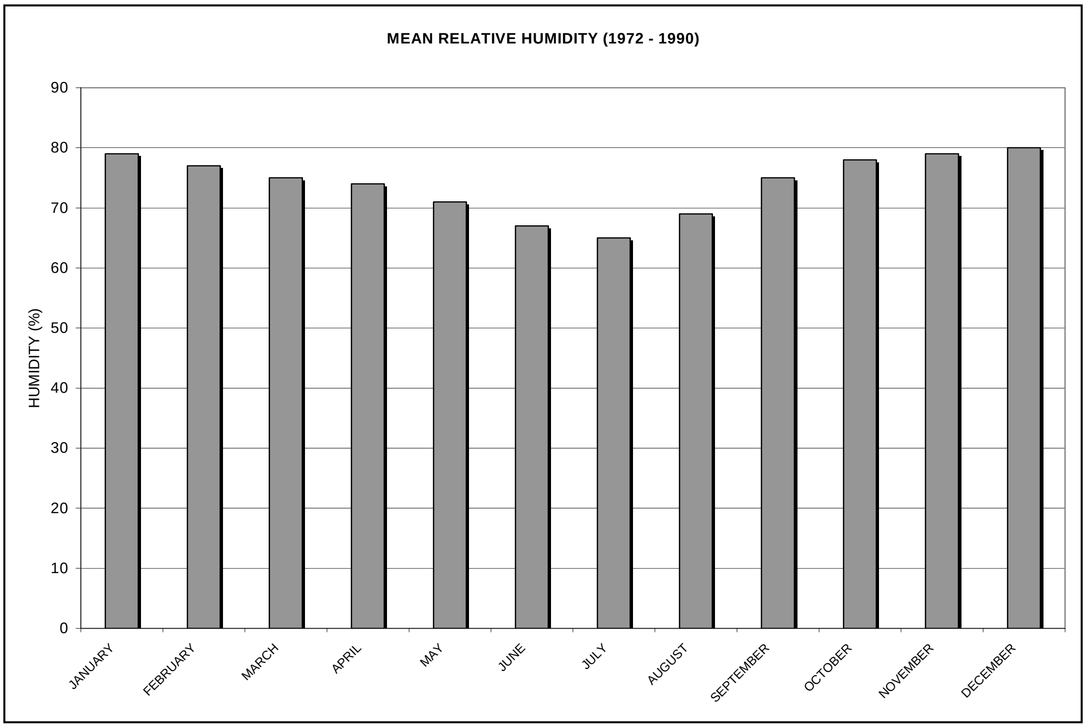

Figure 2: *Mean monthly relative humidity (1972-1990), (http://boreal.inm.es/wwc/html/dclimat/PALMA_.html).*

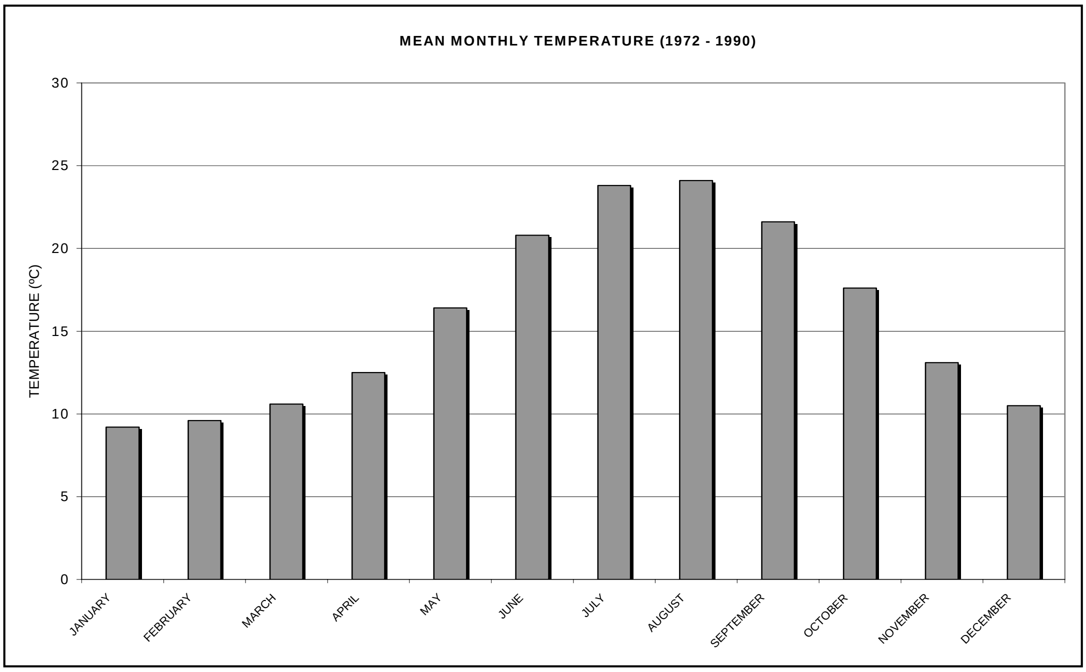

Figure 3: *Mean monthly temperature (1972-1990), (http://boreal.inm.es/wwc/html/dclimat/PALMA_.html).*

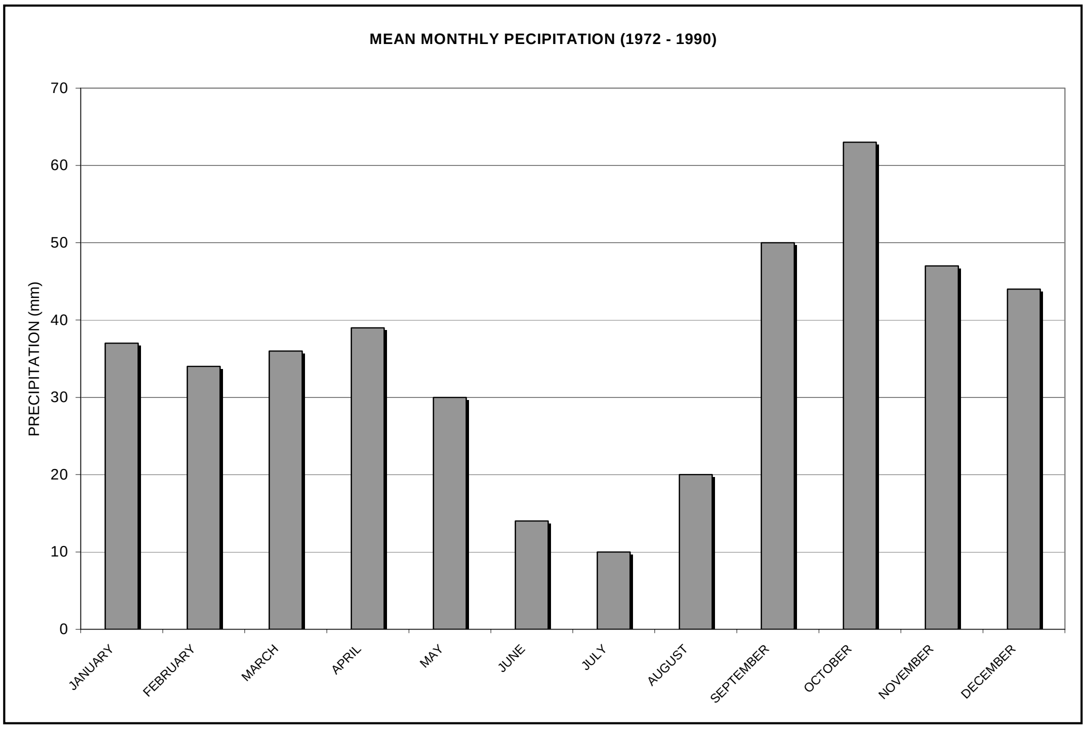

***Figure 4**: Mean monthly precipitation (1972-1990), (http://boreal.inm.es/wwc/html/dclimat/PALMA_.html).*

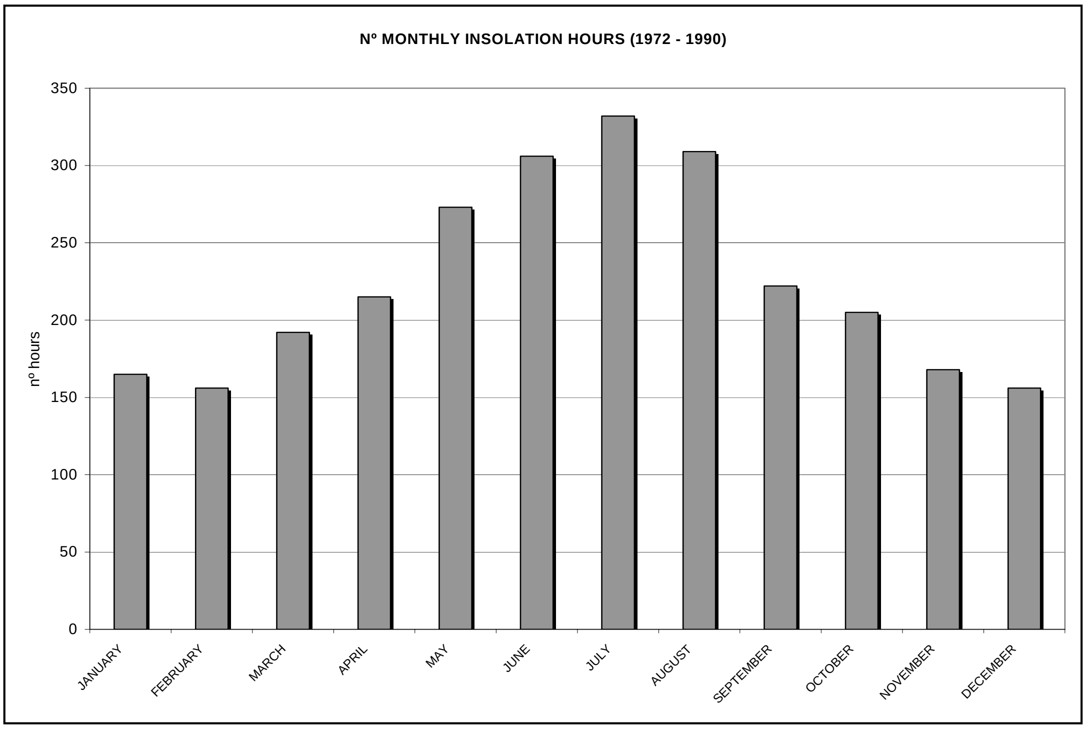

***Figure 5**: Mean monthly insolation hours (1972-1990), (http://boreal.inm.es/wwc/html/dclimat/PALMA_.html).*

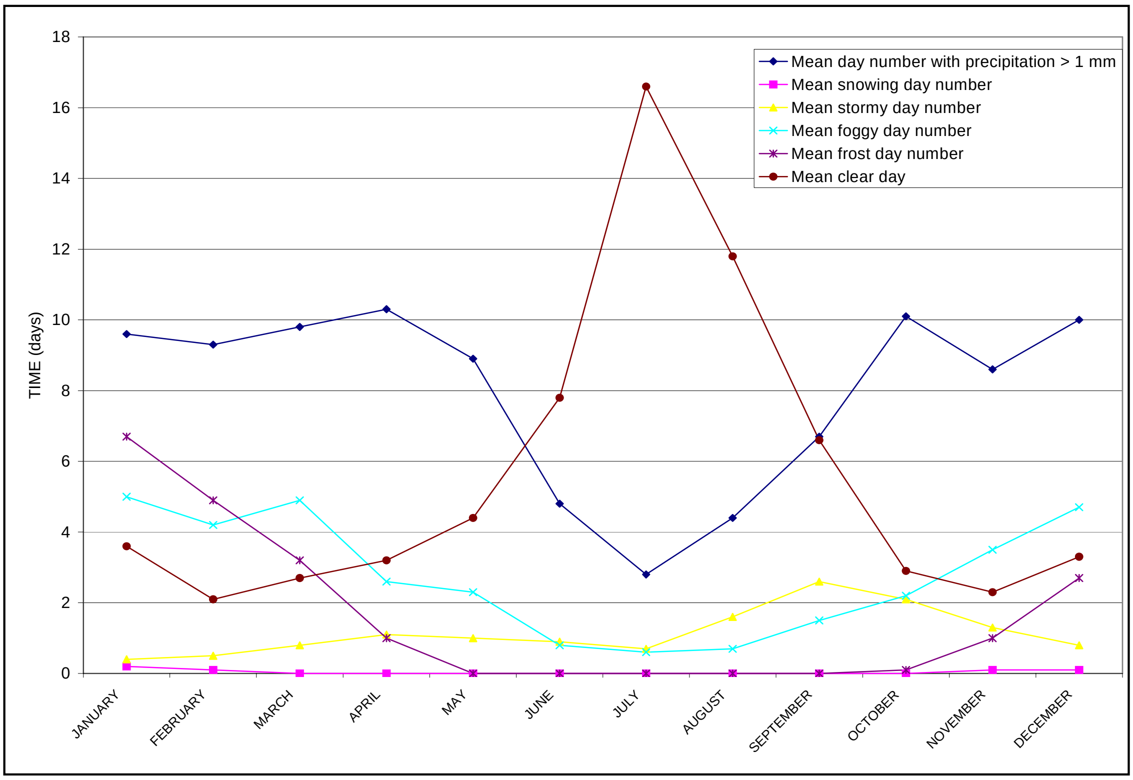

***Figure 6**: Mean monthly meteorological parameters (1972-1990), (http://boreal.inm.es/wwc/html/dclimat/PALMA_.html).*

1.1.2 Aridity index

The mean annual precipitation is 625mm/yr and the mean annual evapotranspiration accounts for 1,090mm/yr for Majorca island (evapotranspiration being the mean of the Penman-Monteith and the Hargraves values presented in paragraph 1.1.1. The aridity index (defined as the ratio of precipitation to potential evapotranspiration) is shown in table 1. According to the available data, the average aridity index is 0.57, which corresponds to a subhumid type.

***Table 1**: Aridity index classification.*

Aridity index	Classification
<0.03	hyper arid
0.03-0.20	arid
0.20-0.5	semi-arid
0.5-0.65	subhumid
0.65-0.75	moist subhumid

1.1.3 Geomorphology

Majorca is the largest island of the Balearic archipelago with a total surface of 3,640km^2. It is diamond in shape, with a maximum distance of 80km in the North-South direction and 200km in East-West sense. The coastal line has a total length of 555km.

Topography varies between the mountainous land of the *Tramuntana* range in the northwest, with various peeks higher than 1,000m (*Puig Mayor* 1,443m high), and the flat lowland in the *Central* plain, *Palma* Plain and *Inca-Sa Pobla* Plain, showing heights of few tens of metres.

From *a* morphological point of view, the island is divided into three well-differentiated units: the *Tramuntana* range, the Central plains and the *Llevant* range:

- the *Tramuntana* range in the North-West of the island reaches an elevation of 1,400 metres (*Puig Major, Puig Massanella*),
- the *Central* plains defined by a smooth topography and maximum heights of about 150 metres (excluding the *Randa* massif with 540m and the *Puig de Bonany* with 317m) *and*
- the *Llevant* range, located in the eastern side of the island, shows a smoother topography than that of the *Tramuntana* range with maximum heights of about 500 metres.

Along the northwest coast, cliffs of hundreds of metres high are found which have small caves at their base. The large and sandy beaches are located in the South (*Palma* bay) and in the North of the island (*Pollença* and *Alcúdia* bays).

Most of the *Llevant* range is limited by a flat littoral fringe of 4-5km wide composed by limestone and molasses, dissected by the upstream river reaches.

1.1.4 Geology

Majorca's complex geology is the consequence of the Alpine ranges formation (Betic belt) and its outcrop in the centre of the western Mediterranean basin. Rocks are mainly from the Secondary, Tertiary and Quaternary age and only a small outcrop of Palaeozoic rocks dating back to Carboniferous times, similar to those of Menorca island, exists in Majorca.

The Mesozoic sequence starts with the Triassic of Germanic facies (Bundsandstein, Muschelkalk and Keuper) followed by a thick layer of Jurassic limestone. They constitute the majority of the materials of high elevations and cliffs and many of the overthrust materials are controlled by the lower Jurassic layers. The rest of the Mesozoic sequence consists of marine deposits. Mesozoic outcrops in the north-west (*Tramuntana* range) constituting a rugged zone with a complex fractured structure. It consists of superimposed folds made up by Jurassic and Cretaceous dolomite, marls and limestone on top of Triassic materials together with conglomeratic levels, detritic Limestone and Miocene marls and clay. Limestone enables the development of a karstic topography. The *Llevant* range (SE) presents a similar geologic structure to that of the *Tramuntana* range but with a smoother topography.

Regarding tertiary rocks, the lower tertiary of the island is not very well known, as a consequence of the emersion of the area and subsequent erosion. The existing tertiary deposits belong to the middle Eocene, Oligocene and Miocene. Oligocene deposits are alluvial-fan sequences, coming from the northwest and the coastal sediments. Middle to upper Miocene, Pliocene and Pleistocene rocks were originated in a restricted postorogenic closed basin and coastal environments. Miocene and Quaternary materials horizontally oriented are the infilling of the *Central* Plains. Powerful Miocene marls, conglomerates, limestone, sandstone, molasses and sandy marls and alternating Quaternary loose conglomerates, sandstones and mud, constitute Cenozoic materials. Deposits of coastal lacustrine facies, consisting of blue and yellowish marls, lacustrine and continental deposits, marine terraces and sand dune deposits more or less consolidated are also present.

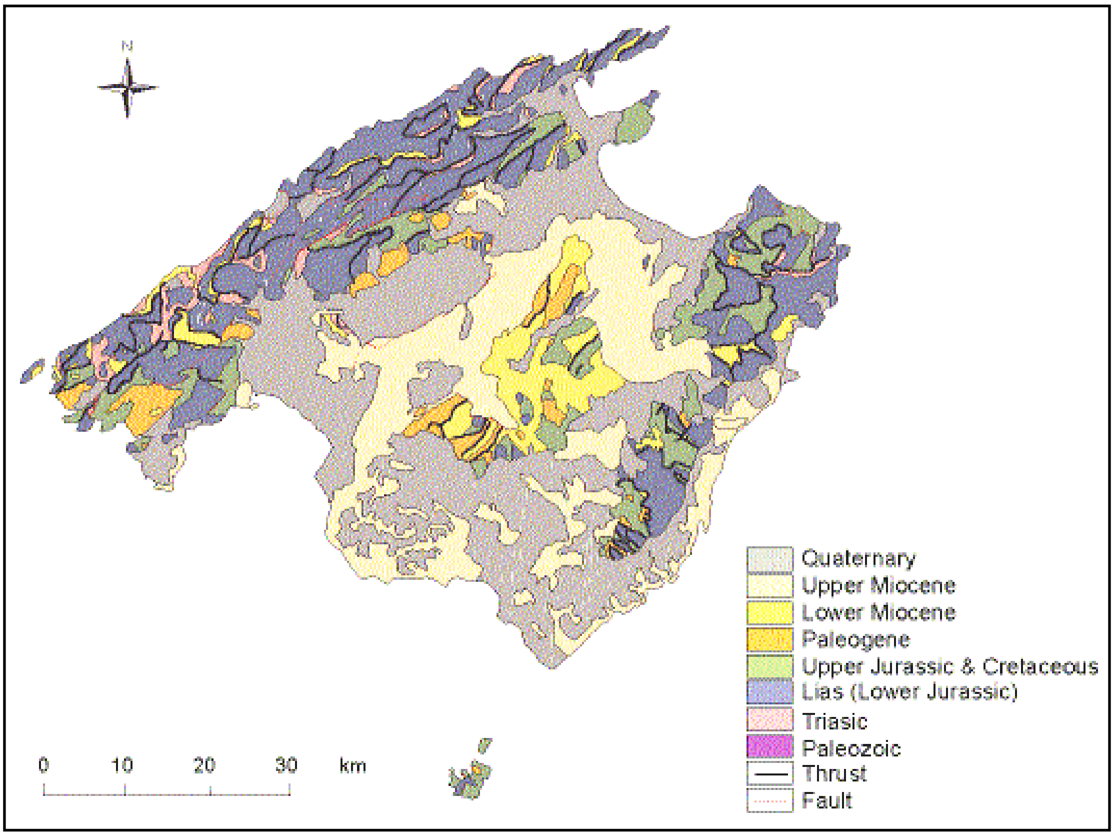

Figure 7: *The geological map of Majorca, (http://nibis.ni.schule.de/~trianet/Majorca/physic1.htm).*

1.1.5 Groundwater hydrology

The main existing aquifers of Majorca correspond to rocks of the tertiary and quaternary age of the island's plains: *Palma, Inca-Sa Pobla* and *Llucmajor-Campos*. In the upper ranges (*Sierras*) the aquifers are calcareous formations with an important karstic development, giving place to the existence of important springs.

Due to the important geologic heterogeneity, hydraulic conductivity shows a wide range of variability. Groundwater recharge is by direct infiltration from precipitation or from surface water streams when hydraulic connection is present. Aquifers are generally unconfined, although changes in facies and geological structures may impose confined or semi-confined conditions.

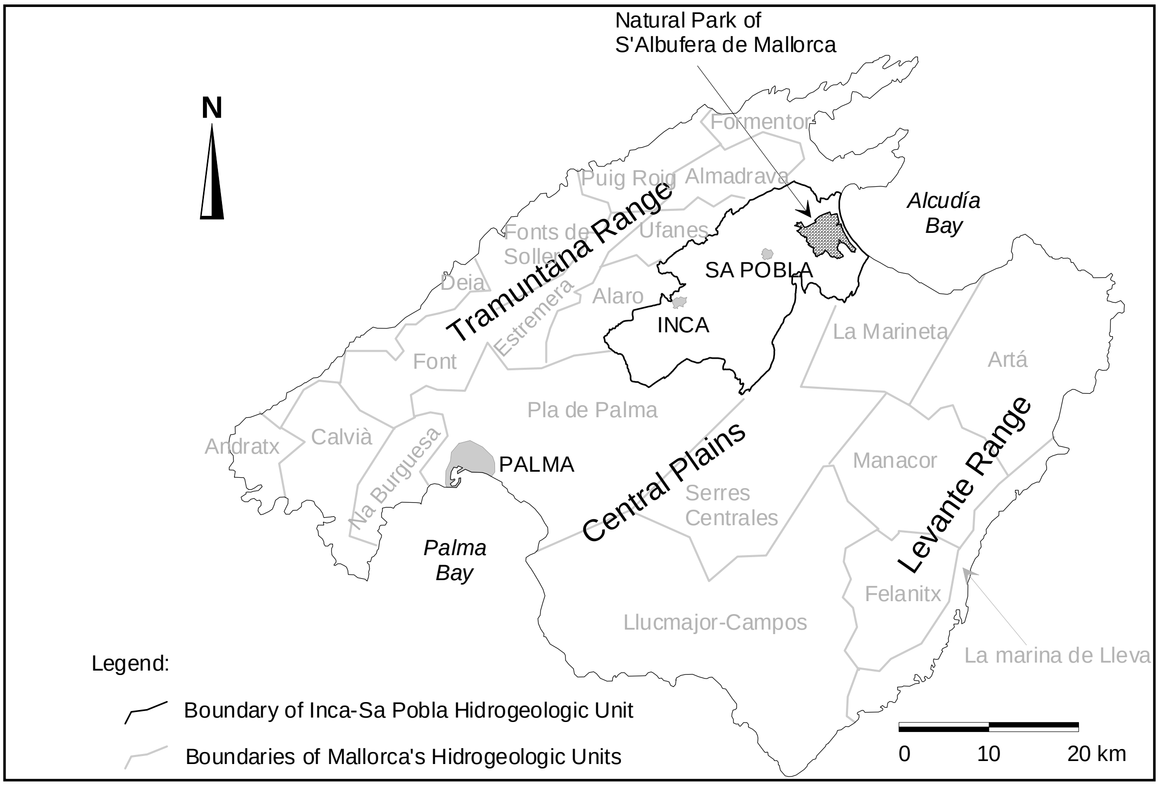

Figure 8: *Map of the hydrogeologic units of Majorca.*

1.1.6 Surface hydrology

Perennial streams do not exist in Majorca; surface water is reduced to small temporal creeks. Streams are only significantly fed when precipitations are long lasting and where an important flow is produced. Flash-flood events are frequent. The most important streams are those originating in the *Tramuntana* range and the *Canyamel* stream of the *Llevant* range.

Rainfall patterns and morphologic characteristics of the area do not favour surface water resources regulation. For this reason, with the purpose for serving as drinking water supply, two dams were constructed in the area of the *Tramuntana* range, those being:

- cúber with a capacity of 2.7Mm^3/yr *and*
- Gorch Blau with a capacity of 13.5Mm^3/yr.

1.2 Water balance

As the main water resources in Majorca correspond to groundwater, the water balance of the island is based on the defined hydrogeologic units, which also constitute management units.

For the total recharge contributions the following terms have been considered: precipitation, irrigation return flows, losses of distribution networks, infiltration from streams and wastewater reuse. For some specific hydrogeologic units, two extra components are also taken into account: the flow drainage between different hydrogeologic units, and the sea-water inflow, which is of great importance as it represents a deterioration of quality.

Regarding the outflows, the main component considered is groundwater pumping for drinking water supply and irrigation, drainage from springs and streams and groundwater flow to the sea. Although total estimated groundwater flow to the sea is important, its dependent on the specific hydrogeologic units and therefore many aquifers are prone to seawater intrusion.

In 1999 the estimated total potential (renewable) water resources of Majorca were 275.5Mm^3/yr (PHIB, 1999), originating from:

- groundwater: 250Mm^3/yr,
- surface water (two reservoirs, Cúber and Gorch Blau): 7.2Mm^3/yr *and*
- treated wastewater: 18.3Mm^3/yr.

A desalination plant, with a capacity of 23Mm^3/yr, was put into operation in Palma de Majorca in 1999. In March 1999, production was 16.8Mm^3/yr and, due to water scarcity, production increased up to 19.3Mm^3/yr in August 2000. Another 4 minor desalination plants are also located in the south-western tourist areas, with a total capacity of 5.5Mm^3/yr.

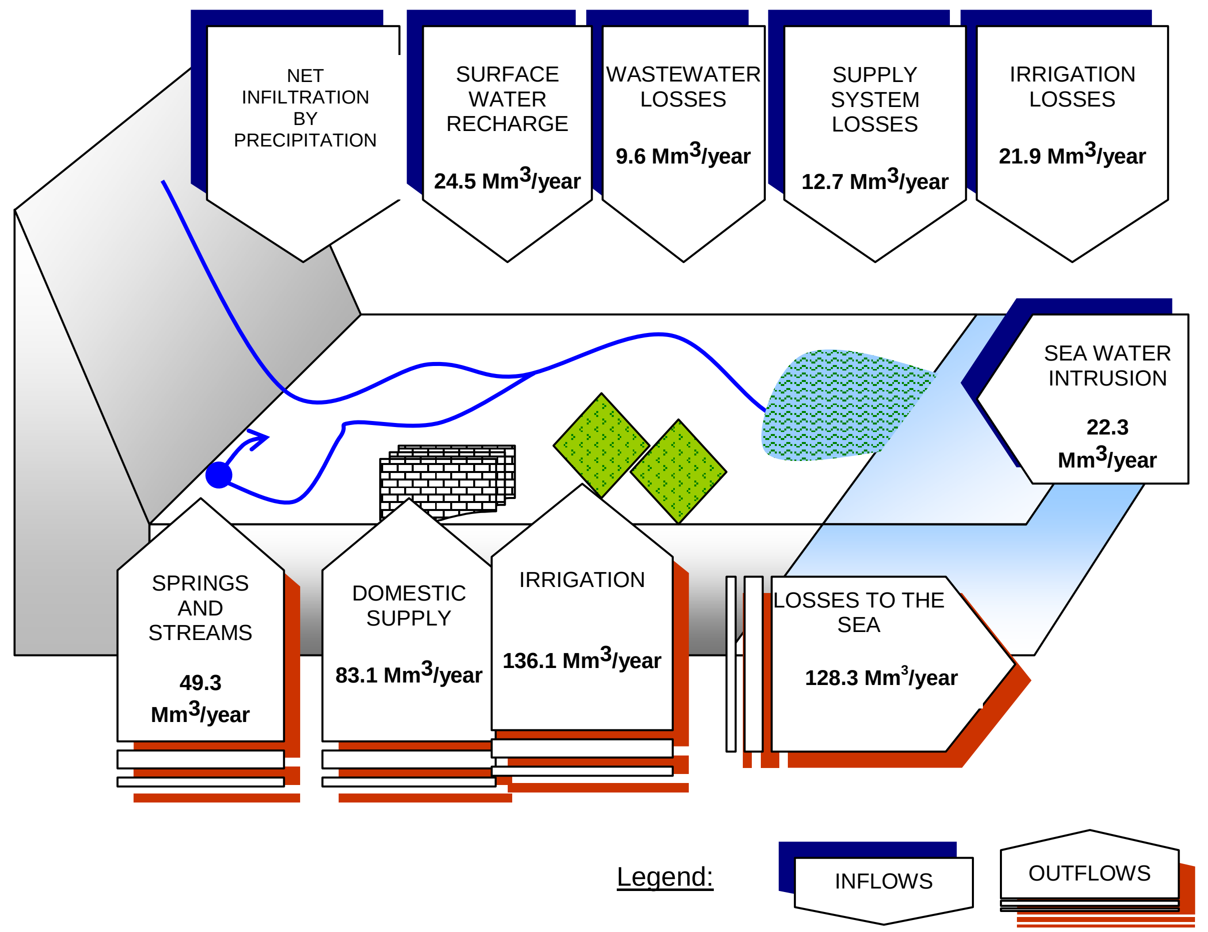

***Figure 9**: Schematic representation of the groundwater balance for Majorca Island, (PHIB, 1999).*

The average annual surface water resources are about 120Mm³/yr (estimated from gauges), including 7.2Mm³/yr available from dams. The remaining amount of surface water originates from springs and creeks. The contribution of surface water to the entire potential water resources is about 24%, but the real contribution (used water) is roughly 1.5%, indicating that almost the entire quantity of water used in Majorca comes from groundwater.

In the following paragraphs some indicators regarding water availability in Majorca are shown. For the calculation, 609,150 inhabitants were considered permanent population and 819,523 inhabitants when including seasonal population (average of tourists considering all year):

- total renewable water resources (natural available) per capita (PHIB, 1999); considering as total renewable water resources: 494Mm³/yr:
    - total renewable water resources per capita for the permanent population is 811m³/yr/person and
    - total renewable water resources per capita for the population including mean seasonal population is 603m³/yr/person.

- total exploitable water resources for use per capita, considering as exploitable water resources 275.5Mm^3/yr:
  - total exploitable water for use per capita for the permanent population is 452m^3/yr/person *and*
  - total exploitable water for use per capita for the population including mean seasonal population is 336m^3/yr/person.
- abstracted water resources per capita (considering as abstracted water resources: 246Mm^3/yr):
  - abstracted water resources per capita for the permanent population is 404m^3/yr/person *and*
  - abstracted water resources per capita for the population including mean seasonal population is 300m^3/yr/person.

1.3 Water demand and supply

The total water demand in Majorca is 246Mm^3/yr (PHIB, 1999); table 2 depicts the distribution and the origin. Figure 10 depicts the origin of the total water supply in Majorca (data from 1996). The seasonal water demand according to the different uses, cannot be specified as no data are available.

Table 2: *Water demand by uses and origin.*

Water demand by uses and origin	**Water demand Mm^3/yr**	**Total water demand Mm^3/yr**
Domestic water demand		**90,3**
Groundwater	83.1	
Surface water	7.2	
Irrigation for agriculture		**150,2**
Groundwater	136.1	
Urban treated wastewater	14.1	
Industry		**0.5**
Groundwater	0.5	
Golf courses		**3,22**
Groundwater	0.8	
Urban treated wastewater	2.4	
Other (irrigation of parks and gardens of Palma city)		**1.8**
Urban treated wastewater	1.8	

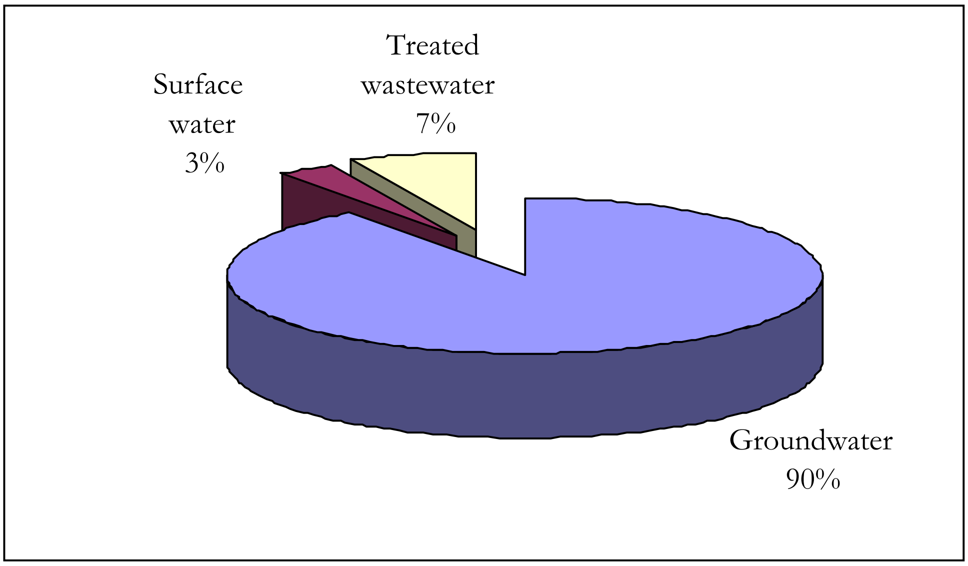

Figure 10: *Sources of water supply in Majorca, (PHIB, 1999).*

In absolute terms, the water consumption (water supply minus distribution losses) is: Groundwater used for domestic supply, irrigation, industry, and golf courses accounts for 220.5-11.4 = 209Mm^3/yr, surface water existing reservoirs, used for domestic supply for 7.2-0.4 = 6.8Mm^3/yr, urban treated wastewater used for irrigation, golf courses, parks, gardens etc. accounts for 18.3 – 0.9 = 17.4Mm^3/yr and desalinated water 0Mm^3/yr. The production of desalinated water began 1999. In order to estimate the existing pressure on water, the following indexes have been calculated. These calculations do not take into account water demand for the environment, temporal or spatial variability of resources and demand, and considers consumption of 233.4Mm^3/yr:

- Consumption index: Water consumption (233.4Mm^3/yr)/renewable water resources (494Mm^3/yr)= 47%
- Exploitation index: Water supply (246Mm^3/yr)/renewable water resources (494Mm^3/yr)= 50%

1.4 Environmental protection

1.4.1 Surface water

Water quality in dams is dependent on the water quality of the water they receive (precipitation, streams, etc.), the amount of evaporation, presence of stratification as well as vertical changes along depth of the water mass. In the *Cúber* and *Gorch Blau* dams, due to their geographic situation (*Serra de Tramuntana* mountain) eutrophication problems are not expected as the dams are not affected by human activities. Results of water chemical analysis from the dams, indicate that water is of good quality, fit for any purpose. Due to the important water flow variation of most streams, no control monitoring networks exist. Natural quality of water is considered to be acceptable, although natural salinity may exist as some of the streams drain salt-rich terrains (Triassic evaporites and tertiary saline deposits). Moreover, the possibly negative impact of uncontrolled wastes (solids or liquids) dumped in streams should be considered. When a more permanent water flow originating from springs and aquifer drainage exists, water quality is similar to the aquifer it drains.

1.4.2 Groundwater

The main difficulty concerning groundwater quality is seawater intrusion of the coastal aquifers. Other problems are related to the high nitrate content in areas with important irrigated agriculture, pollution caused by uncontrolled solid wastes leaching, low depurated wastewater as well as sewerage systems and septic tank leakages. In the *"Llano de Palma*" hydrogeologic unit, the two existing aquifers present seawater intrusion caused by excessive over-pumping. The important extraction for *Palma's* supply, from wells located in the *Pont d'Inca* area, produced salinisation of the deep aquifer (directly connected to the sea) presenting Cl^- concentrations of about 8,000mg/l. Since 1971 only the upper aquifer has been exploited, but a gradual salinisation has occurred reaching up to 4,000mg/l. Since 1994 the chemical quality of the upper aquifer has improved due to the reduction of extractions, the increased use of treated wastewater for irrigation in the *Sant Jordi* area and by discarding the use of the salinised wells. At present, Cl^- concentration of the upper aquifer varies between 600 and 2,400mg/l in the *Pont d'Inca* wells.

Another issue refers to the effluent quality from sewage treatment plants. Although environmental authorities carry out chemical analyses, unfortunately they are not done systematically. Sewage treatment plants with long records of water analyses exist, although in many cases they do not take into account wastewater peaks, thus results can only be considered as a guide. However, some of the effluents analysed comply with the Decree 13/1992 of the COPOT (Balearic Government), which regulates monitoring liquid dumping from urban sewage treatment plants. This aspect thus needs to be improved. In the *Inca-Sa Pobla* plain, the main reason for the deterioration of groundwater quality is the presence of nitrate in elevated concentration due to the intensive use of fertilisers in agriculture. High NO^{3-} concentration has been recorded in different hydrogeologic units (*Valldemosa-Soller, Llano de Inca-Sa Pobla, Llano de Palma, Manacor, Llucmajor-Campos*) mainly as a consequence of intensive agricultural activities, although sometimes (e.g. in *Felanitx* and *Marina de Llevant*) contamination is produced by wastewater dumping and the presence of damaged septic tanks or sewage systems.

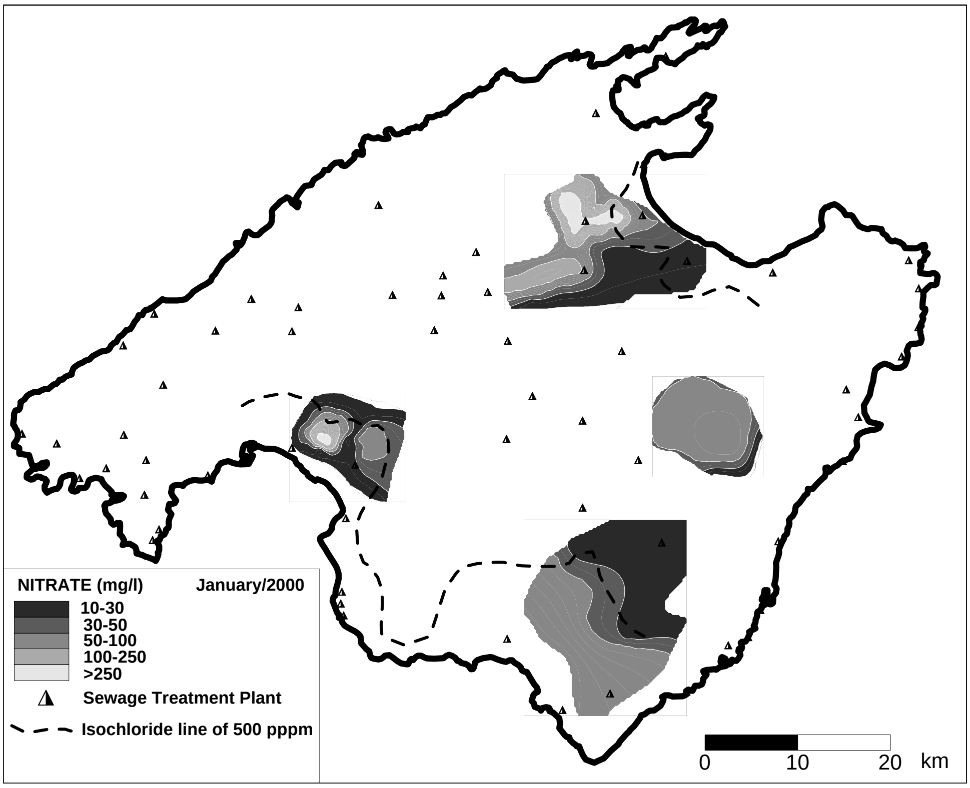

Figure 11: *Presence of nitrate pollution and saltwater intrusion in Majorca's aquifers, (modified from PHIB, 1999).*

1.4.3 Wastewater

The priority of the regional government has been to comply with the Directive 91/271. IBASAN is a public enterprise of the *Conselleria de Medi Ambient*/Regional Ministry of Environment created in 1989 to promote, construct, operate and finance wastewater treatment plants in support of the Municipal Councils who are ultimately responsible for the collection and disposal of wastewater. An average yearly investment of more than 18,000,000€/yr have been invested by IBASAN on wastewater treatment and discharge between 1995 and 2002. As a result, more than 97% of the population is connected at least to a wastewater treatment plant with secondary treatment. And 70% is connected to a plant with tertiary treatment (IBASAN, 2003). The total treated volume is approximately $66Mm^3/yr$ (table 3).

Table 3: *Main characteristics of the wastewater treatment plants in Majorca, (IBASAN, 2003).*

Wastewater treatment plants in Majorca	Municipal term	Popu-lation	Annual flow in 2001 m^3/yr	Level of treatment	Invest-ment (€)	Year of cons-truction
Algaida Montuiri	Algaida	7,000	193,502	Secondary	2,245,100	1994
Andratx		15,000	345,111	Tertiary	2,591,180	1999
Artà		6,773	792,350	Aeriation lagoon	800,270	1990
Banyalbufar		1,000	30,879	Secondary	332,520	1994
Binissalem		5,000	195,875	Secondary	2,701,335	1993
Cala d'Or	Santanyí	39,667	933,601	Tertiary	5,037,370	1992
Cala Ferrera	Felanitx	8,750	232,174	Secondary	1,502,530	1988
Cales de Mallorca	Manacor	22,917	699,117	Secondary	2,988,790	1991
Cales de Manacor	Manacor	16,000	791,653	Secondary	2,983,515	1992
Camp de Mar	Andratx	4,083	120,225	Lagoon	739,845	1994
Campanet		3,083	86,451	Secondary	864,005	1997
Campos		7,000	30,055	Secondary	832,080	1998
Canyamel	Artà	13,125	170,251	Secondary	905,630	1990
Capdepera-Cala Rajada		52,500	1,788,895	Tertiary	4,914,660	1996
Colónia Sant Jordi	Ses Salines	21,000			1,600,000	2003
Colónia Sant Pere	Artà	2,167	38,897	Secondary	545,720	1994
Consell		2,652	99,024	Secondary	1,800,000	1998
Costitx		1,167	12,678	Secondary	409,965	1994
Deiá		2,500	58,444	Secondary	919,080	1993
Estellencs		790	25,527	Secondary	150,255	1992
Felantix		10,000	691,859	Secondary	3,000,000	1982
Font de Sa Cala	Capdepera	8,750	8,750	Secondary	1,111,875	1991
Formentor	Pollença	2,475	33,279	Secondary	903,185	1995
Inca	Inca	25,725		Secondary		2000
Lloret de Vistalegre		1,400	46,787	Secondary	527,230	1994
Lloseta		7,605	218,255	Secondary	1,300,345	1993
Llubí		3,646		Aeriation lagoon	823,771	2001
Lluc	Escorca	875	25,730	Secondary	215,435	1996
Mancor de la Vall		1,400	43,717	Secondary	370,160	1995
Muro (Nucli Urbà)		9,375	288,000	Tertiary	1,513,960	1978

Table 3 continued.						
Wastewater treatment plants in Majorca	**Municipal term**	**Popul-ation**	**Annual flow in 2001 m^3/any**	**Level of treatment**	**Invest-ment (€)**	**Year of cons-truction**
Muro-Santa Margalida	Muro	62,115	1,986,793	Lagoon/ Secondary	9,278,470	1992
Pollença		60,000	1,753,602	Secondary	7,194,115	1993
Porreres		4,813	201,738	Secondary	844,620	1994
Portocolom	Felanitx	22,500	346,855	Secondary	2,343,950	1991
Puigpunyent		875	27,187	Secondary	377,160	1995
Randa	Algaida	938		Secondary	403,445	2001
Sa Barca Trencada	Santanyí	3,000	111,427	Secondary		1990
Sa Calobra	Escorca		30,132	Sieve	251,670	1995
Sa Pobla		15,000	472,039	Secondary	1,872,695	1991
Sa Ràpita	Campos	8,750	57,439	Secondary + Filters	1,895,155	1995
Sant Elm	Andratx	5,833	37,231	Secondary	1,126,990	1993
Sant Joan		2,000	42,157	Secondary	457,356	1994
Santa Eugènia		1,313	76,304	Secondary	574,240	1996
Santa Margalida		6,417	98,369	Secondary	901,235	1994
Santa Maria		5,833	134,311	Secondary	932,540	1998
Santanyí		17,500	85,384	Tertiary	3,060,995	2000
Selva-Caimari	Selva	2,500	97,540	Secondary	480,810	1995
Ses Salines		2,188	37,297	Secondary	470,875	1995
Sineu-Petra-Maria-Ariany	Ariany	11,667	209,891	Secondary	3,020,740	1994
Sóller		16,847	942,638	Tertiary	3,846,480	1992
Son Serra de Marina	Santa Margalida	4,667		Secondary	1,000,000	2002
Son Servera		67,500	2,700,033	Secondary	2,500,815	1996
Valldemossa		3,120	127,194	Secondary	925,365	1992
Vilafranca		3,500	86,631	Lagoon	902,400	1994
Alcúdia*	Alcúdia	44,000	4,015,000	Secondary		1982
S'Arenal*	Llucmajor	25,000	1,460,000	Tertiary		1975
Bendinat*	Calvià	33,600	1,370,000	Secondary		1986
Calvià*	Calvià	1,800	164,250	Secondary		1975
Capdellà*	Calvià	720	65,700	Secondary		1978
Esporles*	Esporles	4,000	365,000	Secondary		1975
Llucmajor*	Llucmajor	10,000	328,500	Secondary		1980
Manacor*	Manacor	11,200	1,022,000	Secondary		1974
Peguera*	Calvià	16,000	1,460,000	Secondary		1972
Palma 1*	Palma	34,000	3,102,500	Secondary		1971
Palma 2*	Palma	272,000	24,820,000	Secondary		1974
Porto Cristo*	Manacor	25,000	1,825,000	secondary		1986

*****_Wastewater treatment plants that are not managed by IBASAN. They are managed by the municipalities directly._

1.5 Water laws and regulations

1.5.1 Legal framework

At present the legal framework for the management of water resources in the Balearic Islands is mainly determined by

- the Spanish Water Act 29/1985 (modified in 1999, 2001 and 2003) which sets the overall framework,
- the Decree 129/2002 on the *Organización y Regimen Legal de la Administración Hidráulica de las Isalas Baleares* (Organisation and Legal Regime of the Hydraulic Administration of the Balearic Islands*)*
- *Plan Hidrológico de las Islas Baleares (*the Hydrological Plan of the Balearic Islands*)* approved by the Royal Decree 378/2001, *and*
- the Decree 88/2000 on Medidas Especiales para la Gestión de los Recursos Hídricos en las Islas Baleares (*Special Measures for the Management of Water Resources in the Balearic Islands).*

The enforcement of the Directive 2000/60/EC in Spain through its transposition into Spanish law via Article 129 of the *Ley de Presupuesto* (Budget Law) of 31st December 2003 entailed a series of changes to Spanish water legislation. Although the Water Act 29/1985 and its amendments already included some of the principles of the new WFD (Embid, 2003), the way the Water Framework Directive has been transposed into the Spanish law was heavily criticised by a large sector of society.

1.5.1.1 Development of the overall legal framework in the Balearic Islands

According to Barón (2001) the evolution of the legal framework for the water management in the Balearic archipelago may be separated into three distinct periods (see table 4):

1) 1879-1969: only the Water Act of 1879 was in force,
2) 1969-1985: the Special regime for the Balearic archipelago was in force *and*
3) 1985 onwards: the Water Act of 1985 (and its amendments in 1999, 2001 and 2003).

Water act of 1879 (1879 –1969)

Most of the legal texts of the period refer to surface waters, where the water law and the *Código Civil* (Civil Code) were considered as part of the public domain. Therefore the use of surface water was necessarily subjected to administrative concession.

The *Ley de Aguas de 1879* (Water Act of 1879) established the difference between public and private ownership of water, declaring private all groundwater abstracted from a well located on private land, as long as this did not harm any public water. Only the groundwater extraction of public ownership was subject to administrative concession. A 1934 law (Decree 1934) obliged registration of springs and groundwater extractions at the Mining Administration.

Special regime for the Balearic Islands (1969-1985)

The deficiencies in the existing law, the will to obtain short-term profit and the lack of knowledge have induced an uncontrolled and irrational exploitation of groundwater resources, leading to a critical situation of different zones of the Balearic archipelago. In light of this situation, and in order to avoid irreversible processes, a series of laws known as the *Régimen Especial de las Islas Baleares* (Special regime), was introduced to solve this situation.

The Act 59/1969 on *Régimen Jurídico de los Alumbramientos de Aguas Subterráneas en la Isla de Mallorca* (Legal Regime Regarding the Extraction of Groundwater in Majorca), was approved in June 1969. It fostered the co-ordination between the different ministries involved in water resources management (public works, industry and agriculture), and the Comité de *Coordinación para el Estudio Regional de los Recursos Hidráulicos Totales* (Committee for the Regional Study of the Total Water Resources of the Majorca Island), was set up. The Committee established a deadline for the studies elaboration and temporarily prohibited the construction of new wells.

In 1972 the new Decree 632/1972 regarding groundwater extraction in the Balearic archipelago and extending the 1969 law application to Ibiza was approved. It also included the authorisation of the construction of new wells in some areas, conditioned by maximum flow rate restriction. The new procedure for the new extractions permit required exhaustive descriptions and tests of the well construction as well as information regarding the final use of water.

In 1973, once the *Estudio Regional de los Recursos Hidráulicos totales de las Baleares* (Study of the Total Water Resources of the Balearic archipelago), was executed, the new Decree 3382/1973 defining the use of groundwater resources in the Balearic archipelago was approved. The decree which divided the archipelago into 9 zones also defined the technical requirements to be fulfilled in order to obtain a water extraction permit. According to this law, new water rights were granted depending on the estimated availability according to of the *Estudio Regional de los Recursos Hidráulicos totales de las Baleares*. The authorisations were only of temporal character for a minimum period of 10 years and subject to revisions, according to the piezometric level evolution and the groundwater quality. The law also established the necessary hydrologic information to obtain the concession. It also defined the involvement of the different government departments in the management and policy of water resources development and established regulations for treated wastewater reuse.

Water act 29/1985 (from 1985)

In 1986 the Royal Decree 849/1986 regarding the Regulation of the Public Hydraulic Domain and in 1988 the Royal Decree 927/1988 on the Regulation of the Public Water Administration and the Hydrological Planning were passed.

The Spanish Water Act 29/1985 establishing groundwater as part of the public domain ruled out the Balearic law from 1973 (Decree 3382/1973). To allow the change from the previous private management domain into public domain, the law foresaw two different possibilities to be adopted within three years after enforcement of the law. According to the first one, those owners of rights for private groundwater exploitation would voluntarily integrate their wells into the public water domain after registering in the *Registro de Aguas* (Water Register). In turn, they would be granted over 50 years the temporal allowance to extract groundwater. There was also a second choice, to maintain his private rights on water extraction, although without any protection from the administration. The owners had three years to register these wells to the *Organismo de Cuenca* (Basin Authority), in the *Catálogo de Aprovechamientos de Aguas Privadas en la Cuenca* (Inventory of private water uses in the watershed).

In any case, any change in the extraction conditions or regime requires a new concession according to the Water Act of 1985. Three different modalities of groundwater extractions can be defined, implying some troubles according to Barón (2001).

These are:

a) Surveys for volumes under 7,000m^3/yr,

   According to the law, permission is not required for less than 7,000m^3/year volume extraction from a private land, unless the aquifer has been officially declared overexploited. However, the law foresees some exceptions if special regimes are set in place. This was the case in Majorca where since the Special Regime, authorisations were also required for less than 7,000m^3/yr.

b) Research licenses *and*

   For extraction volumes greater than 7,000m^3/yr from private or public land, the Spanish Water Law requires a special permission from the *Organismo de Cuenca*/Water authority. The *Organismo de Cuenca* is in charge of the definition of the extraction authorisation for a limited period time, the allowed extraction rate, requirements for the work construction and the required information.

   Once the license for exploitation is obtained, a concession is needed. This is when problems arise, because unless surveys are performed on public land, exploitation permits are rather unlikely to be obtained.

c) Concessions.

The law foresees that extractions greater than 7,000m^3/yr require a concession granted when technical requirements are fulfilled. The problem lies in the procedure of obtaining a concession since different legal regulations and public organisations are involved. As a consequence, in Spain the following steps are generally taken:

- authorisation of the well through the mining administration for safety regulations (Royal Decree 863/1985),
- when a well is under construction, a concession for extracting water is usually submitted to the Hydraulic Administration, which cannot request any further technical requirements than those established by the water law for the well's construction, as the well is legally built *and*
- once the concession is granted, for the operational performance (water-elevation pumps and connection to the electricity distribution network) is submitted to the Industry Ministry.

In order to solve this problem, the Autonomous Community of the Balearic Islands has established one specific register covering the first two steps (requirements for safety regulating mining activities and for a proper groundwater extraction concession as described in the water law).

In 1984 and 1985 the Central Government had already transferred to the Autonomous Government the tasks and services related to groundwater and hydraulic works behaviour plan. In 1990 the Autonomous Administration of the Balearic Islands approved the Decree 106/1990 to create an autonomous basin authority, the *Junta de Aguas de Baleares*. The *Junta de Aguas de Baleares* were put in charge of public and private water resources, as well as hydraulic works by the Autonomous Community. In 1993 this law led to the reunification of all functions under the rule of one institution allowing an integral and efficient management of the groundwater resources in the Balearic Islands.

The Royal Decree 115/1995 transferred further responsibilities regarding resources, extractions and hydraulic works from the Central State to the Autonomous Community, thus re-structuring the Balearic Water Administration. In *1996* by derogation of the Decree 106/1990 the *Junta de Aguas de Baleares* became a non-autonomous basin authority, being dependent on the *Dirección General de Recursos Hídricos* (General-Directorate of Water Resources), integrated in the *Consejería de Medio Ambiente* (Autonomous Ministry of Environment).

The water law in the Balearic Islands is thus in a process of transition, as a consequence of the changes that the Spanish water law has been undergoing (Embid, 2003).

1.5.1.2 Legal framework in the Autonomous Community of the Balearic Islands

The Decree 129/2002 regulates the organisation and competencies of the Hydraulic Administration of the Balearic Islands; legal jurisdiction lies with the Government Council of the Balearic Islands. The General-Directorate of Water Resources which depends on the Autonomous Ministry of Environment, the main body defining policies on water resources, is responsible for the management and policies in the public water domain.

***Table 4**: Development of the legal framework of water resources management, (Barón, 2001).*

	Water Act of 1879 1879-1969		**Special Balearic Regime 1969/73-1985**		**Water Act of 1985 (mod. 1999) 1985-present**
	Surface water	Groundwater	Surface water	Groundwater	Surface- and groundwater
Domain	Public	Private (ordinary court)	Public	Private (intervened)	Public domain
Competencies	State	(Decree 1934)	State	State	State & increasingly the Autonomous Government
Involved Administrations	MOP(1)	Industry	MOP	MOP Industry Agriculture	From 1993 onwards the DGRH(2)

(1) MOP: Ministry of Public Works (State);
(2) DGRH: General Directorate of Water Resources

The severe drought of the late 90s, and the important population growth (permanent as well as seasonal) was accompanied by a proportional increase of water consumption. Consequently an unsustainable situation occurred, which induced a risk of irreversible harm to groundwater resources. In light of this situation and based on Article 56 of the Water Act 29/1985 the Government of the Balearic Autonomous Community approved the Decree 88/2000 on *Special Measures for the Management of Water Resources*.

The decree was necessary to implement actions foreseen in the *Plan Hidrológico de las Islas Baleares* (PHIB, 1999), not yet approved by the Central Government as will be further explained. Its main objectives were to equilibrate the water balance of the aquifers, to reduce the overall losses from distribution networks to values below 15% and to decrease the water demand by 20%. A process was applied for new water concessions for each hydrogeologic unit, including well construction definition and maximum pumping rates. The decree also identified the endangered hydrogeologic units being defined as '*classified*' with the interdiction of any new concessions, except when connection to municipal water supply did not exist. It entailed the *Consejería de Medio Ambiente* /Autonomous Ministry of Environment, to reduce or cancel any concessions including the already existing, setting maximum limits of water allocation for drinking, industrial and agricultural uses. In order to reduce water consumption, improve use efficiency and avoid water resource quality deterioration several measures were taken. It established the compulsory installation of meters for water supply entities, granting a ten-year time limit for old buildings to have individual meters. For any new building, water-saving plumbing infrastructure had to be incorporated.

The *Hydrologic Plan of the Balearic Islands* (PHIB, 1999) was approved by the Spanish Government through the Royal Decree 378/2001 and in accordance to the Spanish Water Law is a legally binding document. Approved by the Government of the Balearic Islands in 1999, it described the situation of water resources, exploitation and demands for the year 1996, estimating water demands up until 2006 and 2016 and thus determining the main lines of actions and principles of management. The Hydrological Plan is a legally binding document that set the framework for water management policies in the public domain.

The *Order of the Autonomous Ministry of Environment of 16th December 2002* complemented the Decree 88/2000, and further specified conditions for the new groundwater authorisations and concessions establishing that only legal houses in rural areas could apply for concessions and also defined maximum rates. Concessions could neither be issued for agricultural use, nor for any use within 1 km from the coastline. Concessions in non-classified hydrogeologic units were restricted to the renewable volumes according to the hydrologic plan and registered in the General Directorate of Water Resources. All new concessions would be granted under the restriction that they could be updated without indemnification depending on the aquifer evolution. Finally it specified detailed technical conditions for the construction of new wells.

The Decree 49/2003 on *Declaración de Zonas Sensibles*/Declaration of Sensitive Zones, complied with the Directive 91/271/CEE on urban wastewater treatment and its transposition to the Spanish law through Royal Decree 11/1995 and 509/1996, defined sensitive, normal and less sensitive zones in the Autonomous Community of the Balearic Islands and set the minimum quality standards that the effluents of wastewater treatment plants had to fulfil for discharging into the respective zones.

The Decree 50/2003 establishes the *Centro de Intercambio de Derechos para el uso del agua en agricultura*/Centre for the Exchange of Rights for Agricultural Water Use. The Agricultural Water Bank was thus created in order to overcome the negative consequences of the restrictions imposed on new exploitation rights over the agricultural sector. It foresaw a farmers possibility to voluntarily transfer their rights for water use in agriculture to the Agricultural Water Bank for a specified time span receiving an economic compensation. In turn accredited farmers could buy available water rights from the Bank to be used for a given time span. The Agricultural Water Bank has rather been an artificial mechanism designed to legalise the replacement of agricultural activities of a specific group of farmers. It has nevertheless the possibility for farmers of not losing their water rights, even if they are without using them for a period greater than three years. Given this situation farmers are rather reluctant to declare to the authorities that their rights are temporarily out of use.

1.5.1.3 Anticipated future changes to legislation

The present Minister of Environment intends to adopt the Water Framework Directive to the Spanish law as a separate law to the Water Act 29/1985 and repeal its last amendment (2003). There are no ongoing discussions to elaborate any change in legislation regarding water resources or services in the *Govern de les Illes Balears* (*Government of the* Autonomous Community of the Balearic Islands).

1.5.2 Pricing policy

In Majorca, water at consumer level is only paid by households, farms, enterprises, commercial bodies and/or industries connected to the municipal distribution networks. All households, farms, enterprises, commercial bodies and/or industries that own a well only pay for the expenses of building, maintenance of infrastructure and operation. For groundwater, sanitation taxes over half of the extraction concession is applied.

As can be seen from figure 12 in most municipals a progressive batch water rate has been implemented. It is also important to point out that substantial differences in prices exist, which implies more a pricing policy frequently subject to political decisions and electoral debate, more than the real costs.

Besides, the drinking water supply price usually includes a fixed service quota which includes infrastructure use and maintenance and a variable consumption quota. The water bill also includes sanitation taxes. For all island a tax is applied in the water bill for wastewater collection and treatment services. The levy consists of a fix quota of 2.75€/month and a variable consumption quota of 0.07€/m^3 calculated on the basis of the drinking water supply.

Water price for domestic, industrial and commercial users are set by each municipal on the basis of a municipal rate. When the service is offered by a private or public company the final price is negotiated between the company and the city council and has to be authorised by the *Comisión de Precios* (Price Commission), which regulates the prices for public utilities being under monopoly.

A lack of the system is that new consumer-price negotiations never consider a revision of the last negotiation agreement in order to study the previous predictions and control the profits. This has allowed municipal enterprises such as EMAYA and CALVIA2000 to make big profits by overestimating their predicted requirements of expensive desalinated water achieving a high water price, thus big revenues and stressing the cheap water resources.

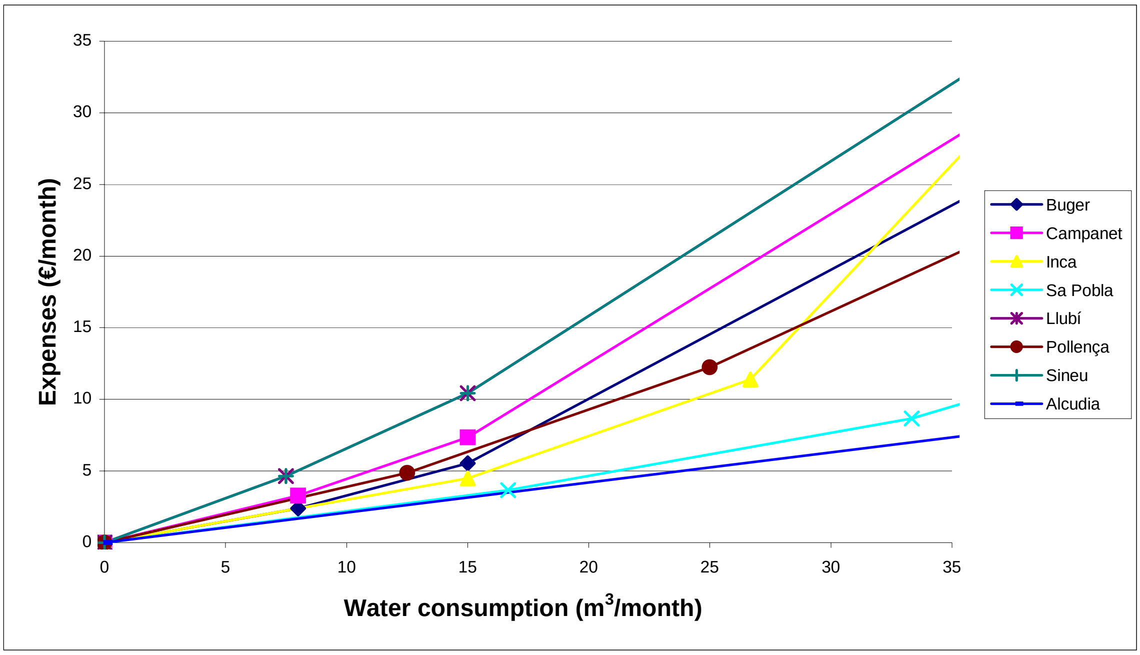

Figure 12: *Comparison of water prices for some municipalities of the hydrogeologic unit* UH18.11.

Also, no regulation exists regarding the price set by enterprises for bulk water supply. This has generated situations when a distribution company buys bulk water quantities at expensive rates from a collided enterprise, and may thus negotiate a higher price for consumers by adding high costs of production/purchase.

The *IBAEN* manages some sources of bulk water supply *(Bahía de Palma* desalination plant and wells of *Llubí)* and sells this water to EMAYA and CALVIA2000 that supply *Palma* and the tourist area of the *Calvià* municipal respectively. IBAEN sells the water from desalination plants at real costs, without including the investment cost as for the desalination plants paid by the Central Government, however are included when the Balearic Government made the investment. The cost of the water transferred from the *Llubí* wells, located within the *Inca-Sa Pobla* Hydrogeologic Unit was negotiated and fixed over several years according to an agreement between *IBAEN* and the water supply companies.

Among the majority of the stakeholders interviewed during the project, the idea of an island-wide homogeneous price for bulk water supply to be managed by a public company or institution was highly favoured.

Water for agricultural use is not subject to pricing as farmers obtain it from their individual well. The cost of extraction mainly depends on the depth of the water table and the price of electricity. The irrigation community of the *Pla de Sant Jordi* gets treated wastewater of the *Palma* II treatment plant for free.

Water pricing for the industrial sector related to the municipal water supply is subject to negotiations between the supplier and the industries and to final approval by the *Comisión de Precios*. Unofficial negotiations between the water supply companies and some individual industries, however, are thought to take place.

1.5.3 Informal, traditional social arrangements

Nowadays, the already existing traditional social arrangements for water use should have been transformed into registered water rights under the Special Regime on Water Management, the latest when Water Act 29/1985 was applied. Although most of the highly productive wells have been regularised, there are still a large amount of traditional water uses that have neither been registered in the *Inventory of Private Water Uses of the Watershed* nor in the public *Water Register*.

1.5.4 Taxes and subsidies

1.5.4.1 Taxes

A 7% VAT tax is added to the consumption-variable-quota of the water services and a 16% VAT tax is paid over the fixed-services-quota of the water services.

1.5.4.2 Subsidies

A budget has been granted by the Central State as well as the Autonomous Government for building infrastructure for municipal water supply and sanitation services. There are no subsidies foreseen at the consumer level. There are no subsidies on water services for the agricultural sector. Regarding irrigation with treated wastewater the Ministry of Agriculture, the Autonomous Government and EMAYA made investments for the cost of construction, treatment and distribution to the farms. An average price of 0.2€/m^3 is applied to hotels and golf courses for treated wastewater supply.

In the past there have been some subsidies available for the agricultural sector to improve irrigation practices. EU subsidies also exist, sometimes rendering profitable to the farmer an unprofitable crop and thus, leading to the selection of non-water-efficient agricultural management and even to the waste of water.

1.5.5 Other economic, political and social instruments

In recent years the hydraulic administration of the Balearic Islands has promoted diverse initiatives to educate the population with regards to water resources, in order to encourage water saving and participation in water management. Some of the most important actions have been:

a) *L'ecoauditoria de l'aigua al teu centre educatiu. Compte cada gota, cada gota compte*: a project to foster education in water resources at the Balearic Islands school level. As a final result, diverse materials for teachers and students have been developed (http://dgrechid.caib.es/ecoauditoria/inici.ct.htm),
b) *Forum de l'Aigua*: project to encourage the participation of all society sectors to discuss and define policies for the management of water resources on each specific island. (http://www.caib.es/govern/sac/fitxa.ct.jsp?fitxa=15911&coduo=209) *and*
c) *El agua vale mucho, aprecia el agua:* Campaign launched during the severe drought of the late 1990's to rise public awareness and promote water saving attitudes (http://dgrechid.caib.es/estalvi/agua.html)

1.6 Institutional framework, constraints and plans

Institutions and authorities involved in the different management tasks of the island's water resources are indicated in the following:

- water supply: regional, island level, Health Ministry, Water Works Ministry, *Dirección General de Recursos Hídricos* / General Directorate of Water Resources (regional), municipalities,
- wastewater: Municipalities, Balearic government through IBASAN (public enterprise),
- crops, agrochemicals: Ministry of Agriculture,
- waste water dumping control: General Directorate of Water Resources (regional),
- aquifer protection: General Directorate of Water Resources (regional),
- wetland protection: General Directorate of Water Resources (regional) *and*
- floods: *Dirección General de Uso y Planificación del Territoriol* / General Directorate of Land Management and Planning).

The Government of the Balearic Islands is the only one responsible for agricultural water management, however, there are no specific regulations regarding use of water. The Ministry of agriculture is in charge of crops management and use of agrochemicals without little implication in water resources. The main water problems faced on Majorca rely on the presence of pollution caused by agricultural activities, aquifer overexploitation and seawater intrusion. The main constraints are given in table 5.

Table 5: *Constraints facing the water sector.*

Natural	• Irregular distribution of reserves. • Irregular distribution of precipitations (spatial and temporal): There is more precipitation in the mountains and less on the coast where at the same time the demand is higher.
Man-Made	• Irregular distribution of population that is concentrated in big cities and coastal areas. • Irregular arrival of tourists (spatial and temporal) concentrated in certain areas. • Important allocation of water for irrigation. • Groundwater pollution by agricultural activities and salinisation.

The *Plan Hidrológico de las Islas Baleares* (1999) Hydrological Plan of the Balearic Islands aims at:

1) defining the available resources for sustainable exploitation,
2) ensuring the quantity and quality of the water available for urban supply,
3) avoiding the risks that might derive from an inadequate distribution of resources by different sectors to attend water demand,
4) promoting less water consumption and political and technical means to provide incentives to water-saving strategies and to penalize overuse,
5) ensuring water resource protection of natural good quality, reserving specific zones for urban supply,
6) enforcing a maximum reuse of wastewater within the limits of economic rationality and sanitary requirements,
7) controlling and rationalising the exploitation of hydrological systems and in particular, defining rules accordingly,
8) improving the supply guarantee by increasing the available resources,
9) defining the enactment rules and civil works necessary to prevent and slow down the potential damage due to floods or drought situations *and*
10) defining the enactment rules necessary for a complete environmental conservation related to hydrological patterns.

1.7 Management, institutional and policy options

The most important development priorities, conflicts, measures and management strategies are the following:

- a conflict of interests exists as a result of scarce water resources, especially between agriculture and other uses (e.g. tourism, domestic supply),
- water management and water reuse are the main issues,
- as agriculture is the main water user, management strategies are directed to convince farmers of using treated wastewater and to reduce consume *and*
- there is a general interest to sustain the traditional agricultural activities in order to maintain the land-use management and environment, although no specific programmes and incentives are applied.

The only administrative authority responsible for water management is the regional autonomous government. The priorities for water allocation according to the PHIB (1999) in case of water scarcity are as follows:

- drinking water supply to residents and tourist population, including low-consuming industries connected to the municipal network,
- animal husbandry and irrigation of farms up to 2 10^{-3}km^2 ,
- irrigation and other agricultural uses,
- industrial use not included in a.),
- leisure including golf courses,
- artificial recharge of aquifers,
- aquaculture *and*
- other uses.

Until now, the Hydraulic Administration has never intervened the existing water concessions.

1.8 Agricultural situation

Agriculture and animal husbandry have been declining in importance throughout the last decades. The contribution of this sector to the GDP of the Balearic Islands has declined from 8.1% in 1970 to 1.7% in 1996 (rates are similar for the main island of Majorca). Similarly, the working population has fallen from 16,000 in 1987 to 6,900 in 1996, and at the same time getting older, thus 55% of the farmers were more than 55 years old in

1996. The traditional small size of the farms and the improvement of communications have been the main factors rendering farming to become a secondary job. Animal husbandry has been of minor importance and is sharply decreasing due to the important production costs and low market prices. Regardless of the above-mentioned evolution, it is still considered a crucial sector within the economy of the Balearic Islands (PHIB, 1999).

1.8.1 History of irrigated agriculture in Majorca

There are no ancient remains indicating the presence of irrigated agriculture in Majorca during the Roman times. Although irrigated agriculture was likely to exist at an early period in history, it is especially during the Muslim period that irrigation schemes were developed. During the Middle Ages Islamic canalisation was used both, for domestic purposes and irrigation, even at that time giving rise to conflicts of interest between different user groups (PHIB, 1999).

During the late eighteenth century, drainage projects in the marshy zones of *Pla de Sant Jordi* and *Albufera de Alcudia* (the latter is part of the *Inca-Sa Pobla* Hydrogeologic Unit) were undertaken. Nevertheless, the drained land was only used for agriculture to a small extent due to high soil salinity. Since the nineteenth and twentieth century, there has been a renewed and constant development of irrigated agriculture, mainly as a result of technological progress that allowed extraction of larger quantities of groundwater at lower costs (PHIB, 1999). In the beginning, the construction of large diameter wells to extract water was done with animal force. In the second half of the nineteenth century, windmills were used. In 1914 the first explosion engine connected to a hydraulic pump was installed in *Sa Pobla* (part of the *Inca-Sa Pobla* Hydrological Unit). Gas and petrol engines were gradually replaced by submergible electric pumps during the second half of the twentieth century. A growing economic activity triggered by a rising tourist industry also explains the crucial development of irrigated agriculture that took place during the 1960s and 1970s (figure 13). Since the 80s there has been an inversion of the previous trend, with a steady decrease of the irrigated land surface taking place parallel to the Common Agricultural Policy. Both, market conditions producing a shift of the labour force to the tourist sector and increased water costs, are some of the factors that may account for this change. Since the 1990s many of the former farms have been transformed and turned into rural residences, i.e. people living there and making agricultural activities as a secondary job (mainly fruit trees and vegetable gardens) or carrying out a complete refurbishment into second residences for leisure.

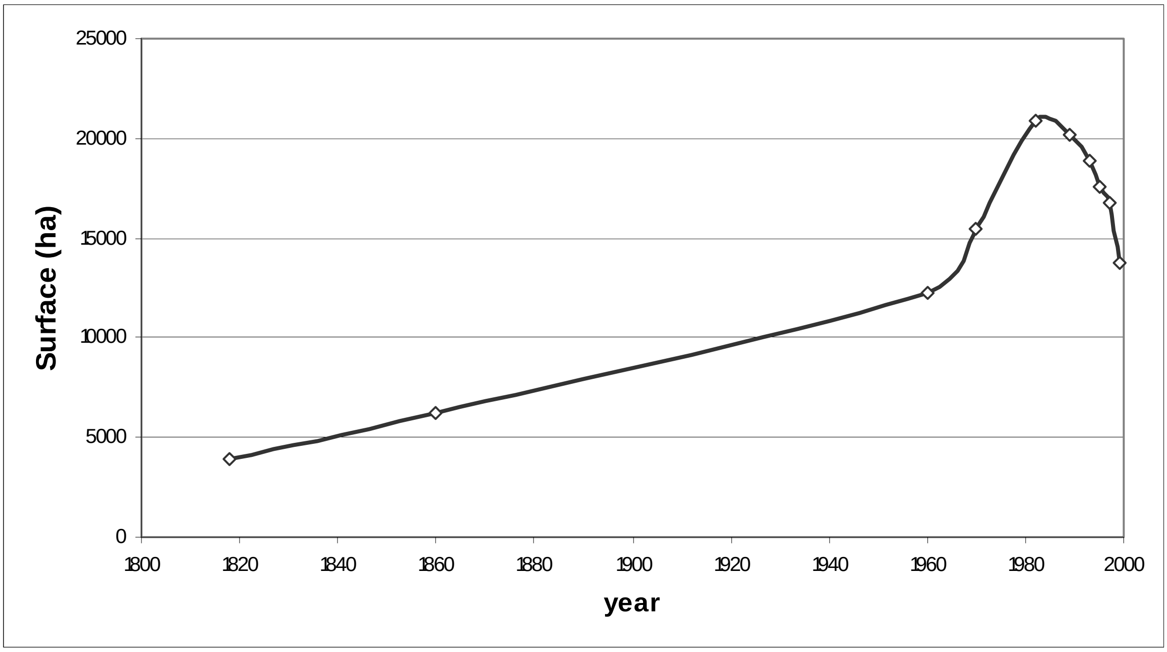

***Figure 13**: Development of the surface of irrigated agriculture on Majorca in the nineteenth and twentieth century, (PHIB, 1999; Santarrufina, 2001).*

1.8.2 Land used for agriculture

The total agricultural surface of Majorca is 2,862km², the agricultural land accounting for a total of around 1,775km² (Cens Agrari, 1999). In the PHIB (1999), the total agricultural surface of Majorca was estimated to be of 2,205km². Table 6 shows the total cultivated area divided into arable areas (herbaceous crops and fruit tree crops) and pasture. Further detailed information is presented in tables 7 and 8.

***Table 6:** Agricultural land uses in Majorca, (Cens Agrari, 1999).*

Total Agricultural Surface (TAS)	**2,862.53** [km²]	**100%**
Agricultural Land	1,775.70	**62%** of TAS
• **Arable Area**	1,554.50	
Herbaceous Crops	956.67	
Fruit tree crops	597.83	
• **Pasture**	221.20	
Permanent pasture	13.34	
Other pasture	207.86	
Forest Land	**560.86**	**19.6%** of TAS
Other Lands	**525.97**	**18.4%** of TAS

***Table 7**: Herbaceous crops, (Cens Agrari, 1999).*

Type of herbaceous crop	Total surface [km^2]
Grain cereals	542.1
Wheat	85.8
Barley	216.9
Oat	220.2
Rice	0.06
Indian wheat	2.12
Other grain cereals	0.017
Industrial crop	1.73
Sunflower	0.46
Other industrial crops	1.27
Forrage crops	206.2
Alfalfa	29.3
Forrage pulses	15.5
Green forrage	2.9
Other annual greens	154.7
Other forrage crops	3.8
Pulses	20.7
Potatoes	13.9
Vegetables	24.9
Other herbaceous	0.74

***Table 8**: Fruit tree crops, (Cens Agrari, 1999).*

Type of fruit free tree corp	Total surface [km^2]
Citrus	22.5
Orange tree	19.8
Mandarin tree	0.5
Lemon tree	1.7
Other citric trees	0.48
Olive tree	81.8
Fruit tree	26.4
Apple tree	1.7
Pear tree	0.8
Apricot tree	3.8
Peach tree	1.8
Fig tree	16.5
Other temperate climate trees	1.69
Subtropical tree	0.3
Nut tree	335.5
Almond tree	335.3
Other dry fruit tree	0.2
Vineyard	9.01
Other trees	122.2

There has been a progressive reduction in the number of plots from 41,421 in 1972 to 15,209 in 1999 representing a decrease of more than 60%. Table 9 also shows the reduction of plots extension along time; more than 60% of the plots in the cultivated areas have less than 0.05km². Table 10 shows the reduction in herbaceous crops cultivation since 1996, whereas the surface allocated for tree crops has remained rather constant throughout the years.

Table 9: *Temporal development of the number and size of plots on Majorca, (Cens Agrari , 1999).*

Number of plots	1982	1972	1989	1999	1999 [%]
Majorca total	22,296	41,421	22,695	15,209	100
≥0.1 to <1 *10^{-2} km^2	4,673	12,880	6,348	3,379	22.2
≥1 to <5 10^{-2} km^2	9,373	19,161	9,305	5,906	38.8
≥ 5 to <10 10^{-2} km^2	3,463	4,892	2.966	2,281	15
≥ 10 to < 20 10^{-2} km^2	2,168	2,328	1,790	1,504	9.9
≥ 20 to < 70 10^{-2} km^2	1,539	1,254	1,323	1,373	9
≥ 70 to < 100 10^{-2} km^2	532	407	469	238	1.6
≥ 100 to <200 10^{-2} km^2	314	374	267	277	1.8
≥ 200 10^{-2} km^2	234	125	227	251	1.7

Table 10: *Variation of the cultivated area according to crops from 1996 to 2001, (http://www.caib.es/ibae/reco/xif/cat/pag66.pdf).*

Crops	1996	1997	1998	1999	2000	2001	% var 01/00	% var 01/96
Grain cereals	336.11	341.20	344.44	329.47	240.27	312.72	30.15	-6.96
Pulses	20.79	21.15	8.45	20.98	22.08	18.35	-16.89	-11.74
Tubers for human consumption	28.60	29.30	29.00	31.70	31.60	31.60	-	10.49
Industrial Crops	1.66	2.66	1.95	0.10	0.81	0.81	-	-51.20
Flowers and ornamental plants	2.12	2.11	2.15	1.00	0.38	0.38	-	-82.08
Forage crops	398.87	311.77	281.21	396.88	420.08	277.99	-33.82	-30.31
Vegetables	65.67	66.04	70.84	73.01	72.63	74.81	3.00	13.92
Total herbaceous crops	**853.82**	**774.23**	**738.04**	**853.12**	**787.85**	**716.66**	**-9.04**	**-16.06**
Citrics	33.19	33.19	33.19	33.19	32.19	32.19	-	-3.01
Fruit	747.51	762.21	762.59	736.57	736.92	744.92	1.09	-0.35
Grapes	14.39	15.74	15.67	17.63	12.87	13.44	4.43	-6.60
Olive Trees	84.38	82.00	82.00	82.00	81.73	81.73	-	-3.14
Other crops	147.63	152.05	152.05	152.05	146.52	146.52	-	-0.75
Total fruit tree crops	**1027.10**	**1045.19**	**1045.50**	**1021.44**	**1010.23**	**1018.80**	**0.85**	**-0.81**
General total	**1880.92**	**1819.42**	**1783.54**	**1874.58**	**1798.08**	**1735.46**	**-3.48**	**-7.73**

* *Conselleria d'Agricultura i Pesca. Govern des Illes Balears. (Department of Agriculture and Fisheries. Government of the Baleraric Islands).*

1.8.3 Irrigated agriculture in Majorca

The present surface area under irrigation in Majorca is estimated to be between 160 and 200km² according to different sources (table 11), which corresponds to approximately 10% of the total available agricultural land of the island. The agricultural census of 1999 estimated that only 137.48km² were irrigated (INE, 2002). This difference emerges from water scarcity prevailing at that time due to a drought during the previous years.

***Table 11**: Surface of irrigated agriculture in Majorca.*

	PHIB	INE
Irrigated surface [km²]	195.18	169.83 irrigable 137.48 irrigated

PHIB, Govern de les Illes Balears, 1999. Data for 1996
INE, Censo Agrario, 1999 (2002).

According to the data from the *Plan Nacional de Regadios* (PNR, 1999)/National Irrigation Plan, 134Mm³/yr are used in Majorca to irrigate 184.78km², which corresponds to a mean allocation of 725,000m³/km²/yr (PNR, 1999). Currently 137.5km² are irrigated. If 725,000m³/km²/yr are applied, on average 99.67Mm³/yr of water for irrigation is obtained. Additionally, water used for golf course and park irrigation estimated as 14Mm³/year, has to be added to this amount (PHIB, 1999). Figure 14 shows the spatial distribution of irrigated areas on Majorca.

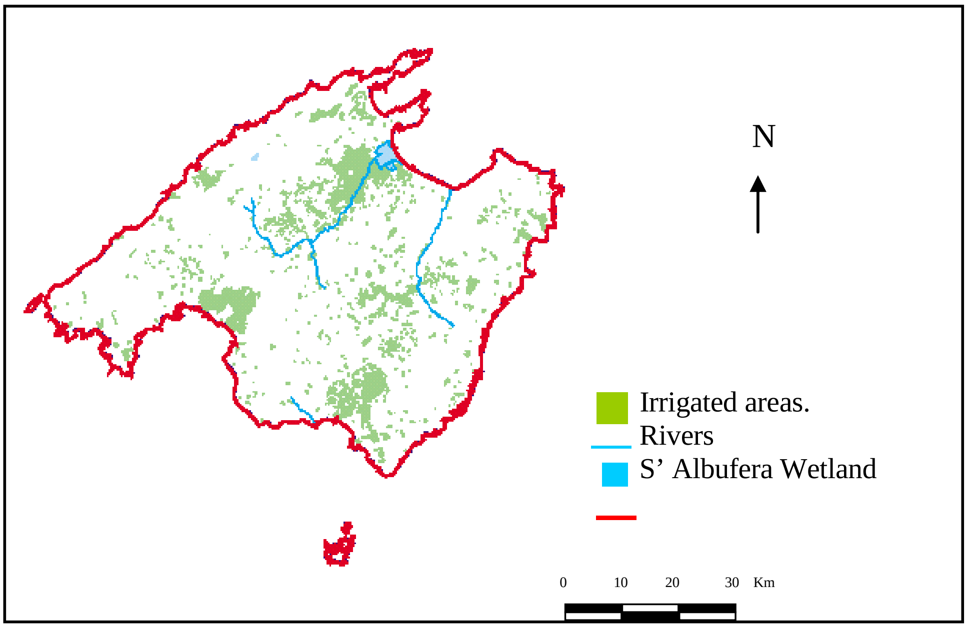

***Figure 14**: Spatial distribution of irrigated areas in Majorca, (modified from http://www.mapya.es/desarr/pags/pnr/eps/mapa39baleares.pdf).*

1.8.4 Water use, sources and quality

For political reasons, the total water used for irrigated agriculture in Majorca was slightly overestimated in the Hydrological Plan of the Balearic Islands (A. Rodríguez, 2004, pers. comm.). Therefore water use is more likely to be 101.2Mm^3/year (Santarrufina, 2001) than 150.2Mm^3/year (PHIB, 1999). The majority is of groundwater origin extracted from private boreholes located on farms. Only 14.2Mm^3/year (12.8Mm^3/year according to Santarrufina, 2001) correspond to treated wastewater reuse mainly in the south-eastern region of *Pla de Sant Jordi*, where around 10.5km^2 are irrigated.

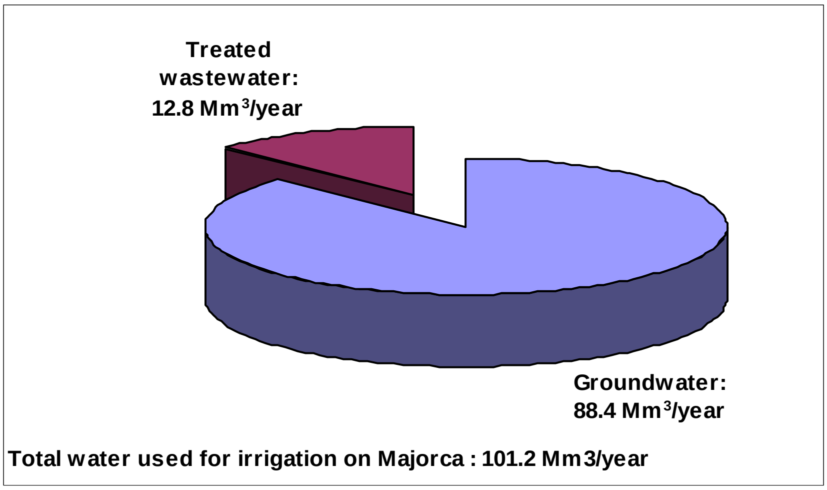

***Figure 15**: Source of water for irrigated agriculture in Majorca, (Santarrufina, 2001).*

Table 12 shows the type of irrigation water for Majorca and the irrigated surface area by the different sources and figure 16 depicts the origin of the irrigation water used and the irrigated areas within the municipalities.

***Table 12**: Origin of irrigation water, (Cens Agrari, 1999).*

Origin of irrigation water	Total surface [km^2]	% of the total irrigated surface
Groundwater	123.58	90.0
Surface water	5.08	3.6
Treated water	7.83	5.7
Desalinated water	0.99	0.7

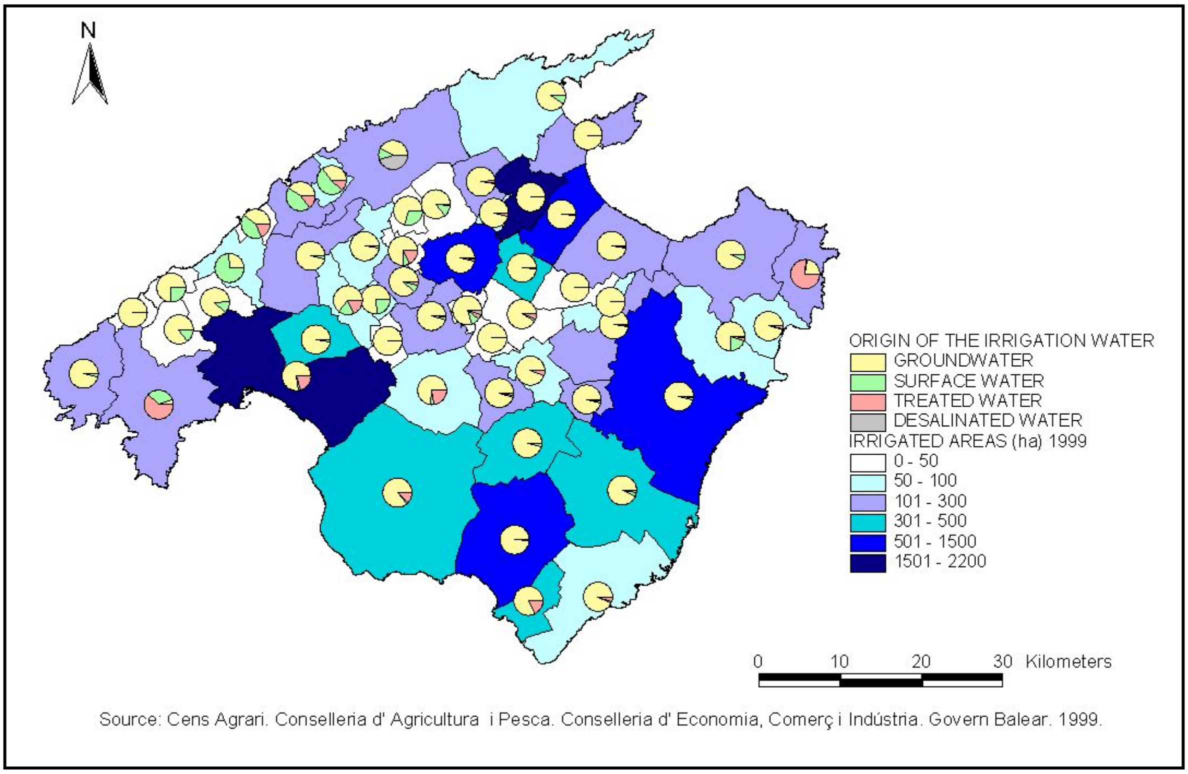

Figure 16: *Sources of irrigation water and irrigated surface in the different municipalities.*

As the irrigated surface of Majorca has recently decreased, it has led to a reduction of the abstracted water. As well, the improvement of irrigation methods has reduced these abstractions: e.g. replacement of subsurface irrigation by sprinklers and in some cases by dripping. In addition many summer crops have lately been replaced by winter and spring crops.

Irrigation efficiency is estimated between 0.8 and 0.9 while in saline areas is 0.7. Water losses estimated by the *Balearic Hydrological Plan* (PHIB, 1999) are of about 21.9Mm^3/yr, which represent 10-20% of the irrigation water losses. 90% of the water used for irrigation comes from wells.

The quality of irrigation water depends on the geological nature of the aquifers, which are of Mesozoic and Tertiary calcareous formations and Tertiary and Plioquaternary detrital formations (figure 7). The calcareous aquifers (*Costa de Llevant*, the *Marineta* Unit) show very high transmissivity rates and are connected to the sea. Water in the calcareous and detrital units of the Tertiary and Plioquaternary presents variable salinity (*Llanos Centrales* and coastal zones). The limestone formation usually displays calcium bicarbonate waters with low salinity.

Due to the intense water demand and significant agricultural activity in the coastal aquifers, overpumping has produced seawater intrusion creating high concentrations of sodium chloride. This phenomenon is observed in the *Llano de Palma, Campos Depression, Serra de Na Burguesa* and the surroundings of *Calvià*.

The water quality of the detrital aquifers has changed due to the presence of diffuse nitrate pollution emerging by excessive fertilizer application in agriculture and from liquid urban spills (sewage system and septic tanks). In many points of the island, values of up to 50mg/l and more can be detected, except in the mountainous areas, where agricultural activities do not exist. In irrigated zones with high nitrogen application, values of nitrate exceed 100mg/l and even 250mg/l. Areas with greater problems of nitrate concentration are *Sa Pobla- Muro* (selected catchment), *Llucmajor-Campos, Sant Jordi* (Palma Plain), *Manacor* and some points located in the eastern part of the island.

Coastal aquifers suffer especially from seawater intrusion caused by overpumping. The main affected areas are located in *Pla de Sant Jordi* (Palma Plain); *Llucmajor- Campos* (*Ses Salines), Marina de Llevant*, Coastal Zone of *Son Servera* and *La Marina*, *Calvià* and *Na Burguesa*.

1.8.5 Cultivated crops

The main crops cultivated on Majorca are shown in figure 17. Figure 18 depicts the subcategories (crop distribution): grain cereals (38.5% of the total cultivated area) followed by nut trees, (almonds 23.8% of the total cultivated area) and forrage crops (14.6% of the total cultivated area).

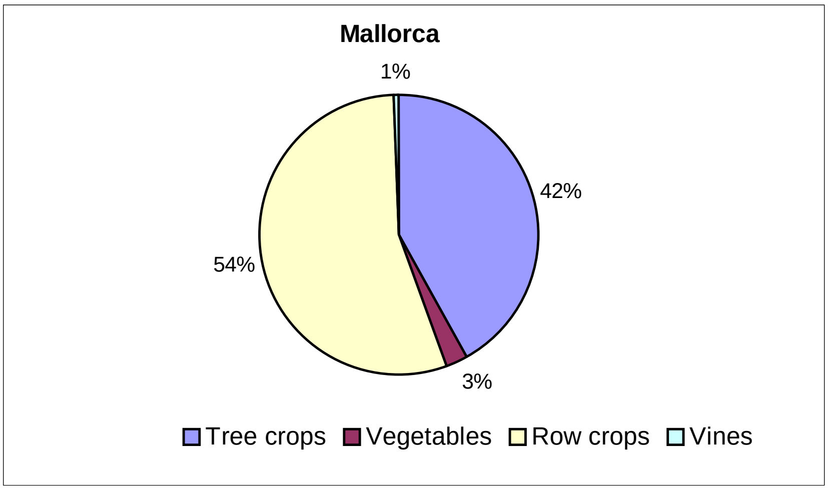

Figure 17: *Main crops of Majorca.*

The main irrigated crops and the extension area are shown in tables 13 and 14 according to data from the PHIB (1999) and the Cens Agrari (1999) respectively.

Table 13: *Principal irrigated crops of Majorca, (PHIB, 1999).*

Crops	Surface [km^2]	% of irrigated land
Cereals	7.16	3.7
Fruit tree	5.26	2.7
Citrus tree	19.99	10.2
Vegetable	38.52	19.7
Tuber (2nd harvest)	20.62	10.6
Fodder	100.02	51.2
Pulse	1.34	0.7
Industrial crops	2.27	1.16

Table 13 indicates that fodder crops, vegetables, tuber (2nd harvest) and citrus trees occupy the largest part of the irrigated land.

Table 14: *Principal irrigated crops, (Cens Agrari, 1999).*

Crops	Surface [10^{-2} km^2]	% of irrigation land
Cereals	2,886	21.0
Industrial crops	148	1.1
Forage crops	2,943	21.4
Pulses	158	1.1
Potatoes	1,385	10.1
Vegetable	2,203	16.0
Other herbaceous crops	172	1.3
Citric	2,252	16.4
Olive trees	98	0.7
Fruit trees	432	3.1
Subtropical trees	30	0.2
Nut trees	739	5.4
Vineyards	159	1.2
Other trees	143	1.0

Table 14 shows a slightly different distribution, however forrage crops occupy the largest part of irrigated land in both cases. They are followed by cereals, citrus trees, vegetables and potatoes. Water allocation for the different types of crops in Majorca is shown in table 15.

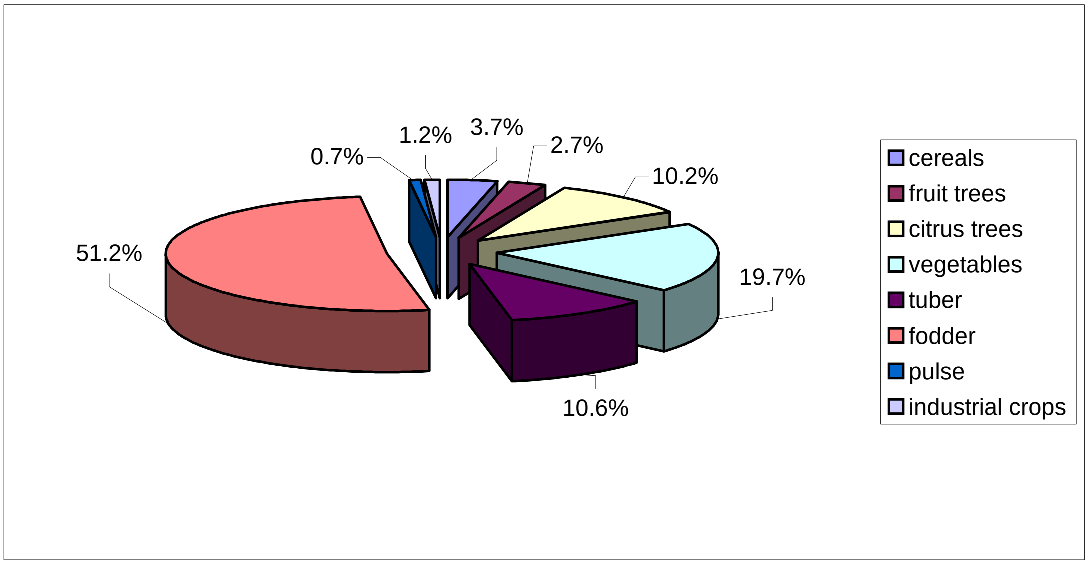

***Figure 18**: Surface extension of the main irrigated crops of Majorca.*

According to table 15 the highest water consumers are fodder crops (60.8%), vegetables (17.5%), potatoes (9.4%) and citrus trees (8.3%). Pulses show a large demand for irrigation water (600,000m³/km²) but only occupy a small part of the irrigated land (1.34km²). The portion of agricultural water consumed by each crop is well illustrated in figure 19. Total amount of water used for irrigation (101.2Mm³/yr), after Santarrufina (2001) correction, according to crops distribution can be observed in figure 18.

***Table 15**: Water allocation for the different types of crops in Majorca, (DGOH, 1994; PHB, 1999).*

Crops	Irrigated area [km²]	Allocation [m³/km²/yr]	Water consumed [m³/yr]	Share of agricultural water [%]
Cereals	7.16	150,000	1,074,000	0.81
Fruit tree	5.26	500,000	2,630,000	2
Citrus tree	19.99	550,000	10,978,000	8.3
Vegetable	38.52	600,000	23,112,000	17.5
Potatoes (2nd harvest)	20.62	600,000	12,372,000	9.4
Forage	100.02	800,000	80,016,000	60.8
Grain Pulse	1.34	600,000	804,000	0.6
Industrial crops	2.27	300,000	681,000	0.52

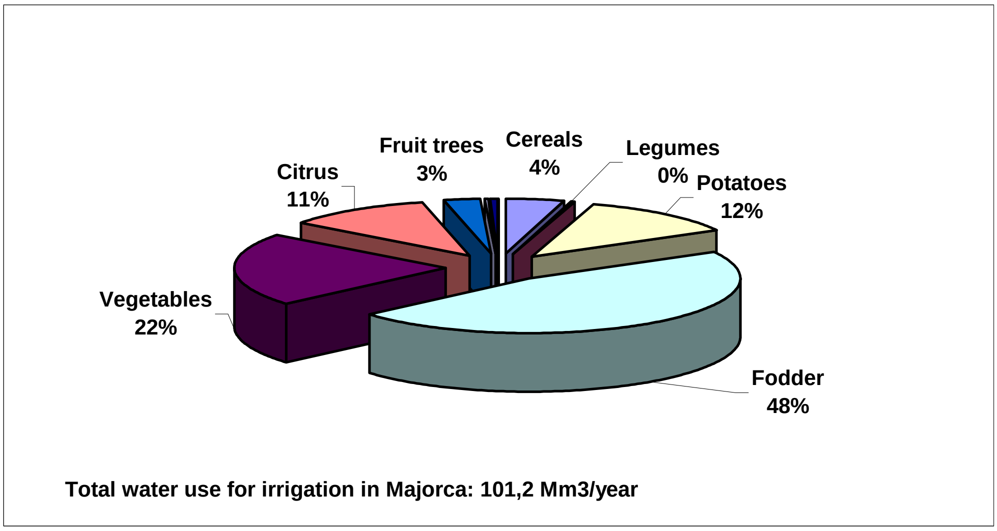

Figure 19: *Fraction of total water used per crop in irrigated agriculture for Majorca (data from Santarrufina, 2001).*

In more detailed form, table 16 shows the major herbaceous and fruit tree crops from irrigated and non-irrigated land respectively (based on a total of 195km² of irrigated land). The herbaceous crops occupy a total surface of 956.64km² of which 90% are in non-irrigated areas. The total surface occupied by fruit free trees is 597.84 km²; 94% are in non-irrigated areas (table 16).

Table 16: *Herbaceous and fruit free tree crops in Majorca from irrigated and non-irrigated land, (Cens Agrari, 1999), (THC: Total herbaceous crops, TFT: Total fruit trees, TAS: Total agricultural surface).*

Crops	Type of crops	Total surface [km²]	Crops in non-irrigated areas [km²]	Crops in irrigated areas [km²]
Herbaceous crops 956.66km² 62% of TAS*	Grain cereals (57% THC)	542.10	513.24	28.86
	Wheat	85.83	77.83	8.00
	Barley	216.86	209.29	7.57
	Oat	220.22	210.31	9.91
	Rice	0.06	0.00	0.06
	Indian wheat	2.12	0.07	2.05
	Other grain cereals	17.01	15.75	1.27
	Industrial crops (0.2% THC*)	1.73	0.25	1.48
	Sunflower	0.46	0.12	0.34
	Other Industrial Crops	1.27	0.13	1.14
	Forrage crops (21.5% THC)	206.24	176.81	29.43

Table 16 continued.

Crops	Type of crops	Total surface [km²]	Crops in non-irrigated areas [km²]	Crops in irrigated areas [km²]
Herbaceous crops 956.66km² 62% of TAS*	Alfalfa	29.32	7.80	21.51
	Forrage pulses	15.49	15.19	0.30
	Green forrage	2.89	2.10	0.78
	Other annual greens	154.70	148.35	6.35
	Other forrage crops	3.82	3.34	0.49
	Pulses (2.2% THC)	20.72	19.14	1.58
	Potatoes (1.5% THC)	13.93	0.08	13.85
	Vegetables (2.6% THC)	24.90	2.87	22.03
	Flowers and ornamental plants (0.1% THC)	1.08	0.09	0.99
	Seeds (0.002% THC)	0.02	0.00	0.02
	Fallow (15% THC)	144.61	144.61	0.00
	Orchards (0.06% THC)	0.59	0.00	0.59
	Others (0.08% THC)	0.74	0.62	0.12
Total fruit tree crops 597.84km² 38% of TAS	Citric trees (3.8% TFT)	22.52	0.00	22.52
	Orange trees	19.78	0.00	19.78
	Mandarin trees	0.52	0.00	0.52
	Lemon trees	1.74	0.00	1.74
	Other citric trees	0.48	0.00	0.48
	Olive trees (13.7% TFT)	81.76	80.78	0.98
	Fruit trees (4.4% TFT)	26.35	22.03	4.32
	Apple tree	1.74	0.74	1.00
	Pear tree	0.81	0.50	0.31
	Apricot tree	3.83	3.24	0.59
	Peach tree	1.76	0.22	1.54
	Fig tree	16.52	16.40	0.12
Total fruit tree crops 597.84km² 38% of TAS	Other temperate climate trees	1.69	0.93	0.76
	Subtropical climate trees (0.05% TFT)	0.30	0.00	0.30
	Nut trees (56% TFT)	335.51	328.12	7.39
	Almond trees	335.31	327.94	7.38
	Other dry fruit trees	0.20	0.18	0.01
	Vineyards (1.5% TFT)	9.01	7.42	1.59

1.8.6 Irrigation methods

According to the agricultural census of 1999, of the 137.48km^2 irrigated in Majorca 52% were irrigated by sprinklers, 33% through localised irrigation methods, 13% by gravity methods and the rest by other types (Cens Agrari, 1999). These figures indicate that rather efficient irrigation systems are in place. The return flows from irrigation that recharge the subsurface water bodies are estimated to be 21.9Mm^3 (PHIB, 1999). This indicates that less than 15% of the applied irrigation water undergoes deep infiltration.

***Table 17**: Irrigation methods (Cens Agrari, 1999).*

Irrigation methods	Total surface [km^2]	% of the total irrigated area (Majorca)
Sprinkler	71.81	52
Drip Irrigation	45.29	33
Subsurface Irrigation	18.45	13.5
Other	1.92	1.5

1.8.7 Social aspects

After the agricultural census of 1999, the average size of a farm was 0.117km^2, with 96% of the farms (64% with regard to the surface) being exploited by the owners. The working force on the farms consisted of 75% family members and 25% external labour force (Cens Agrari, 1999). Throughout April and May of 2004, a set of interviews with different sector representatives was performed. During these interviews it was often raised the difficulty for the agricultural sector to stop the labour force from moving to the tourist sector, which is much more appealing to young people and offers better salaries and fixed working hours. As a consequence, this has lead to an aging of the agricultural sector population.

1.8.8 Water user groups and institutions

As mentioned above, due to the scarcity of surface water, irrigated agriculture in Majorca has been based on groundwater resources.

Groundwater ownership used to be linked to the land and thus, had a long tradition of private ownership until 1985. Traditionally, in Majorca wells constructed for irrigation purposes were a result of private entrepreneurship, so each farm had its own well resulting in thousands of constructed wells widely distributed. Hence, there was very little need for the creation of *Comunidades de regantes* (Irrigation Communities), a legal self-regulating management institution for irrigation practices among others, as had already been common in mainland Spain. An exception is the *Comunidad de Regantes del Pla de Sant Jordi*, where irrigation was made with reclaimed wastewater from the treatment plant of Palma. The community manages the irrigation network mainly of fodder crops established in the 1970s, nowadays extending over 10.50km². There are some other minor irrigation communities sharing water from springs.

In the Sa Pobla plain there are two agricultural cooperatives (*S'Esplet* and *Illacamp*) composed by some 70 farms each. These cooperatives have lately turned into a new legal body called *Sociedad Agrícola de Transformación* (SAT) having a private company legal status with limited shareholders (proportional to the land owned). Both entities mainly focus on growing potatoes for export. From an official point of view they are not involved in policy making, but their contribution is to directly provide advice the farmers union.

Large agricultural businesses are not common in Majorca, although market conditions have favoured the rise of large-scale enterprises. Yet, only a few farmers have been able to gather bigger amounts of land under their management, whereas in the trading sector some enterprises have prospered by buying the local farmers production and selling it for export. In the study area the main companies are *Mateu Uco, Viuda Antoni Serra* and *Matutano*. Owners of agricultural businesses also lobby their opinions and demands mainly through a farmers union, but also directly by the Autonomous Ministry of Agriculture.

The *Comunidad de usuarios de aguas subterráneas* (Groundwater Users Community), is a legal body created by the Water Act 29/1985 that allows the association of all extraction permit owners of a given groundwater body in order to self-regulate the management of the resource. In the mid-1990s, there was an attempt to create a users community by the farmers of *Llubí* (located within the MEDIS case study catchment), as a response to the proposal of new well field developments in the area for the Palma supply. Although it has been formally constituted (*Comunidad de Usuarios del Camí Vell de Muro*) reaching agreements among all water-permit owners (agricultural, tourist and governmental sector), so far it has not been activated.

Two farmer unions (*Unió de Pagesos* and *Asociación Agraria Jóvenes Agricultores)*, lobbying for agriculture have a big impact on Majorcan politics representing the regional branches of nationwide unions. *Unió de Pagesos* is closer to the left-wing parties and nationalist, whereas *Asociación Agraria Jóvenes Agricultores* is closer to right-wing parties.

For social and land planning reasons all governments, through the Autonomous Ministry of Agriculture, have traditionally been interested in maintaining the agricultural activity of Majorca as a matter of inheritance. Despite the fact that the groundwater is highly polluted with nitrates, the government has slowly taken measures towards the improvement of the problem, such as the implementation of "good agricultural practices" in vulnerable zones declared following the European Directive 91/676/CEE.

1.8.9 Employment in the agricultural sector

About 2.3% of the active population of the island works in the agricultural sector, representing 1.5% of the GDP, however uses 65-70% of the total available water. Problems with livestock farming are mainly due to the high costs of production, for instance the costs for energy and fodder. At the same time, low product prices decreasing profitability and increasing competitiveness have led to the decline of livestock farming.

1.9 Socio-economic situation

In the following paragraphs, the most important statistical data and indicators for the socio-economic situation of Majorca are presented.

1.9.1 Social profile

1.9.1.1 Population

In 2001, the population density of Majorca was 185.8 persons per km², for all Spain 79 persons per km² in average During the summer months population can reach up to 1,013,713 inhabitants due to increased tourism which leads to an average seasonal mean of 819,523 inhabitants. As table 19 shows, population of the Balearic Islands has increased rapidly from 685,100 in 1981 to 916,968 inhabitants in 2003, showing a growth of 33.8%.

Table 18: *National population of Spain, in the region of the Balearic Islands and Majorca, (INE, 2004).*

	2003			**2001** (census)	**1991** (census)	**1981** (census)
	Both genders	Male	Female			
National total	42,717,064	21,034,326	21,682,738	40,847,371	38,872,268	37,682,355
Balearic Islands	947,361	474,248	473,113	841,669	709,138	655,909
Majorca island	753,584	375,834	377,750	676,516	568,065	534,511
Palma de Majorca	367,277	180,458	186,819	333,801	296,754	290,372

***Table 19**: Historical demographic data of the Balearic Islands province and capital Palma de Majorca.*

Year	Balearic Islands	Palma de Majorca
2003	916,968	-
2000	845,600	333,900
1999	821,820	326,993
1998	796,500	-
1996	760,400	304,300
1995	788,000	-
1991	709,100	325,100
1988	-	314,600
1986	754,800	321,100
1981	685,100	304,400

***Table 20**: Main demographic indicators, (INE, 2004).*

Birth rate per 1,000 inhabitants by Autonomous Community and Period Units: births per 1,000 inhabitants					
	1996	**1997**	**1998**	**1999**	**2000**
National total	9.23	9.30	9.26	9.59	9.91
Balearic Islands	10.64	11.05	11.04	11.50	11.92
Total fertility rate. National total and Autonomous Community Units: children per woman					
	1996	**1997**	**1998**	**1999**	**2000**
National total	1,166	1,180	1,160	1,198	1,231
Balearic Islands	1,346	1,392	1,386	1,433	1,471
Death rate per 1,000 inhabitants. National total and Autonomous Community Units: deaths per 1,000 inhabitants					
	1996	**1997**	**1998**	**1999**	**2000**
National total	8.95	8.88	9.14	9.37	9.00
Balearic Islands	9.26	9.41	9.41	9.64	10.13
Infant mortality rate per 1,000 births. National total and Autonomous Community Units: deaths of children under 1 year old per 1,000 births					
	1996	**1997**	**1998**	**1999**	**2000**
National total	5.54	5.03	4.86	4.47	3.88
Males	6.32	5.52	5.24	4.80	
Females	4.71	4.51	4.44	4.12	
	1996	**1997**	**1998**	**1999**	**2000**
Balearic Islands	5.77	2.57	4.57	4.29	3.08
Males	5.26	3.06	4.63	5.05	
Females	6.32	2.04	4.52	3.50	

Table 20 continued.					
Life expectancy at birth. National total and Autonomous Community Units: years					
	1996	**1997**	**1998**	**1999**	**2000**
National total			78.71		
Males			75.25		
Females			82.16		
	1996	**1997**	**1998**	**1999**	**2000**
Balearic Islands			77.92		
Males			74.46		
Females			81.46		

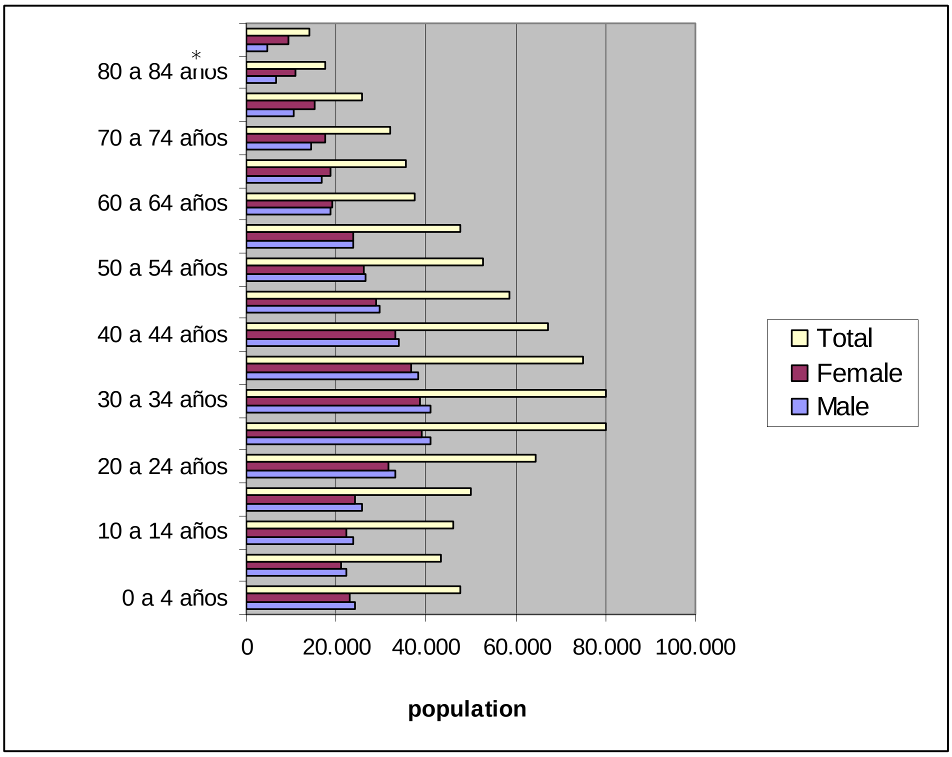

Figure 20: *Projections for the Balearic Islands population (31.12.2002) by age and gender, (INE, 2004). (*anos = years.)*

1.9.1.2 Family structure

Table 21: *Household size 2001, (INE, 2004).*

	Households	**Persons**	**Average household size**
National total	12,937,970	39,253,015	3.03
Balearic Islands	269,761	742,885	2.75

1.9.1.3 Education

Table 22: *Percentage of population over 16 years and reached level of education by gender. 2001 data, (INE, 2004).*

Education	Both genders		Male		Female	
	National	Balearic Islands	National	Balearic Islands	National	Balearic Islands
Illiterate	3.3	2.4	2.1	1.4	4.4	3.5
Primary education	38.1	35.8	35.8	32.8	40.3	38.6
Secondary education. First stage	23.2	28.7	25.3	31.7	21.2	25.7
Secondary education. Secondary stage	16.8	19.4	17.3	19.5	16.3	19.3
Education and working with high school diploma (second stage)	0.1	0.1	0.1	0.1	0.1	0.1
Higher Education, except doctorate	18.3	13.5	19.2	14.4	17.6	12.7
Doctorate	0.2	0.1	0.3	0.1	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table 23: *Primary education data for the academic year 1998-99, (INE, 2004).*

	Primary education [number of centres]			Mixes of Nursery and primary education [number of centres]			Number of registered students [number of students]		
	Total	Public centres	Private centres	Total	Public centres	Private centres	Both genders	Males	Females
Total National	116,816	82,683	34,133	3,048	3,004	44	2,562,785	1,323,188	1,239,597
Balearic Islands	2,255	1,423	832	13	13		55,600	28,691	26,909

Table 24: *Education by gender and academic year (secondary education: students registered in 98-99, for the forth year students graduated in 97-98), (INE 2004).*

	First year: 1st academic year		First year: 2nd academic year		Second year: 3rd academic year	
	Both genders	Females	Both genders	Females	Both genders	Females
Spain	457,946	222,389	545,517	256,625	577,366	280,818
Balearic Islands	9,476	4,590	11,328	5,262	11,465	5,478

Table 24 continued.				
	Second year: 4th academic year		Students who graduated after fourth academic year	
	Both genders	Females	Both genders	Females
Spain	309,176	158,562	187,501	102,578
Balearic Islands	7,552	4,074	4,994	2,929

***Table 25**: Students in Higher education; academic year 1999-2000, (INE 2004).*

	Total	Males	Females
Total Spain	1,587,055	741,708	845,347
Balearic Islands	14,272	5,909	8,363

In 2001-2002, a total of 95,351 students were enrolled in public schools, representing 64% of the total number of students. In all, 148,939 pupils were enrolled in public and private schools.

1.9.1.4 Health

***Table 26:** Health indices (2000), (INE, 2004).*

	Beds occupied by 10,000 inhabitants			Distribution of the beds [%]		
	Total	Public	Private	Total	Public	Private
National total	**40.80**	**27.56**	**13.24**	**100.00**	**66.67**	**33.33**
Balearic Islands	46,30	29.86	16.45	100.00	66.16	33.84
	Hospitals by 100,000 inhabitants			**Distribution of the hospitals [%]**		
	Total	**Public**	**Private**	**Total**	**Public**	**Private**
National total	**1.93**	**0.79**	**1.14**	**100.00**	**41.12**	**58.88**
Balearic Islands	3.04	1.14	1.9	100.00	37.50	62.50

***Table 27**: Working personnel in hospitals by 10,000 inhabitants. 2000 data, (INE, 2004).*

	Total	Other workers	Doctors	Nurses
National total	91.92	64.84	12.89	25.96
Balearic Islands	102.79	72.41	12.28	29.64

1.9.2 Economic profile

1.9.2.1 Gross Domestic Product (GDP)

The *GDP* of Spain was 464,250 million € in 1996 rising to 609,319 in 2000. The *GDP* of the Balearic Islands was 2.39% of Spain's total (11,816 million €) in 1996 and increased up to 15,276 in 2000, reaching 2.51% of the national total. The *GDP* per capita was 19,362€ in 2000. The contribution of the GDP by sectors is 1.5% from agriculture, 6.6% from industry, 8.5% from construction and 83.4% from services. The agricultural sector was described in detail in chapter 1.8. In the industrial sector of Majorca, leather products are the most important goods produced. Within the tertiary sector, tourism is the main tertiary sub-sector, making a substantial contribution to the GDP and the employment.

Table 28: *Gross Domestic Product (GDP) of market prices. Current price: value, percentage structure and rate of inter annual variation, (INE, 2004).*

	Balearic Islands			Total National		
Year	**Value (thousand Euros)**	**% of the national total**	**% Rate of inter-annual variation**	**Value (thousand Euros)**	**% of the national total**	**% Rate of inter-annual variation**
1997	11,816,498	2.39	-	494,140,000	100,00	-
1998	12,717,956	2.41	7.63	527,975,000	100,00	6.85
1999*	13,970,113	2.47	9.85	565,199,000	100,00	7.05
2000*	15,276,093	2.51	9.35	609,319,000	100,00	7.81

**forecast*

Table 29: *Gross Domestic Product (GDP) per capita.*

	Balearic Islands			Total National		
Year	**Value (Euros)**	**% of the national total**	**% Rate of inter-annual variation**	**Value (thousand Euros)**	**% of the national total**	**% Rate of inter-annual variation**
1997	15,982	127.27	-	12,558	100.00	-
1998	16,921	126.45	5.88	13,382	100.00	6.56
1999*	18,173	127.41	7.40	14,263	100.00	6.58
2000*	19,362	126.87	6.54	15,261	100.00	7.00

**forecast*
Current prices: value, index and rate of inter annual variation, (INE, 2004).

Table 30: *Value distributed according to activity sectors in the Balearic Islands (constant price), (INE, 2004). Units: thousands of euros*

Activity branches	1996	2000*
1. Agriculture, animal husbandry and fisheries	**216,873**	**230,388**
Agriculture, animal husbandry, hunting and forestry	199,178	218,208
Fishing	17,695	12,180
2. Industry (incl. energy and building construction)	**1,713,228**	**2,257,408**
Energy	*383,969*	*376,275*
Extraction of energy products, other minerals and refining of petroleum	14,757	18,882
Electric energy, gas and water	369,212	357,393
Industry	*659,927*	*804,797*
Food, drink and tobacco	181,287	198,806
Textile, clothing industry, leather and footwear	105,017	113,979
Wood and cork	41,287	52,833
Paper, and graphic arts	50,236	67,120
Chemical industry	5,722	7,142
Rubber and plastic	11,321	14,440
Other mineral non-metallic products	60,567	82,067
Metallurgy and metallic products	81,591	106,296
Machinery and mechanic equipment	25,269	32,789
Electric equipment, electronics and optics	11,503	13,240
Manufacturing of material for transportation	20,997	26,389
Diverse manufacturing industries	65,130	89,696
Building construction	*669,332*	*1,076,336*
3. Tertiary activities	**8,367,837**	**11,837,972**
Services of market (wholesaling and retailing)	*7,235,646*	*10,353,570*
Commerce and repair	940,900	1,393,075
Hotel - businesses	2,584,448	3,961,192
Transport and communications	1,166,786	1,601,752
Financial intermediation	448,202	636,766
Real estate and enterprise services	1,496,411	1,909,989
Education and health care	335,028	465,852
Other social activities and other services of market	263,871	384,944
Nonmarket services	*1,132,191*	*1,484,402*
SIFMI	**-414,204**	**-533,764**
Total	**9,883,734**	**13,792,004**
Total national	**426,890,000**	**550,123,000**

Reading tourism, statistical records for all Spain show an average stay of travellers of 3.72 nights with 222,554,781 overnight stays and a total of 59,868,813 travellers having been recorded throughout 2002 (INE, 2004). As compared to the data from Majorca, Palma's overnight stays accounts for 16% of the island, and for 8% of the national total. Also, average stays in Majorca are of 7.39 nights as compared with 3.72 of the national data.

The majority of tourists who visit the Balearic Islands come from the U.K which represents 32.96% of the total, followed by Germany with 30.2%, Italy with 4.39%, France 2.86%, Belgium 1.42, Switzerland and Liechtenstein with 1.31%. Other countries contribute with less than 1%. Tourists from the European Union represent 77.75% of the total of visitors whilst 17.39% come from mainland Spain.

Table 31: *Tourism indicators by islands. Data for 2002, (INE, 2004).*

	Palma-Calvia	Majorca	Menorca	Ibiza-Fortementera	Palma de Majorca
Tourists (total)	2,469,230	4,866,848	458,730	980,278	1,273,291
Overnight stays	15,888,040	35,980,484	3,667,977	7,706,903	7,281,625
Average stay	6.43	7.39	8.00	7.86	5.72

1.9.2.2 Employment

In terms of employment the main activity of the Balearic Islands is the tertiary sector (74%), followed by construction (15%), industry (9%) and agriculture (2%). Overall, the active population has increased significantly from 275,000 in the beginning of 1996 to 373,000 in the end of 2002. The increase in the active population corresponds mainly to the expansion in the tertiary sector (namely tourism); an increase in the construction has also contributed to a smaller extent. The employment in the industrial and agricultural sector has remained more or less stable between 1996 and 2002. Nevertheless, there are important seasonal variations in the employment associated to the tourism (figure 21).

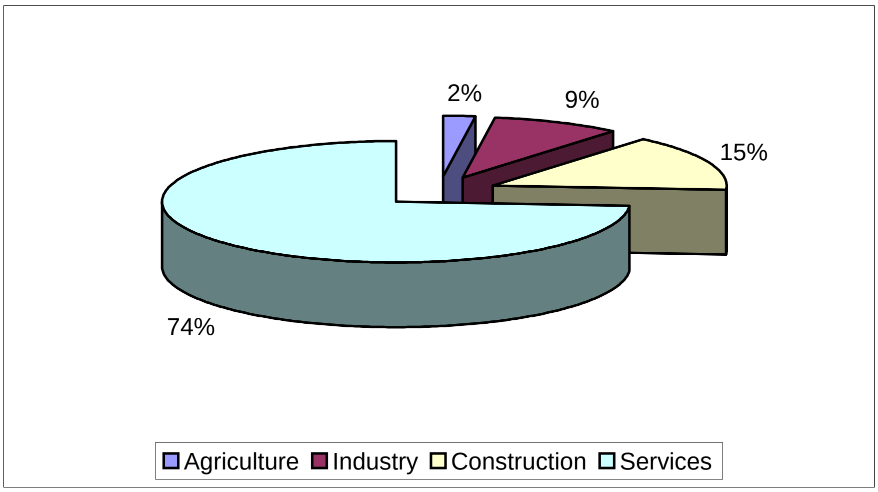

Figure 21: *Distribution of the working population in the Balearic Islands by economic sector. Data for October-December 2002, (adapted from INE, 2004).*

Therefore, generally during the high tourism season (trimesters II and III) unemployment is very low (5-7%) whereas during low seasons unemployment is approximately 10%.

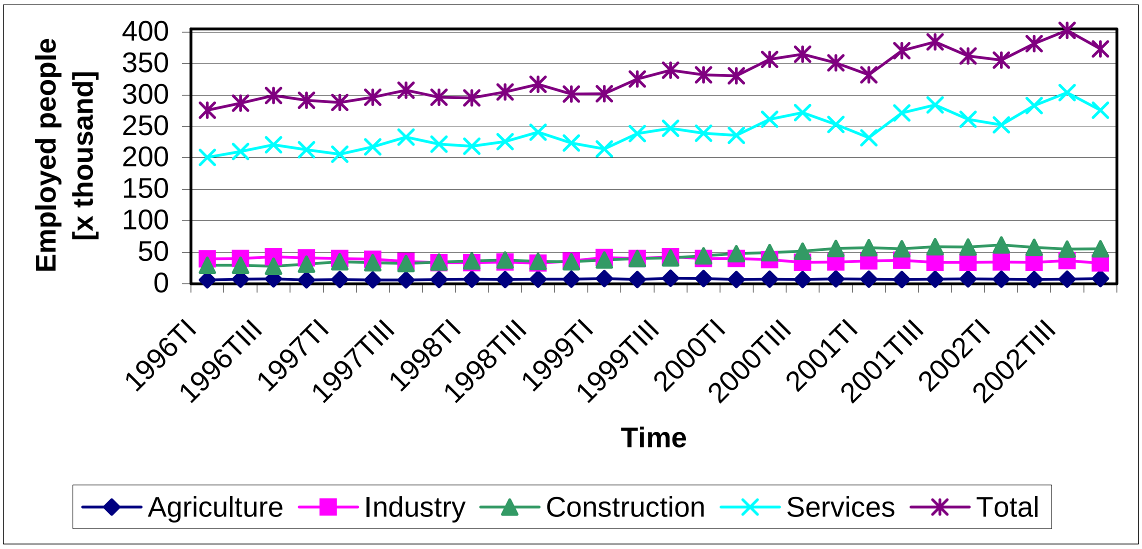

Figure 22: *Evolution of the active population in the Balearic Islands by economic sector, (trimesters from 1996 to 2002), (adapted from INE, 2004).*

Table 32: *Employment in the Balearic Islands. Data for four trimesters of 2002, (INE 2004).*

		Total	Agri-culture	Industry	Construction	Services	Unemployed who seek for first employment
2002 TI	Employed	291,600	6,200	41,200	31,400	212,800	
	Unemployed	34,600	200	1,000	3,200	26,000	4,300
	Unemployment ratio	10.6	3.1	2.4	9.2	10.9	
2002 TII	Employed	301,800	7,400	36,000	34,800	223,600	
	Unemployed	27,200	300	1,200	3,900	16,500	5,300
	Unemployment ratio	8.3	3.9	3.2	10.1	6.9	
2002 TIII	Employed	351,300	7,800	34,600	56,000	253,000	
	Unemployed	24,500	0	1,100	3,300	13,700	6,400
	Unemployment ratio	6.5	0.0	3.1	5.6	5.1	
2002 TIV	Employed	373,400	8,100	33,100	55,800	276,200	
	Unemployed	32,900	200	1,900	5,200	19,300	6,300
	Unemployment ratio	8.1	2.4	5.4	8.5	6.5	

1.10 Summary table

***Table 33**: Summary table: characteristics of Majorca Island*.*

Natural water conditions and infrastructure	**Regional context**	Area	3,640km^2
		Climate type	Mediterranean, temperate
		Aridity Index	0.57
		Permanent population	609,150 (1996)
		Tourists (arrivals)	Total arrival of tourist 7,610,738 people (1996), tourist stay on average 10-11 days, therefore the mean equivalent population is 210,373 people
	Water availability	Precipitation	625mm/yr
		Renewable Water Resources /Availability (Mm^3)	494Mm^3/yr
		Water resources • Surface water • Ground water • Storage/dams/reservoirs • Desalination	 120Mm^3/yr 374Mm^3/yr 7Mm^3/yr 0Mm^3/yr
		Water availability per capita and year	603m^3/p/yr
		Transboundary water	Not existing
	Water quality	Quality of surface water	good
		Quality of groundwater	poor, NO^-_3, salinity
		Quality of coastal water	
	Water supply	Supply coming from: • Groundwater • Surface water • Desalination • Recycling • Importing	Used for: 220.5Mm^3/yr (90%) 7.2Mm^3/yr (3%) Not in 1996 (Now approx. 20Mm^3/yr) 19.3Mm^3/yr (8%) No
		Network coverage: • Domestic • Irrigation • Sewerage	100% in urban settlements Not applicable (wells at plot)

Table 33 continued.			
Economic and social system agriculture and tourism	***Water use***	Water consumption by category: • Domestic • Irrigation • Industry • Golf courses • Other (parks irrigation, leisure)	 36.7% 61.1% 0.2% 1.3% 0.7%
		Water consumption For **domestic** coming from • Groundwater • Surface water • Desalination • Importing	**36,7%** 91.75% 8.25% 0 0
		For **irrigation** coming from • Groundwater • Surface water • Recycling • Desalination • Importing	**61,5%** 90.6% 0 9.4% 0 0
		For **golf** coming from • Groundwater • Surface water • Recycling • Desalination • Importing	**1,3 %** 25.8% 0 74.2% 0 0
		For **other** (parks and garden) coming from • Groundwater • Surface water • Desalination • Recycling • Importing	**0,8%** 0 0 0 100% 0
	Water demand	Water demand trends	Increasing
		Consumption index	47%
		Exploitation index	50%

Table 33 continued.

Economic and social system agriculture and tourism	***Agriculture issues***	Area used	2,205 km²
		Irrigation area	195.18 km²
		Cultivated crop types (per area) [km²/crop]	Cereals 7.16 Fruit tree 5.26 Citrus tree 19.99 Vegetable 38.52 Tuber (2nd 20.62 harvest) Fodder 100.02 Pulse 1.34 Industrial crops 2.27
		Irrigation methods	Flooding, drip, microsprinklers
		Water used for irrigation (per area)	Allocation: 721,600m³/km²/yr with 195.18km² Water use: 140.76Mm³/yr
		Water demand per corp and area 10²m³/km²/yr)	Cereals 1,500 Fruit tree 5,000 Citrus tree 5,500 Vegetable 6,000 Tuber (2nd 6,000 harvest) Fodder 8,000 Pulse 6,000 Industrial crop 3,000
		Fertilizer used – average [10²kg/km²]	Ammonia, nitric, ammonia-nitric, ureic, organic manure
	Social and ecomoic situation	Employees in agriculture	7,160 person
		tourist sector	262,184 person
		other sectors	92,836 person
		Importance of water scarcity	High
	Pricing system	Average household budget for domestic water	
		Average household budget for agricultural water	
		Average household expenses	21,807.4€/yr
		Contribution of agriculture to the island´s economy	1.5% of GDP
		Water prices	0.18 – 2.4€/m³ for municipal supply

Table 33 continued.			
Economic and social system agriculture and tourism		Cost recovery	Infrastructure and wastewater treatment
		Price elasticity	
	Social capacity building	Public participation in decisions	Balearic Water Council
		Public education on water conservation issues	High
		Acceptability in using treated waste water	Low for agriculture. High for public parks and golf courses irrigation
Decision making process	***Water resources management***	Water ownership	Public and private
		Decision making level (municipal, regional, national) regarding: Water supply for each sector Water resources allocation for each sector	Municipal Regional
	Water policy	Local economic basis	
		Development priorities	Drinking water supply

**Most data is taken from the PHIB (1999) which is elaborated with data from 1996.*

Chapter II: Selection of a representative catchment

2.1 Introduction

The *Llano de Inca-Sa Pobla* located to the North West of Majorca Island, is the study area chosen for the MEDIS project. The area was selected as it shows important hydrologic and socio-economic characteristics rendering the existing catchment as an ideal for the type of study requested. These characteristics are:

- the Llano de *Inca-Sa Pobla* constitutes the main agricultural area on Majorca Island,
- the Natural Park of *S'Albufera* is a natural wetland located in the north-western part of the area,
- important tourist development area in the western part *and*
- water management conflict of interests between users in the catchment area.

The study area is located within the *Inca-Sa Pobla* Hydrogeologic Unit, which constitutes the only existing water resource for water supply. The most important towns are *Inca* and *Sa Pobla*.

The hydrogelogic unit is constituted by detrital and carbonate material deposited over the Central Plains of Majorca, between *Marratxi* and the *Alcudia Bay* (figure 23). The *Inca-Sa Pobla* unit is limited by the Tramuntana range at the North, by the sea in the north-east, in the south by the *Pla de Palma* (separated only by an impervious area near *Marratxi*) and the *Central* ranges and the *Sa Marineta* Hydrogeologic Unit in the south-east.

2.2 Catchment description

2.2.1. Main characteristics

The *Inca-Sa Pobla* basin is longitudinally oriented from southwest to northeast. It stretches along 35km from *Pòrtol-Santa Maria del Camí* to the *Alcudía* Bay. Its width varies between 5-10km, with its landscape being narrower in the western part and wider in the coastal area. It extends over a lowland area of 360km^2 with an elevation below 100 m.a.s.l except for *Campanet* and *Puig de Santa Magdalena*.

Population (data from PHIB, 1999) Autochthonous: 52,166 inhabitants:

- Seasonal (May - September) (max): 101,897 residents *and*
- Seasonal (May - September) (average): 78,026 residents.

The main economic activities in the catchment area are: tourism which is the most important sector followed by agriculture with 48km² of irrigated land and to a smaller degree the leisure activities in the *S'Albufera* wetland (17km², Natural Park, RAMSAR, ZEPA) which constitutes a marginal income. The *Inca-Sa Pobla* plain is the most important agricultural area in Majorca Island with agricultural production being concentrated principally in the municipalities of *Sa Pobla, Muro* and *Llubí*. Cultivated surface is about 216km², 25% of which is under irrigation.

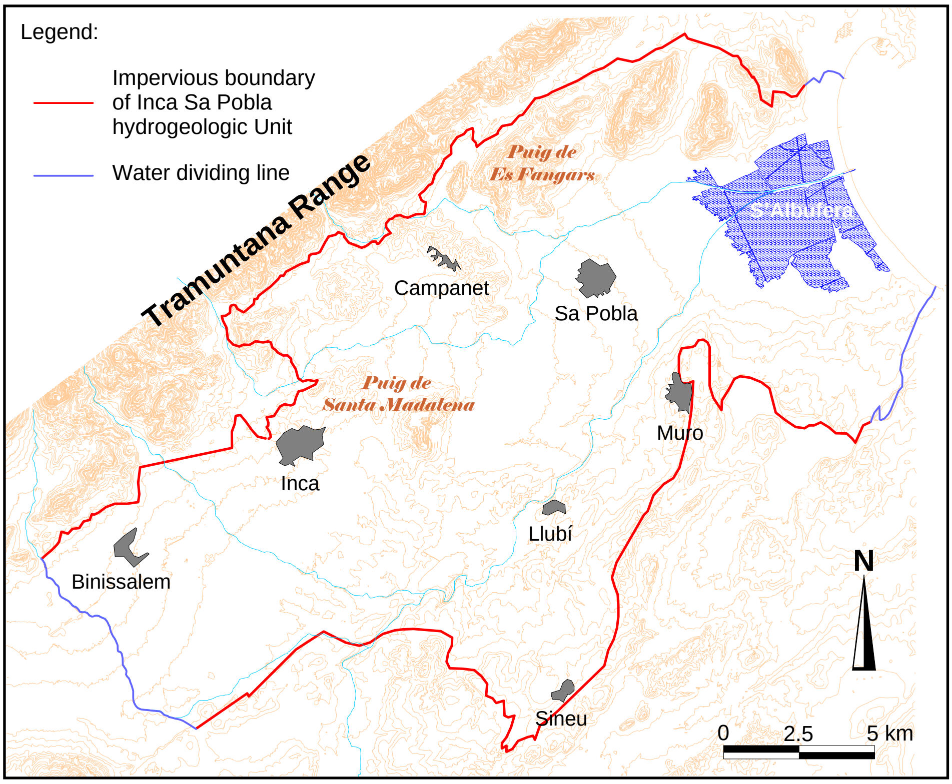

Figure 23: *Location map of the Inca-Sa Pobla hydrologic unit indicating main features.*

Water demand in the basin, according to different uses is:

- Municipal (water supply): 11.6Mm^3/yr (groundwater),
- Irrigation: 30Mm^3/yr (groundwater) *and*
- Environmental: 30Mm^3/yr (to the wetland and minimum discharge to sea).

2.2.2 Climate

The climate is Mediterranean temperate; with mean yearly temperatures between 17ºC and 19ºC. Minimum and maximum temperatures are near 8ºC in winter and around 30ºC in summer. Precipitation is unevenly distributed, where 60% of total annual precipitation occurs between October and January. During the summer season only 10% of the total annual precipitation occurs. Figure 24 shows the spatial distribution of precipitation in the study area for 1994-2000 period and obtained from 14 meteorological stations. Precipitation shows a decreasing trend from the vicinity of the *Tramuntana* Range (up to 750mm) to the southeast (500mm). The Mean annual precipitation is 670mm.

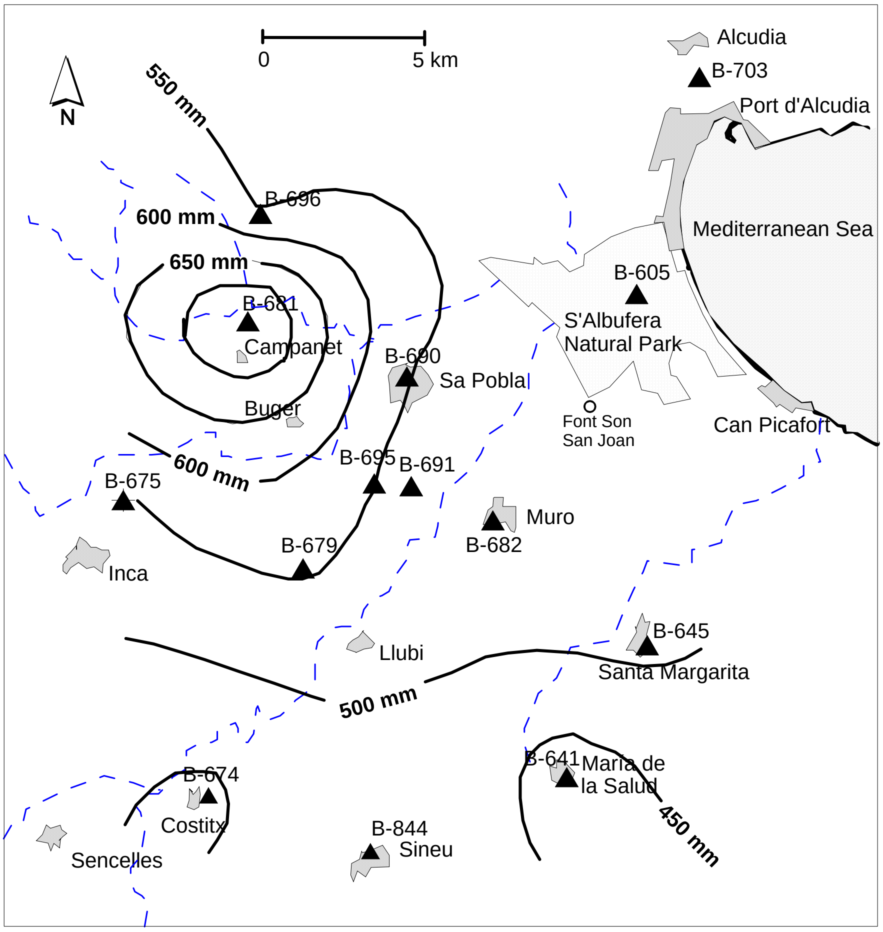

***Figure 24**: Spatial distribution of precipitation in the Inca-Sa Pobla plain. Average for 1994-2000 period based on 14 meteorological stations, (adapted from Hernández, 2001).*

2.2.3 Aridity index

The aridity index is 0.74, obtained considering mean precipitation of 670mm and potential evapotranspiration between 800-1,000mm (LBA, 2000). The area can be classified as moist sub-humid.

2.2.4 Geomorphology

The catchment area is predominantly flat, surrounded by a hilly landscape of tectonically deformed Mesozoic and a Tertiary impervious basement. The natural wetland *S'Albufera* constitutes the aquifer drainage to the sea. It is located to the NE of the study area covering a total area of 17km^2 and it is practically at sea level (figure 23).

2.2.5 Geology

From a Geological point of view, the catchment area is a north-east/south-west tectonic subsiding sedimentary basin, filled with post-tectonic Miocene, Pliocene and Quaternary materials with a tectonically deformed lower Miocene and a Tertiary impervious bedrock figure 25). The basin is constituted by three separate sub-basins: *S'Albufera* (near the sea), *Sa Pobla* (north-east) and *Inca* (south-west), these last two are divided by the *Puig de Sta Magdalena*. In the northern part, Miocene and Pliocene materials show a detritic facies similar to the Quaternary (red silt, gravel and conglomerates) and are discordant. At the centre of the basin, the Upper Miocene can be differentiated as follows:

- calcisiltits and grey marls (Tortonian),
- shelf limestones and reef complex (Tortonian-Messinian, M45-M52),
- grey marls with organic matter (Messinian, M3),
- oolitic limestones in the upper level (Messinian) *and*
- Terrigen complex (M53).

The lower Pliocene is constituted by sandy marls with 'ammusium' (PL_1) and the upper part is made up of limestones with lumachelly levels (PL_2) changing into marly material towards the *Inca* sub-basin.

The Quaternary (Q) is basically of detritic origin and is made up of red silt, gravel, eolian sand, grey silt and clay from the *S'Albufera* with an important amount of organic matter. Due to the great number of lateral facies changes, the stratigraphy of the basins is rather complex.

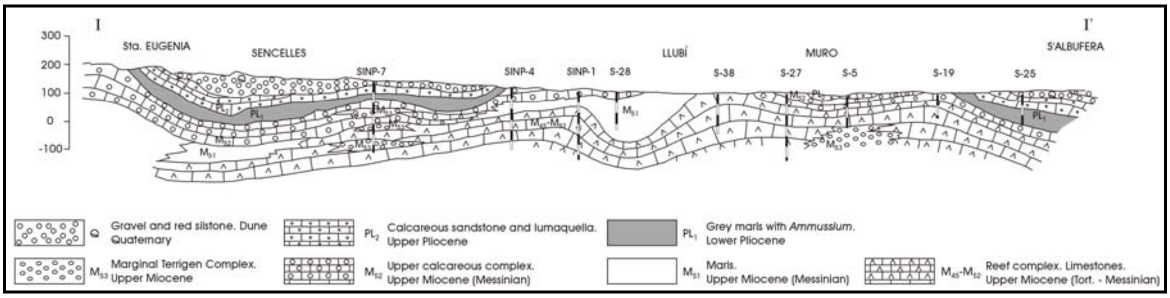

Figure 25: *SW-NE geological cross section along the Inca-Sa Pobla hydrogeologic Unit, (adapted from Junta d'Aigües, 1999).*

2.3 Surface water

Although surface hydrology is not a very important component in the study area due to the lack of perennial streams, surface water contribution for the *S'Albufera* wetland is important. The streams *Torrente de Almadrá* or *Muro* and the *Torrente de San Miquel* coming from the *Sierra Tramuntana*, are only functional during storms, however runoff can be very important for a limited period of time.

2.4 Groundwater Hydrology

The *Inca and Sa Pobla* units are characterised by six different aquifer materials, grouped into two different systems according to their hydrogeologic characteristics: the upper aquifer and the lower aquifer (figure 26). The upper aquifer consists of Quaternary-Q silts and gravels and Pliocene-PL2 calcareous sandstones and eolianites, sometimes associated to the Terrigen Complex (M53). The lower aquifer consists of Messinan limestones and Tortonian limestones. In the coastal area, the central part of the *Sa Pobla* sub-basin and in the central area of the sub-basin of Inca thick layers of Pliocene marls are present, disconnecting the upper from the lower aquifer, where it is confined.

The Quaternary deposits constitute an important unconfined aquifer formation. Its thickness varies between a few metres up to 70m, with the greatest thickness corresponding to the centre of the basin. The Quaternary is also hydraulically connected with all aquifer formations existing in the area. Transmissivities are between 50 and 100m^2/d and hydraulic conductivity between 8 and 15m/d. Near the *S'Albufera* area transmissivity can reach up to 1,000m^2/d, and hydraulic conductivity up to 300m/d.

The upper Pliocene constitutes an unconfined aquifer. It can be associated to the Quaternary deposits as well as to the Messinian when the lower Pliocene marls disappear (*Sa Pobla* area, between *Muro* and the *Marineta*). Pliocene calcarenites may cover

Quaternary deposits and only outcrop on the southern fringe between *Santa Eugenia* and *Muro*. Its thickness shows a maximum of 75m at the southern edge of the basin (*Sencelles-Muro*). The transmissivity range is from 1,000 to 5,000m²/d.

The lower aquifer consists of Messinian aquifer materials (M52 and M4-5) and Lias limestones and dolomies. The Messinian can also constitute an independent aquifer by itself. Its thickness can vary, although never exceeding 100m. The Tortonian outcrops at the southern border of the basin. Its thickness varies from a few metres to more than 200m, being the most regular thickness bigger than 100m. Messinian aquifers can be either unconfined or semiconfined. Their transmissivity is about 500-5,000m²/d and sometimes even higher than 10,000-15,000m²/d.

Lias limestone and dolomies always constitute an unconfined aquifer that leans upon the base made up of Keuper clays and gypsum. It is laterally connected with the Plio-Quaternary and the Miocene formations of the *Sa Pobla* rolling plain. Transmissivity here varies between 200 and 10,000m²/d.

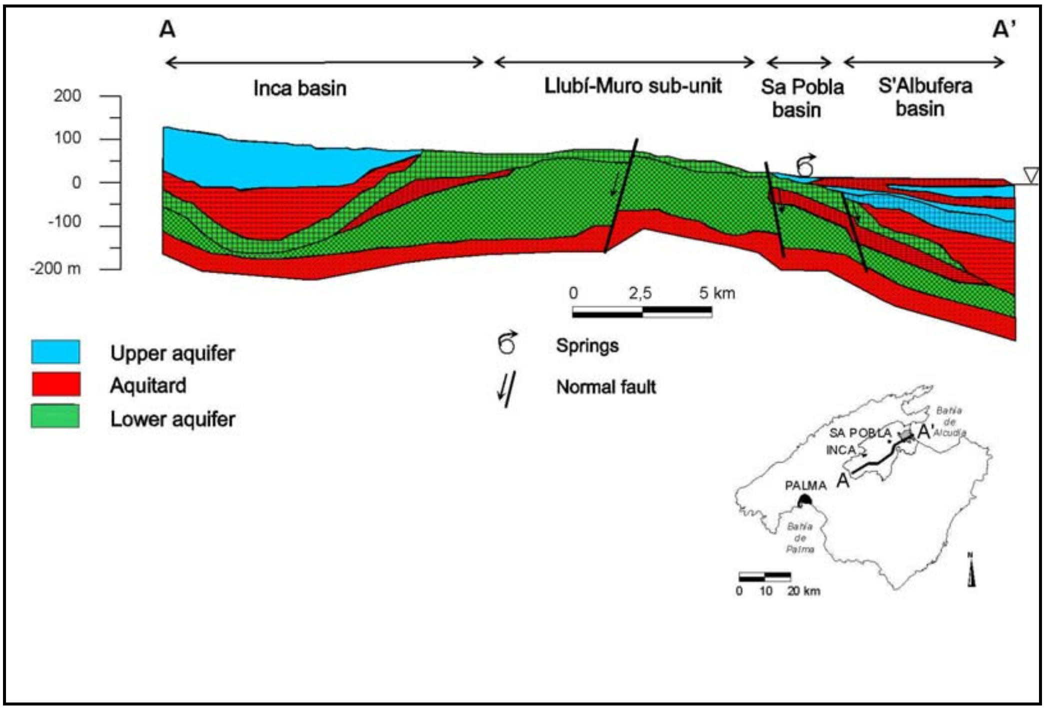

Figure 26: *Hydrogeologic cross-section from SW to NE, (modified from Manzano et al, 2002).*

2.4.1 Piezometry

The *Inca-Sa Pobla* basins general flow is to the sea through the *S'Albufera* wetland (SW-NE) with seasonal water level variations up to 2m (maximum piezometric values during spring and minimum in autumn). The general annual trend of groundwater fluctuations remains stable.

Lower aquifer

This aquifer always shows piezometric values above sea level. In the *Santa Eugenia–Sencelles* area (south-east) water level oscillates between 30 and 40m above sea level, reaching 5 and 4m in the *Llubí* area. From *Llubí* down to the sea, the hydraulic gradient is lower, where the levels decrease reaching as low as 0.5 metres near the *S'Albufera* wetland. The hydraulic gradient near the *Es Fangar* area (north) is greater, where depression cones are present due to intensive pumping for *Alcudia* water supply. Over-pumping of the aquifer for water supply has caused seawater intrusion in coastal areas, and values up to 1000ppm of Cl^- have been detected in some wells (Baron, 2003).

Upper aquifer

Figure 27 shows piezometric levels of the aquifer for January 2000. As shown in the figure, the upper aquifer follows the general SE-NW flow trend although piezometric gradients are greater than the lower aquifer. An important water level decline occurs in the western part of the hydrogeologic unit to the centre. The two important depression cones near *S'Albufera* are related to the existence of pumping wells for water supply in the coastal areas.

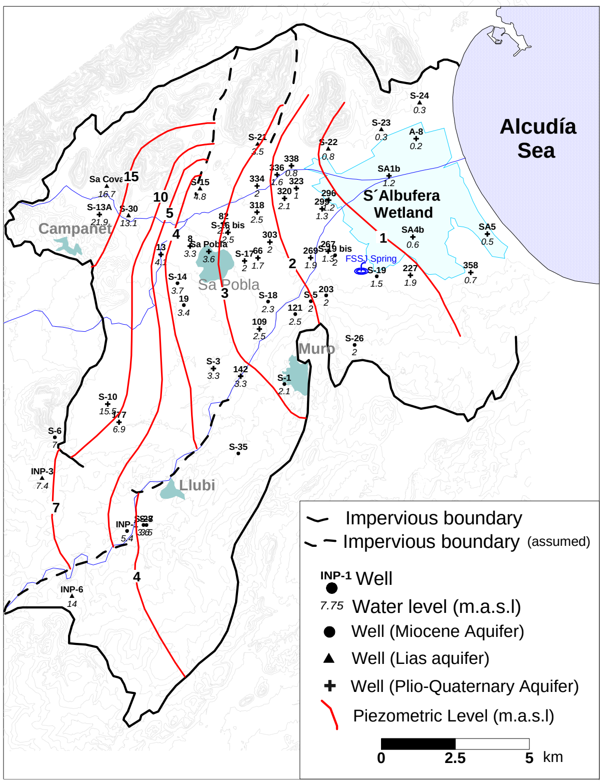

Figure 27: *Piezometric surface of the upper aquifer in the Inca-Sa Pobla sub-basin for January 2000.*

2.4.2 Water quality

The most relevant factor of water pollution is seawater intrusion as identified through high chloride concentration in groundwater, with values greater than 1,000mg/l along the eastern boundary of the *S'Albufera* wetland having been found (Junta d'Aigües, 1999). Presence of Cl^- was detected in the central part of the *Inca-Sa Pobla* basin in 1988 (with concentrations of 500mg/l of Cl^-). During the last few years, an increase in chloride concentration has appeared in the surroundings of the *Font San Joan* in the southeaster margin of the S'Albufera: In 1991 the maximum value was 542mg/l in 1997 it was found to be 900mg/l. This effect has been caused by the significant increase of extractions for domestic supply in the coastal areas, but it remains stationary for the rest of the hydrogeologic unit (figure 28).

The second important contaminant present in water is the presence of nitrate from agricultural activities. Regarding the nitrate concentration of groundwater, two different areas are affected (figure 29). The area located between *Sa Pobla* and the *S'Albufera* wetland shows a maximum value of 700mg/l and mean values around 400mg/l, while the area of *Muro* reveals maximum values of 200mg/l and mean values of 150mg/l. High contents found in some wells located near *Sa Pobla* should not be regarded as being representative for the groundwater quality, as it could be caused by either possible direct introduction of fertilisers in the extraction wells by accident or by uncontrolled dumping.

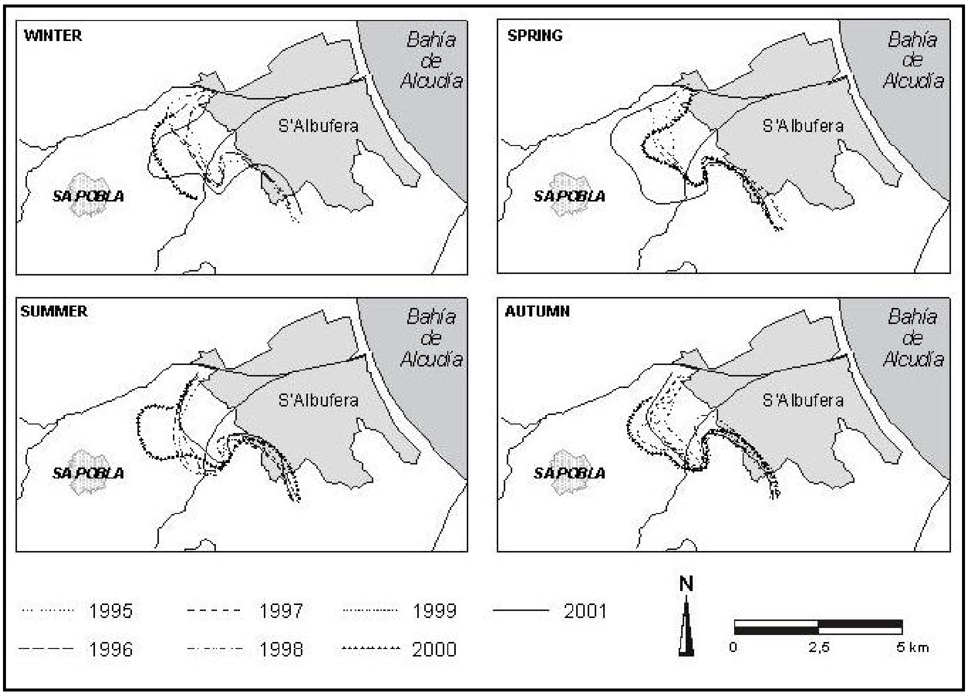

Figure 28: *Temporal evolution and seasonal variations of the saline intrusion in the Inca-Sa Pobla plain. Lines showing the isochloride line of 500 ppm for the different years, (adapted from Galimont et al, 2003).*

2.4.3 Water balance

Table 34 shows the estimated water balance for the study area. For the balance calculations the following input data were considered**:** 50Mm^3/yr water recharge from precipitation, 4.6Mm^3/yr irrigation return, 3.7Mm^3/yr wastewater infiltration, 10Mm^3/yr from streams infiltration and 1.7Mm^3/yr losses from pipelines.

The output is mainly due to the discharge to the wetland, pumping from wells for irrigation and urban water supply. No drainage to the sea is produced, as seawater intrusion exists in the area.

Table 34: *Water balance in the Inca-Sa Pobla basin, (PHIB, 1999).*

Input	**Mm^3/a**	**Output**	**Mm^3/yr**
Infiltration by rainwater	50	Discharge through S'Albufera	30
Infiltration from streams	10	Irrigation	30
Irrigation return	4.6	Domestic supply	11.6
Wastewater infiltration	3.7		
Domestic supply losses	1.7		
Seawater intrusion	1.6		
Total	**71.1**	**Total**	**71.6**

2.5 Irrigated agriculture in the *Inca-Sa Pobla* hydrogeologic unit

2.5.1 Main areas of irrigated agriculture

The biggest development of irrigated agriculture in Majorca takes place in the *Pla de Sant Jordi* to southeast of *Palma* and in the *Llano de Sa Pobla* located in the northern part of Majorca. According to the *Plan Nacional de Regadíos*/National Irrigation Plan (PNR, 1999), approximately 26% of all irrigated land surface in Majorca island is located within the *Inca-Sa Pobla* hydrogeologic unit. The extension of irrigated agriculture in the *Llano de Sa Pobla* reached 71.21km^2 in the census of 1970, representing nearly half of Majorca's irrigated agriculture (155km^2 in 1970). Since the mid-80´s there has been a decline of irrigated agriculture reaching 48km^2 in 1996 and some 45km^2 nowadays (Perelló, 2002).

2.5.2 Water use and sources

The total volume of water used for irrigation in the Inca-Sa Pobla hydrological unit is approximately 30Mm^3/year, coming entirely from groundwater extraction through private wells located in the farms. Around 4.6Mm^3/year are returned from irrigation (PHIB, 1999), which are estimated to count directly as aquifer recharge. Water allocation is totally dependent on the irrigation method and type of crop. As crop rotation is a common agricultural management during the year, estimation of irrigation dose is not straightforward. However values between of 2000 and 7500m³/km²/yr are common. Main water allocation corresponds to alfalfa and vegetables.

2.5.3 Main crops

Several crops are produced throughout the whole year, figure 29 illustrates that in the study area the main fraction of water for irrigation is used for vegetables and potatoes, followed to a smaller extent by citrus trees and fodder. Potato cultivation is of special importance to the area for export, which has been steadily increasing during the last years.

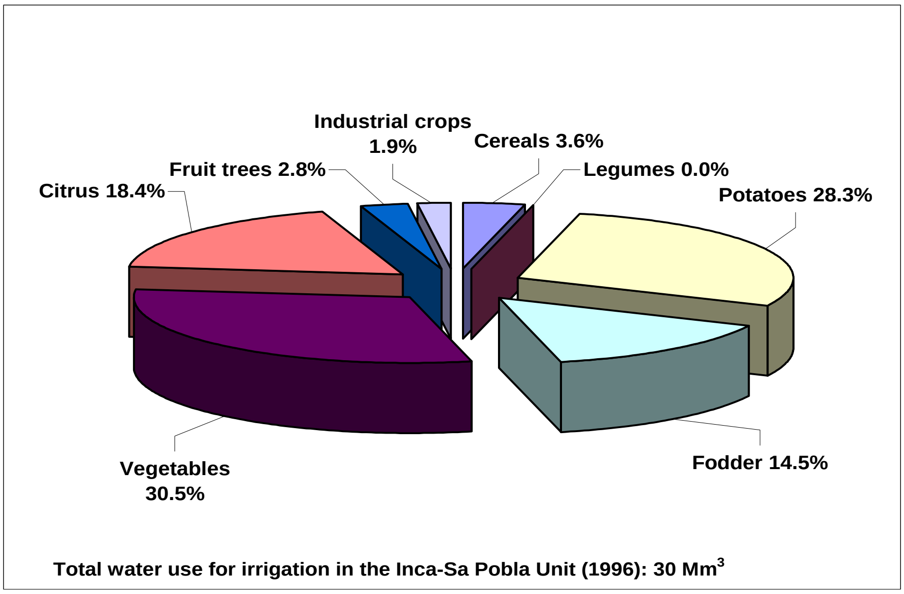

Figure 29: *Total water use (%) per crop in irrigated agriculture of the Inca-Sa Pobla Hydrogeologic Unit, (adapted from PHIB, 1999).*

2.5.4 Social aspects

With regard to social aspects the basin shows the same basic traces established in paragraph 1.9 as for the whole island. However, being the most important agricultural area of the island the basin concentrates the highest active population in the agricultural sector. For the agricultural sector and a population of 3,500 farmers (figure 30), in the *Inca-Sa Pobla* hydrogeologic unit, more than 60% of the farmers are older than 55, occurring as a result of the tertiary sector demand (tourism) for young people. For more than 60% of the farmers, agriculture represents its only income for living.

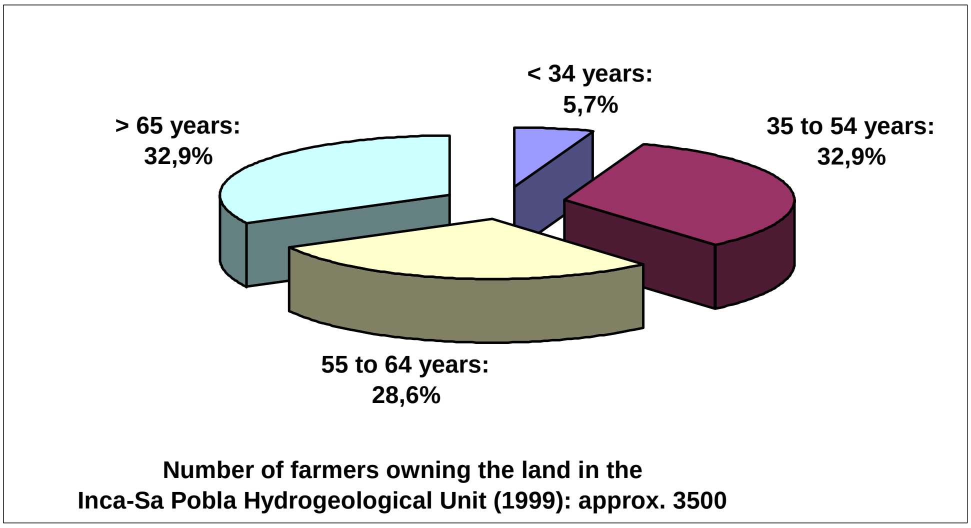

Figure 30: *Age distribution among land-owning farmers, (Cens Agrari, 1999).*

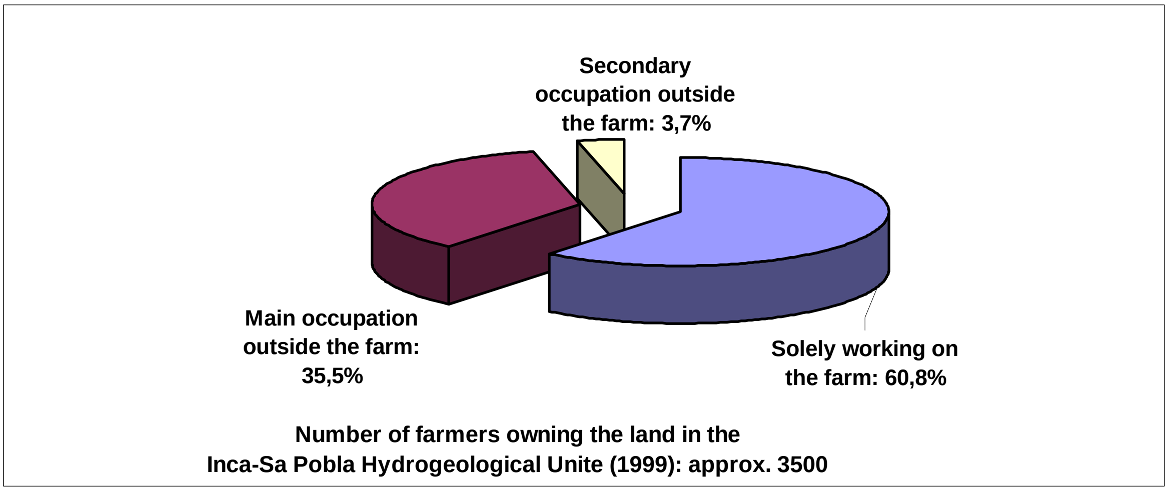

Figure 31: *Occupation of land-owning farmers, (Cens Agrari, 1999).*

2.6 Analysis of conflicts in the study area

A simple definition by Huggins of "conflict" in watershed management studies, is 'a situation where actors have *incompatible goals*' (Huggins, 2004) and where goals include status, power and/or resources. According to this definition, conflict is manifested in purposeful behaviour by the protagonists in order to capture more of the scarce resources or to overcome the strategies of other protagonists.

Conflicts exist on the use and allocation of scarce water resources in the *Inca-Sa Pobla* plains. Traditional agriculture and new growing tourism business are the major sectors abstracting groundwater resources. Overexploitation causes saline intrusion and agriculture nitrate pollution. Deteriorated quality restricts even further the usable water resources. It also induces important pressure over the quantitative and chemical status of the wetland that interacts with groundwater and surface water. In summary this situation affects tourism, agriculture, environment and environmentalists as well as the water administration in different ways.

The geographical distribution of the resource within the *Inca-Sa Pobla* Hydrogeologic Unit is in conformity with the conflict. Important groundwater resources are available inland, in the *Sa Pobla* plain, whereas extraction of groundwater near the coastline at the bay of *Alcudia* is restricted due to seawater intrusion. Minor resources are karst springs in the foot of the *Tramunatana* range that drain towards the plain and eventually to the wetland. Surface water resources are only available during short periods after intense rainfall events in flash-flood type of regime and are therefore not exploited. Nevertheless, they are significant resources for the wetland.

Temporal distribution of the resources is also relevant to the conflict. Recharge of the groundwater reservoir occurs during the rainy periods in autumn and spring, whereas the major extractions and use occur during summertime, producing a temporal disequilibrium between availability and demand. Groundwater resources are able to buffer to some extent these seasonal variations, however, inter-annual variations including dry periods stress greatly the reservoirs and induce irreversible damage to the resources (saltwater intrusion) as well as impacts the socio-economic situation (bad quality of water supply services in quantity and quality). Therefore the level of conflicts over time is directly correlated with the climatic conditions which are more intense during long lasting dry periods and more relaxed during wet periods. In addition, water resources frequently becomes an issue in political election periods especially at municipal level, but also during regional (the regional elections of 2003 opposed two different development models including opposed water policies – see below) and national elections (An important divergence in the political programs of the two main parties during the elections in 2004 was regarding the national water policy). Isolated hydraulic projects have also had influence on the evolution of the conflict (as will be explained later).

The main disagreements between the interest groups originate from ethical values given to water ownership and to traditional water uses, as well as to economic interests. Furthermore, disagreement exists regarding responsibilities the extend of environmental deterioration and the responsibilities concerning remediation actions. Disagreements regarding technical aspects include the extend to which each party is responsible for the deterioration of water quality and the actions that need to be taken for the remediation. Disagreements on socio-economic aspects include the development of cost's repartition and the operation of new water sources. All interest groups agree that it's a necessity to maintain agriculture in order to manage the hinterland and the scenery. At the same time this benefits tourism and social values such as the right to maintain a traditional activity. Many representatives of the tourism business, although not all, agree upon maintaining the agricultural activity as agriculture produces fresh food which is then supplied to the tourism industry. This action positively affects both sectors. An additional agreement exists upon maintaining a sound wetland which on the one hand meets the interests of environmentalists and on the other attracts tourists and thus best makes for the tourism business.

The causes of conflict can be classified as proximate or structural causes. Proximate causes, also known as triggers, are sudden changes which act as catalysts. Structural causes, usually less visible and less directly linked, are underlying phenomena of political, socio-economic, cultural or other nature that create an environment where conflicts can occur (Huggins, 2004). Proximate causes that have led to evident and explicit conflicts in the last decade include:

- Inter-annual dry periods,

  Mediterranean climatic conditions on Majorca present recurrent periods of two to four dry years in a row. During these periods (1992-1993 and 1997-2000) smaller recharge rates and sustained or even increased groundwater extraction rates led to bad water quality in the municipal supply (salinity) and to water shortages. The latter situation resulted in increasing the animosity between the tourism business, agriculture and the local inhabitants which manifest in rude communication patterns.

- Water transfer from the *Franja de Llubí-Muro* wellfield to the *Palma* bay region for municipal water supply *and*

  In 1992 the Regional Government, backed by the water supply company of *Palma de Mallorca* (*EMAYA*), proposed a project aiming at transfering groundwater resources from the *Franja Llubí-Muro* to the municipal water supply of the *Palma* bay region. The project rose social unrest among farmers and civil society living in the source region, especially in *Llubí*. General animosity towards the government authorities and the tourism business was observed as locals had the feeling that the project would restrict their future development opportunities enlarging even more the gap between the developed coastal zones and the less developed interior zones. Technical reasons against the project were locally highlighted in order to raise the consciousness among local authorities and population regarding environmental impacts (seawater intrusion) which could be caused by high pumping rates. Due to local rejection of the project, a technical commission composed of representatives of the local population, local authorities and the regional government was set up. The commission culminated three months later with the establishment of a strict extraction plan including a monitoring programme of the impacts on the surrounding water resources. In the first couple of years of operation, however, tension rose again when government authorities did not follow the limits set for pumping groundwater.

The population as well as farmers reacted with organising a demonstration. Initial distrust among the local population and the operators of the wellfield was caused which seems now to be reduced after the authorities respected the negotiations. No negative impacts have been reported so far. Initially there was a lot of distrust among the local population towards the government´s operation of the wellfield. Eventually the conflict has decreased as the authorities respected the terms of the negotiation and no negative environmental impacts have been reported so far.

- Exploitation of the *Ses Ufanes* spring.

  Ses Ufanes is a non-perennial spring discharging big flows during short periods of time (2-3 days) and this only after long-lasting precipitation events. This water flows into the *San Miquel* creek and to the *S'Albufera de Mallorca* Natural Park. In 1999 the private water supply company of *Alcudia* (ACASA) proposed to exploit this water resource by drilling wells in the aquifer near the spring. This project found opposition especially among the population of the nearby town of *Campanet* and environmental NGO's, as they perceived the uniqueness of the spring and its natural interest were in danger. Farmers of the *Sa Pobla* plain were also against this project as they believe that the recharge of the *Sa Pobla* plain aquifer will be negatively affected by any exploitation of this spring. The conflict manifested through the creation of a civil platform formed mainly by young inhabitants of *Campanet*.aiming at protecting the natural state of the spring. Eventually the regional government declared the *Ses Ufanes* spring and the nearby area as a National Monument explicitly forbidding any exploitation of the water resources and thus conflict decreased. In 2002 the regional government promoted a project to divert part of the resource of the naturally discharged water to an artificial groundwater recharge project ultimately designed to augment the water supply of *Alcudia*. Again opposition to the project rose. After the government changed (2003), the project was halted and conflict decreased again. The level of conflict is currently very low since no project t is foreseen o exploit the spring. Furthermore, recently (2005) the government has bought the property where the springs are located. It can be foreseen, nevertheless, that conflict level may rise again in the future as different interest groups have diverse ideas on how to manage and use this resource.

Structural Causes that create an environment feasible for conflicts include:

- Not too accurate knowledge of the system dynamics as a consequence of a complex geological setting and too little research. This creates a disagreement and uncertainty about the causes of deterioration and consequences of actions over the system.

- The Spanish Water Law of 1985 introduced a change in the legal regime regarding groundwater ownership. As a consequence there is a situation that can be considered as chaos regarding the administrative control of extractions (Llamas, 2003; Martínez and Hernández-Mora, 2003 and Sanchez, 2003). It is widely accepted that there are plenty of illegal wells (11,000 legal and 23,000 under administrative control, (Rodríguez, 2004, personal communication) and total extractions from wells are unknown. This situation fosters a behaviour were private interests are pursued (and achieved by those with the larger political and/or economical power) without regulation in detriment of general public interests.

Conflict may be nested within a larger conflict in terms of geographical or conceptual scope (Huggins, 2004). In the Balearic Islands there is an ongoing conflict over the development model to be followed in future that is latent across the society and apparent between political parties. The opposed models defend a liberal development model of high economic growth based on the development of the tourism industry promoting development of public infrastructures. This model is accompanied by a water policy focused on water supply which is increased by desalination. The other model defends a development model of slow economic growth based on slowing down the development of the tourism industry and promoting the primary and secondary sectors. This model is accompanied by a water policy regarding water supply which is increased by artificial recharge accompanied by demand management and re-use of water.

The first symptoms of conflict in the area started/rose during the construction of the *Ses Murtera* power plant. This project triggered activism among the environmentalists interested in protecting the wetland suffering increased pressure over its ecological status from reduced water quantity and quality. Creation of the *S'Albufera de Mallorca* Natural Park in 1988 decreased conflict level. The overall development of the conflict can be related to the steady growth in tourism and steady decrease in agricultural activity along the past decades. It has been observed that some people have the feeling of growing socioeconomic injustice produced by the gap in social welfare between the developed coastal zones and the less developed interior zones. Water resources have not been an underlying cause for this economic development. Discussions on water policies nevertheless, have been a floor to denounce this social problem. The specific water development projects mentioned previously under the proximate causes have marked explicit peak conflict levels during the last decades in the area. Their wide coverage in the media has raised the overall awareness rendering water resources a sensible subject in the regional politics.

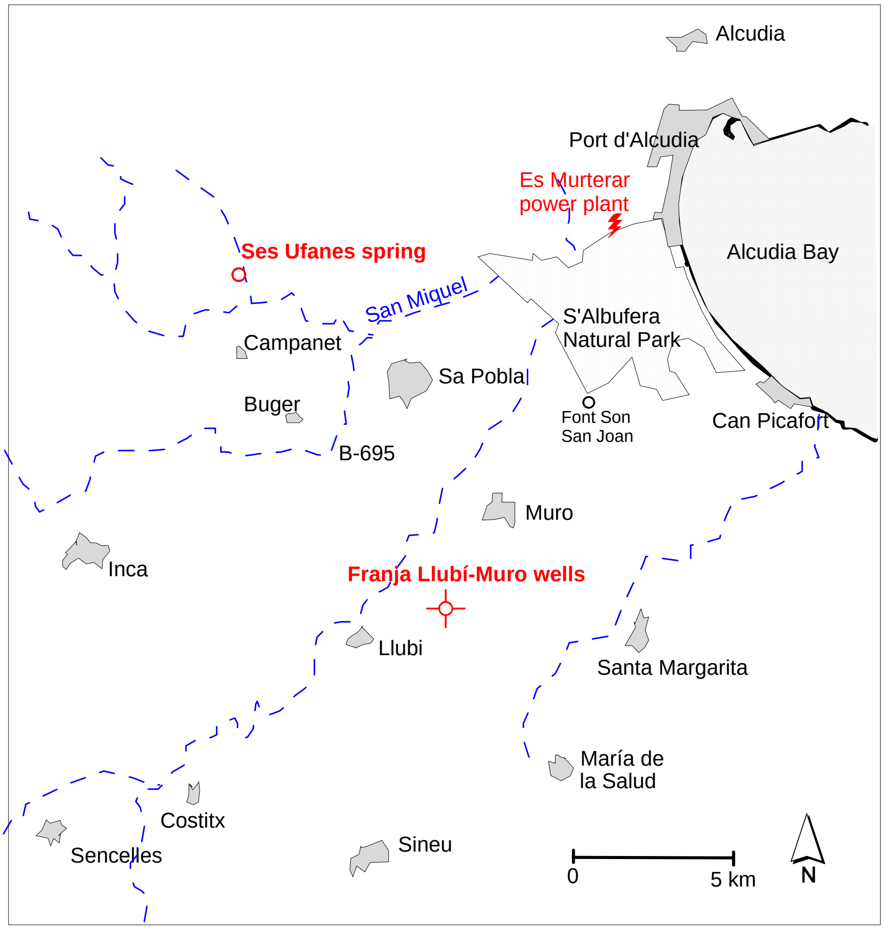

***Figure 32**: Location of conflict points in the study area.*

2.7 Water management actions

As the area suffers from water scarcity and water restriction especially during some of the most severe droughts, and in order to improve the fragile water balance, some actions have been taken. The actions include the construction a desalination plant in *Alcudia* with a capacity of 5Mm^3/yr. Its purpose is not only to provide a potable water supply, but also to reduce the aquifers extraction pressure and hence, to fight against seawater intrusion. Actions to implement EU legislation programs on 'good agricultural practices', to avoid agrochemicals pollution from agriculture, still need to be enforced. Water management actions also include projects such as the reuse of treated wastewater for agriculture and irrigation of parks and golf courses, the interdiction of new wells construction, to reduce water losses in the municipal distribution networks as well as projects to raise public awareness.

***Table 35**: Summary table: characteristics of the Llano de Inca-Sa Pobla catchment.*

Background	**Description**
Climate	In general the climate is Mediterranean temperate; with mean yearly temperatures of 17 –19ºC. Minimum and maximum are respectively near 8ºC in winter and 30ºC in summer. The mean annual precipitation is 670mm. Between September and May, 90.5% of annual precipitation occurs. Summer receives just 9.5% of the annual precipitation.
Aridity index	0.74 moist sub-humid
Geomorphology	It is a lowland area with a smooth relief formed of a tectonically deformed Mesozoic and a Tertiary impervious basement.
Geology	It is constituted by a tectonic subsiding basin in a northeastern–southwestern direction. The *Inca-Sa Pobla* basin is filled with post-tectonic Miocene, Pliocene and Quaternary materials, with a tectonically deformed Miocene and Tertiary impervious bedrock. Two sub-basins can be defined: *Inca* (SW) and *Sa Pobla* (NE), separated by the *Puig de Sta Magdalena*. The Miocene is basically composed of carbonate (limestones) materials and marls. The Pliocene is discordant with upper Miocene the lower part is constituted by sandy marls and the upper part by limestones changing into marly materials towards the *Inca* sub-basin. The Quaternary is mainly detritic and is made up of red silt, gravel, eolian sand, grey silt and clay from *S'Albufera* with of organic matter.
Groundwater	Three different aquifers levels, more or less hydraulically connected, can be distinguished: The Miocene aquifer (reef limestones); The Pliocene aquifer (calcarenites); The Quaternary aquifers (detritic). The aquifers receive recharge from net infiltration through precipitations, infiltrations from streams and from other connected aquifers.
Surface Water	Only ephemeral streams are present, however, its contribution to the *S'Albufera* wetland is important (*Torrent de Aumedrá*, *Torrent de Massana* and *San Miquel*, coming from the *Serra Tramuntana*).

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Acknowledgements

The authors greatly acknowledge Mr. Baron and Ms Gonzalez from the Water Resources Authority for their help. We also thank Ms Wallis for the report editing.

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Report on Corsica

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Abstract

Corsica, a Mediterranean island located between South continental coast (160km) and Sardinia (12km), is a French administrative area, having a surface of 8682km² and a permanent population of 260,196 inhabitants (in 1999). There is a significant increase during the summer season, since the island welcomes about 2 million of tourists. This island is divided in two departments: High Corsica and Corsica of the South.

Corsica has a Mediterranean climate with a shortage of precipitation in summer. Rainfall is not uniformly distributed throughout the year and it mainly occurs during the winter months. Yet its unequal distribution is also geographical. Indeed, there is a significant variation of precipitation when we pass from the littoral to the high tops: precipitation can vary from 800mm to more than 1,500mm. The average annual precipitation is estimated at 900mm.

The average annual temperature is about 12°C. Temperatures also constitute 3 main zones from the littoral to the mountains. In a low zone from 0 to 600m, the mean temperature is about 17°C. In a second zone, ranging between 600 to 1,200m, the mean temperature is about 13°C, and in the highest zone, the mean temperature can be inferior to 10°C. The island receives 8 $10^9 m^3$ of water per year.

Thus the potential renewable water resources are about 8 $10^9 m^3$, but 50% are lost by runoff to the rivers and finally to the sea, and 20% are infiltrated to recharge groundwater. Corsican specialists estimate that about 30% of the precipitation is lost through evapotranspiration. By using this data, however, losses through evapotransiration can even reach up to 1,035mm a year.

The geology of Corsica permits to say that this island is a real mountain in the sea. It is made up of two distinct geological zones, both mountainous. The larger one is called "Crystalline Corsica". It occupies the major part of the island, from the extreme South to the western North. The second one, called "Alpine Corsica" covers the North of the island. In a very general way, the current water needs of Corsica (water supply) are estimated at $86Mm^3$ per annum:

$68Mm^3$ (79%) are provided by surface waters (dams and reserves), and $18Mm^3$ (21%) come from ground water with the following repartition: $13Mm^3$ originate from alluvial aquifers and $5Mm^3$ from the aquifers of the fractured base yet the real amount consumed is about $61Mm^3$.

For the 28 principal watersheds of the island, the annual average aggregate rate is about $105m^3/s$, which represents a potential resource of about 3.5 $10^9 m^3$, if the resource could be entirely mobilized (with dams for example).

In Corsica, there are different types of aquifers, such as alluvial aquifers, sedimentary basin aquifers, and a base aquifer. Domestic water use, including tourism, accounts for about 44% of the total water extracted, and 49% of the total consumption. 40% of the

drinking water of Corsica's 360 municipalities is provided from surface water. The remaining 60% come from groundwater (mainly alluvial aquifers). Industrial water use represents 1% only of the water extracted and 2% of the consumption and is therefore negligible. The third, but not the less significant field of water use, is irrigation in agriculture which is responsible for 55% of the total water supply and 49% of the consumption. The total irrigated surface was about 223.3km^2 in 2000. The water used for irrigation mainly comes from surface water.

The main crops grown on Corsica are vine, orchard (citrus fruit, plums, peaches) olive-trees, nut-trees, chestnut-trees, almond trees, kiwi, cereal and fodder. These are mainly grown in the plain (Eastern Plain and Marana Casinca Plain) whereas animal husbandry - bovine, sheep, goat, pig and hive - is mainly located in mountains.

The total surface area used for agriculture is about 1,559km^2, which represents 18% of the regional territory.

The Corsican Agency for the Hydraulic Equipment (OEHC) ensures 50% of the water supply on a definite perimeter, which is essentially located in the eastern coast. The other 50% are provided by private companies. The water distributed in this way is for domestic uses and irrigation. For the water supply in mountains, the Agency for the Agricultural Development of Corsica (ODARC) takes over the tasks of the OEHC. Regarding the management of water, each of the 360 municipalities of Corsica is responsible for organising water management. Some of the municipalities have formed together trade union (SIVOM) to manage their water needs. The other municipalities can choose to apply a direct management (French: "régie"), an intermediary management ("gérance") or a delegated management ("affermage").

The two Departments, the Territorial Collectivity (local Governement) with its 6 Agencies, have settled on some measures to improve current water management with the objective of a durable development:

- Monitoring of water quality and protecting surface water resources against pollution,
- carrying out studies for estimating the potential groundwater resource and establishing a water plan for a water management,
- construction of dams in mountains to stock an important quantity of surface water,
- improving the information services in rural scale *and*
- applying modern irrigation methods.

Introduction

Corsica is a Mediterranean island under French administration. Its surface is about 8,682km^2 and its permanent population is 260,196 inhabitants. There is a significant increase in summer season, since the island can welcome about 2 millions of holiday-makers. This island is divided into two departments: High Corsica and Corsica of the South. The main economic activity is tourism, essentially concentrated along the coasts.

Agricultural activity concerns the growing of trees in the plains (citrus trees, almond trees, kiwis, etc) the production of hard-shelled fruits in mountains (chestnut trees) and animal husbandry in the mountains (goat, sheep, bovine, pig, and hives). The total GDP of Corsica is about 4,862 million of euros and represents 0.35% of the national GDP.

The climate is considered Mediterranean with relatively cold winters with significant precipitation as opposed to dry and warm summers. The average annual precipitation is estimated to be 900mm, the potential renewable water resources are 8 10^9m^3 and the water extracted is about 86Mm^3 per year with a real consumption of 61Mm^3

Corsica is a real "water tower". Indeed, the existing amount of water resource is significant. Corsica, however, faces water shortages in summer, when both, irrigation and tourism create water peak demands. Hence, the water problem in Corsica seems to relate to problems in management rather than to an insufficient presence of the water resource. The situation would thus be improved by establishing strategic policies based on integrated water management.

This report aims at presenting the situation of the island regarding its water resources management including a presentation of some social and economic data.

The first part describes Corsica in general with its physical characteristics, its water demand, its institutional context, and water management of the island as well as the socio-economic situation of the island.

In a second part, the chosen catchment for the study in MEDIS will be presented in more details. The catchment is the GOLO watershed located in northern Corsica, near the city of Bastia.

Chapter I: Overview of the Island

1.1 Physical characteristics

1.1.1 Climate

Corsica's climate can generally be described as Mediterranean because of a shortage of precipitation in summer. However, the significant variations in temperature and precipitation from the coast to the high mountains distinguish three principal climatic sets:

- *Mediterranean climate, mild and wet (0-600m),*

  The annual average temperatures vary from 14 to 17°C. Abundant, yet irregular rains appear with a long dry period in summer.
- *mediterranean climate of altitude (600-1,200m) and*

  The annual average temperature ranges between 10 and 13°C. Precipitation are about 800 to 1,500mm.

  The dry season is shorter, but dryness is still significant in summer.
- *alpine climate (> 1,200m).*

  This term is based on temperatures only. The winters are very rigorous. There are seasonal and daily fluctuations in temperatures and precipitation are very abundant.

Rainfall is not uniformly distributed throughout the year and mainly concentrates in the winter months (3/4 between October and April). The average annual precipitation is estimated at 900mm. From November to April, there is a permanent snow-covered coat on the relief (above 1,400m in slopes north and 1,700m in southern slopes). This snow plays a significant role as a potential reserve for the months following May.

On average Corsica receives approximately 8 $10^9 m^3$ of rainwater a year. Undeniably this amount represents a potential richness, in particular in the domain of water management. This water, however, is not entirely recoverable or even usable. The study of annual precipitation averages from 1971-2000, shows a rather unequal distribution of rain, with values varying from simple to triple (Figure 2):

- 500 to 600mm on the coastal fringes of the north of the Corsica Cape, Conca d'Oro, Balagne, Valinco and Sartenais like in the area of Bonifacio *and*
- more than 1,500mm on the mountainous areas of the central chain from Incudine to Cinto.

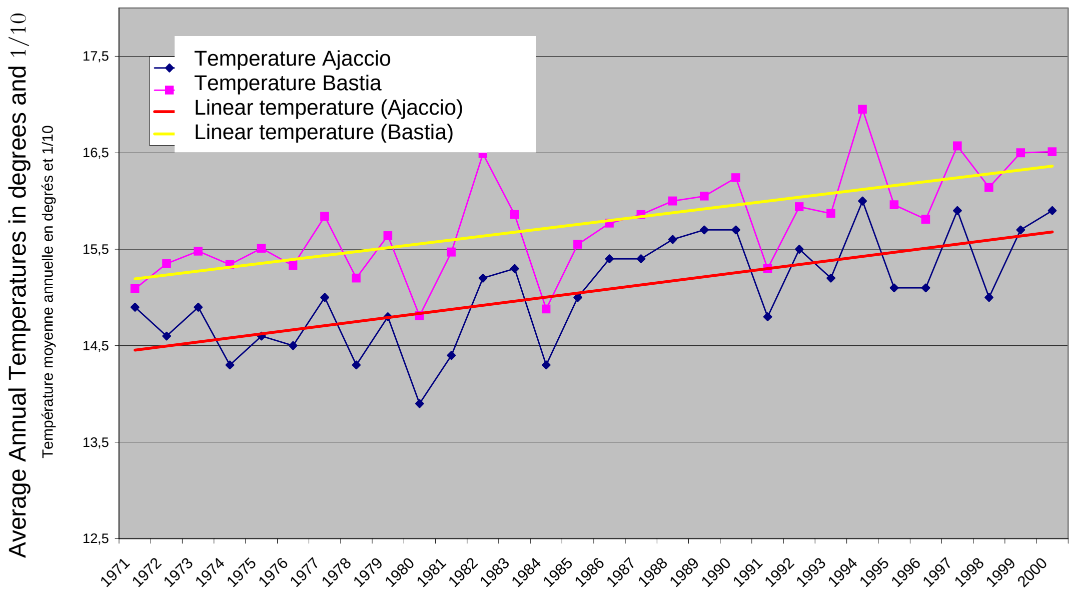


Figure 1: *Annual average temperatures in Bastia and Ajaccio between 1971 and 2000,(Meteo France, CDRom "Synthesis Convention on Water" OEHC, 2003).*

Table 1: *Statistics of climate in Corsica, (Meteo France, http://www.environnement.gouv.fr/rhone-alpes/bassin_rmc).*

Months	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Air (max average °C)	13	14	16	18	21	25	27	28	26	22	18	15
Air (min average°C)	3	4	5	7	10	14	16	16	15	11	7	4
Water (average °C)	13	13	13	14	16	20	24	25	22	20	17	15
Rainfall (number of days)	11	10	11	9	5	3	1	2	5	9	10	11
Sunshine (nb H)	133	139	191	225	278	316	369	333	265	210	148	124

Three pluviometric stations were selected to document the rainfall (Figure 4):

Figures 5, 6 and 7 present the rainfall measured in the following 3 stations:

- Calacuccia (high valley of GOLO, interior of island),
- Petreto Bicchisano (Taravo valley, western frontage of the island) *and*
- Ghisoni (High valley of Fium'Orbo, Eastern frontage of the island).

The inter-annual variations of rainfall (hydrological season from September to August, Fig. 5-7) are quite striking. Regarding the 3 last decades we can observe that:

- The 1971-1980 decade was basically "wet",
- the 1981-1990 decade was "very dry" *and*
- the 1991-2000 decade was characterised by a succession of significant abundance and deficits.

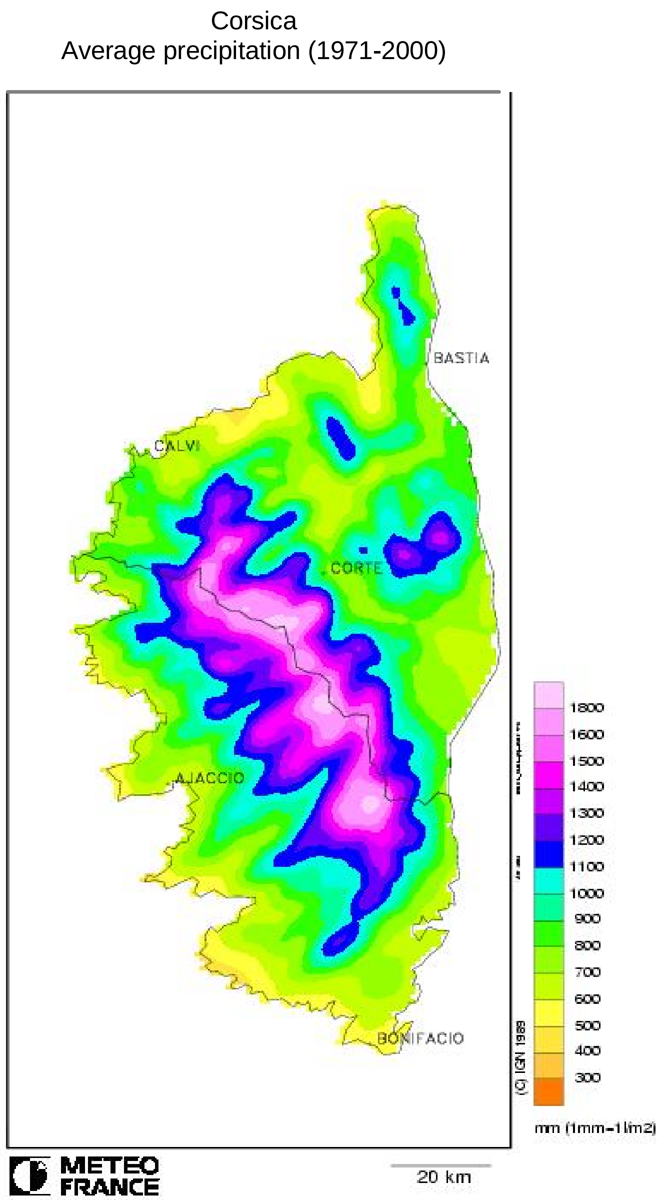


***Figure 2**: Annual average precipitation (mm), (Meteo France, CDRom "Synthesis Convention on Water", OEHC, 2003).*

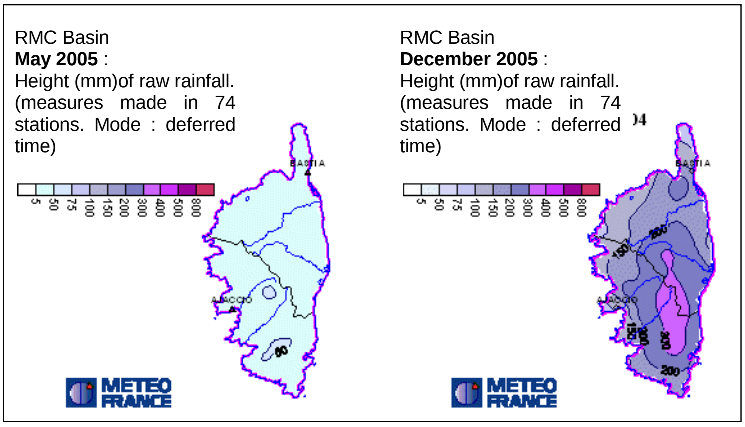


Figure 3: *Comparison of height (mm) of raw rainfall in May and December 2005, (Meteo France, http://www.environnement.gouv.fr/rhone-alpes/bassin_rmc).*

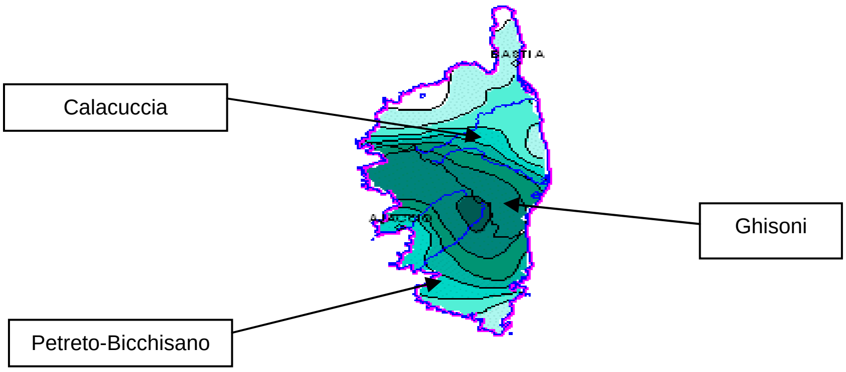


Figure 4*: Location of the 3 rainfall measure stations.*

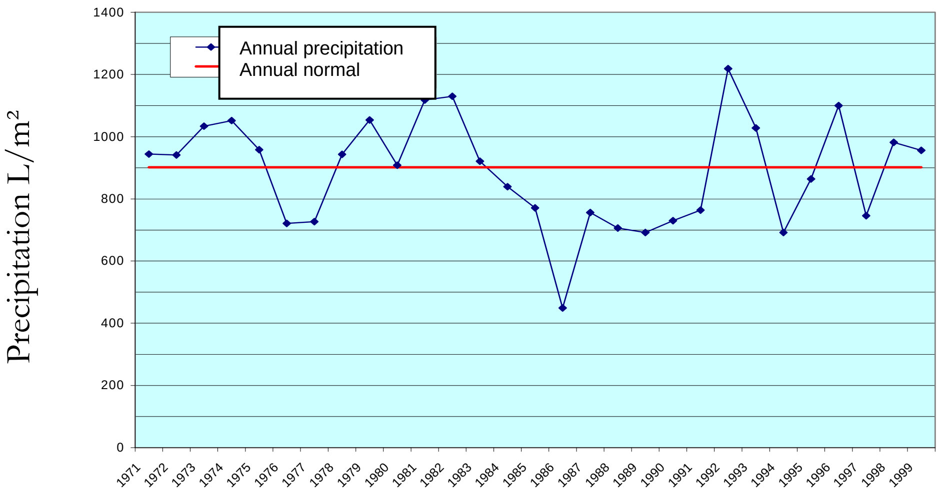


Figure 5: *Annual precipitation in Calacuccia 1971-1999, hydrological year September-August, (Meteo France, CDRom "Synthesis Convention on Water", OEHC, 2003).*

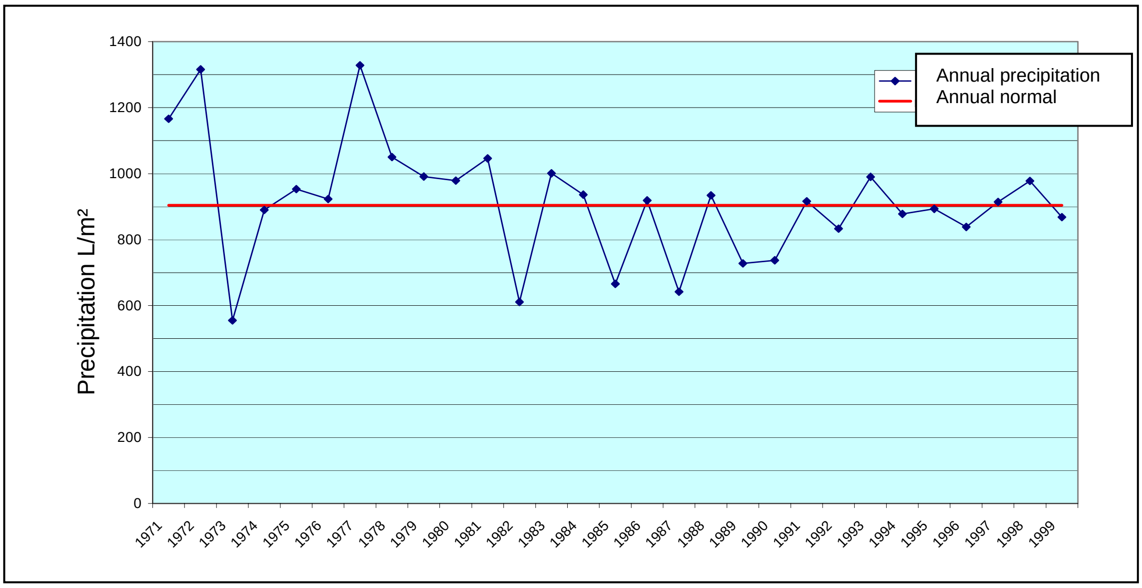


Figure 6: *Annual precipitation in Petreto Bichisano 1971-1999, hydrological year September-August, (Meteo France, CDRom "Synthesis Convention on Water", OEHC, 2003).*

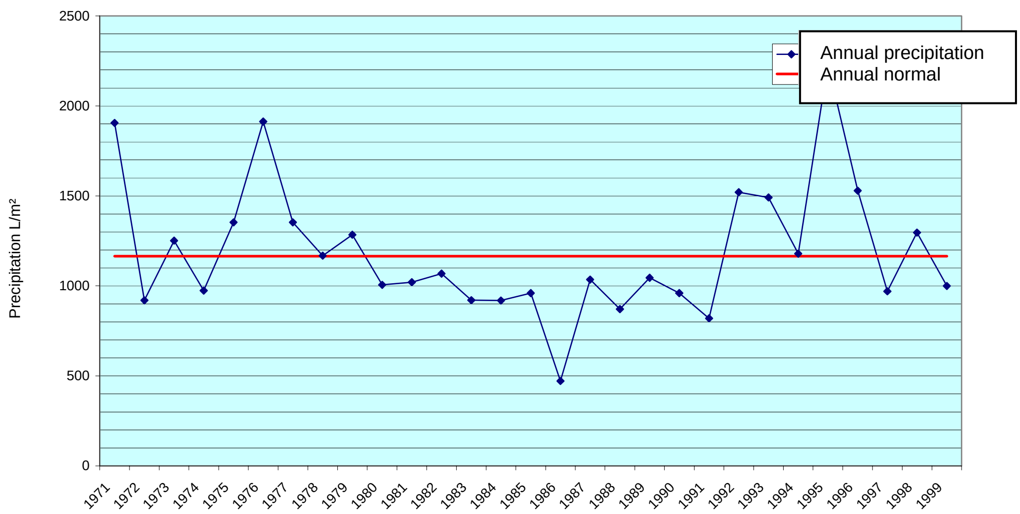


Figure 7*: Annual precipitation in Ghisoni 1971-1999, hydrological year September-August, (Meteo France, CDRom "Synthesis Convention on Water" OEHC, 2003).*

The tendency of the annual rainfall between 1971 and 2000 shows a significant change since 1984, as witnessed in the Calacuccia station:

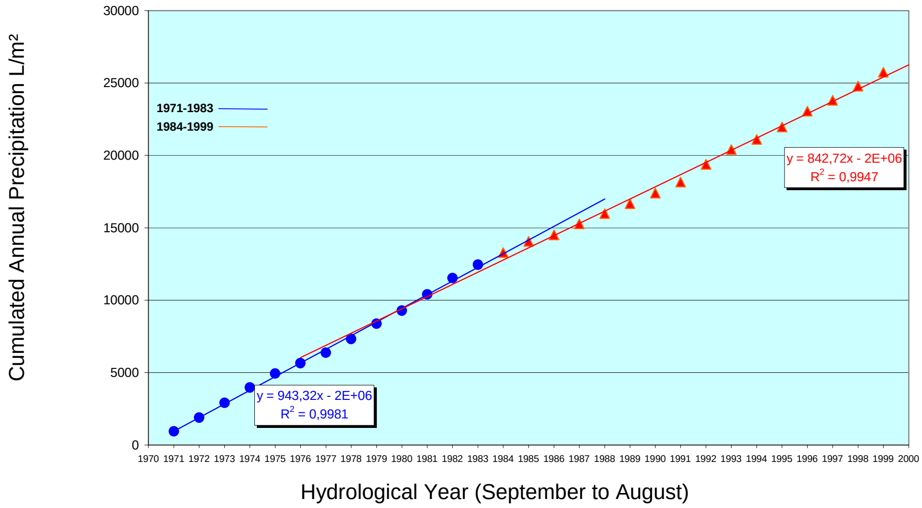


Figure 8: *Changing in rainfall since 1970 to 2000, (Meteo France, CDRom "Synthesis Convention on Water", OEHC, 2003).*

This change is detected through the rainfall collected between the beginning of autumn and the beginning of spring (October to April) in the Calacuccia and Petreto Bichisano stations. Ghisoni is less concerned. Thus it is likely that the regions of the interior and those of the western frontage of the island are rather affected than the regions of the eastern frontage.

1.1.2 Aridity index

The mean yearly precipitation is 900mm and the mean yearly evapotranspiration is 1035mm. The aridity index (precipitation to potential evapotranspiration calculated according to the Penman-Monteith equation) is classified in table 2:

Table 2: *Aridity index ranges and classification.*

Aridity index ranges	Classification
<0.03	hyper arid
0.03-0.20	arid
0.20-0.5	semi-arid
0.5-0.65	Sub-humid
0.65-0.75	moist sub-humid

In Corsica the aridity index is 0.87 and thus moist sub-humid.

1.1.3 Geology

Corsica is a real mountain in the sea. The island presents two main geological regions: Crystalline and Alpine Corsica (Figure 9).

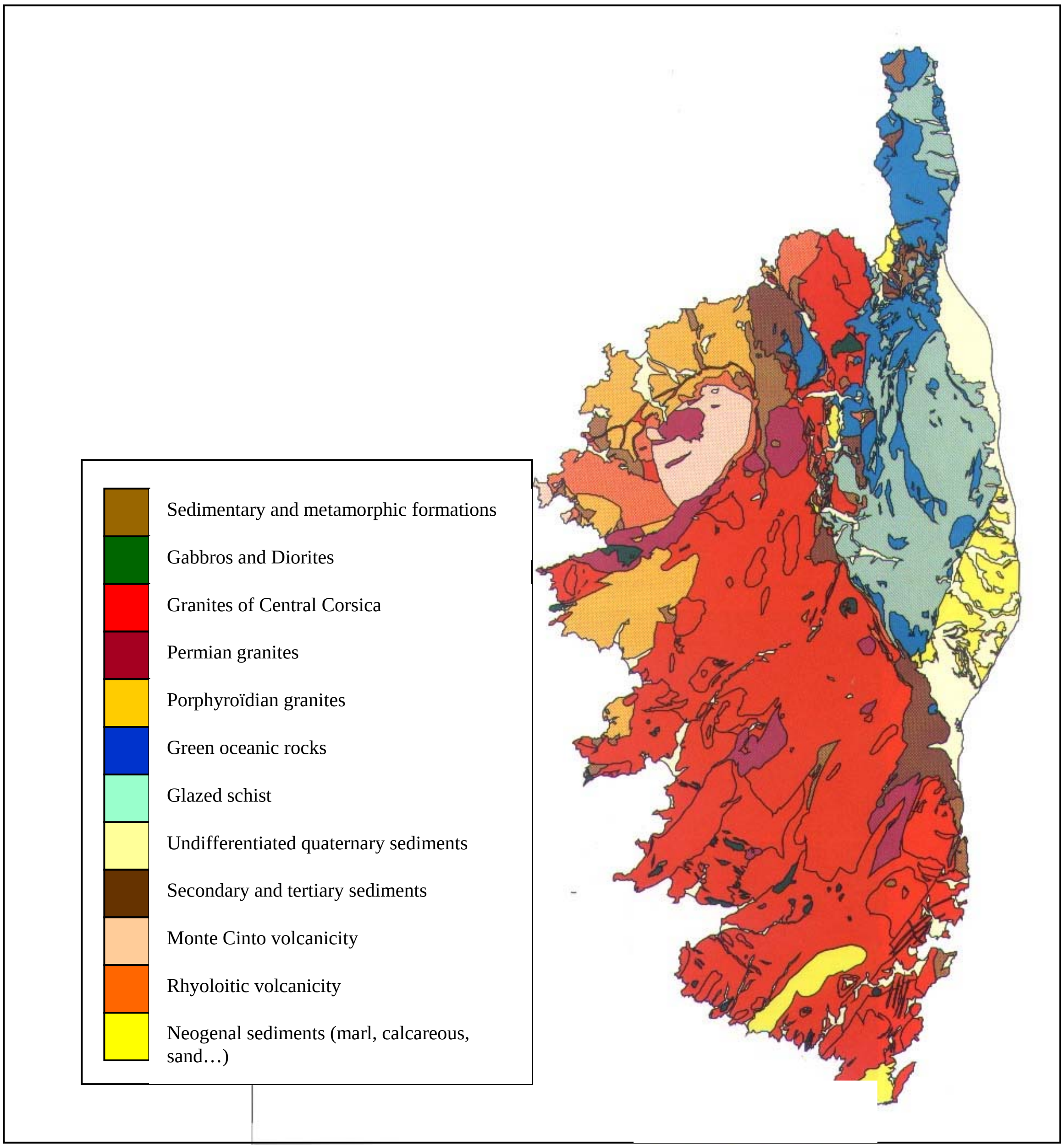


Figure 9: *Geology of Corsica, (BRGM/DIREN).*

Crystalline Corsica (in red on the map)

This zone represents the most important part of the island and extends from the extreme South to the Western North.

The main relief belongs to this part of the island. We can distinguish:

- Monte Cinto the highest mountain peak of Corsica with 2,710m,
- a set of mountain peaks exceeding 2,500m: Capu Biancu, Capu a u Berdatu, Punta Minuta, Cap u Larghja, Capu Falu, Paglia Orba) *and*
- Monte Rotondu (granitic) 2,625m.

The mountains decline slightly towards the south:

- The mountain peaks of Bavella reach 1,900m only,
- Ospedale *and*
- Monte di Cagna.

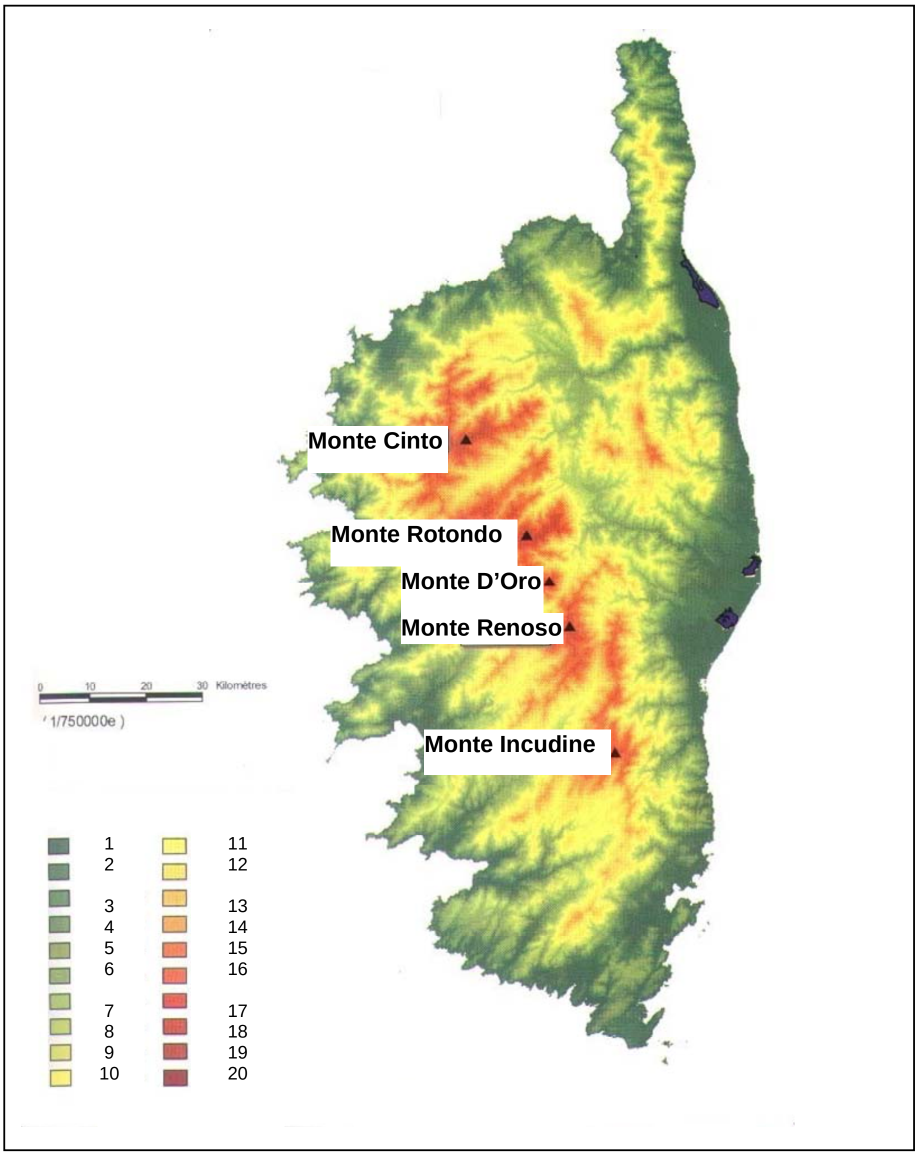
Alpine Corsica (in blue on the map)

Alpine Corsica is located in the northeast of the island with a shorter relief. There are:

- The chain of the Corsican Cap with the Monte Stellu in the north reaching 1,307m,
- Massif of Tenda (1,533m),
- San Pedrone (1,766m) *and*
- Monte Pianu Maggiore and Monte Tre Pieve which make up the high basin of the Fium'Altu.

Furthermore we can distinguish:

- The central furrow (in brown on the map) separating the Alpine Corsica from the Crystalline Corsica and constituting a 150km long depression made of a succession of small basins from north-west to nouth-east (Alisu, Ostriconi, Golu, Tavignanu, Solenzara);
- on the Eastern coast there is the eastern Plain which is an alluvial plain extending from Bastia to the mouth of Solenzara (in yellow on the map) and
- the Calcareous Corsica (in yellow on the map) consisting of:
  – Miocenes limestones of Saint Florent,
  – outcrops of Caporalino and San Angelu de Lanu,
  – outcrops of Plain of Aleria *and*
  – the platform of Bonifacio.



Legend:

1	1 to 50m	11	801 to 950m
2	51 to 100m	12	951 to 1100m
3	101 to 150m	13	1101 to 1250m
4	151 to 200m	14	1251 to 1450m
5	201 to 250m	15	1451 to 1650m
6	251 to 350m	16	1651 to 1850m
7	351 to 450m	17	1851 to 2050m
8	451 to 550m	18	2051 to 2300m
9	551 to 650m	19	2301 to 2550m
10	651 to 800m	20	2551 to 2900m

Figure 10: *Main relief of Corsica, (Atlas of main environmental data 2000, Observatory of the Environment of Corsica (OEC), BD Alti IGN).*

1.1.4 Surface waters

Rivers

Corsica has many rivers which flow through the whole island, and their water resources are better known than groundwater.

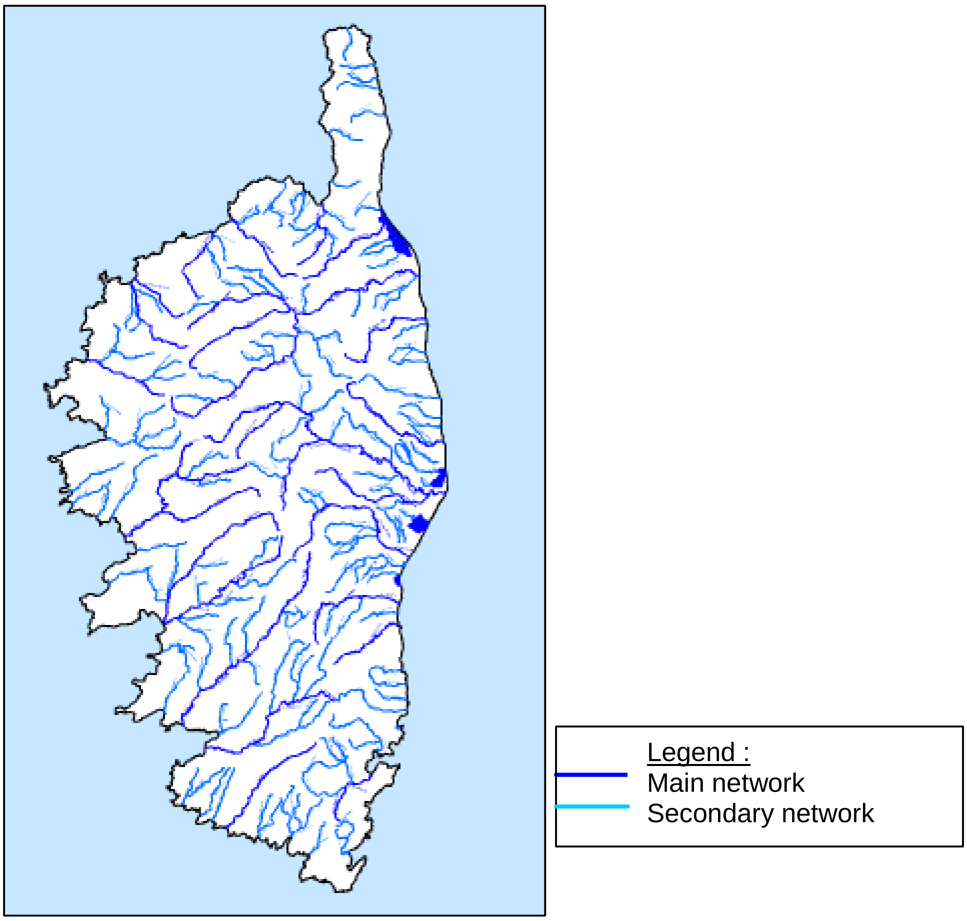


***Figure 11**: Hydrographical network of Corsica, (http://www.rdbrmc.com/cartordbrmc/cartordbrmc.php?vphp=vregion_c,vhydro1_2,vcdr_1,vzoom_1600)*

For the 28 principal watersheds of the island, the annual average rate is about 105 m^3/s, which leads to a potential available resource of about 3.5 $10^9 m^3$ (if the resource could be entirely mobilized with dams for example) yet only 25% (900M m^3) of it are exploitable.

The following figure depicts the length of the main rivers of Corsica in kilometres. The watershed studying in MEDIS, the GOLO River is depicted in yellow.

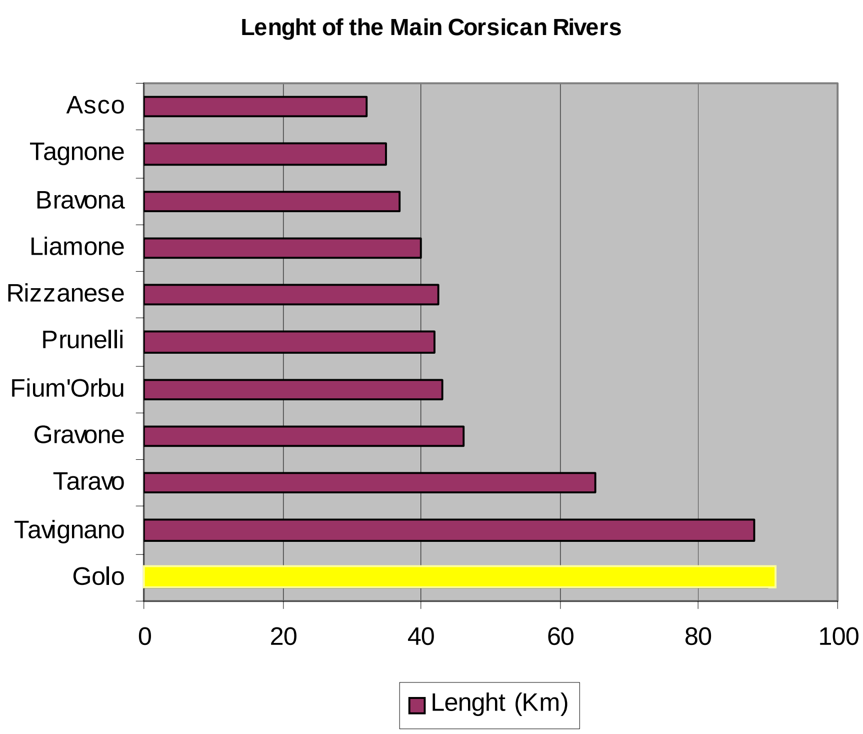


Figure 12: *Length of principal rivers of Corsica (km), (Atlas of main environmental data 2000, Observatory of the Environment of Corsica).*

From the 8 $10^9 m^3$ of precipitation per year, only $4.10^9 m^3$ contribute to river flows (figure 20) and 1.6 $10^9 m^3$ to groundwater recharge (figure 20). For the 28 main watersheds the average annual flow is about $105 m^3/s$ and the area $6,204 km^2$ which makes up 70% of the island's surface area. These average values are of great variability due to the island's morphology and the Mediterranean climate:

Space variability:

Owing to the organisation and the partitioning of the watersheds, eight watersheds have a surface area superior to $250 km^2$ and hold more than 72% of the water resource having an average flow of $76 m^3/s$.

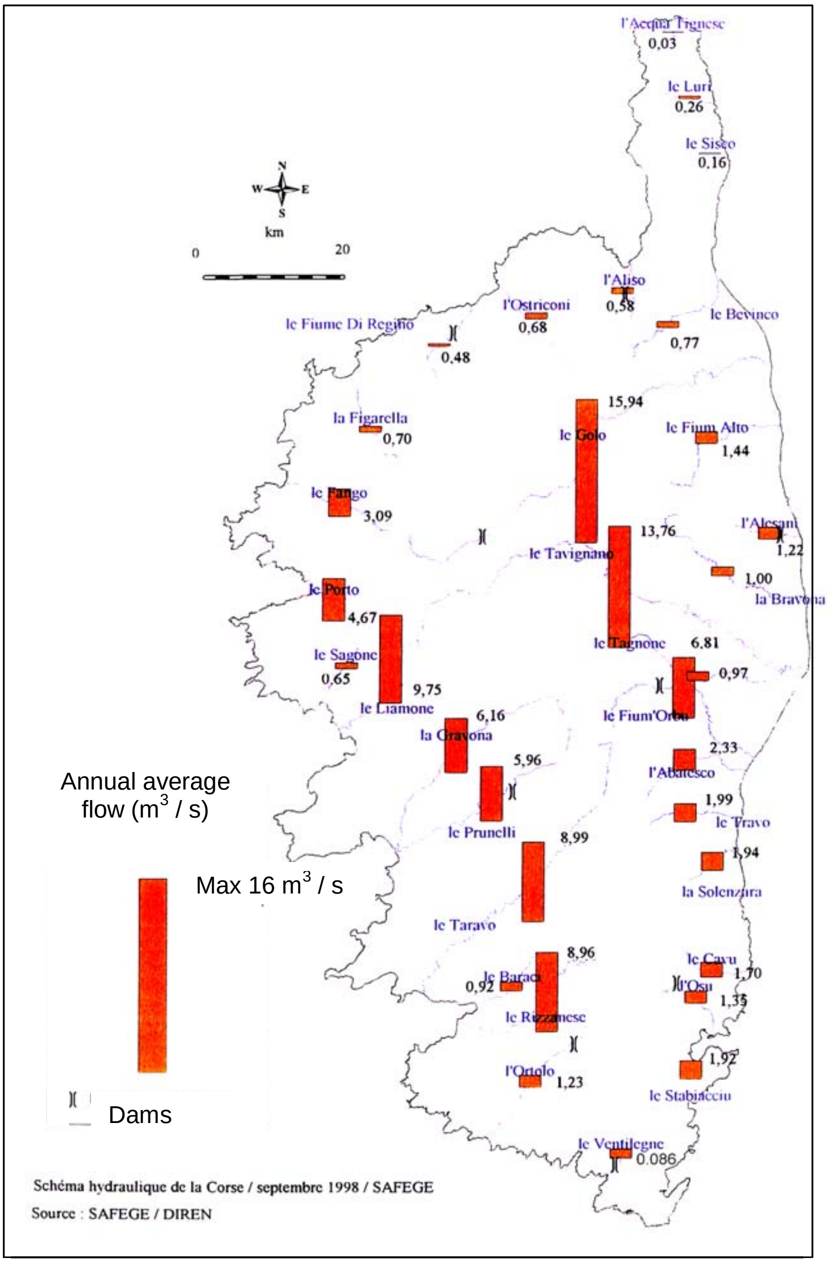


Figure 13: *Annual average flow of the main Corsican rivers [$m^3\ s^{-1}$], (SAFEGE/DIREN).*

Time variability:

We can distinguish two kinds of variability:

- *Inter-annual variability and*

  Inter-annual variations are directly corresponding to climatic variations. Each year the average water inflow varies significantly which is why the inflows could be termed as "period of return". There can for example be a decennial dry inflow or a decennial wet inflow, which corresponds to an average volume which is only reached once every 10 years, or reached one time on 10 in one year.

- *monthly variability.*

  The annual inflows are also irregularly distributed throughout the year. Then, Corsica's surface water resources, which are estimated higher than $100m^3/s$ (annual average) reach only about $7m^3/s$ in periods of low precipitation, with 74% ($5.2m^3/s$) on the eight main watersheds.

Surface waters are used by the big cooperatives. It should be noted that the surface waters require a complete treatment which is very expensive before they can be used as drinking water. Moreover, this resource must be managed by specialists. Consequently it is very often not affordable for small rural municipalities.

The surface water resource has been detected for more than 30 years now. The current question is the development of this resource in the future.

Ponds and lakes

The Corsican Mountains have a lot of lakes, the coasts predominately ponds. Both of them represent a significant natural reserve of water, but they are neither used for water supply of the municipalities located in mountains, nor for irrigation.

Ponds and lakes are attractive for tourism and tourists activities such as: fishing, walking, camping, canoeing, bathing. However ponds are primarily used for fishing and shellfish breeding.

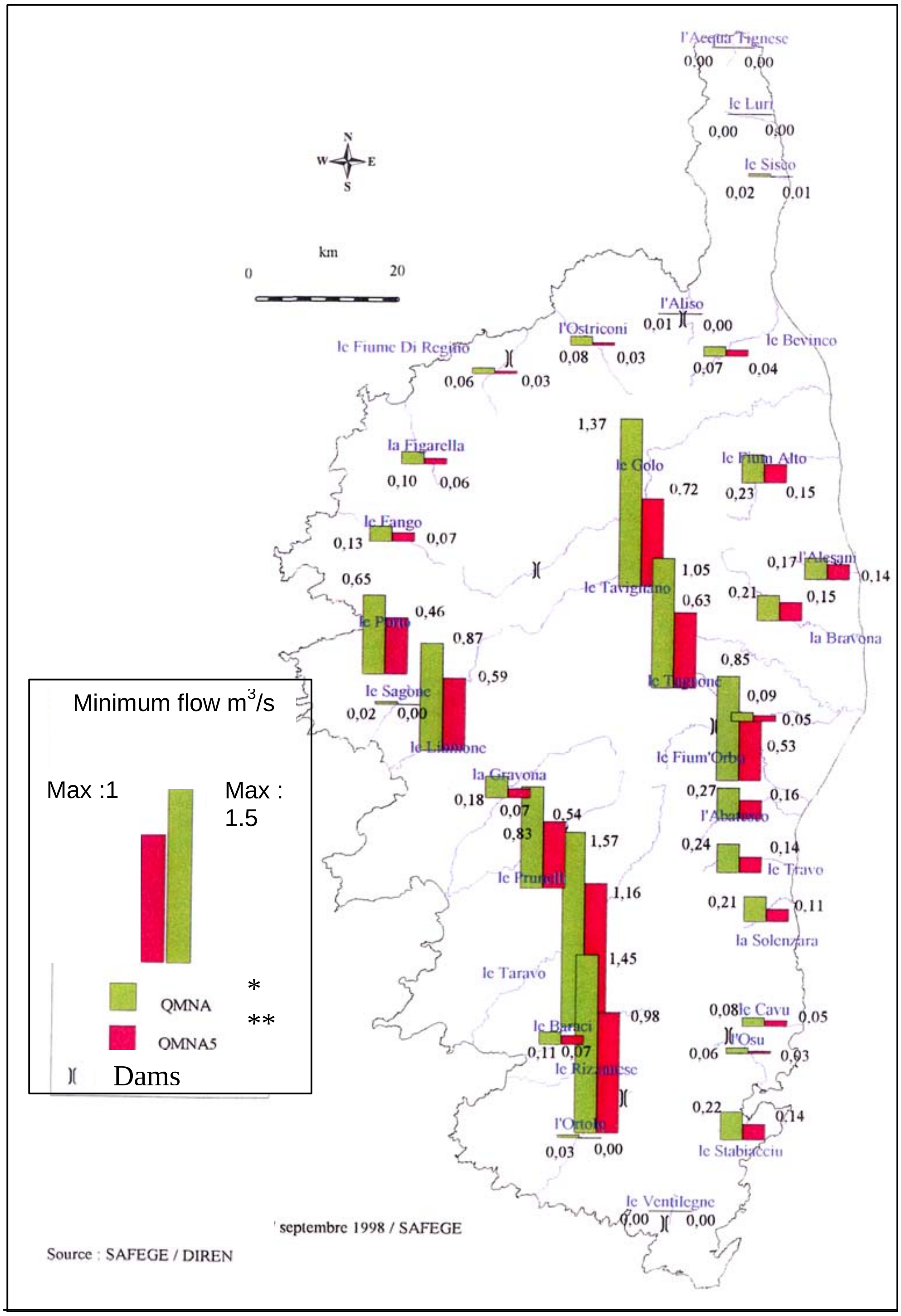


Figure 14: *Flow during the dry period (low water level) of the main rivers of Corsica, (SAFEGE/DIREN).*
*(*QMNA: Monthly minimal flow for each calendar year,*
***QMNA: Monthly minimal flow with a five-year dry frequency).*

Table 3: *Rivers basic flows in June 2002 and February 2003, (Hydro climatic situation of Corsica, DIREN SEMA).*

River	**Station**	VCN 3 *$m^3 s^{-1}$ **2002 June**	VCN 3 *$m^3 s^{-1}$ **2003 February**
Aliso	Padule	0.008	0.172
Asco	Ponte Leccia	0.365	3.310
Bevinco	Lancone	0.054	0.338
Bravone	Tallone	0.110	0.443
Fango	Galeria	0.141	0.427
Fium'Alto	Acitaja	0.337	0.637
Fium'Orbo	Ghisonaccia	0.786	2.280
Golo	**Albertacce**	**0.341**	**1.300**
Golo	**Barchetta**	**1.820**	**9.170**
Gravone	Peri	0.584	3.180
Liamone	Truggia	1.430	5.140
Luri	Piazza	0.010	0.081
Ortolo	Vignalella	0.019	-
Porto	Ota	-	-
Rizzanese	Pt de Zoza	0.589	2.630
Solenzara	Can. + Tafo.	0.217	1.63
Taravo	Bridge of Abra	1.270	5.420
Tavignano	Antisanti	1.610	5.800
Vecchio	Noceta	0.564	2.210

**VCN 3: Mean flow for 3 consecutive days of low water level during the considered period.*

In the WFD (DCE in French), ponds have been considered and declared as coastal waters, whereas natural lakes have not been taken into account due to their small size (< 0.50km²).

Table 4: *Mountainous lakes of Corsica, (Atlas of the main Environmental data 2000, observatory of the environment of Corsica).*

Name	**Department**	**Altitude (m)**	**Area (km²)**
Lake of Bellebone	2B	2,321	0.075
Lake of Nino	2B	1,743	0.062
Lake of Melo	2B	1,711	0.061
Lake of Capitello	2B	1,930	0.055
Lake of Gloria	2B	1,852	0.046
Lake of Bastiani	2B	2,089	0.041
Lake of Creno	2A	1,310	0.025
Lake of Niellucio	2B	1,919	0.012
Lake of Oriente	2B	2,061	0.012
Lake of Rinoso	2B	2,065	0.011
Lake of Oro	2B	1,970	0.011
Lake of Rina	2B	3,688	0.011
Lake of Cinto	2B	2,289	0.010
Lake of Vitalaca	2A	1,777	0.009
Lake of Bracca	2A	2,085	0.009
Lake of Maggiore	2B	2,344	0.008

Table 4 continued.			
Name	**Department**	**Altitude (m)**	**Area (km²)**
Lake of Cavacciole	2B	2,015	0.006
Lake of Scapuccioli	2B	2,338	0.004
Lake of Gialicatapiano	2B	1,523	0.003
Lake of Oro	2B	1,563	0.003
Lake of Pozzolo	2B	2,300	0.002
Lake of Ghiarghe Rosse	2B	2,182	0.002
Lake of Muvrella	2B	1,850	0.002
Lake of Argentu	2B	2,200	0.001

***Table 5**: Ponds of Corsica, (Atlas of the main Environmental data 2000, observatory of the environment of Corsica).*

Name	Department	Area [km²]
Pond of Biguglia	2B	13.679
Pond of Urbino	2B	7.582
Pond of Diane	2B	5.491
Pond of Palo	2B	1.122
Pond Del Sale	2B	1.067
Pond of Santa Giulia	2A	0.346
Pond of Balistra	2A	0.301
Pond of Terrenzana	2B	0.271
Pond of Tanchiccia	2A	0.21
Pond of Padulatu	2A	0.188
Pond of Gradugne	2B	0.136
Pond of Padulu Tordu	2A	0.127
U Stagnolu	2B	0.125
Pond of Ventilegne	2A	0.099
Pond of Arasu	2A	0.089
Pond of Canniccia	2A	0.083
Pond of Cannuta	2B	0.076
Pond of Pisciu cane	2A	0.070
Pond of Canettu	2A	0.054
Pond of Loto	2B	0.053
Pond of Povu Santu	2A	0.046
Pond of Prisarella	2A	0.039
Pond of Piantarella	2A	0.033
Pond of Crovani	2B	0.027
Pond of Palombaggia	2A	0.024
Pond of Saline Sotane	2A	0.024
Padule Maggiore	2A	0.023
Pond of Sperone	2A	0.018
Pond of Casavone	2A	0.014
Pond of Panecalellu	2B	0.014
Pond of Stagnolu	2A	0.009
Mura Dell'Una	2A	0.008
Pond of Saline Soprane	2A	0.007

Water storage (surface water)

The majority of water mainly stored as dams or reserves in Corsica is not intended for single use and could have several purposes, such as irrigation (I), drinking water (AEP), or hydropower (E) (Table 6). The Electricity Organisation of France (EDF) and the Corsica Agency for the Hydraulic Equipment (OEHC) exploit and manage these reserves.

***Table 6:** EDF Dams, (Atlas of the main Environmental data 2000, observatory of the environment of Corsica).*

Location of EDF dams	Capacity [Mm^3]	Destination
Calacuccia	25.000	E I
Corsicia	0.080	E
Sampolo	2.000	E I
Trevadina	0.247	I
Tolla	32.000	E I AEP
Ocana	0.022	E
Total	**≈ 60 [Mm^3]**	

E: Energy; I: Irrigation; AEP: Drinking Water.

The OEHC has some "Water rights" on the EDF dams, which permit to the OEHC to use the water stored in EDF dams. Examples:

- *Calacuccia and*

  Maximal capacity: $25Mm^3$.
  OEHC used $14.7Mm^3$ in 2001.
  This water permits to ensure the water supply of Bastia in summer. $10.3Mm^3$ were used for energy.

- *Tolla.*

  Maximal capacity: $32Mm^3$.
  OEHC used $13.6Mm^3$ in 2001:
  10 10^6 for irrigation and drinking water and 3.6 10^6 for the drinking water supply of Ajaccio.
  About 18.4 10^6m^3 were used for Energy.

***Table 7:** Dams and reserves of OEHC, (Atlas of the main Environmental data 2000, observatory of the environment of Corsica).*

OEHC Dams		
Location of OEHC dams	**Capacity [Mm^3]**	**Destination**
Codole	5.000	I AEP
Padule	1.400	E I
Alesani	11.300	E I
Ospedale	2.250	I AEP
Ortolo	2.800	E I
Figari	5.500	I AEP
Total	**≈ 30 [Mm^3]**	

Table 7 continued.		
OEHC Reserves		
Location of OEHC reserves	**Capacity [Mm^3]**	**Destination**
Salvi	0.041	AEP
Rogliano	0.047	AEP
Guazza	0.300	E I AEP
Peri	2.900	I
Teppe Rosse	4.349	I
Alzitone	5.070	I
Bachiana	2.500	AEP
TOTAL	**≈ 15 [Mm^3]**	

E: Energy; I: Irrigation; AEP: Drinking Water.

The water stored by the OEHC dams and reserves is about 45Mm^3.

Thus, we can estimate the potential available water resource from surface water at about 105Mm^3. This amount, however, is not significant and should not be considered as a reliable figure because the filling of the dams and reserves varies from a year to year according to precipitation and water demand (EDF can fill the same dam twice in one year).

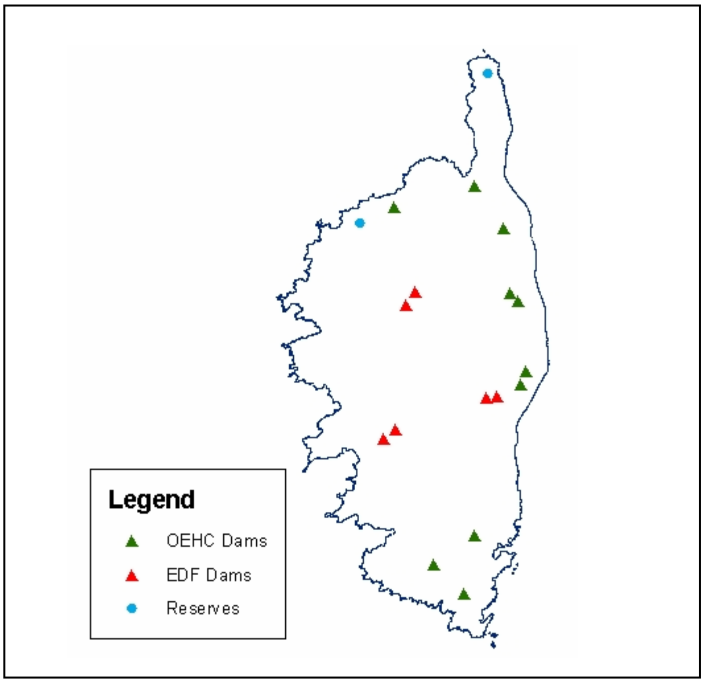


Figure 15: *Location of main dams and reserves, (Atlas of main environmental data 2000, Observatory of the Environment of Corsica).*

***Table 8**: Stored volumes in some EDF dams from September 2002 to February 2003, (Hydro climatic situation of Corsica _DIREN SEMA).*

EDF Dams							
Name	**Maximal Capacity 10^6 m^3** (Potential resource)	**Real Volume stored**					
		Sept 30-02	Oct 31-02	Nov 30-02	Dec 31-02	Jan 31-03	Feb 28-03
Tolla	32.000	25.081	27.154	30.020	27.083	24.543	15.327
Calacuccia	25.000	14.622	19.307	23.027	21.874	15.656	7.442
Sampolo	1.600	0.902	1.108	0.857	1.202	0.837	0.944

***Table 9**: Stored volumes in some OEHC dams and reserves from September 2002 to February 2003, (Hydro climatic situation of Corsica_DIREN SEMA).*

OEHC Dams and Reserves							
Name	**Maximal Capacity 10^6 m^3**	**Real Stored Volume**					
		Sept 02-02	Oct 07-02	Nov 04-02	Dec 02-02	Jan 30-03	Feb 03-03
Alesani	11.33	4.285	3.369	2.257	1.398	3.625	4.344
Peri	2.900	0.535	0.838	1.508	1.239	1.476	2.305
Codole	5.000	2.080	2.798	3.150	4.737	6.600	6.600
Altzitone	5.070	2.862	2.763	3.053	3.401	2.972	2.630
Teppe Rosse	4.349	2.171	3.549	4.073	4.231	4.276	4.349
Ospedale	2.250	1.701	1.635	2.003	2.452	2.907	3.220
Rogliano	47000	9.500	12800	15000	15800	26500	4200
Figari	5.500	2.340	2.160	2.320	2480	3.033	4.405

1.1.5 Hydrogeology

In Corsica the subsurface is a fractured environment which contains different types of aquifers.

Alluvial aquifers:

There are 40 alluvial aquifers near the coastal regions. The major part of the water quantity used in Corsica comes from surface water, but 120,000m^3/d are taken from alluvial aquifers in the summer period as well, which leads to a total flow of 1,3m^{3}s^{-1} for the entire island. The use of some of the coastal aquifers (Calu for example) is restricted to summer to avoid seawater intrusion. The GOLO aquifer is used throughout the year for the drinking water supply of 7 municipalities. They are the main resource for the drinking water needs of the municipalities and have the advantage of generally requiring a basic treatment of disinfections. But as their exploitation is restricted, other resources must be used.

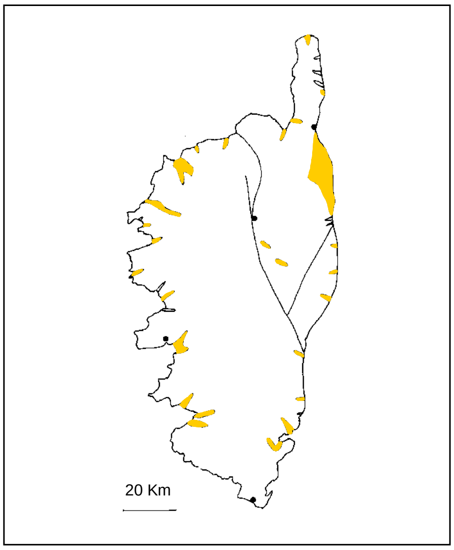


Figure 16: *Alluvial aquifers of Corsica, (DIREN SEMA).*

Aquifers of sedimentary basin:

These aquifers have a limited extension and are not commonly used. Only the coastal Miocene basins probably have some significant aquiferous tanks.

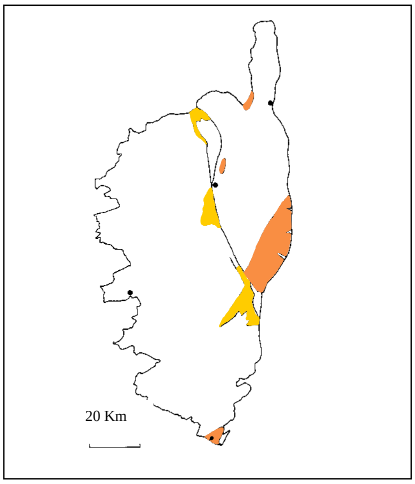


Figure 17: *Location of sedimentary aquifers, (DIREN SEMA).*

Aquifers of the granitic base:

This base type that is granitic as well as metamorphic, makes up more than 80% of the geological conditions in Corsica. These aquifers are still traditionally used in the mountainous villages of central Corsica. Both natural springs and wells are used for exploitation by the smaller municipalities. The exploited water is not measured, thus the amount can not be quantified. However, as this resource has a low flow its exploitation and consumption can be considered negligible.

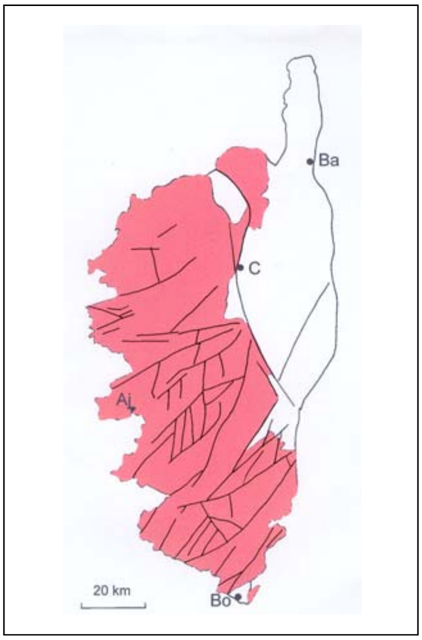


***Figure 18**: Aquifers of the granitic base: the fractures of the ground contain water, (DIREN SEMA).*

The rocks of this base are most commonly found on the island's surface. An existing aquifer in these rocks aquifers would be a significant economic resource for the villages of the island's interior. For example:

$2m^3/h$	$48m^3/d$	200 inhabitants
$5m^3/h$	$120m^3/d$	600 inhabitants
$10m^3/h$	$240m^3/d$	1200 inhabitants

There are several private boreholes and pumping wells on the island but there are neither institutions or public services to control and measure the volumes abstracted nor is there a census recording the location and capacity of these boreholes. Research projects are currently being carried out by the BRGM to obtain necessary data about these aquifers.

1.1.6 Water balance

Precipitation

The average annual precipitation is estimated at 900mm. The island receives $8Mm^3$ of water per year. Thus, the potential renewable water resources are about $8Mm^3$.

The repartition of the precipitations is:

- 500 to 600mm on the coastal fringes of north Corsica *and*
- More than 1500mm on the mountainous areas of the central chain.

50% are lost by runoff to the rivers and the sea, and 20% are infiltrated to recharge groundwater (see figure 21).

Evapotranspiration (ETP)

Regarding the losses through evaporation, the Corsican specialists can only estimate the losses as there are only few stations to obtain these data. The stations are at Poretta, San Giuliano and Ghisonaccia. Evapotranspiration calculated by the Penman equation at Poretta for more than 30 years is slightly superior (by 5 to 10%) to this of the stations at San Giuliano and Ghisonaccia. The average values determined at Poretta which remained relatively stable for more than 30 years and have a low monthly variation are thus usable for calculating the water balance in Corsica. The minimum and the maximum values are also available and can thus be used for futher analysis.

Table 10: *ETP values during 30 years (Poretta) in mm, (ODARC, 2002).*

Month	**1st Decade (10 days)**			**2nd Decade (10 days)**			**3rd Decade (10 days)**			**Sum by month**
	Mini	**Mean**	Max	Mini	**Mean**	Max	Mini	**Mean**	Max	
January	4	**9**	17	4	**9**	14	7	**11**	17	29
February	6	**12**	24	10	**13**	21	9	**12**	17	37
March	11	**18**	24	14	**21**	31	16	**27**	19	66
April	19	**26**	41	24	**30**	45	22	**33**	42	89
May	22	**35**	45	27	**38**	51	38	**46**	61	119
June	35	**46**	57	37	**49**	59	39	**53**	64	148
July	45	**57**	63	44	**57**	66	51	**62**	69	176
August	45	**54**	63	41	**50**	57	38	**47**	58	151
September	28	**38**	46	25	**32**	39	24	**28**	35	98
October	20	**24**	32	13	**19**	26	12	**17**	24	60
November	8	**12**	17	6	**10**	25	5	**10**	18	32
December	5	**10**	18	3	**10**	27	4	**10**	20	30

According to table 10, the Penman-Monteith evapotranspiration can be estimated at 1,035mm for a year.

Infiltration

Regarding water infiltration in the ground, a map has been drawn up from approximations. A coefficient can be calculated to estimate the water infiltration according to several factors, such as soil characteristics, geology, fissuring, and precipitation. The following map shows five grades of infiltration, determined by the infiltration coefficient. The accuracy of the infiltration coefficient varies locally. In Alpine Corsica 65% of the determined coefficients are very low, while they are higher in Crystalline Corsica. As high mountains are less fissured, the coefficient is weaker than in the regions around. Moreover, the precipitation in the mountains are concentrated in winter and mostly occur in form of snow. Snow means that there is a significant mobilisation of water which is not infiltrated. The piedmont is more fissured than the upstream and precipitation only occur in form of rain, hence the water infiltration is more significant.

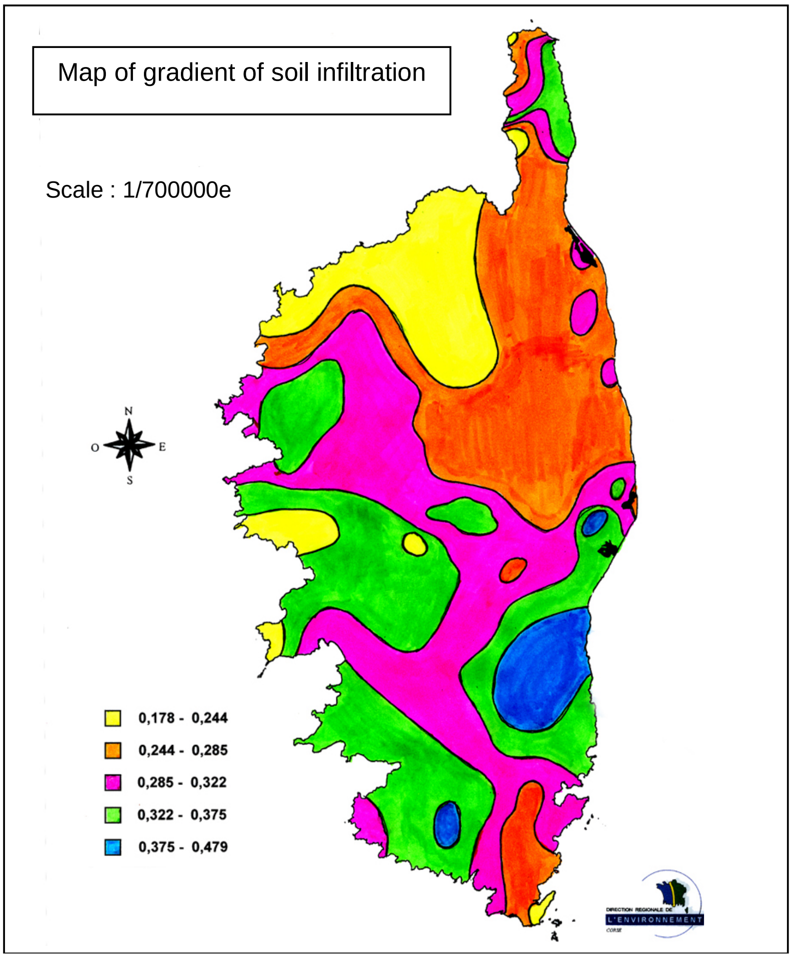


Figure 19: *Map of the water gradient of infiltration in the ground, (DIREN SEMA).*

Water Balance

Regarding the outflows, the main component is surface water which is stored in several dams and is used for drinking water supply and irrigation. Some villages in mountains exploit their water from springs, but there are no figures as to evaluate volume abstracted. Also, there is no significant sea water intrusion.

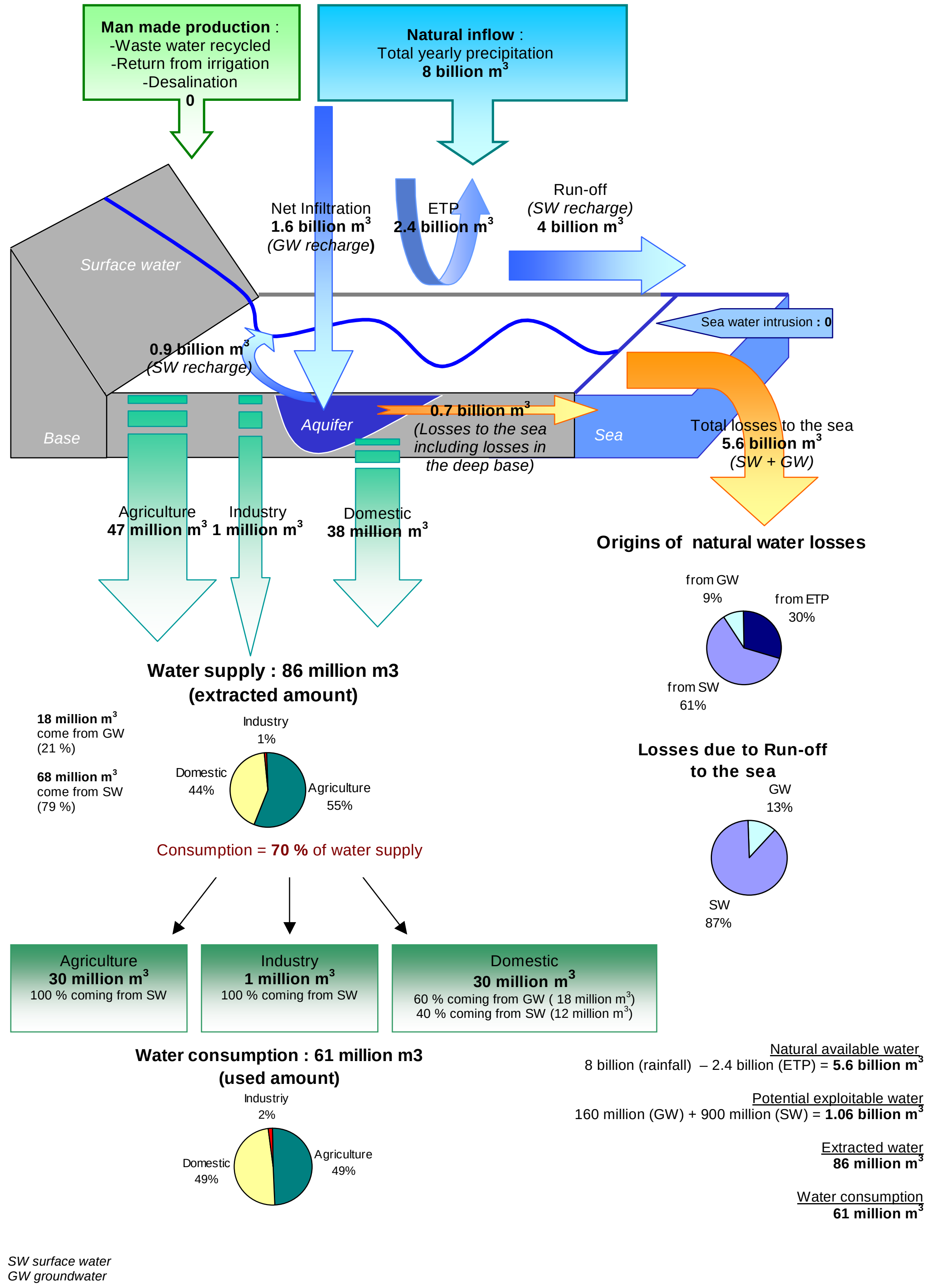


Figure 20: *Hydrological balance of Corsica.*

The water available for consumption (all sources) can then be calculated to 86Mm³ stored in dams and taken from alluvial aquifers and the water availability per capita and year is 330.5 (86M/260196m³) based on 86Mm³ water available for consumption. In taking into account the two million tourists visiting Corsica throughout the year, the water availability per capita and year is then about 201.5 (86M/426863 equivalent population). Then the direct repartition of water balance due to precipitation can be summarised as follows:

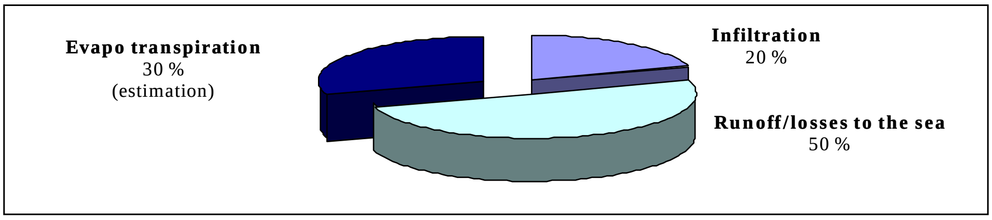


Figure 21: *Destination of the 8 $10^9 m^3$ of water provided by precipitation.*

1.2 Water demand and supply

1.2.1 Water consumption

Even if the potential renewal water resource is about 8 10^9m³, the real water extracted is about 86Mm³/year only, all purposes included. The contribution of surface water is very important and represents 79% of the water used.

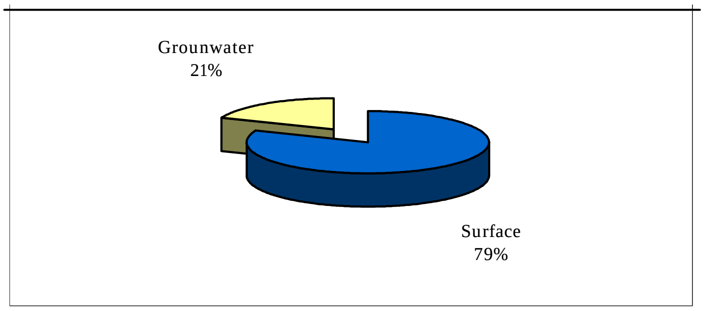


Figure 22: *Origin of the real amount of water extracted per year, (OEHC, 2002).*

In Corsica, agricultural and domestic needs are the most important sectors regarding water consumption and practically hold an even share. Agriculture makes up 55% of the total water supply and 49% of the consumption. The total surface area used for agriculture is about 1,559km² (18% of the total island area) and the corresponding irrigated surface (SI) was estimated at 223.3km² in 2000 (according to the agricultural general census 2000). Yet this value varies according to the crops cultivated. Also, water used for irrigation is higher in summer and spring. Domestic uses, including tourism, represent 44% of the water supply and 49% of the volume consumed with household consumption showing a peak during the summer season. Industrial uses (water bottling companies, hydropower plant etc.) make up only 1% of the water supply and 2% of the consumption.

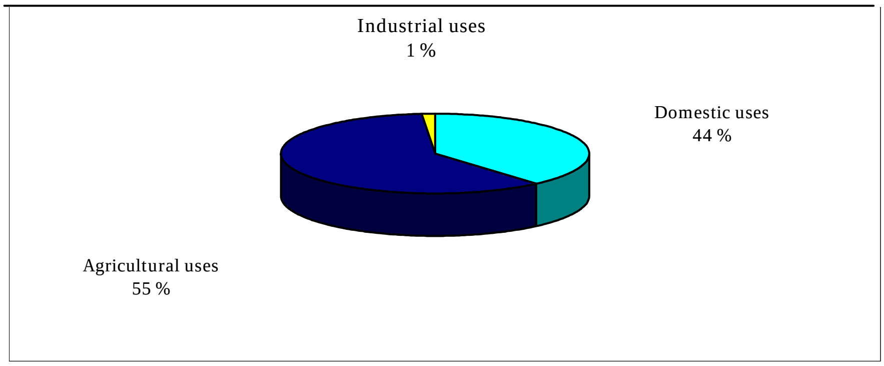


Figure 23: *Repartition of water supply [86Mm^3/yr] according activity sector, (OEHC, 2002).*

The water consumption per capita and day is 200l with an annual consumption amounting to 104m^3 (for permanent and seasonal population), while the total potential water resources per capita and year amounts to 7,250m^3 if all resources could be made available. Thus the consumption index given in percentage (water consumed/total water resources) is 1% (61 10^6/5.6 10^9) and the exploitation index (water distributed/stable water) 2% (86 10^6/5.6 10^9). Estimations were made regarding the volumes consumed by the main activity sectors, but a significant uncertainty remains with respect to the volumes extracted by pumping wells, private boreholes and the spring's outflows. In figure 24 the main known locations of water extraction and use are depicted.

Table 11 demonstrates that the domestic sector is the only one in Corsica which has an ensured supply by surface and groundwater. Indeed, 60% of the water used come from groundwater and amounts to 18 million of m^3. 40% come from surface water with a corresponding volume of about 12 million of m^3. Regarding the 18Mm^3 of ground water, 13Mm^3 are located in alluvial aquifers and 5Mm^3 in aquifers of the base. Figure 25 presents the general water distribution network of OEHC.

Table 11: *Estimation of water demand in Corsica by category (consumed water).*

Water demand by category	%	**Mm^3**
Total water available		**86**
Water used for irrigation:	**49**	**30**
• Coming from ground water (= drillings, springs and wells) • Coming from treated wastewater • Coming from surface water (= dams) • Coming from desalinated water		0 0 30 0
Water used for domestic uses (including tourism):	**49**	**30**
• Coming from ground water (= drillings, springs and wells) • Coming from treated wastewater		18 0
• Coming from surface water (= dams) • Coming from desalinated water		12 0
Water used for industry:	**2**	**1**
• Coming from ground water (=drillings, springs and wells) • Coming from treated effluent • Coming from surface water (= dams) • Coming from desalinated water		0 0 1 0
Total Water Resource used	**100**	**61**
• Coming from ground water (= drillings, springs and wells) • Coming from treated effluent • Coming from surface water (= dams) • Coming from desalinated water		18 0 68 0

1.2.2 Sewerage and wastewater treatment

Wastewater is collected through a sewerage system and is then treated in 239 treatment plants (figure 26) by the following type of treatment systems (Atlas of main environmental data, OEC, 2000) (figure 28):

- Activated sludge (1),
- bacterial bed (2),
- decanter (3),
- physicochemical treatment (4),
- biological disc (5),
- wetlands (6)*and*
- macrophytes bed (7).

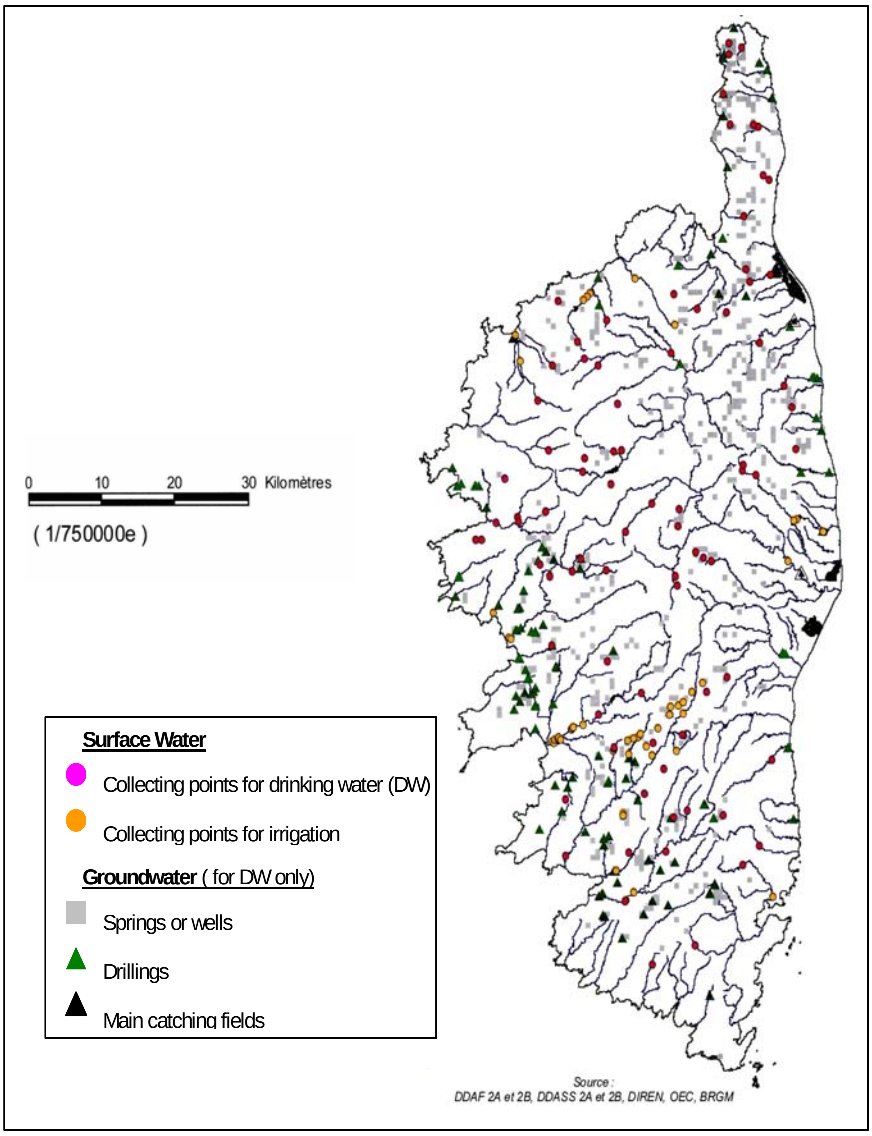


Figure 24: *Points of water abstraction, (Atlas of main environmental data 2000, Observatory of the environment of Corsica OEC).*

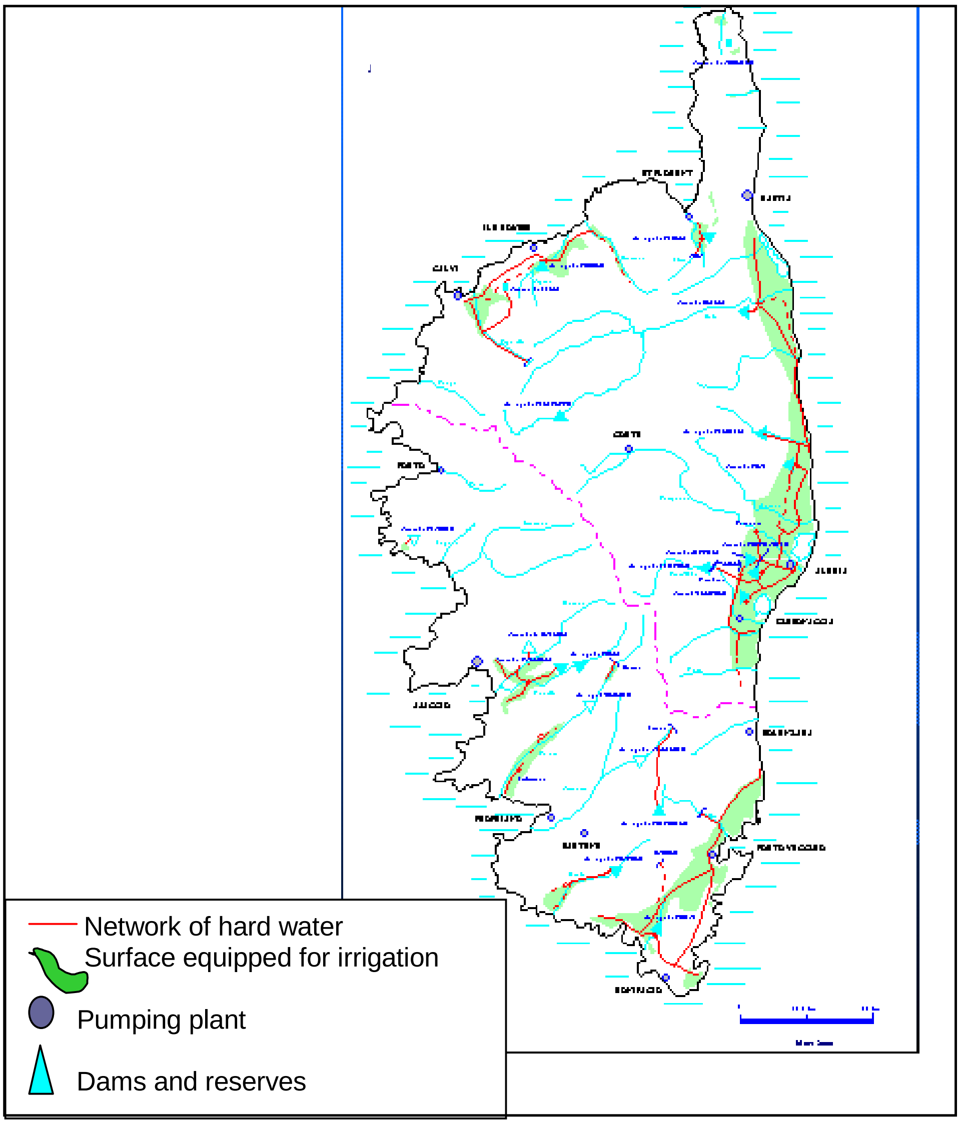


***Figure 25**: OEH distribution network, (CD-Rom Synthesis of Water Convention, 2003).*

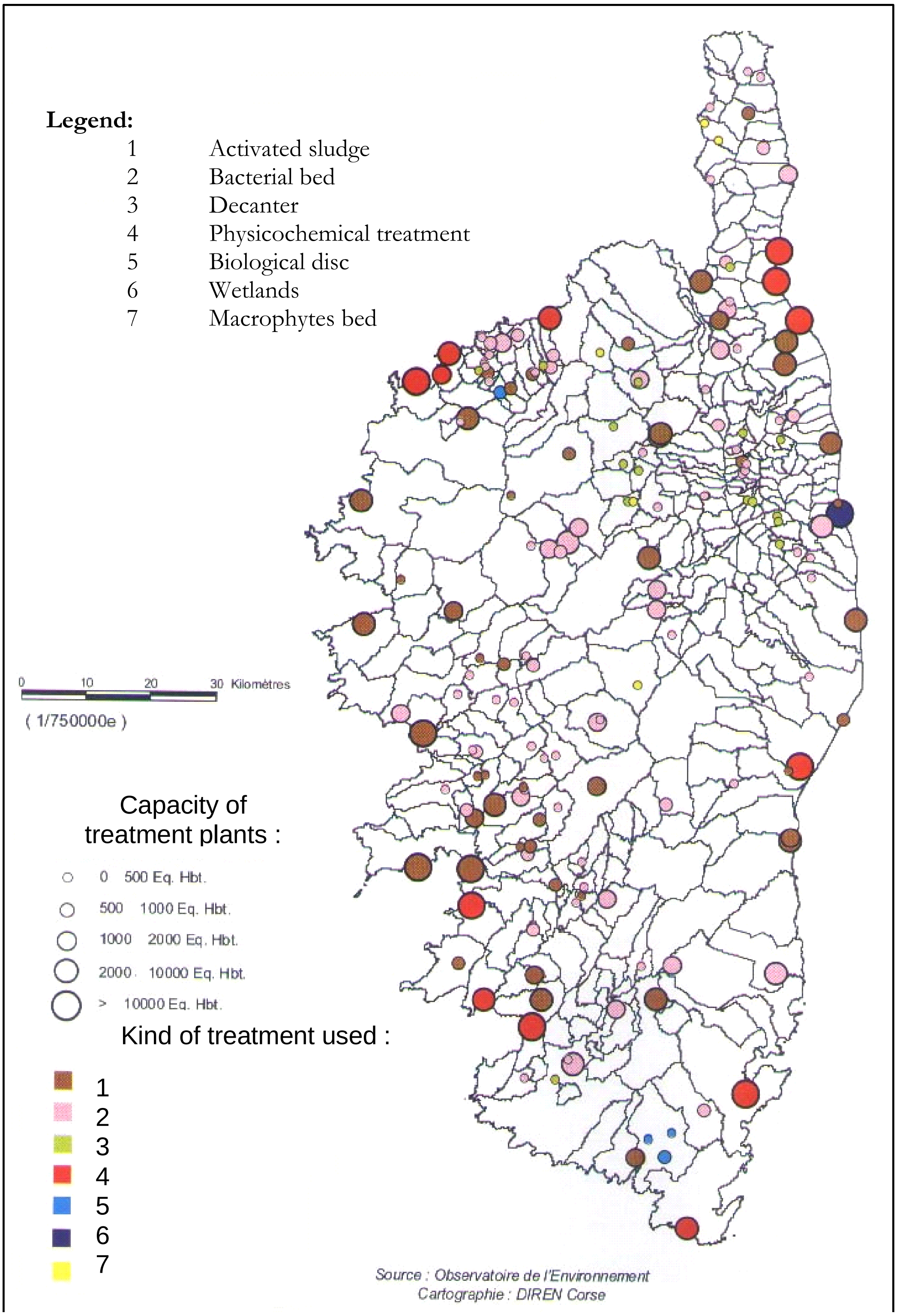


Figure 26: *Wastewater treatment plants in Corsica: capacity and location of the different types, (Atlas of the principal environmental data 2000, Observatory of the Environment of Corsica (OEC)).*

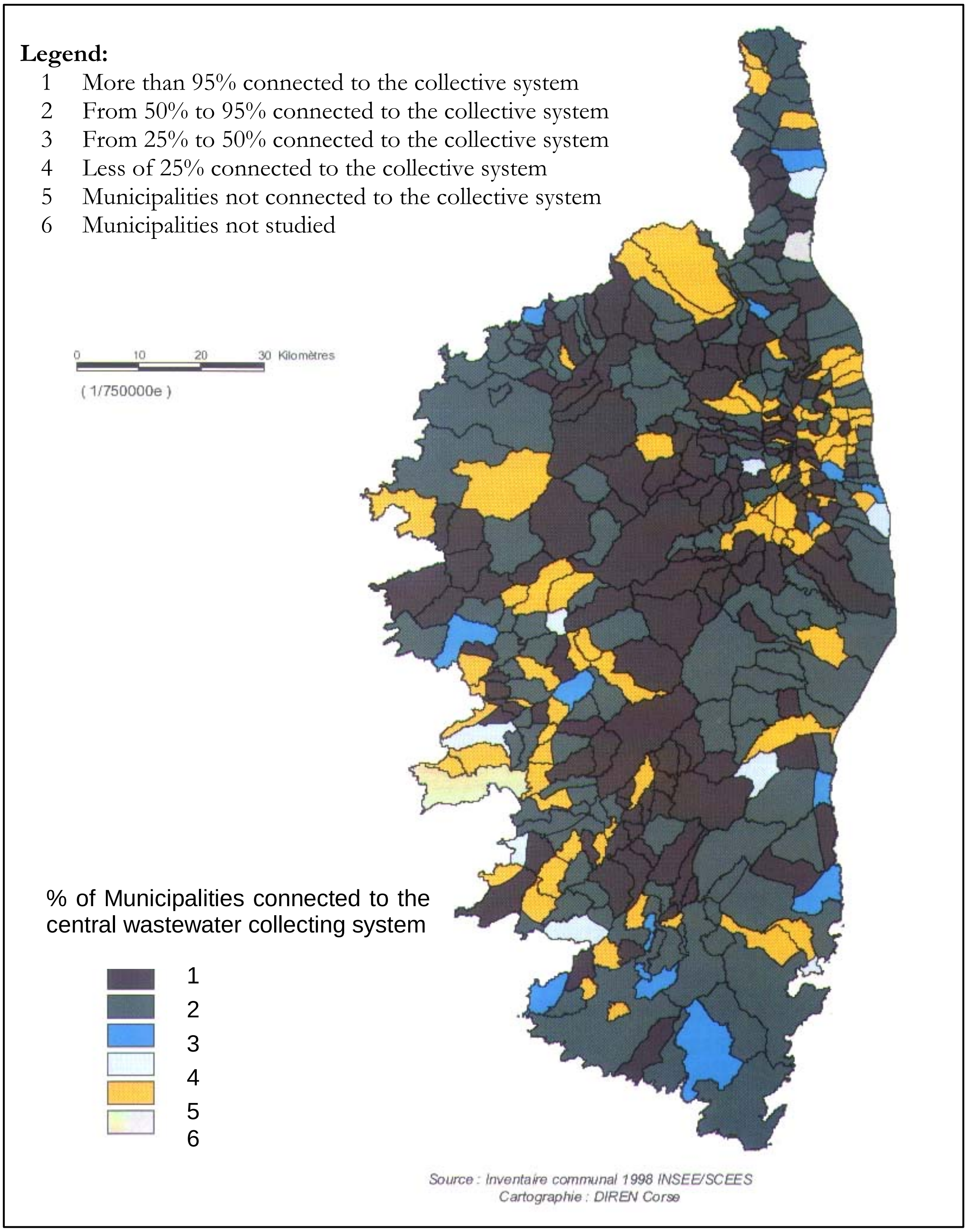


Figure 27: *Corsican municipalities connected to the central sewerage system which collects wastewater and transfers it to the plants, (Atlas of the principal environmental data 2000, Observatory of the Environment of Corsica (OEC)).*

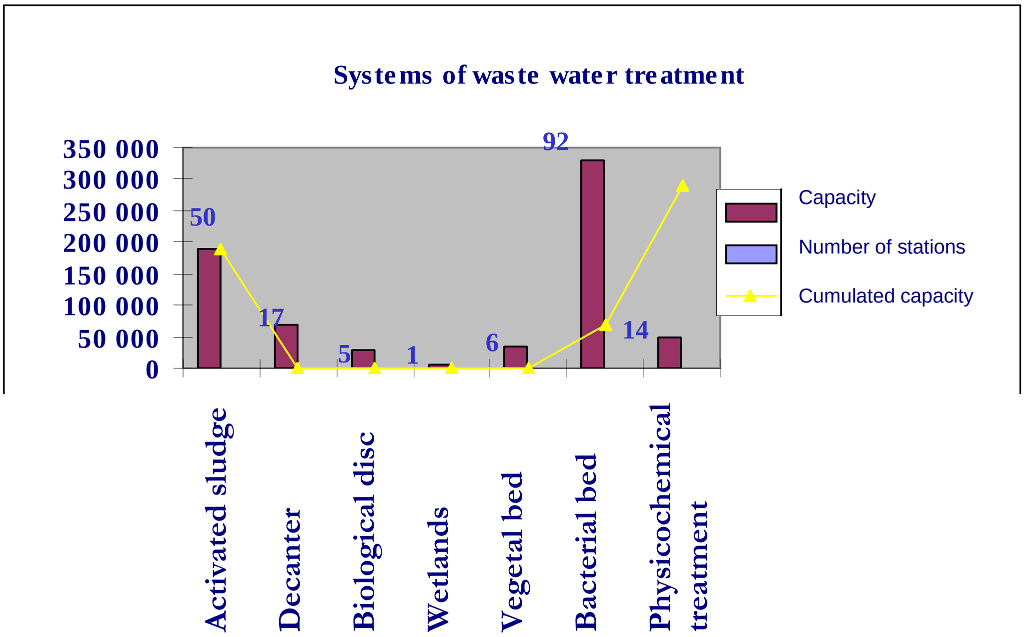


Figure 28: *Repartition of systems for wastewater treatment, (Atlas of main environmental data 2000, Observatory of the Environment of Corsica).*

Concerning the physical and chemical systems, there is a service provided by the OEHC which helps contractors to operate treatment plants in a good way in order to limit organic pollution for example. This service, called SATESE (Service d'Assistance Technique à l'Exploitation des Stations d'Epuration) includes a diagnosis and technical orientations to improve the operation. However, it often happens that the municipalities do not have sufficient financial means to carry out to the aforementioned improvements which causes an organic pollution of the rivers, and is the principal source of surface water pollution on the island. Treated wastewater is not used for irrigation in Corsica.

1.3 Environmental protection

1.3.1 Monitoring of surface water quality

The control of the surface water quality is organized by three networks. They are financed by the State (Ministry of the Environment), the RMC Water Agency and the Agency for the Environment of Corsica OEC, which is one of the six Agencies of the Corsican Territorial Collectivity (CTC). We can distinguish:

- The National Network of Basin (RNB, in French) with three stations,

- the Complementary Network of Basin (RCB in French) with seven stations *and*
- the Regional Complementary Network (RCR in French) with forty two points.

Their objective is to ensure the quality of the rivers regarding physicochemical, biological and bacteriological status thus determining the management of the respective water resources. While the RNB monitors the water quality once a year, the other two networks do so every three years. These measurements consist of different types of analyses in order to evaluate the pollution regarding the bacterial micro organisms, organic matter, heavy metals or pesticides. These studies are supplemented by an evaluation of the biological quality, based on an inventory of invertebrates watery (insects, molluscs, shellfish and worms).

The new system of evaluating the rivers quality (called SEQ-EAU) permits to define the physical and chemical quality of water, indicating several kinds of deterioration in quality. Both a classification system and an index system ranging from 0 to 100 have been developed. On the basis of a physicochemical analysis the impact of domestic waste, diffused pollution, river arrangement, and the extraction of water can be studied.

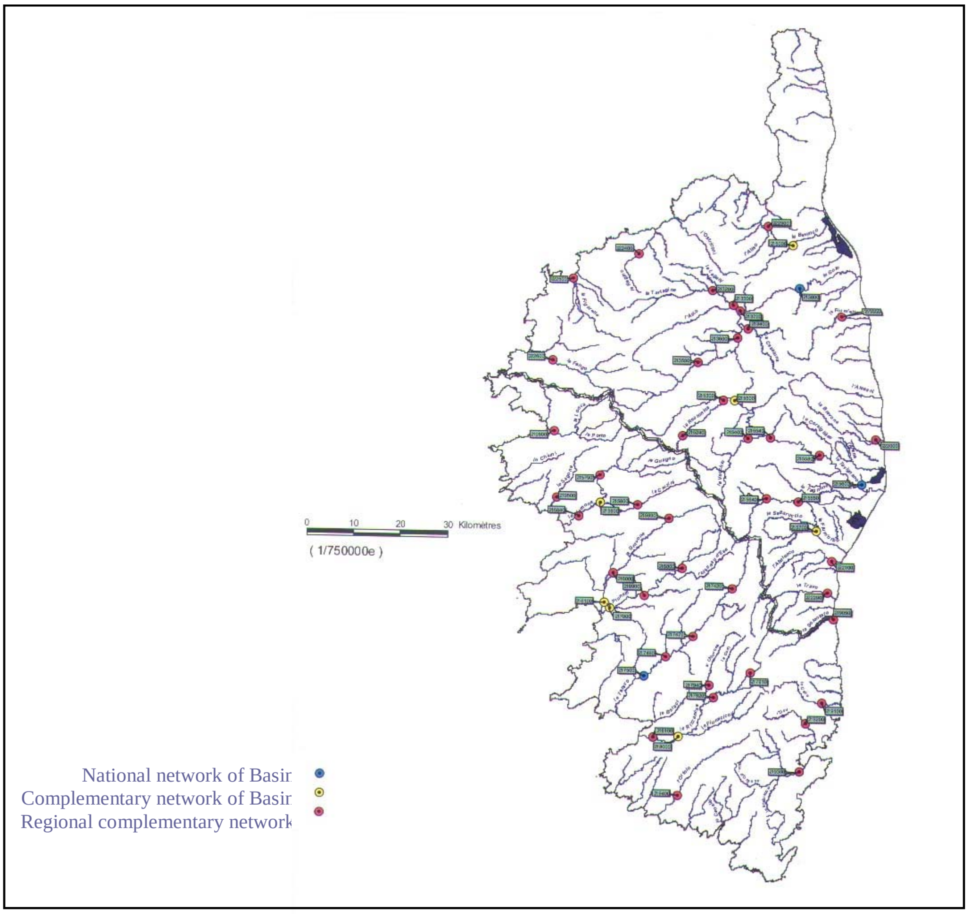


Figure 29: *Network for water quality control, (DIREN SEMA/OEC).*

1.3.2 Quality of groundwater and coastal waters

Groundwater quality

DDASS (Sanitary Departmental Direction) mainly ensures the quality of water destined for human consumption. On behalf of the municipalities, this authority checks the different kinds of water coming from drillings (groundwater), or directly from rivers and the quality of the springs which supplies villages with drinking water.

DIREN SEMA (Regional Direction of the Environment) monitors the quality of groundwater used for the drinking water supply.

Coastal waters quality

IFREMER (French Institute of Research for the Exploitation of the Sea) manages two main monitoring networks: REPHY (bacterial micro organisms) and REMI (micro biological). The RNO (phytoplankton) network is followed by IFREMER and the Ministry of the Environment. In collaboration with the Water Agency, IFREMER has developed a network called RINBIO on the whole Mediterranean littoral. DDE (Departmental Direction of the Equipment) manages a network (REPOM) monitoring the water quality of harbours. DDASS supervises the quality of bathing water and is responsible for 157 (Atlas of the principal environmental data 2000, OEC).

1.3.3 Main sources of pollution

Suspended matter

All the rivers have a very good quality regarding pollution through suspended matter.

Organic and oxydable matter (domestic polluants)

The origin is the combination of domestic pollution, high temperatures, and reductions of flow due to draw-off. 73% of the monitored points have a good or very good quality. The main polluted zones are located in the small coastal rivers with a weak flow, downstream of zones with significant rejects or of big agglomerations.

Nitrogenous matter (ammonium and nitrites)

Nitrogenous contamination is caused by domestic discharges and animal excrements. Only the towns of Corte and Porto Vecchio have a significant impact on the environment.

Nitrate

No pollution from the agricultural fertilizers. Nitrates which are present in water are due to the domestic discharges. The river quality is satisfactory.

Metals and pesticides

Metals in water are of geologic origin, pesticides usually from agriculture. Pesticides can only be found in Tavignano and Fium'Orbo where the agricultural development represents a risk. The absence of pesticides in these regions shows that there is no pollution.

Micro organismes (coliformes, streptococcus faecals)

Sign of water contamination by domestic and animal discharges. Water has a bad quality regarding this source of pollution because the treatment plants do not treat these substances. Data of a routine analysis that has been carried out for water quality of the GOLO river in Calacuccia (centred Corsica) is given as an example in the following table:

***Table 12**: Analysis of the GOLO river's water quality, (RNDE).*

Date	Support	Temperature	pH	Oxygen dissolved	Oxygen dissolved (saturation)	Conductivity
		° C		mg/l	%	µSiemens/cm
17/01/1989	water	5	7.4	12.5	98	67
15/06/1993	water		7.2	10		66

Date	DBO (biochemical oxygene demand)	DCO Permanganate Oxydability	Ammonium	Nitrites	Nitrates	Phosphates	Chloride
	mg/l	mg/l	mg/l NH_4^+	mg/l NO_2^-	mg/l NO_3^-	mg/l PO_4^{3-}	mg/l
17/01/1989	2.4	0.8	0.08	< 0.01	2.3	0.06	
15/06/1993	1.1		< 0.01	< 0.01	3.5	< 0.01	7

1.4 Water laws and regulation

National laws and codes are applied in Corsica. The most important laws and regulations are listed below.

Water supply

- Sapin Law 1993. Organisation and management of the municipal services of water and wastewater treatment,
- reform on the Water Law 2002: Healthiness of drinking water,
- code of Public Health (Article 9),
- code of Town Planning (L-126 & R-126.1),
- code of Municipalities (Art L 321.1 & L 322.6): Regulation of water supply and water price,

- budgetary Nomenclature M49,
- decree 28.03.57: Monitoring of mineral waters *and*
- decree 3.01.89: Monitoring of water for consumption except mineral waters.

Sewerage services

- Spain Law 1993. Organisation and management of the municipal services of water and waste water treatment,
- law 15.07.75: Treatment of the waste water of towns,
- law 19.07.76 concerns the standardised installations (obligation of results regarding the quality of waste water),
- decree 1994: Collection of waste water,
- decree 3.06.94 n° 94.469: Treatment of waste water *and*
- directive ERU 1991 n°91.271.

Protection of water resources

- Law 1919: Regulation of hydroelectricity,
- fishes Law 1984. Obligation to conserve a reserved flow in the rivers,
- barnier Law 1995. Reinforcement of environmental protection,
- new Law on water 03.01.1992. This law envisages in particular the safety distance around the collecting points of drinking water,
- decree 1.08.2002-1027 *and*
- environmental Code.

Quality of Water

- Law on water 1964: Implementation of the principle “the polluter pays”,
- reform of the Water Law 2002 *and*
- decree 29.03.93 n° 93.742.

Agriculture

- Rural code,
- decree August 1993,
- decree 22.11.1993: Good agricultural practise *and*
- EU Nitrate directive 1991.

Management

- Law LOADT 1999,
- reform of the Water Law 2002 : Decentralisation,
- SDAGE Rhône Méditerranée Corse Law on Water 3.01.92 *and*
- creation of the Corsican Basin, January 2002.

1.5 Institutional framework and constraints

1.5.1 Responsibilities

Water supply

- Drinking water : Agency for the Hydraulic Equipment of Corsica (OEHC), an Agency of the Territorial Collectivity/Private companies (Vivendi, SUEZ, Compagnie Générale des Eaux, Lyonnaise des eaux),
- water for irrigation: OEHC and ODARC (Agency for the agricultural development of Corsica),
- wastewater: Management by Municipalities alone, or by an association of several municipalities (SIVOM),
- crops/agronomical : Room of Agriculture, INRA,
- protection of aquifers: Environmental Agency of Corsica (OEC) an agency of the Territorial Collectivity, DIREN (state organisation) and prefecture authorities,
- monitoring of the quality of coastal water: IFREMER, DDE and DDASS (state organisations),
- monitoring of the quality of groundwater and surface water : DDASS/DIREN SEMA,
- monitoring of drinking water quality: DDASS,
- protection of wetlands and ponds: Prefectures, Academy of the Littoral *and*
- inundation: Prefectures.

1.5.2 Problems

Even though there are a lot of organisations responsible for water management, there is no sufficient communication between them. In addition, responsibilities are often not clearly determined.

1.5.3 Main contraints

Natural

- Unequal distribution of precipitation which is more important in mountains than on coasts; and
- Relief of the island which makes the implementation of the inter communality or the transfer of water from a watershed to an other, very difficult (to expensive).

Human

- Significant population increase in summer,
- unequal repartition of tourists: they are more present in the South of the island,
- isolation of the little villages located in mountain areas with few inhabitants *and*
- organic pollution due to the bad operation of the wastewater treatment plants.

Technical
Lack of qualified staff for the maintenance of the wastewater treatment plants.

Financial
Lack of financial means of smaller villages on the island.

1.6 Management, institutional and policy options

1.6.1 National level

Since the water law of 1992, the French territory has been divided into six sectors which are called "basins". A SDAGE (framework for the development of a concerted management between the main actors of the water domain) is associated to each one of the six basins.

There are six water agencies (WA) for each one of the 6 basins. All the WA are structured in the same way (see figure 30). The Water Law has also implemented the principle of the "Polluter pays".

Corsica used to belong to the Rhône Méditerranée Corse Basin (RMC) and depended on the RMC Water Agency. Yet this situation has changed with the Low of January 2002 which allowed the creation of a Corsican Basin. Today, Corsica manages its own basin with its own Committee of Basin. Thus, regarding the water management, there has been a transfer of competencies from the State to the Territorial Collectivity of Corsica.

Nevertheless, the island still depends on the Rhône Méditerranée and Corse Water Agency.

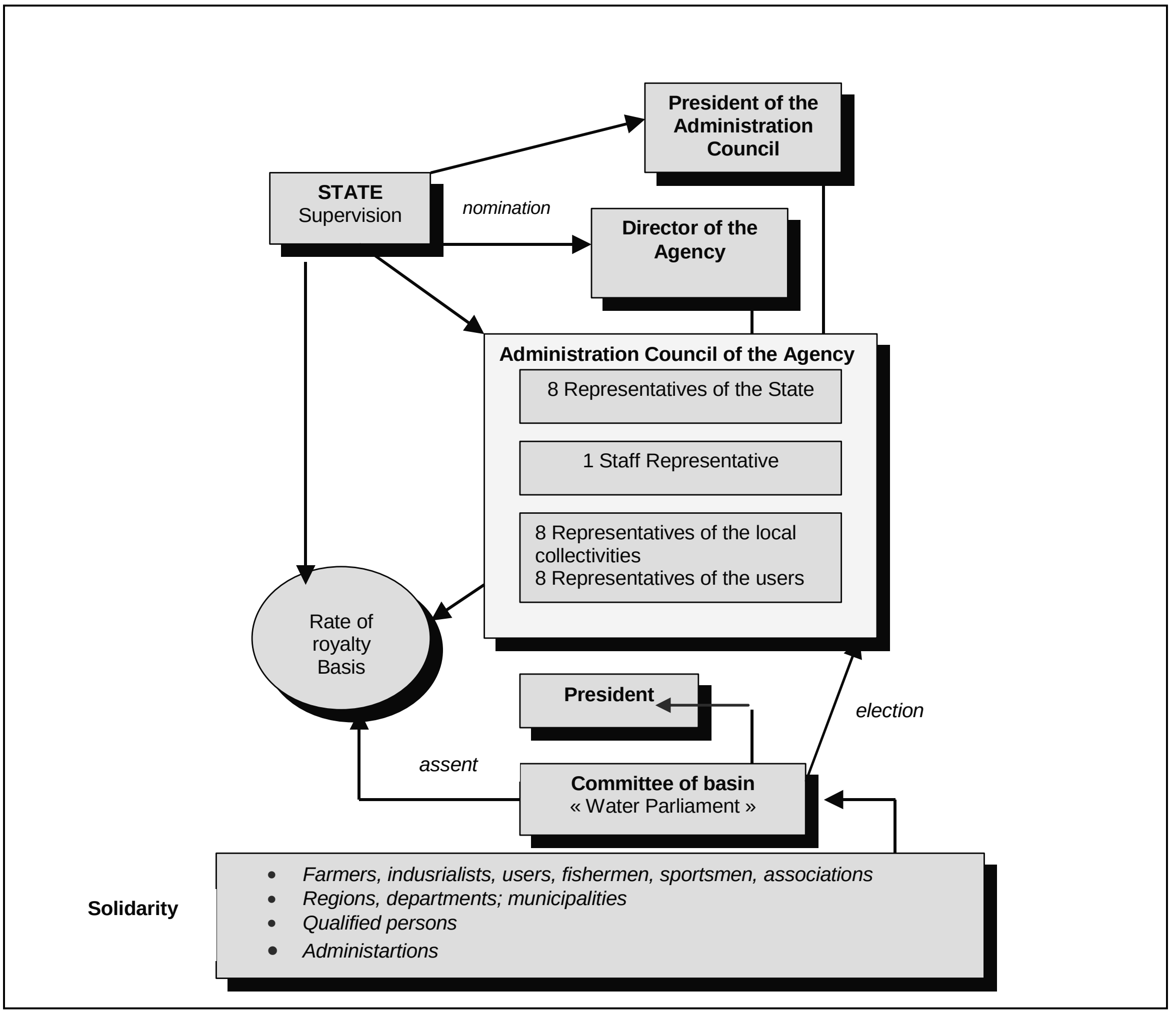


Figure 30: *Organisation of the water agencies, (www.oieau.fr).*

1.6.2 Regional level

SDAGE

For each basin, a SDAGE (framework for the development of a concerted management between the main actors of the water domain) has been established, in order to improve and set up a durable water resource management. Two main tools exist in order allow the development of a concerted water management in each Basin (figure 31).

SAGE

The aims of a SAGE are the following :

- to fix some objectives of quality which have to be reached in a given period of time,

- to define an equal distribution of the resource regarding the different uses,
- to identify and protect the sensible aquatic environment *and*
- to identify possibilities of protecting the resource and preventing inundations.

The SAGE must be compatible with the SDAGE of the Basin. It has a juridical influence. Two SAGE have been launched in the Corsica Basin. One of it concerns a zone of the Golo catchment (figure 31): the Biguglia Pond located in the South of Bastia. The second one has been abandoned.

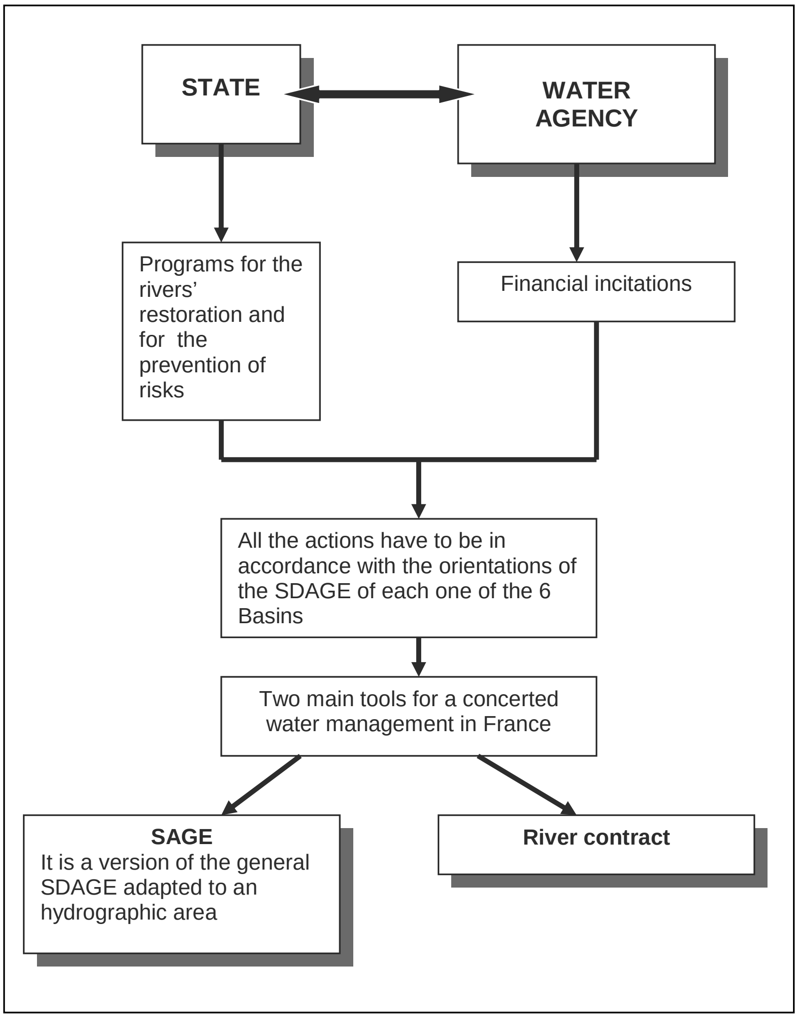


Figure 31: *Tools of a concerted water management.*

A Local Commission of Water (CLE) exists and gathering all the actors involved in this area. The commission meets regularly in order to set up a concerted and complete management. The SAGE, which is organised in different phases, is only at the beginning of its beginning and the implementation will probably still take another five years.

Figure 32: *The two SAGE initiated in the Corsican Basin, (Network of RMC Basin http://rdb.eaurmc.fr/).*

River contract

The River contract (RC) is a tool at a watershed scale. It corresponds to a complete program comprising several studies realized by a permanent technical team. Its goal is to reach the main objectives of the SDAGE in a given watershed. The difference between SAGE and RC is that a RC is not meant to realize a common project for the water in the watershed. Indeed, the aim of a RC is to come up with a program of actions (studies, works, etc.) to be initiated within a period of five years and financed by its partners. Finally, the RC objectives don't have a juridical influence. A River contract exists in Corsica and concerns the Taravo River. It aims at reducing the pollution of the river. The River Agreement is still at project stage. Its installation will be long and delicate, as different stakeholders have to be involved.

The fact that Corsica is an island sometimes makes it difficult to take action. For example, the Agency of Water (which is a French national agency) takes less actions in Corsica as follow-ups and control are more difficult to ensure due to the distance.

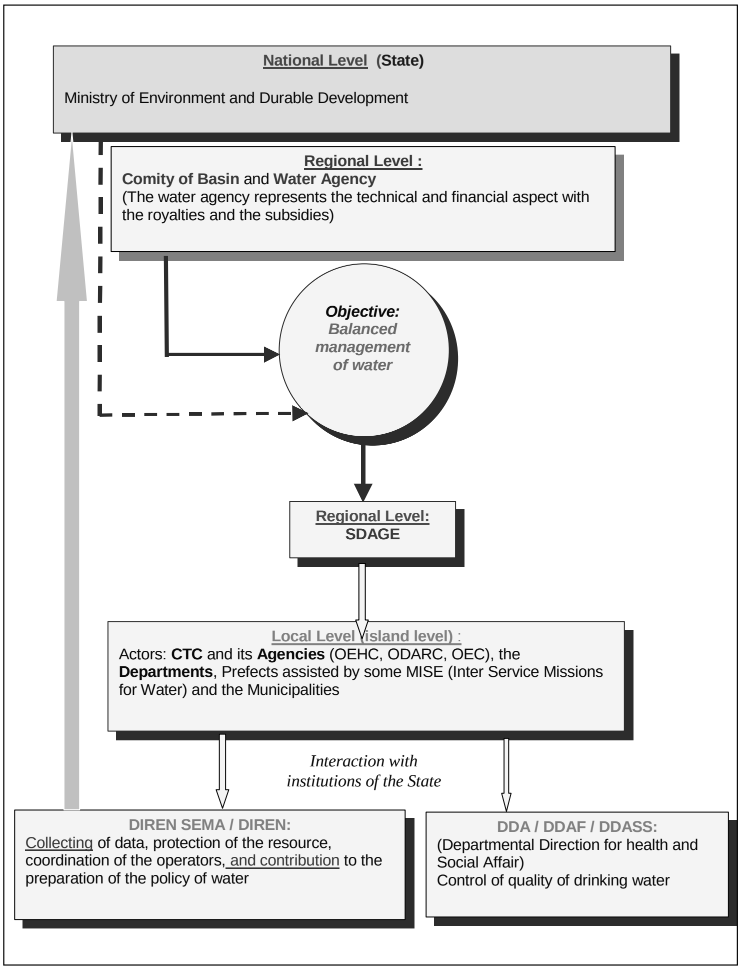


Figure 33: *Levels of the French Institutional Framework.*

The role of the Local Government: the Territorial Collectivity of Corsica (CTC) and its six Agencies

Since the Law of May 1991, Corsica has been a Territorial Collectivity of the French Republic and has a particular statute. The CTC is organized into three institutions:

- CESC (Economical, social and cultural council),
- executive Council *and*
- assembly of Corsica.

Since the last law concerning decentralisation (January 2002), the CTC has been able to manage some of the island's business by itself regarding several fields like the budget, education, transports, economical development, agriculture, wastes, and environment. To ensure all these functions efficiently, the CTC is divided into six agencies which are public authorities:

- OEC (Agency for the Corsican Environment),
- OEHC (Agency for the Hydraulic Equipment of Corsica),
- ODARC (Agency for the Agricultural Development of Corsica),
- ADEC (Agency for the Economical Development of Corsica),
- ATC (Agency of Tourism) *and*
- OTC (Agency Transports).

The two Agencies directly involved in the water management are OEHC and ODARC. The Law of January 2002, has entailed significant changes: Corsica constitutes an hydrographical basin (according to the articles L. 212-1 to L. 212-6 of the Environmental Code). Consequently, a Committee of Basin has been created. It is constituted by:

- Representative persons of the CTC, Departments and Municipalities,
- representative persons of the user groups *and*
- socio professional members designated by the French State and the CTC.

Today the Rhône - Méditerranée - Corse Basin does not exist any more, it has been split up into Rhône- Méditerranée and Corsica Basin. Corsica posseses its own Committee of Basin but the island is still depending on the RMC Water Agency. The aim of the new Corsican Committee of Basin is to work according to the WFD. Currently, one of the first tasks which has to be carried out, is to split up all the water units of the island (groundwater, surface water, coastal water) in distinct water bodies. Since the realisation of these measures is difficult, it will take time.

1.6.3 Local level

Several possibilities of water management exist to ensure an adequate supply and distribution of water. The municipalities can ensure the water distribution themselves or use the services of OEHC or any other private society (Vivendi, Compagnie Générale des Eaux, Suez, Lyonnaise des eaux, etc) to establish and entertain their distribution network. Thus, we can distinguish between the different modes of management which are depicted in detail in figures 34-37:

- Delegated Management (1) AFFERMAGE,
- Delegated Management (2) CONCESSION,
- Direct Management REGIE *and*
- Intermediary Management GERANCE.

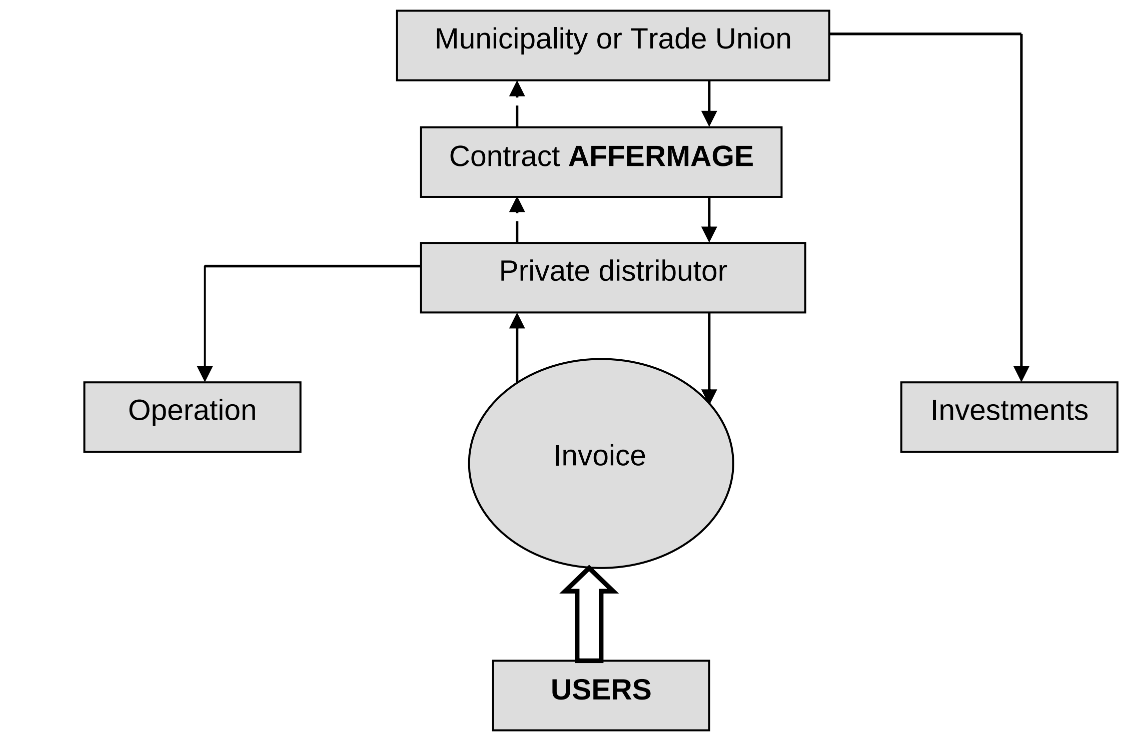


Figure 34: *Delegated management (1): Affermage, (www.oieau.fr).*

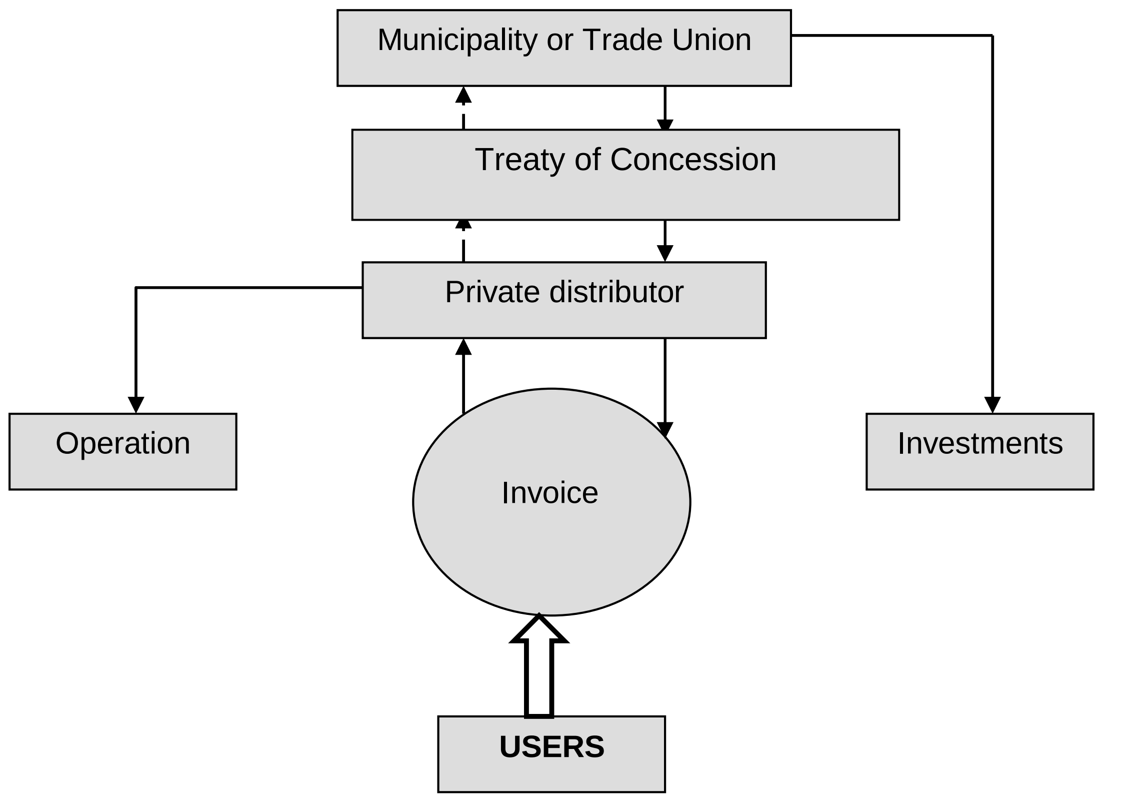


Figure 35: *Delegated management (2): Concession, (www.oieau.fr).*

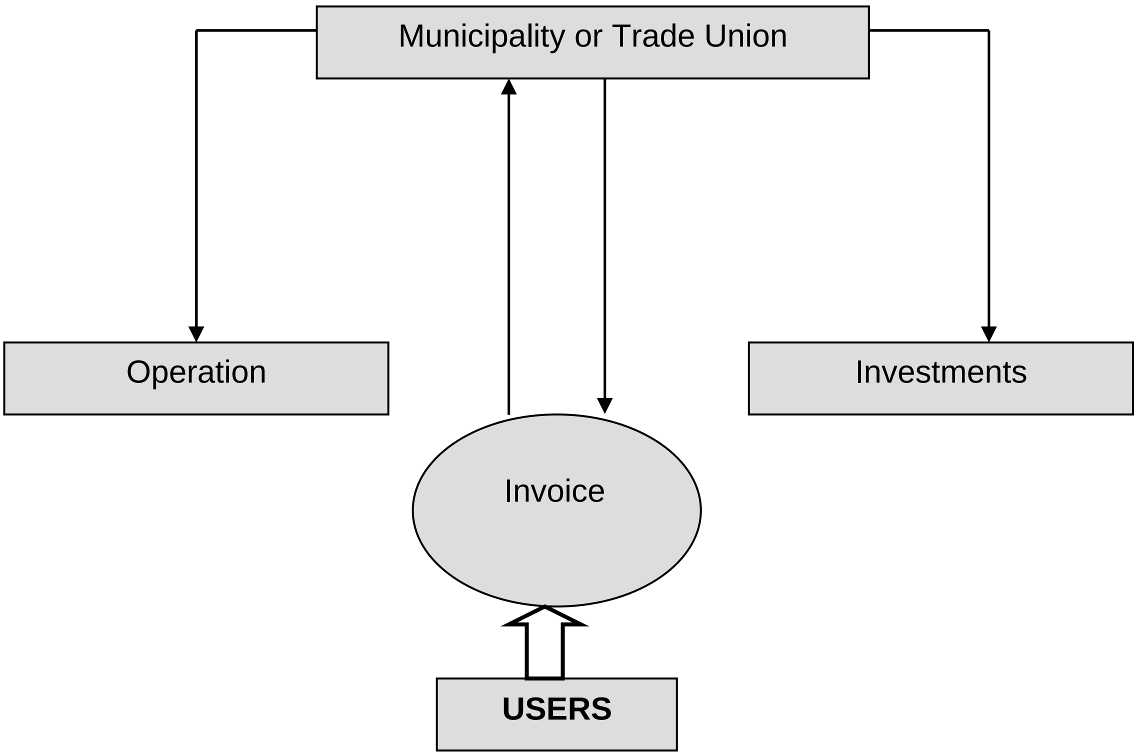
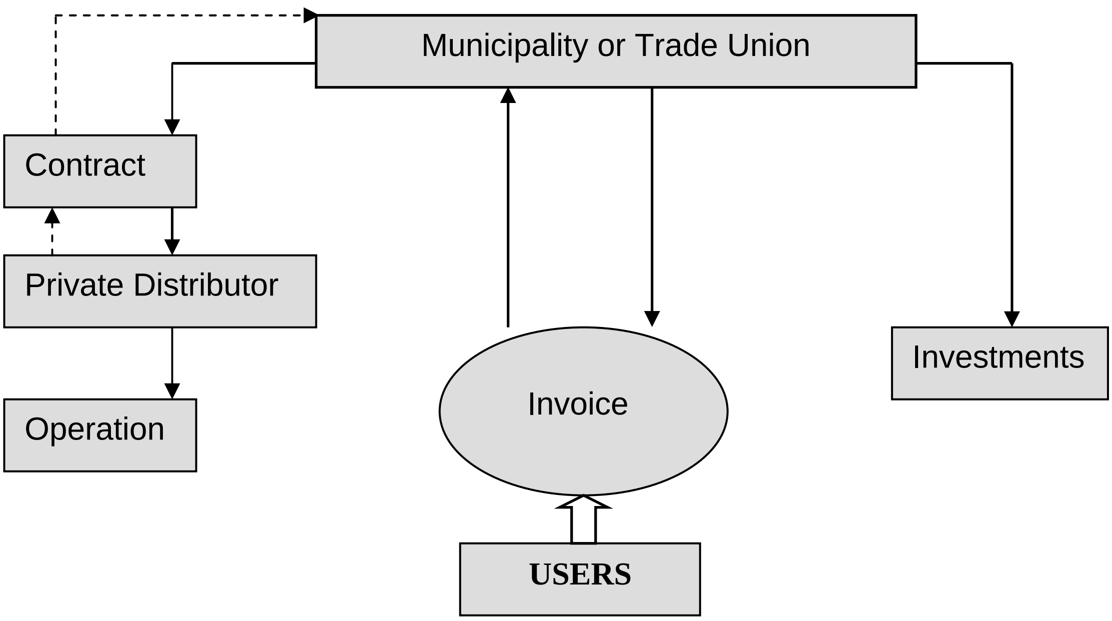


Figure 36: *Direct Management: Regie, (www.oieau.fr).*



Figures 37: *Intermediary Management: Gerance, (www.oieau.fr).*

In the summer of 2002 a desalination plant was installed at the port of Maginaggio in order to supply the municipality of Rogliano with water after it has suffered from water scarcity through the summer. It was the first desalination plant to be built in Corsica. Expensive, however this experience has turned out to be effective.

The plant produced about 25,000m^3 of drinking water in two months, a quantity sufficient for the daily needs of the approximately 3,000 inhabitants and visitors of the port. The off-season water supply is also ensured with 4,000 to 5,000m^3 of water in the reservoir of Rogliano, which is almost dry at the beginning of the summer.

1.6.4 Policy options

Water resources management has become a key issue in Corsica, which is mainly due to the spatial and temporal variation of rainfall, and the significant water needs for farming and tourism. The main difficulty in water management is the uneven geographical distribution of water resources. In general there is an abundance of water (rivers rainfall and dams) in the centre of Corsica and at the eastern and western coasts. But in the south and north of the island (Cap Corse, Balagne, Bonifacio) where tourism is much more important, water resources are restricted. Under these conditions, the two Departments, the Territorial Collectivity and its Agencies have taken into consideration some actions in order to improve the current water management towards a durable development. The action plan includes:

- the monitoring of surface water quality to be controlled by the following three networks : one national network of basin (RNB), one complementary network of basin (RCB) and one regional complementary network (RCR). These networks are financed by the Ministry of the Environment, the RMC Agency of Water and the OEC. DIREN SEMA and DDASS ensure the follow-up of the monitoring,
- studies concerning the estimation of groundwater resources contained in the fractured environment of the ground (DIREN SEMA/BRGM),
- establishment of a water plan for improve water management (Prefecture/OEHC),
- construction of dams in the mountains in order to guarantee a significant quantity of surface water (OEHC/EDF),
- improvement of rural information services (Agricultural Chamber) *and*
- application of modern irrigation methods (Agricultural Chamber/ODARC/ OEHC).

The plan leaves some of the problems unsolved, thus more proposals should be taken into account in order to achieve real sustainable management, such as:

- inter communality and inter basin transfer of water when it is economically possible,
- control of groundwater abstractions (licences declaration etc),
- exploitation of unexploited aquifers (e.g. base aquifers) *and*
- treatment of water as a true economical resource by selling it primarily to those areas where water is needed most (transfer Corse/Sardinia project).

Currently, Corsica does not necessarily need to take measures like:

- protection of coastal aquifers from possible saline intrusion,
- implementation of artificial recharge of aquifers *and*
- reuse of water after treatment.

1.6.5 Responsibility of each authority

Table 13: Policy options in Corsica.

Activity	Municipal authority/ water utility	Private company (EDF)	Regional authorities (CTC and its agenies)	Prefecture authorities	Ministry of development	Ministry of environment (DIREN, DASS)	Ministry of agriculture (CA)	Ministry of finance
Surface water								
Use	X	X	X					
Storage	X	X	X					
Recharge								
Diversion			X					
Quality monitoring	X		X	X		X		
Assessment		X	X					
Ground water								
Use	X	X	X					
Storage	X							
Recharge								
Quality monitoring	X		X					
Assessment			X					
Well/drill permits				X				
Irrigation network								
Rehabilitation			X				X	
Modernisation			X				X	

Table 13 continued.

Activity	**Municipal authority/ water utility**	**Private company (EDF)**	**Regional authorities (CTC and its agenies)**	**Prefecture authorities**	**Ministry of development**	**Ministry of environment (DIREN, DASS)**	**Ministry of agriculture (CA)**	**Ministry of finance**
Reuse								
Drainage water								
Wastewater								
Desalination								
Introduczion of technology					X			
Efficient water utilisation								
Domestic	X		X					
Industrial					X			
Irrigation	X		X					
Legislation								
Regulation and codes					X	X	X	
Standards								
Policy setting	X		X			X	X	
Water allocation			X			X		X
Project financing				X	X	X		X
Project design	X		X		X	X	X	
Project implementation	X		X	X				
Operation and maintenance	X		X					
Pricing	X	X	X					X
Enforcement	X	X	X					
Water data records						X	X	

1.7 Agricultural situation

In Corsica, the Total Agricultural Area (TAS) represents about 18% of the regional territory and comprises 1,559km². The irrigated surface is about 223.3km² and the corresponding consumption of water is about 30Mm³. The Corsican agriculture has two distinct faces: A first one located on the mountain (for the extensive breeding and the chestnut trees culture) and a second one, located on the coastal plain (for the modern agriculture, vegetables, fruits and vine production). High Corsica represents 71% of this 18% of TAS, because this part of the island offers a large zone of plain. The specialised productions (market gardening, arboriculture, and vine growing) highlights contrasted evolutions: in High Corsica, the increase of the orchards production and the valorisation of vine surfaces are opposed to the decrease of the market gardening. Regarding husbandry, the increase of cow breeding which leads to increased cow milk production is in contrast with a decrease in goat, bovine and porcine breeding. In this context the Corsican agriculture shows potentialities to be developed to foster sustainable management such as combining tourism with farming or supporting biological agriculture.

1.7.1 Corsican exploitations

With 3,600 units of agricultural production in 2000, Corsica had suffered from a decline of 30% since 1988 (comparable with the French average) with 1,540 units disappearing in 12 years. These 3,600 units also include very small units (olive and chestnut grower etc.) above all the mountain of South Corsica are in big difficulties. The following table presents the number of exploitations per department.

Table 14: *Number of exploitations in Corsica,(AGRESTE source, agricultural censuses 1988 and 2000).*

Number of exploitations	2A South Corsica		2B High Corsica		Corsica	
	1988	2000	1988	2000	1998	2000
Main farms	656	623	1428	1311	2084	1934
Other farms	1361	758	1671	886	3032	1644
All farms	2017	1381	3099	2197	5116	3578
0.1km² and more	1236	909	1638	1514	2874	2423

The following map (Figure 38) identifies the main areas of animal and vegetable productions in Corsica, representing both the diversity of its agricultural systems its main technical and economic industries for each community (OTEX). Large crops, vine and fruit productions are mainly located at the coast, whereas breeding prevails in the mountains.

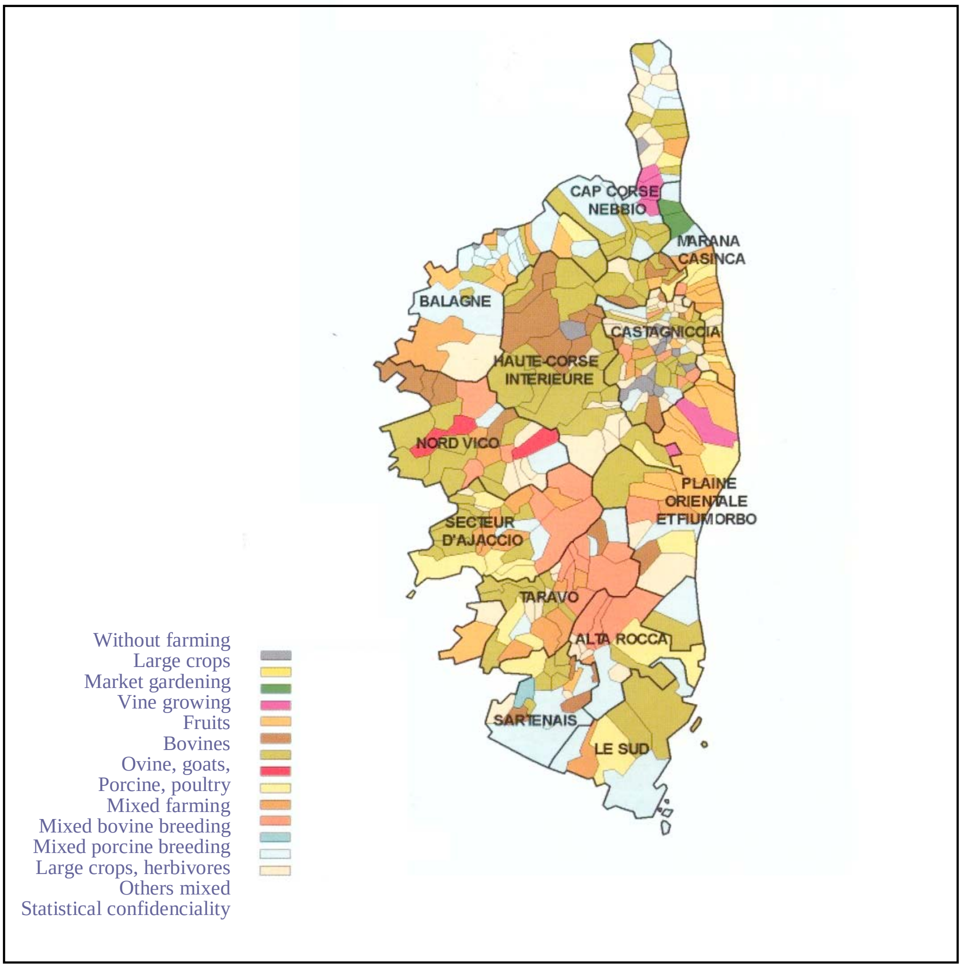


Figure 38: *Agricultural systems of production in Corsica, (AGRESTE, agricultural census 1998 and 2000).*

1.7.2 Main crops and breeding

The main cultures of Corsica are tree orchards (citrus fruits, kiwis, plum trees, chestnut- and almond trees, and olive-trees), vine growing, cereals, vegetables and fodder crops. In this chapter, the areas occupied by each culture, their development and their geographical distribution progression during the past ten years will be described.

1.7.2.1 Tree growing

Tree crops occupies an area of 79.47km² or 4.5% of TAS including 32.5% of citrus fruits, 25.6% of shelled-fruits, 22.8% of olive-trees, the remainder (22.3%) being occupied by other orchards (Kiwi, plum trees etc).

Citrus trees

Citrus-trees occupy an area of 23.35km² and are the main fruit crop, mainly located in the eastern Plain and Fiumorbu, covering 60% of the total area. After a rise until the mid-nineties, the surface area of tree orchards returned to the level of 1988 with 23.35km² including 19.9km² of clementine cultivation. The pomelo areas have relapsed since 1994 to 2.6km² from their former 3km². The areas covered by lemon cultivation have increased steadily and reached 0.45km² in 2000 whereas orange cultivation has experienced a decrease to less than 0.03km² in 2000, which used to be still 0.06km² in 1994 and 1.35km² in 1988.

Kiwi and plum trees

Other orchards mainly consist of kiwi- and the plum-trees. The surface area of kiwi cultivation (5.4km²) has suffered from a significant fall since 1990 (2.7km² fewer). 56% of its production is achieved in Marana-Casinca plain, the remainder in the eastern Plain and Fiumorbu. The area covered with plum-trees experienced a rapid growth with the cultivation area doubling in twelve years to reach a size of 5km² including 4.3km² of Ente's plum-trees. 75% of the crops are produced in the eastern plain and Fiumorbu, 25% in Marana-Casinca.

Hard-shelled fruits (chestnuts, almond)

The dynamism of nut-tree crops (primarily chestnut and almond trees) has doubled since 1988. The production of chestnuts has been increasing from an orchard of 2.5km² to reach 12km² in 2000, which are primarily used for the production of the traditional chestnut flour. 50% of the chestnut-trees are grown in Castagnicia. Interestingly, this surface area represents only a small percentage compared to the wild chestnut forest (several thousands hectares). 37.5km² of these forests are pastured (1/4 in the middle of High Corsica and ¼ near to Ajaccio). Contrary to chestnut orchards, almonds account for a considerable part of Corsica's crops owing are to a plantation program which has launched in 1980. As a result, its surface area increased from 6.4km² in 1988 to 7.8km² in 2000 with 60% of almond trees are cultivated in the eastern plain and Fiumorbu.

Olive trees

With an increase by 12km² since 1988 (to reach 18km² area in 2000) olive-trees have experienced a revival in Corsica. Half of olive-tree cultivation takes place in Balagne where 63% are harvested to produce oil. Furthermore an additional area of 8km² is pastured.

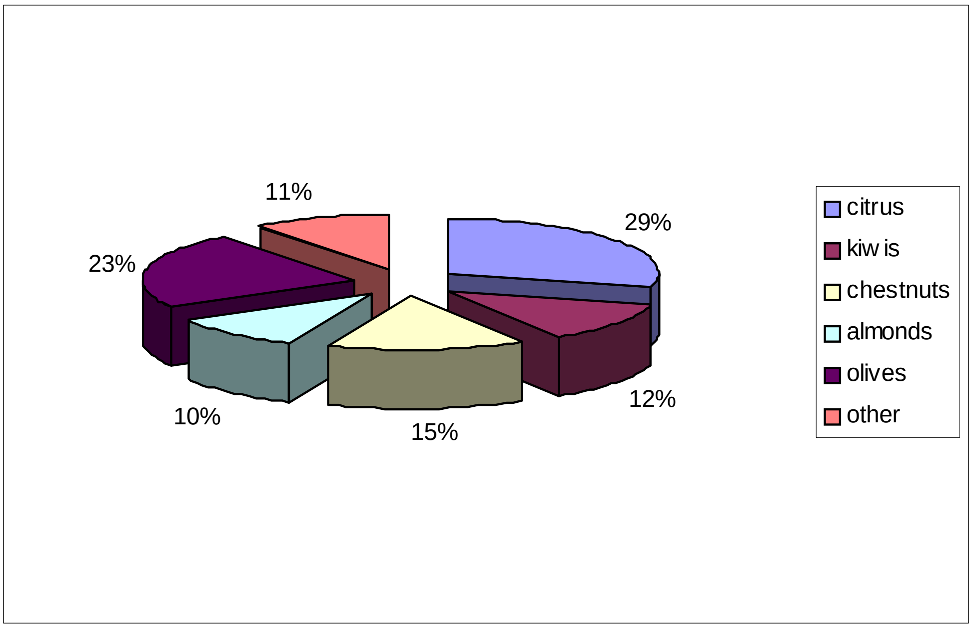


Figure 39: *Repartition of tree growing in Corsica.*

1.7.2.2 Vine growing

On average vine growing occupies a surface area of 70.9km² (62.14km² in High Corsica and 8.76km² in Southern Corsica) including 30.78km² of vine grown in the country:

- 37.6km² of vine is grown under a controlled name *and*
- 1.62km² of vine is grown as table vine.

The production of vine has been decreasing since 1988 with quality being given priority over quantity.

1.7.2.3 Fodder crops production

There has been a significant increase in the production of fodder crops. Since 1988 15km² of land have been additionally cultivated, which represents 25% and a surface area of about 70km² in 2000 (for artificial fodders). This evolution essentially concerns 3 regions:

- The eastern Plain,
- Balagne *and*
- Marana Casinca plain.

The island's needs of fodders were about 433,000 quintals in 2000 and predominately concerned the centre of the island where the most significant part of breeding prevails. Indeed, in 2000, 1,900 stockbreeders at least in part used fodders harvested in Corsica and their use directly followed livestock repartition. However, production and sale of fodder crops are still concentrated in the eastern Plain. In Corsica, there are two kinds of fodder production:

- artificial meadows and annual fodders (about 70.32 + 286.73 =~360km²) *and*
- natural meadows and routes, primarily maquis (about 1000km²).

The surface area for fodder production covers 1,360km², with 2,500 different producers.

1.7.2.4 Breeding

Sheep

In 2000 there were 725 farmers sheep left, because of a decrease by 21% during the past 12 years. The corresponding number of animals is about 100,800 ewes: There are 94600 dairy ewes which are 5000 ewes more than 12 years earlier. The livestock increased by 9%. In breeding, a geographical disparity has taken place. There has been a development in the plains of High Corsica with an increase of +40% in Marana Casinca (about 100,00 ewes), going along with a significant decrease in South Corsica which have been brought by the epizooty of the Catarrhale fever in 2000.

Caprine (goat)

In 2000 there were 340 producers owing 29,600 goats which were 8,000 goats less since 1988, and in 2000 there were only 140 farmers breeding more than 100 goats, while there had still 177 in 1988. In general, however, the average size of herds increased from 45 to 86 animals.

Porcine (pig)

There are only half as much producers as there were 12 years before, which also means a decrease in livestock by 1/3 since 1988. Thus, there were 26,400 pigs in 2000 which were usually kept in freedom. Only 1/3 of the farmers have focused on porcines. Generally, porcine farming is combined with the breeding of other kinds of animals. The average size of the animal stock has increased from 40 to 53 during the last 12 years, but it still remains modest.

Bovine (cow)

There is also a significant decrease in breeding and livestock during the 1990s. Since 1988 there has been a decline of about 9,300 cows with a corresponding decrease in the number of stockbreeders from 2,000 in 1988, to 1,250 in 2000. This reduction mainly concerns the very north and south of the island. In contrast, an increase can be observed in the east of High Corsica where the level becomes again comparable with that of 20 years ago:

- Total of bovines in 2000: 63,700 cows with 40,000 nurse cows *and*
- total of bovines in 1979: 54,800 cows with 36,200 nurse cows.

The largest herds with more than 50 nurse cows has increased since 198 whereas herds of less than 20 cows have been reduced by half in 12 years. The bovine production uses:

- 20km² (65%) of TAS,
- 66km² of STH (75%) *and*
- 1km² (50%) of fodders (For further details see Appendix 1, Main crops, surface and number of exploitations (DDA/AGRESTE regional census 2000).

1.7.3 Irrigated area and irrigated crops

1.7.3.1 Irrigated area

Between the years 1965 and 1970, 450km² of Corsica, with 360km² in High Corsica (with 300km² in Eastern Plain) and 90km² in South of Corsica, were identified the first by the OEHC as potentially suitable for irrigation. The first equipments were planted in the Eastern Plain. Today it is important to differentiate between:

- *areas potentially dedicated to irrigation:* 450km²,
- *area equipped for irrigation (SE)*: 315km². The maximum rate of equipment should be 80% but this rate is presently about 70% which represents 315km², including 250km² in eastern Plain *and*
- *areas actually irrigated (SI)*: 223, 30km². This second ration is very difficult to estimate. Tests using the general inventory suggested by the Ministry of Agriculture or Teledetection as used by CEMAGREF, came up with rather poor conclusions.

By applying an average irrigation rate observed in the Casinca area (1 700m³/ha/y) in the eight sectors, the actually irrigated areas should be 223, 3km² (i.e 70% of the equipped areas). In this field, however, there are only estimates rather than reliable figures (Synthesis on Workshop 2: "Water and Agriculture, Convention on Water", OEHC 2003).

The following figure illustrates how the irrigated area (SI) is distributed in the different agricultural zones of the island.

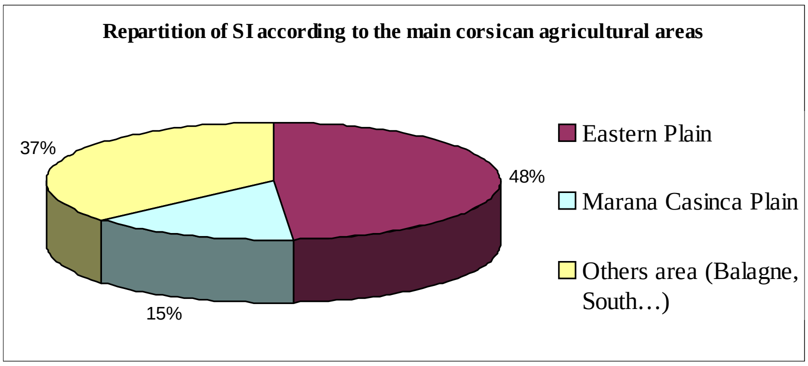


Figure 40: *Distribution of irrigated surface area in 2000, according to the main agricultural area in Corsica, (AGRESTE source, agricultural census 2000 and SAFEGE Report 1998, Plan for the Hydraulic Development of Corsica).*

Almost 50% of the SI area is located in the Eastern Plain. But in the Balagne and the South the SI areas increased since 1988 with a growth of about 5km².

Table 15: *Values of TAS, Equipped area and irrigated area, (AGRESTE, agricultural census 1998 and 2000 and SAFEGE, report 1998 for the hydraulic development of Corsica).*

Type of area	[km²]
TAS of Corsica (Total agricultural area)	1,559
SE 1997 (Equipped area)	315
SI (Irrigated area)	223.3

The water irrigation needs are established by sectors (8 sectors), which correspond to the irrigable perimeters of the Hydraulic Agency of Corsica (OEHC): the Eastern Plain, Corsica course, Balagne, South-East, Sartenais, Taravo-Prunelli, Ajaccio Liamone The Center. These perimeters are defined in term of subscribers' consumption. The Hydraulic Agency of Corsica (OEHC) ensures the water supply on a definite perimeter depicted in green on the map (Figure 41). This water essentially comes from dams. According to this perimeter, the Corsican Agency for the agricultural development (ODARC) ensures the water supply and works within the farms located in mountains. This water essentially comes from wells. Concerning the water supply, two kinds of water are used:

- raw water for agriculture, craft industry and amenities *and*
- drinking water.

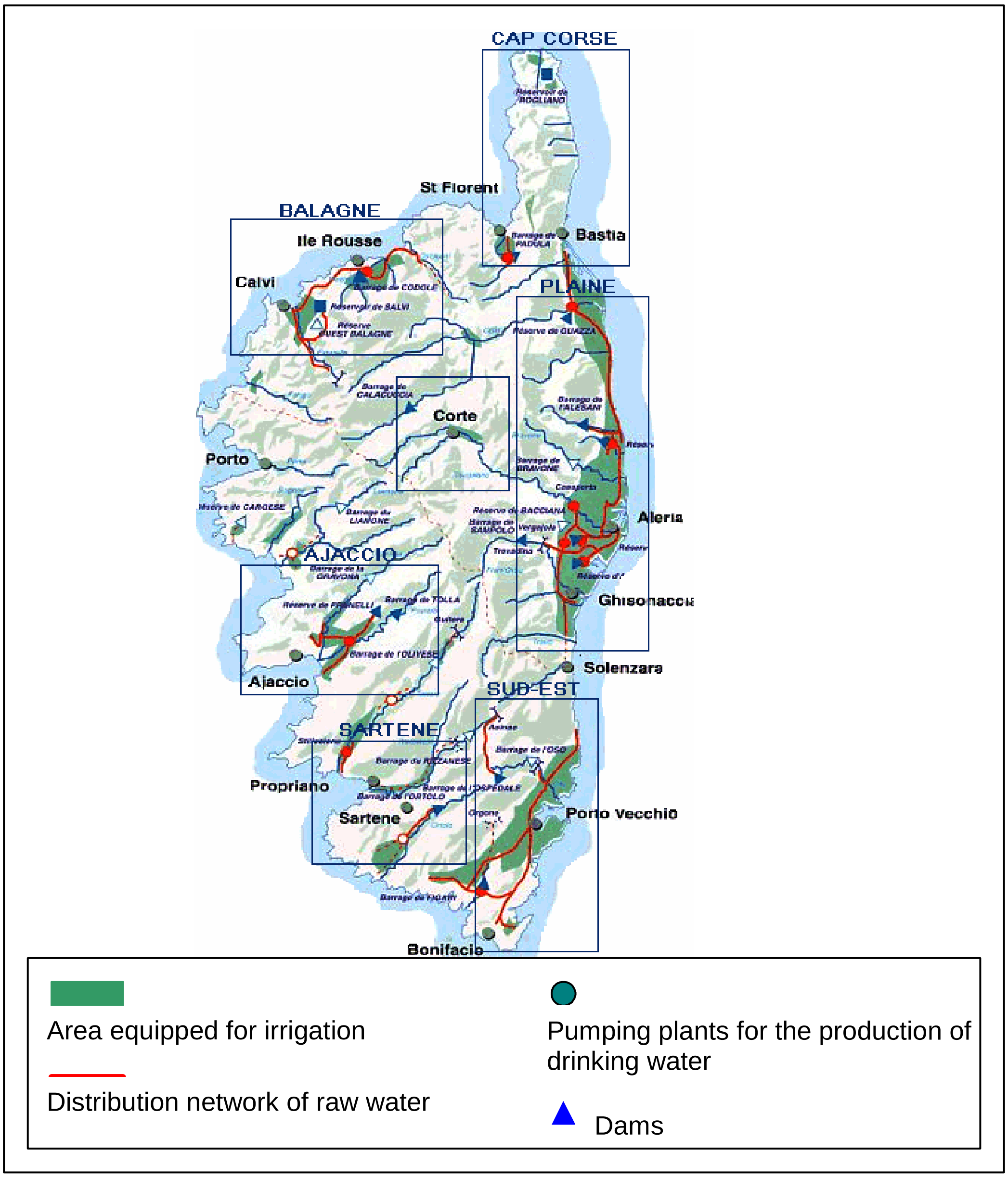


Figure 41*: Irrigable perimeter managed by the Hydraulic Agency of Corsica, OEHC, (http://www.oehc.fr/).*

The following table presents the distribution between OEHC distribution and the others networks.

Table 16: *Distribution of water in the existing networks, (CDRom Synthesis of Convention of Water, 2003).*

Designation	OEHC collective network	Private and independent networks	Total
Raw water	$40Mm^3$	$8Mm^3$	$48Mm^3$
Drinking water	$15Mm^3$	$23Mm^3$	$38Mm^3$
Total	$55Mm^3$	$31Mm^3$	$86Mm^3$

The raw water especially dedicated to agriculture is about 30Mm³. This value is equivalent to the one corresponding to the drinking water.

1.7.3.2 Irrigated crops

The main irrigated crops are the following:

- Orchards (mainly citrus trees) and Kiwi,
- large crops (mainly corn),
- irrigated grass for breeding *and*
- vineyard (when not AOC).

In 1988 fruits (including 50% of citrus fruits) represented the major part of the irrigated surface area with 53%. Similar research was conduced in 1999 but a publication has not been available. The following graphic, for example, presents the development of the main irrigated crops in 2000. In 2000, 100% of the area devoted to corn, was equipped and irrigated, whereas only 25% of the surface designated to other cereals was irrigated. Even though an area might be equipped for irrigation it might not actually be irrigated.

Regarding fodder, only 352,7km² were irrigated (artificial and temporary meadows, annual fodder, part of grass surface) which was 40% of this surface. So, the corresponding irrigated surface (SI) was about 141km². The remainder corresponded to natural meadow and routes which were not irrigated.

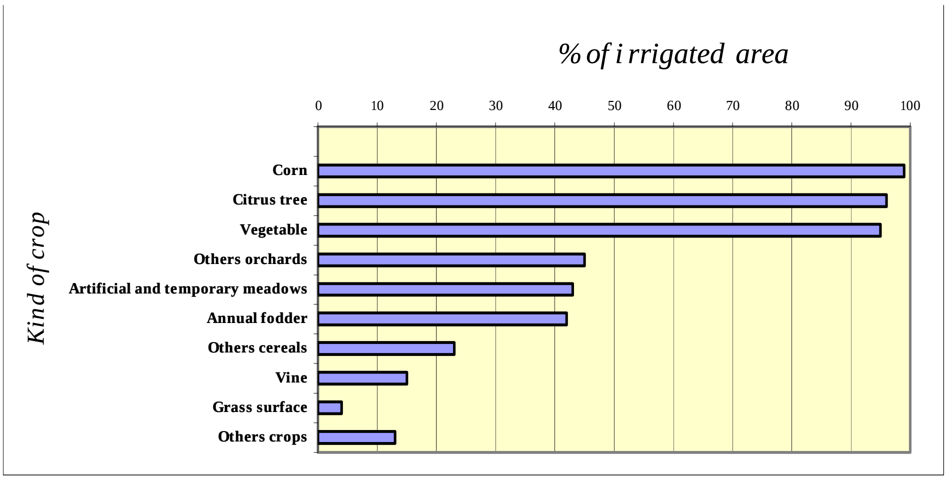


Figure 42: *Irrigated crops in 2000, (AGRESTE, Corse 2002).*

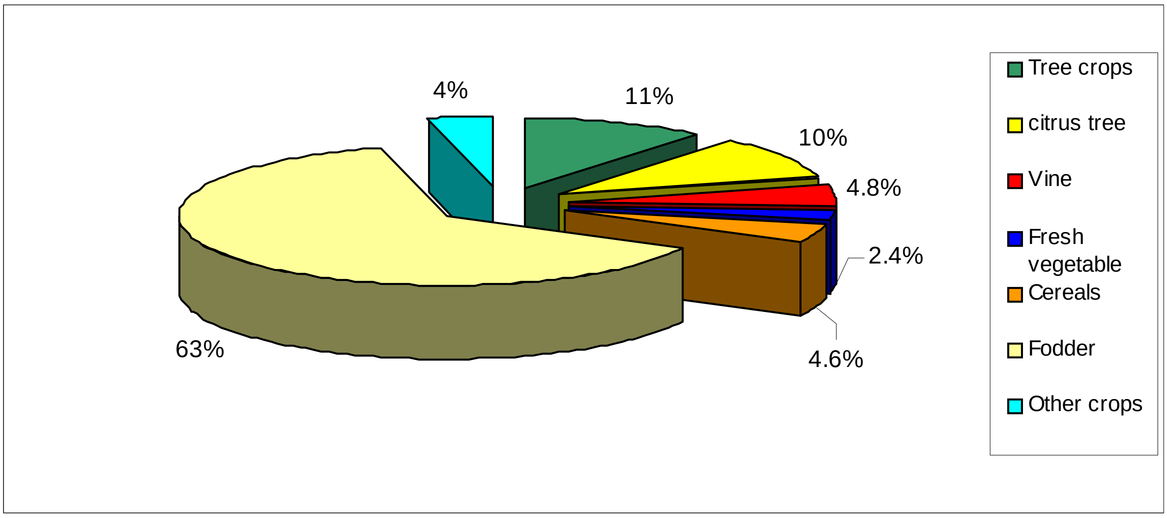


Figure 43: *Distribution of the main irrigated crops on the total irrigated surface.*

The following table gives a summary of the main irrigated crops along with the corresponding surface.

Table 17: *Main irrigated crops in Corsica in 2000, (AGRESTE census 2000, AGRESTE, Corse 2002).*

Crop type	**Crop area (km²)**	**% of TAS**	**% of crop area irrigated**	**Irrigated area (km²)**	**% of total irrigated surface (SI)**
Tree crops (kiwi + other orchards)	56,13	3.5	45	25,25	11
Citrus tree	23,34	1.5	95	22,17	10
Vine	71,82	5	15	10,77	4.8
Fresh vegetable	5,65	0.4	95	53,67	2.4
Cereals (corn)	8,24	0.5	100	8,24	4.6
Other cereals	8,65	0.5	25	2,16	
Fodder	1360	87.5	40	141,08	63
Other crops	25,07	1.6	34	8,56	4
Total	**TAS**	**100 % of TAS**		**SI**	**100 % of SI**

1.7.3.3 Water requirements

The calculation of the water demand depends on the following factors:

- Type of irrigation,
- irrigation system *and*
- natural parameters like pedology (soil) or climatology.

The following table presents both the watering time of crops in Corsica and annual needs in water per square kilometres of cultivated crop.

Table 18: *Time of watering of main crops and annual water needs, (SAFEGE Report for the hydraulic development of Corsica, 1998).*

Irrigated crop	**Time of watering**	**Annual needs $M^3/10^{-2}km^2/yr$ Eastern Plain & Prunelli**	**Annual needs $M^3/10^{-2}km^2/yr$ Balagne**	**Annual volumes for Eastern plot (including Marana Casinca) $m^3/10^{-2}km^2/yr$**
Corn	Summer	4,050	4,658	770
Non permanent crops	Spring/ summer	3,150	3,623	315
Lucerne	Summer/ autumn	3,600	4,140	216
Meadow	Summer/ autumn	1,800	2,070	36
Citrus trees	Summer	3,700	4,255	1,036
Almond	Spring/ summer	1,800	2,070	198
Kiwi	Spring/ summer	4,050	4,658	446
Others fruits	Spring/ summer	2,700	3,105	351
Olives	Summer	1,800	2,070	-
Total m^3/ha/an				**3,367**

The water requirements of the crops are estimated according to the deficit between the evapotranspiration (ETP) and the rainfall. An average value is determined like a value of a decennial dryness. In order to estimate the water crops needs, a coefficient called Kc is used. It integrates the plant's needs according to the hydrologic deficit and the irrigation practises. The Kc is a variable parameter and not constant throughout the year since it depends additionally on climatic conditions. The selected coefficients for the main crops in Corsica are presented in table 19.

Table 19: *Coefficient for the water needs of crops, (The crops water needs in Corsica, ODARC, 2002).*

	Crop	Initial Kc	Maximum Kc	Final Kc	Maximal Height (m)
Trees growing	Almond on naked soil	0.40	0.95	0.65	4
	Grape	0.30	0.85	0.45	1.5 - 2
	Kiwi	0.4	1.05	1.05	3
	Olive tree	0.5	0.7	0.5	5
	Citrus tree (naked at 70%)	0.70	0.65	0.70	4
	Citrus tree (naked at 50%)	0.65	0.60	0.65	3
	Citrus tree (naked at 20%)	0.50	0.45	0.55	2
	Citrus tree (with a cover of leaf about 70%)	0.75	0.70	0.75	4
	Citrus tree (with a cover of leaf about 50%)	0.80	0.80	0.80	3
	Citrus tree (with a cover of leaf about 20%)	0.85	0.85	0.85	2
Cereals and fodder	Wheat	0.3	1.15	0.25-0.4	-
	Corn	0.3	1.20	0.35-0.6	-
	Lucerne	0.4	1.2	1.15	-
	Grass for pasture	0.4	0.85	0.85	-
	Grass in cold season	0.9	0.95	0.95	-
	Grass in hot season	0.8	0.85	0.85	-
Vegetable	Artichoke	0.5	1	0.95	-
	Potato	0.4	1.15	0.7-0.4	-
	Salad	0.7	1.05	0.95	-
	tomato	0.4	1.15	0.65	-

The average demand is from 2,500 to 3,000m^3/ha/yr during maximum 5 months. The peak month is 30 to 40% of the total volume which represents 900 to 1200m^3.

1.7.4 Irrigation modes

Concerning irrigation equipments, farmers and manufacturers agree that there are no good or bad equipments but each one must be carefully selected in order to fit with the following main parameters: crops, land, pressure, discharge.

The most important part of the exploitations is connected to a collective network. Farmers who have access to an individual source (wells, storage of water or others) have decreased by more than half for the past twelve years. But it remains very difficult to estimate the volume of water used in this way.

***Table 20**: Reference mark on the Corsican irrigation, (AGRESTE, Corse 2002).*

Kind of source of water	Exploitations 2000	Exploitations 1988
Collective network	960	1179
Individual network	292	738
Mixed	41	-
Individual drilling	85	191
Individual water storage	38	156
Individual others sources of water	249	655

On a technical level, the gravitating irrigation systems decreased in favour of sprinkling and micro irrigation systems, which came up to about 38% of exploitations in 2000. Examples:

The irrigation methods for fruit-trees are:

- Micro irrigation: 4 to 5 drippers per tree with 4 l/h per dripper and micro sprinkler,
- sprinkling under foliage: small sprinkler 1.5 to 2mm diameter, discharge 500 to 600 l/h *and*
- sprinkling over foliage: nozzle up to 4mm diameter.

The irrigation for large scale farming and grassland:

- Total coverage by sprinklers,
- spout with roll (18 to 24mm diameter) *and*
- pivot (difficult to use due to the shape of the farm).

All these water equipments need pressure:

- Low pressure less than 2 bars for drip irrigation or micro sprinkling *and*
- High pressure 5 to 8 bars for sprinklers, spouts and pivots.

But difficulties remain in the maintenance of the distribution network, which makes the estimation of the water volumes used for irrigation and the correspondence irrigation methods, difficult (Synthesis on Workshop 2: Water and agriculture, Convention on Water, OEHC, 2003).

The main difficulties regarding an estimate of the consumed water volumes for irrigation are:

- In many perimeters it is difficult to figure out the water volume needed both for irrigation and as drinking water,
- Many losses from the network (leakage),

- Instances of “stealing” have been reported,
- Uncertainty on the measurements on the production meters *and*
- Measurement of volumes taken at the fire hydrant.

Quality of irrigation water

By contract with the farmers, OEHC is supposed to deliver raw water without any treatment, which cannot be used as drinking water or any other use than as irrigation water. It appears that the use of dripping irrigation induces the problem of clogging. Generally the quality of the water delivered is good but some problems occur during the very dry summers when dams are nearly emptied or when some high floods bring a lot of sediments in the dam. This is why drip irrigation is rather questionable.

Price of irrigation water

The installation of the equipments is ensured to 80% by the CEE, the state and the Region of Corsica, the remaining 20% are implemented by the OEHC. The exploitation and maintenance are paid by the turnover made in the sale of the water. Due to the problem faced by agriculture in Corsica (mountainous area, islands constraints, lack of infrastructure etc.) the bills arising from the farmers water consumption have been reduced by 50%. The average cost is about 0.05 cents of euros per cubic meters when on the continent the same amount is 3 to 5 times higher. Yet in fact this practise is not sustainable and if the agricultural industry wants to be stronger, the existing water price for irrigation in Corsica should be applied.

1.7.5 Fertilisers and pesticides

1.7.5.1 Fertilisers

Table 20 presents the fertilisers used for the main crops, their respective amounts and period of application. Simple products with phosphate, for example, can also be applied for all crops if the soil analysis shows a deficiency on this element. The distribution can be made by spreading or dissolution in the irrigation water. The choice depends on the level of irrigation equipment: Drip and mini-sprays with pump and dosing are indicated for the distribution of soluble products. The proportion of farmers who apply fertilizers by spreading and by dissolution is practically the same (50% for spreading and 50% for soluble products). Finally we can note that some products can be applied by sprinkling at the leaves level, this is called “foliar plan”. For the citrus trees, for example, the foliar plan is as follow in table 21.

***Table 21**: Fertilisers use, (CANICO GAM-VERT).*

<table>
<tr><th>Crops</th><th>Type of Fertilizers
(N. P. K)</th><th>Amount
[kg/10-2km2]</th><th>Period</th><th>Comment</th></tr>
<tr><td rowspan="7">Same practises for the following crops:
▪ Clementine
▪ Kiwi
▪ Peach
▪ Apricot</td><td>Limestone 54% CAO</td><td>2000</td><td>January</td><td rowspan="7">Treatment applied only if the soil analysis shows that it is necessary</td></tr>
<tr><td>9.3.7 (organic) or 19.19.20</td><td>800 or 400</td><td>February</td></tr>
<tr><td>Phosphate of ammonia 18.46.0</td><td>150</td><td>April</td></tr>
<tr><td>Lime nitrate 15.5%</td><td>200</td><td>June</td></tr>
<tr><td>Perlure 46% or ammonitrate 33.5%</td><td>200</td><td>June - July</td></tr>
<tr><td>or prillor 23.0.23</td><td>200</td><td>July - August</td></tr>
<tr><td>Potassium nitrate 13.0.46</td><td>300</td><td>July - August</td></tr>
<tr><td>▪ Vine</td><td>Organic fertilizer 5.5.15
Or Organic fertilizer 7.14.28
Or Organic fertilizer 7.7.28</td><td>800
400 or 500
400 or 500</td><td>February – March
February – March
February – March</td><td>The application of fertiliser is made only once a year</td></tr>
<tr><td>▪ Tomato</td><td>Organic fertilizer 4.8.12
Organic fertilizer 18.6.26
Organic fertilizer 12.9.34</td><td>800
300
300</td><td>-</td><td>For the gardening market the application mode is mainly by irrigation, not by spreading</td></tr>
<tr><td>▪ Maize</td><td>Organic fertilizer 0.15.30 or 0.25.25
Perlure 46 %
Phosphate of ammonia</td><td>400
400
100</td><td>February
End of February
April</td><td>Application according to the soil analysis</td></tr>
<tr><td>▪ Meadow</td><td>Organic fertilizer 0.12.12 or 0.10.15
Organic fertilizer 0.25.25 or 0.15.30
Ammonitrate</td><td>600
400
200</td><td>Autumn
Autumn
Spring</td><td>-</td></tr>
</table>

***Table 22**: Foliar plan for citrus trees, (CANICO GAM-VERT).*

Product	**Amount**	**Period and effects**
Solufol 30.10.10	6kg	May
Seniphos	8 to 10 l	June (to favour the cellular division)
Solufol 10.10.30	6kg	July (to make the fruit grow)
Solufol 10.10.30	6kg	August
Stopit	10l	September (to conserve the fruit)
Stopit	10l	October

For the year 2003, the amount of fertilizers sold, can be estimated to 9,400,000kg for High Corsica.

1.7.5.2 Pesticides

Different products are applied throughout the year, in order to protect the crops against diseases. The total amount of pesticides sold is not available yet. The following example shows the pesticides application for peaches.

***Table 23**: Peach treatment, (CANICO GAM-VERT).*

Periods	Diseases	Product	Amount/ HL
January	Blight	POMARSOL Z	0.250 kg
February	Blight Greenfly	POMARSOL Z EUPHYTANE	0.250 kg 2 l
Full flower	Blight Monilia Thrips	POMARSOL Z BIALLOR 10 PEP KLARTAN	0.250 kg 0.12 kg 0.06 l
Fall of petals	Blight Oïdium If blight	POMARSOL F THIOVIT CONFIDOR	0. 250 kg 0.750 kg 0.350 kg
End of April	Blight Oïdium, monilia	POMARSOL F ANVIL	0.250 kg 0.06 kg
mid- May	Cochineal first	ULTRACIDE PM	0.2 kg
End of July	Cochineal second	ULTRACIDE PM	0.2 kg
Since May 5th May, every 12 days Until 15 days before the harvest	Oïdium, monilia Leaf roller	ANVIL KARATE	0.06 l 0.035 l
	Californian Thrips	ORYTIS	0.08 l
	If spiders	MASAÎ	0.05 l
Before the harvest	Treatment for conservation	ROVRAL HORISON ARBO BIALLOR 10 PEP	0.150 kg 0.5 kg 0.12 kg
After gathering	Oïdium	ANVIL	0.06 l
Fall of leaves	Bacteriose Canker	HELIOCUIVRE TOPSIN	0.3 l 0.270 l

1.7.6 Conclusions

The Corsican agriculture varies depending on the crops cultivated. Yet agriculture is not the most dynamic economic sector of the island and essentially prevails in two regions: Marana Casinca and the Eastern Plain, whereas breeding is concentrated in mountains. Moreover, agriculture does not seem to face significant problems regarding the availability of irrigation water or water pollution through the use of fertilisers. This pollution is essentially due to breeding, with the manure of animals in freedom, near the rivers in mountainous areas. The main difficulty concerning irrigation is the maintenance of the distribution network, where network losses and unmetered water is used, which in turn makes it difficult to estimate the volume needed for agricultural use.

Consequently, agriculture and its impacts on water, is not a field explicity studied and it's very difficult to obtain information on current practises.

Another problem is the obvious lack of communication between the different actors, in which a lack of training for farmers is included. However, the Convention on Water organized by the OEHC in the summer 2003, made a step towards assessing the agriculture issue. Today specialised studies are conduced for developing more productive endemic species which additionally consume less water, and are fitting to the local geographic conditions. The aim is to reach a reasonable agriculture with appropriate irrigation. Finally, Corsican agriculture does have capabilities of enhancement and development, such as transformation activities, tourism activities combined with farming or biological agriculture. All these possibilities contribute to the current framework of a multi-functional agriculture, and perhaps, they will permit to develop the island's interior regions.

1.8 Socio-economic situation

Administratively, Corsica is divided into two districts – Haute Corse and Corse du Sud. They form the Region of Corsica, established in 1970 with its own regional assembly. The capital of Haute Corse is Bastia that of Corse du Sud is Ajaccio.

1.8.1 Social profile

1.8.1.1 Population

The permanent population of Corsica was 260,196 inhabitants in 1999 (1999 census). The annual variation of the population is +3.9%. About 170,000 are of Corsican origin. 10% of the population are foreigners (of France), of whom the biggest groups are Moroccans (14,000) and Portuguese (4,000). Very small proportions live in the interior - in hundreds of villages and hamlets. It is the least densely populated of all the Mediterranean islands with 2.9 people/km². There are half a million Corsicans on mainland France and about a further million Corsicans are said to live throughout the world - concentrating in places like Marseille, Puerto Rico and Venezuela. Apart from direct emigration, Corsicans traditionally represented the highest proportion of French in the colonies (in 1946, there were 281 per 100,000 inhabitants, versus 56 as a national average). Corsica is still the least densely populated region of France (30 people per km² versus 108 in France as a whole -

and perhaps nearly half the island with less than 10 per km²). Over 6,000 people commute into Ajaccio and Bastia every day, to get to work, though life quality is better in the villages. Even in a small town like Calvi with 5,000 inhabitants, a quarter of the jobs are filled by commuters. The following figures present the repartition of the population regarding sex and age:

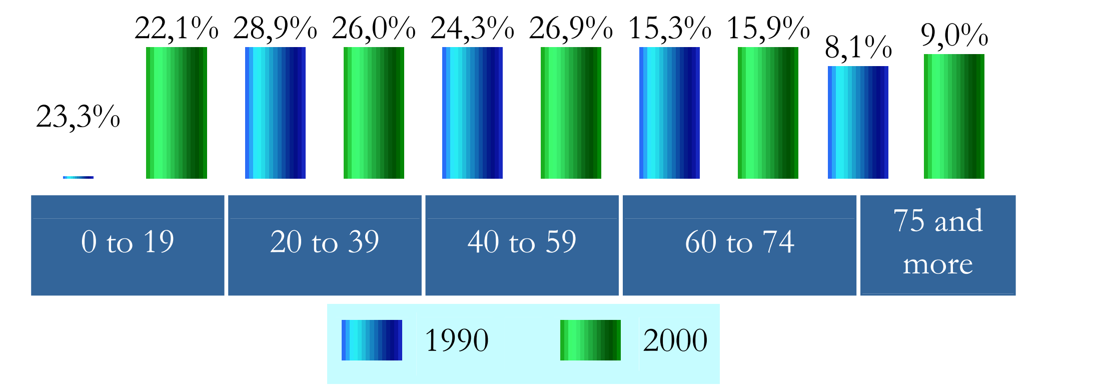


***Figure 44**: Distribution of the population regarding age, (INSEE 2000; SIRENE repertory).*

The agglomeration area of Bastia is most significant with its 54,000 inhabitants, followed by the town of Ajaccio. Between April and October, Corsica welcomes more than 2,200,000 tourists (Data 2001, Tourist Office of Corsica) and is booked for 25.3 million overnight stays.

***Table 24**: Repartition of the population regarding age and sex, (INSEE 2000; SIRENE repertory).*

Total population by age and sex				
Age		**Men**	**Women**	**Total**
0 to 19		23.5%	20.9%	22.1%
20 to 39		26.3%	25.8%	26%
40 to 59		28%	25.9%	26.9%
60 to 74		15.5%	16.2%	15.9%
75 and more		6.7%	11.2%	9%
Total	**%**	100%	100%	100%
	Number	126,902	133,247	260,149

***Table 25**: Population of the main citres of Corsica, (INSEE, 1999).*

Corsica	**Population**
Ajaccio	52,880
Porto Vecchio	10,326
Corte	6,329
Calvi	5,177

Table 25 continued.	
Corsica	**Population**
Borgo	5,002
Sartene	3,410
Propriano	3,166
L'Ile Rousse	2,774
Bastellicacia	2,774
Prunelli-di-Fiumabroi	2,745

1.8.1.2 Family structure

Regarding the composition of households, the census indicates an average of 2.4 persons per household, showing a regular decrease in the average number of people per household.

Table 26: *Composition of households, (CCI High Corsica, Economy of Corsica n°36).*

Persons	Housholds by number of members
1 person	32,183
2 person	32,370
3 person	19,764
4 person	14,381
5 person	7,538

In 1999, the average income of a salaried Corsican inhabitant was 1,400€ per month, calculated for all professions, from agriculture to civil servant. This average, however, covers up different situations. The individual characteristics of employed people (age, sex, professional category, etc) have influences on their remuneration. These influences explain the 83% of variation of wage in Corsica in 1997 (www.insee.fr/fr/insee_regions/corse).

Table 27: *Number of children, (INSEE, 2000).*

	Corsica	France
Number of children residing in 2001	2700	769 300
Number of children / women (average) in 2000	1.67	1.88
Expectation of life at birth in 2000 (year)		
Men	74.8	75.2
Women	82.1	83.1

1.8.1.3 Education

The education is divided into three categories:

- There are more people classified in the first sector: 24,657, from elementary school to the third year before the General Certificate of secondary education (elementary school and "collège"),
- 23,257 people go to high school ("Second degree lycée") *and*
- 5,086 are in higher education (superior study:University) (Ministère de l'éducation nationale).

The results of graduation after secondary education (Baccalauréat) are presented in the following table and relate the French average.

Table 28: *Education in 2001,(Ministry of the National Education).*

Education at the reopening in 2001	
First degree	24 ,657
Second degree	23,257
Superior	5,086

Table 29: *Baccalaureat Results 2001,(INSEE, 2000).*

Baccalauréat session 2001	
Number of students taking the Baccalaureat	2,398
Number of students received the Baccalaureat	1,867

From the 2,398 students who started secondary education only 1,867 received the degree and some of them will get enrolled at university.

Table 30: *Degrees earned at the University of Corsica in 2001,(INSEE, 2000).*

Certificates delivered by the University of Corsica in 2001	
DUT (2 first years)	94
DEUG/DEUST	360
Licences (third year)	476
Maîtrises (fourth year)	203
Fifth year (DESS or DEA)	268

The total numbers of degrees got to the University of Corsica was 1,401 in 2001. Every year this comes up to 1,400 out of approximately 4,000 students. The percentage of graduation after secondary education per generation comes up to 60.6% for Corsica as opposed to 61.9% in France (INSEE, 2000).

1.8.1.4 Health

The health indicators for Corsica are shown in the following table.

***Table 31**: Health indicators for Corsica compared to France (1999), (www.french-property.com/regions/corse/statistics.htm).*

Health indicators	Corsica	France
Hospital beds available, private establishments, continuing care and rehabilitation, per 1,000 pop	1.6	0.9
Hospital beds available, private establishments, short stay, per 1,000 pop	2.2	1.4
Hospital beds available, public establishments, continuing care and rehabilitation, per 1,000 pop	0.6	0.7
Hospital beds available, public establishments, short stay, per 1,000 pop	2.7	2.8
Medical professionals, consultants/specialists, per 100,000 pop	102	66
Medical professionals, dental surgeons, per 100,000 pop	82	52
Medical professionals, general practitioners, per 100,000 pop	128	98
Medical professionals, state qualified nurses, per 100,000 pop	237	89

1.8.2 Economic profile

1.8.2.1 Gross Domestic Product

The Corsican GDP is 30% inferior to that of the French national average. The total represents 0.35% of the national GDP.

***Table 32:** GDP of France and Corsica in 2000, (INSEE, 2000).*

GDP	France 2002	Corsica 2001 (definitive data)	Corsica 2002 (temporary data)
GDP total (2000)	1,497 081 million of €	4,862 million of €	5,052 million of €
GDP /person	25,153€	18,550€	19,133€
GDP / employee (paid person + unemployed)	61,574€	49,72 €	52,484€

The agricultural only accounts for 2.4% of the Corsican GDP compared to 13.6% for industry and 84% for services, including 9.5% for the tourism (http\\www.magnard.fr/geolycee/stats.htm#).

1.8.2.2 Employment

Nearly 100,000 people are active in Corsica both paid and unemployment persons. The total employment increased by 11% during 3 years.

***Table 33**: Active population in 2002, (INSEE, 2002).*

Total population	Total active population	Active persons occupied (employees)	Unemployment
260,196	97,408	84,698	12,710

The unemployment ratio is 10.5% whereas in France it is 8.9% (INSEE, 2002). The following tables present the distribution of employment regarding activity sectors:

Table 34: *Employment according to the main activity sectors, (INSEE, 2000).*

Evolution in Corsica between 1998 and 2001									
	Number of employees (December 31)				Variation of employment				
	1998	1999	2000	2001	1999	2000	2001	1998 - 2001	
Salaried	74,114	76,738	80,316	83,070	3.5%	4.7%	3.4%	8 956	12.1%
Non salaried	12,341	12,797	12,785	12,567	3.7%	- 0.1%	- 1.7%	226	1.8%
Total	**86,455**	**89,535**	**93,101**	**95,637**	**3.6%**	**4.0%**	**2.7%**	**9 182**	**10.6%**
Agriculture	4,904	4,636	4,334	4,164	- 5.5%	- 6.5%	- 3.9%	- 740	- 15.1%
Industry	5,966	5,913	5,992	6,109	- 0.9%	1.3%	2.0%	143	2.4%
Build	7,248	7,530	7,994	8,521	3.9%	6.2%	6.6%	1 273	17.6%
Services	68,337	71,546	74,781	76,843	4.6%	4.7%	2.8%	8 506	12.4%

Table 35: *Repartition of active population in 2002, (INSEE, 2002).*

Sectors	Active population (occupied + unemployed) 2002
Agriculture	3,974
Industry	6,285
Build	8,636
Services	78,513
Total	**97,408**

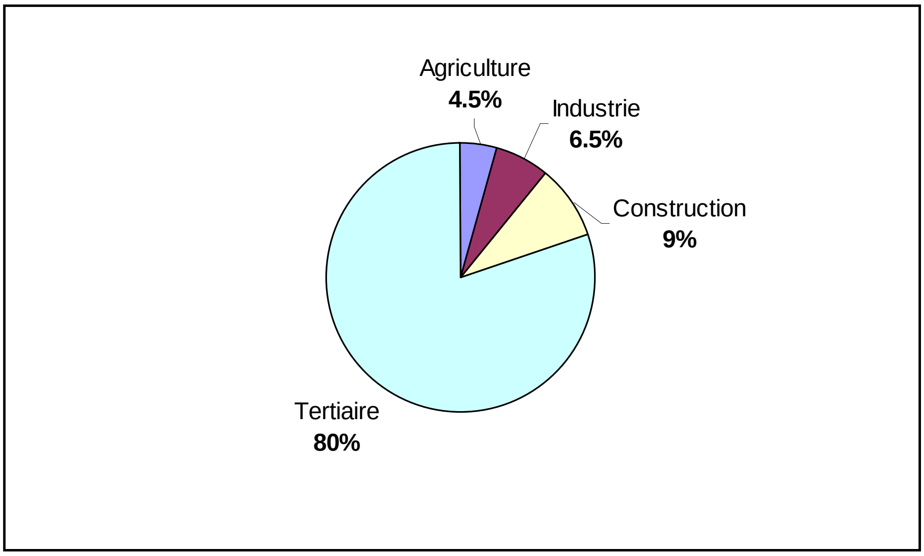


Figure 45: *Estimation of employment by sectors in 2002, (INSEE, 2002).*

Since the last decade the sectoral division of employment has experienced significant changes. The agricultural sector has faced an important drop in employment whereas, at the same time, the service sector (construction, transport, tourism, trade etc.) has developed significantly, reinforcing its position in the island's economy.

In 2000, Corsica had more than 85,000 jobs. Since 1990, the total employment has increased by 3.4%, a development also visible on the continent.

1.8.2.3 The main activity sectors

The service sector is the main regional employer of about 80% of the active population (16% in public functions) and 84% of the GDP. In 2001, 76,843 salaried employees worked in the service sector, representing more than three quarters of local employment. Among the main components of the service sector, public service activities represent a big part of the services, particularly in civil service, regarding health care, social work and to a lesser degree in education. The health sector is the main beneficiary of sectoral growth, having one third employees more. The educational sector has also experienced an increase higher than the national average with an increase of 2% more pupils, while their number has been decreasing in other regions of France.

Tourism

The tourism sector represents 12.5% of the total employment, and 9.5% of the Corsican GDP. Yet it is difficult to determine a solid figure for the tourist sector as it is a transversal sector comprising all kinds of services. The number of employees in this sector usually rises from 46,000 people in January to 54,800 in August (progression of 19%). Between 1990 and 2000, the increase of paid employment was particularly high in transport and particular services sectors, especially in hotels and restaurants. The profitable tourist seasons since 1997 along with the longer summer periods, have not been without consequences on the significance of these two sectors, both of them noting a rise of more than 20% of salaried employees between 1990 and 2000. From 1980 to 2000, the total number of tourists increased by more than 60% with a high concentration between June and September. The two biggest concentration of tourist in Corsica (1999 figures) are in Porto Vecchio (66,000 beds) and Calvi (59,000 beds) regions outside the Bastia region (86,000 beds) which is geographically much larger and includes in Cap Corse. Calvi airport sees the biggest number of foreign tourists (54,000) of any Corsican airport, while the greatest volume passes through Ajaccio (just over 1 million) (www.corsica-isula.com/public.htm). Figure 1.46 gives an idea of the main centres of tourism in Corsica and also accounts for an increased water consumption in these regions.

Table 36: *Key figures of Corsican tourism, (Eurisles).*

Key figures of Corsica tourism	Number
Number of inhabitants	260,196
Number of tourists	2,300,000
Number of tourists in hotels	917,000
Number of overnight stays in hotels	10,836,000
Touristic pressure (n tourists/n inhabitants	7.0

The traditional sector is declining

While the service sector is developing further, traditional sectors are subject to a decline. The decline has been most obviously in the agricultural sector which represents 4% of the employed population and only 2.4% of the total GDP. Between 1998 and 2001, agriculture lost more than 700 jobs, which was 15%. This decrease concerned paid, but also non-paid employment, owing to a declining number of small farms and a decreasing population of farming among the younger generations. Since 1988 the number of managers younger than 35 fell by half. All the systems of production have experienced such a shortage of skilled people.

Several institutions make up the Corsican agricultural world. The main are presented in this chapter.

1) *Agricultural Chambers*

   They are professional and public establishments. In each department and region of France, one Agricultural Chamber (AC) follows these two objectives:

   - it represents the rural world in public *and*
   - it offers services for the farmers (providing technical advices to farmers etc).

   In Corsica, there is 1 regional Chamber and 2 departmental chambers. The rural world is thus represented in AC with 10 electoral colleges which consist of:

   - 5 individual colleges: managers of farms, paid employees in agriculture, paid person of professional agricultural groupings, landowners, former farmers. They represent the main groups of water consumers.
   - Representative persons of the 5 professional agricultural groupings: Co-operatives of production, others co-operatives that are also water user groups, trade-union organisations, agricultural credit, agricultural mutual assurance.

2) *ODARC (*Agency for the Agricultural and rural development of Corsica)This institution depends on the local government authority (Territorial Collectivity of Corsica, CTC). This institution does not exist in the others regions of France. The main activities of ODARC correspond to two main centres of interest:

a) Operations for the agricultural development *and*

This activity mainly concerns all the works for the equipment and the modernisation, requested by agricultural experts (requests individual or collective). It could be:

- development of land utilisation,
- equipment of sheds,
- equipment for irrigation outside the perimeter managed by OEHC (in mountain for example),
- purchase of milking machine,
- diversification of orchards,
- help for the equipment in agricultural material *and*
- works in vineyard.

b) Experiments and studies.

ODARC manages two agronomical experimental stations and does research in farming.

3) *DRAF* (Regional Direction of Agriculture and Forest)

This institution represents the Agricultural Ministry in Corsica. There are two DRAF, one in each "departments". The DRAF applies the national agricultural policy taking into account the specific characteristics of each region and department. The agricultural exports have joined trade unions to defend their interests.

4) *The two main Trade Unions are:*

a) FDSEA (Departmental federation of farmers trade-unions) *and*

There are two FDSEA, one in each Corsican department. The role of this organisation is to help and inform the agricultural experts. It defends their interests and promotes agricultural activities.

b) CDJA (Departmental centre for the young farmers).

There are two CDJA, one in each department. This trade-union permits the defence of the young farmers interests and ensures a role of animation and information.

5) *Associations*

There are also some associations like CREPAC (Regional centre for the Corsican agricultural promotion) which promote the Corsican agricultural products.

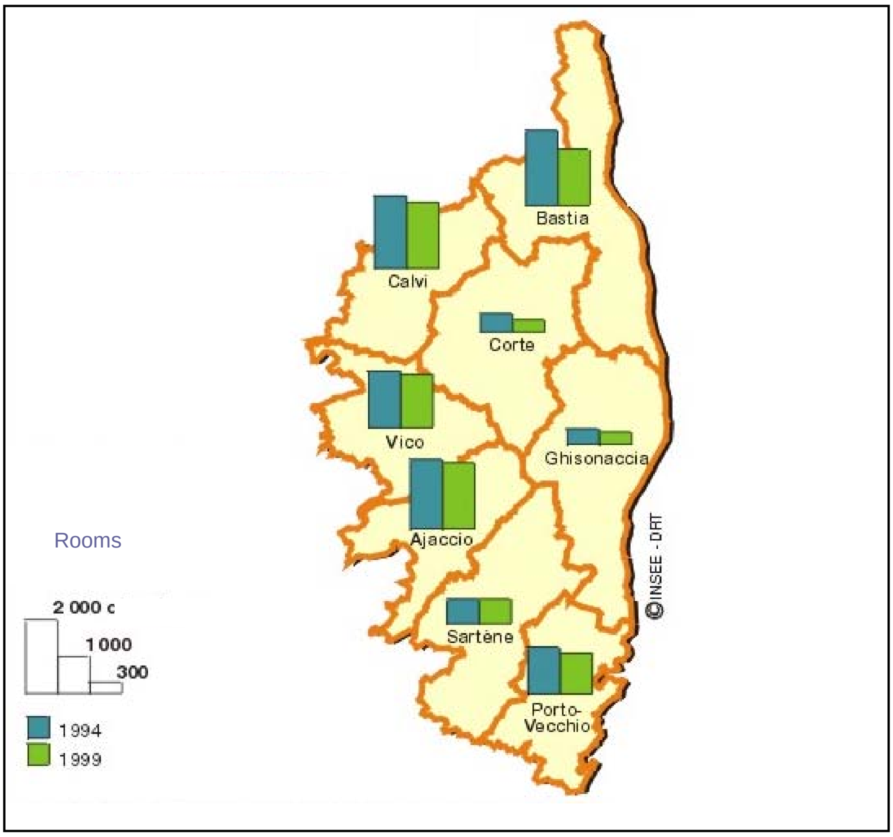


Figure 46: *Evolution of the number of rooms in hotels (from 1994 to 1999), (INSEE, Tourist Direction).*

Industry

Corsica does not possess a significant industrial sector. It represents only 6.5% of the employment (2002) and essentially concerns hydropower production, electricity, and mineral water.

The general characteristics as follows:

- Total power: 524 MW,
- Hydroelectricity: 152 MW *and*
- Micro hydro power stations: 16. 7 MW and 11 places.

Hydroelectricity satisfies 30% of the needs and thus helps Corsica save 9,000 tons of fuel a year. An agreement exists between the power and water utilities. Indeed, in summer EDF has the right to use predetermined weekly quantities; defined in order to satisfy the demand for electricity.

The insularity, weak population numbers, the lack of natural mineral resources and the competition with continental enterprises, are some factors contributing to Corsica's position as the weakest economic region of France. This sector represents 13.6% of the GDP.

Enterprises

The following table presents the number of enterprises according to the main activity sectors.

Table 37: *Enterprises according to activity sectors, (INSEE, 2000).*

Activity Sectors	Number
Industry	1602
Build	2686
Service	15183
Trade	5484
Transport	803
Hotels restaurant	3129

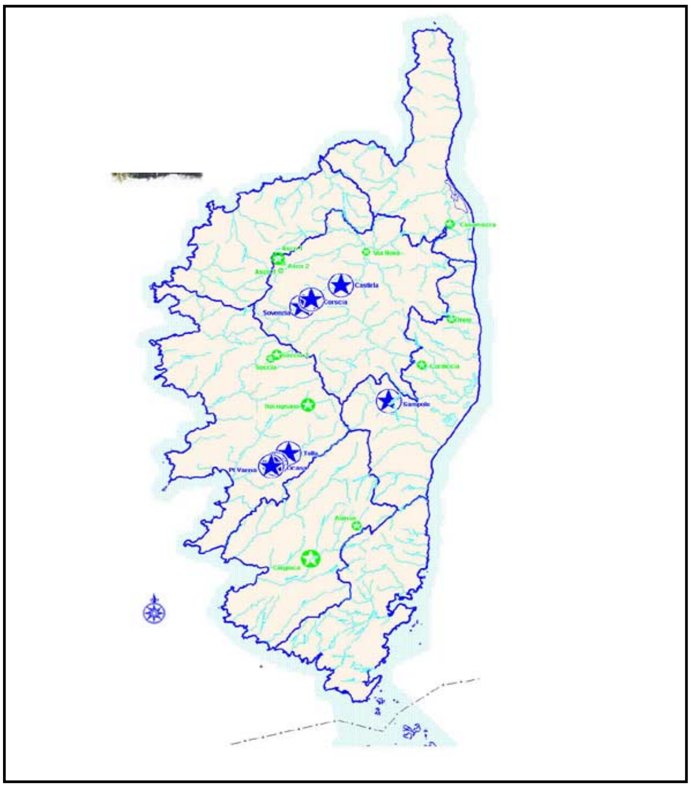


Figure 47: *Hydroelectricity in Corsica: power and micro power stations, (EDF).*

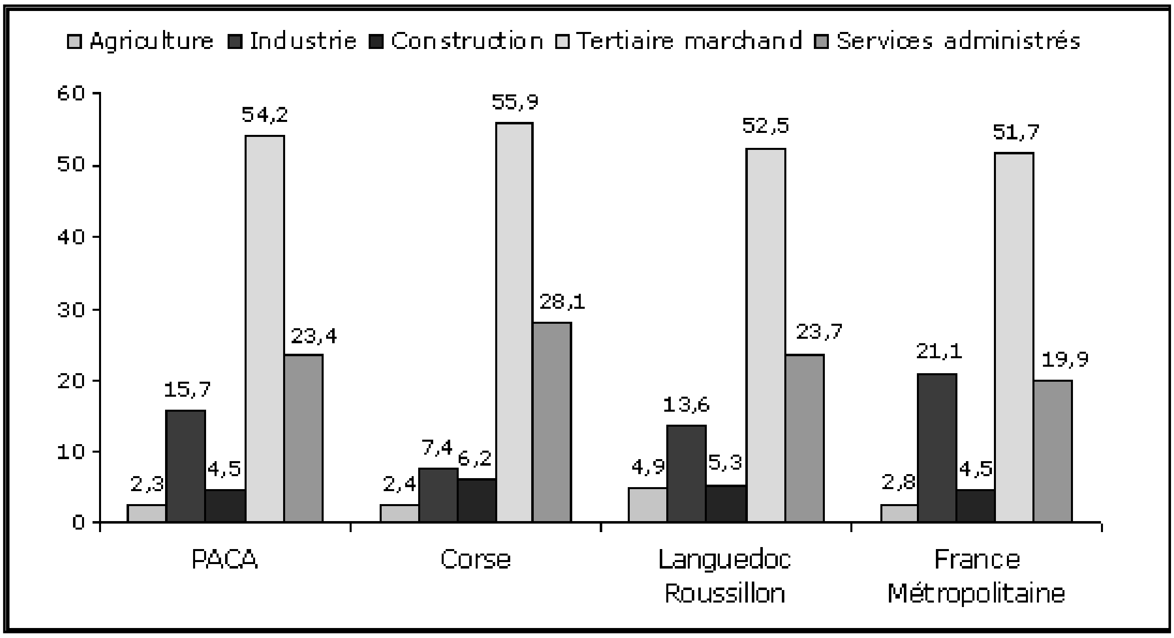


Figure 48: *Added value by activity sector, (INSEE, 2000).*

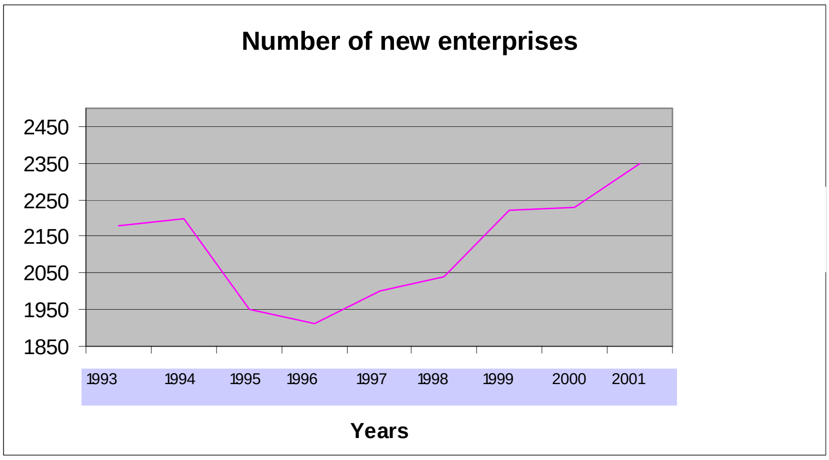


Figure 49: *Foundation of new enterprises creation between 1993 and 2001, (INSEE, 2000).*

Agriculture

The trade sector had to face difficulties during this decade which however has improved since 1997 with a 14% increase of paid employment.

The following table presents the major enterprises by turn-over.

***Table 38**: Major enterprises regarding turnover, (Corsican economy number 32).*

Enterprise	**Activity**	**Place**
Corsair	Air transport	Ajaccio (2A)
Hypermarché Corsaire	Supermarket	Ajaccio (2A)
Pacam 2	Supermarket	Ajaccio (2A)
Compagnie Corse Méditerranée	Air transport	Ajaccio (2A)
Hyper rocade	Hypermarket	Furiani (2B)
Corsica Ferries	Sea transport	Bastia (2B)
Socordis	Retailing	Ajaccio (2A)
Ollandini	Travel agency	Ajaccio (2A)
Bastia Discount	Hypermarket	Bastia (2B)
Lion de Toga	Hypermarket	Bastia (2B)

The economic results of the craft industry (1) in Corsica in 2000 are presented below:

***Table 39**: Economic results of the craft industry (2000), (INSEE, 2000).*

Activities	**Number of enterprises**	**Number of salaried employees**	**Occupied persons**	**Personal expenses**	**Turnover**	**Value added**
	Thousands	*Thousands*	*Thousands*	*Thousands of €*	*Thousands of €*	*Thousand s of €*
Food	**0.49**	**1.5**	**2.0**	**31**	**147**	**44**
Food (except meat and fish)	0.30	1.1	1.4	23	78	30
bakeries	*0.22*	*0.9*	*1.1*	*17*	*49*	*21*
Meat and fish	0.19	0.4	0.6	8	70	13
Metal work	**0.16**	**0.5**	**0.6**	**13**	**52**	**16**
Textile, clothing, leather	**0.03**	**0.0**	**0.1**	**1**	**3**	**1**
Textile and clothing	0.02	0.0	0.1	1	3	1
Leather and shoes	0.00	0.0	0.0	0	0	0
Wood and furniture trade	**0.08**	**0.2**	**0.3**	**4**	**19**	**6**
Other manufactures	**0.24**	**0.6**	**0.8**	**16**	**70**	**24**
Building materials	0.08	0.3	0.4	9	38	12
Paper, printing	0.05	0.1	0.1	3	9	4
Manufacture of various articles	0.12	0.2	0.3	5	23	8

Table 39 continued.						
Activities	**Number of enterprises**	**Number of salaried employees**	**Occupied persons**	**Personal expenses**	**Turnover**	**Value added**
	Thousands	*Thousands*	*Thousands*	*Thousands of €*	*Thousands of €*	*Thousand s of €*
Building	**1.55**	**4.6**	**5.8**	**100**	**345**	**136**
Masonry	0.74	2.4	3.0	50	169	66
Roofing, plumbing, heating	0.19	0.4	0.6	10	36	14
Joinery, locksmith's trade	0.13	0.3	0.4	6	24	9
Installation of the electricity	0.18	0.4	0.6	11	37	15
Fitting, finishing	0.14	0.3	0.5	8	25	10
Earthwork, other works	0.17	0.7	0.8	16	53	22
Transports, repairing, other services	**1.02**	**1.9**	**2.9**	**39**	**147**	**55**
Transport	0.11	0.2	0.3	4	12	7
Repairing	0.34	0.7	1.0	14	77	20
Laundry, dry-cleaning, people's care	0.33	0.5	0.9	9	24	13
Others services	0.24	0.5	0.7	11	34	15
Total	**3.56**	**9.4**	**12.4**	**203**	**783**	**282**

(1) Enterprises with less than 20 salaried employees belonging to the craft industry.

1.8.2.4 Water price

The average price of water was close to 319€/a/household, or 3€ per m^3 in 1999. Between 1992 and 1998, the average price of water rose from 1.8€/m^3 to 2.5€ and it is supposed to increase by another 50%. Investments are definitely necessary for the application of the WFD. On average, water costs account for 1% of the total budget of a household. Prices vary according to the management chosen by each municipality. The market of water is determined by pseudo-prices and unpredictable quantities. The following table presents the average water price in euro per m^3 in both parts of the island, between 1996 and 1999.

Table 40: *Evolution of the water price from 1996 to 1999, (INSEE, 2000).*

<table>
<tr><th></th><th>1996</th><th>1997</th><th>1998</th><th>1999</th><th></th></tr>
<tr><td>Southern Corsica</td><td>2.26</td><td>2.33</td><td>-</td><td>2.39</td><td rowspan="2">Average price for entire Corsica
2.57 €</td></tr>
<tr><td>Northern Corsica</td><td>2.12</td><td>2.26</td><td>-</td><td>2.18</td></tr>
</table>

The price determination process remains almost the same throughout the periode, about 50% corresponds to the cost of the resource. The water price is more an administrative price than a market price. Neither bargaining process, nor equilibrium can be determined.

Example: SIVOM of Marana located in the Golo watershed

The SIVOM of Marana (a co-operation of several municipalities) has existed since 1949 (for 51 years) and gathers 7 municipalities: Biguglia, Borgo, Furiani, Lucciana, Monte, Olmo and Vignale. It distributes the water (principally groundwater) coming from the alluvial aquifer of the GOLO. This trade union is managed by a committee consists of 14 members (2 representatives for each municipality). Act 252 of February 23rd 2000 allows the SIVOM to ensure the supply of water to some of the bordering municipalities under certain conditions. The SIVOM is subject to the budget laws in accordance to article 256 B of the Taxation Code:

- M14 for the road way system budget,
- M49 for the water budget (this financial resource comes from invoicing) *and*
- M49 for the waste water treatment budget (this financial resource comes from invoicing).

The SIVOM of Marana has chosen the water management of Direct REGIE (cf chapter 1.6.2), controlled by the Receiver. More precisely, in France, the organisation responsible for water management is under the responsibility of the municipalities as the French right considers the distribution of water a local problem. Thus, the water price is locally determined. The price of water in the SIVOM of Marana includes:

- Subscription or fixed part (the service has a cost),
- Consumption (variable part of the service),
- Collection and treatment of waste water,
- TVA (2.1%),
- Tax for the FNDEA (i.e. the development of the drinking water supply) *and*
- Water Agency royalties (for the pollution and the taking away of water).

For the year 2001 the amount of royalties was as follows:

- Water price: 0.99€/m³,
- Cleansing water: 0.69€/m³,
- FNDEA: 0.02€ *and*
- Water Agency: 0.16€.

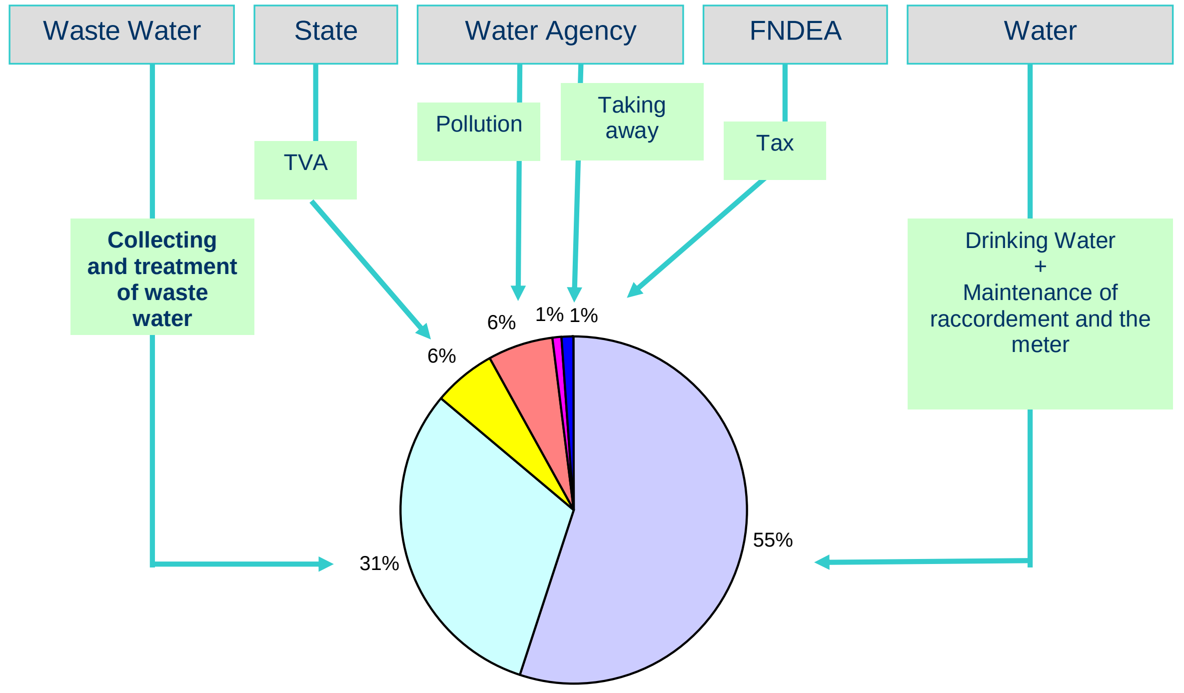


Figure 50: *Composition of the water price, (www.oieau.fr).*

In 2001, the volume of water taken from the alluvial aquifer of GOLO was 2,418,185m³. The invoiced volume was 1,395,037m³. The yield of this network is about 70% and the losses are due to leakage, breaks and not metered extractions.

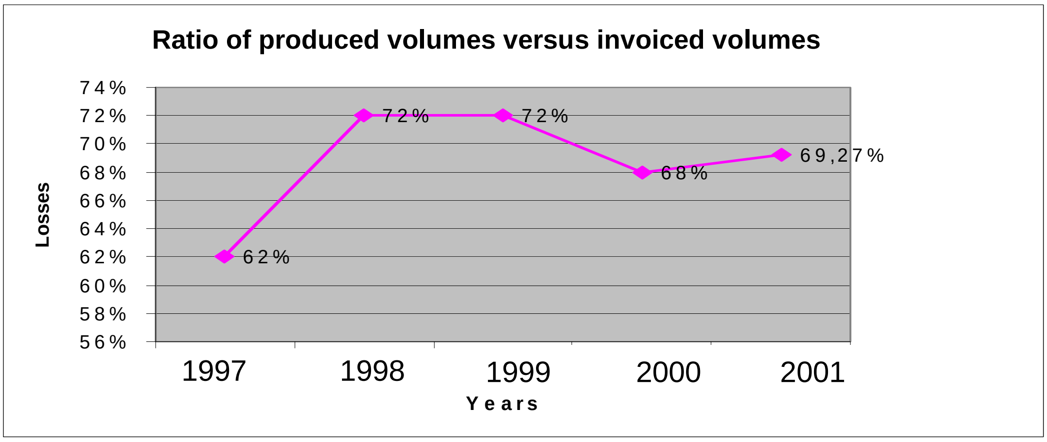


***Figure 51**: Ratio between produced volumes and invoiced volumes, (Appraisal on water, year 2001_SIVOM of Marana).*

1.9 Conclusions

Corsica is not an arid region which suffers from a permanent lack of water. Theoretically, the water resource is available in sufficient quantities, but the current situation may change into a problematic one in the future due to climatic change or an exploitation which can become more and more intensive and thus problematic if badly managed. In this context two main difficulties can be singled out:

- On the first level, the problems results from a seasonal shortage. Spatial and temporal variations of rainfall represent a significant difficulty for the establishment of a sustainable water management. Some regions are naturally at a disadvantaged compared to others *and*
- on the second level, scarcity is caused by man and mainly concerns two main areas.

One problem the island faces is the seasonal population influx. In summer there is a significant increase in water consumption due to tourism since Corsica receives an average of 2 million tourists. The summer consumption affects the water abstraction by putting a strong pressure on the water reserves. In summer, rivers are in low flow, dams and reservoirs are not full, and groundwater cannot be used significantly as this resource has not been evaluated and sufficiently known. Even though this critical situation returns every summer the island still has no water management policy in order to economise this resource. Consequently some restrictive measures must be enforced very soon (legislation, emergency committees meeting in case of drought, general restrictions etc.). A lack of water in summer might result from bad economising in winter. The seasonal variation of the population density also has effects on treatment plants which can not cope with such an increase in population. Yet the technical improvement of these plants is too expensive for the predominately small municipalities. The pollution due to organic matter from the domestic wastewater is thus the main cause of water pollution in Corsica.

Another point having effects on the water reservoirs is agriculture.

In this domain, there is also an increase of water consumption in summer, as agricultural activities require great volumes of water for irrigation and animal husbandry. It seems that there is no real water management, or if a policy of action does exist, it is not rigorous enough. But agriculture also causes a problem regarding the quality of water. For Corsica, analyses show that the resources have not been polluted by pesticides or nitrates. However, breeding is responsible for pollution through organic matters, since animals, whose dejections represent a significant source of pollution, are held are held in freedom near to the rivers.

In order to improve the current situation and avoid future problems, a local water policy should be envisaged to inform and train consumers to use water more reasonably. Another useful action could be to do research and find out about potential groundwater resources in the base aquifers.

Finally, the existing water plan for a water management (Prefecture/OEHC) should be more detailed and precise and spread among the main actors involved in water management in Corsica.

1.10 Summary table

Table 41: *Summary table.*

Natural water conditions and infrastructure	***Regional context***	Area	8 682km^2
		Climate Type	Mediterranean
		Aridity Index	0.87
		Permanent Population	260 196
		Tourists (arrivals)	2 million
	Water availability	Precipitation	900mm
		Total natural exploitable water Total water extracted:	1.06 10^9m^3 86Mm^3
		Water resources (million m^3): • Surface water Storage/dams/reservoirs • Ground water • Desalination	 105 (estimation) 18 0

Table 41 continued.

Natural water conditions and infrastructure	*Water quality*	Water availability per capita and year	201.5 (permanent+ tourist population) 330.5 (permanent population)
		Water availability per capita: • April-September • October-March	
		Trans-boundary water	0
		Quality of surface water	good
		Quality of groundwater	good
		Quality of coastal water	very good
	Water supply	**Supply coming from:** • Groundwater • Surface water • Desalination • Recycling • Importing *	21% 79% 0 0 0
		Network coverage: • Domestic • Irrigation • Sewerage	See figure 25.
Economic and social system agricutlure and tourism	*Water use*	Water consumption by category (m^3) Coming from: • Domestic • Tourism • Irrigation • Industrial and energy production	30M (49%) 8M 30M (49%) 1M (2%)
		Water consumption for domestic (m^3) coming from: • Groundwater • Surface water • Desalination • Importing **For tourism coming from:** • Groundwater • Surface water • Desalination • Importing	**30M** (including tourism) 18M (60%) 12M (40%) 0 **8M** 2M 6M 0 0 **30M** 0

Table 41 continued.

Economic and social system agricutlure and tourism	***Water use***	**For irrigation coming from:** • Groundwater • Surface water • Desalination • Recycling • Importing **For industry coming from:** • Groundwater • Surface water • Desalination • Recycling • Importing	30M 0 0 0 **1M** 0 1M 0 0 0
	Water demand	Water Demand trends	Increasing
		Consumption index	1%
		Exploitation index	2%
	Agriculture issues	Area used	1,559km²
		Irrigated area	223.3km²
		Cultivated crop types (per area)	- Tree crops (kiwi, citrus tree + other orchards and fruit with shell) - Vine - Fresh vegetables - Cereals - Fodder (See Appendix 1)
		Irrigation methods	Sprinkler, drip, mini spray, pivot
		Water used for irrigation (per area)	No data available
		Water demand per crop and area	No data available
		Fertilizer used - average	Use of organic and chemical fertilizers (See chapter 1.7.4)
	Social and economic situation	Pesticides used - average	(See chapter 1.7.4.)
		Unemployment rate	10.5%
		Employees in: • Agriculture • Services: - tourism - public function • Build • Industry	4.5% 80% 12.5% 16% 9% 6.5%

Table 41 continued.			
Economic and social system agricutlure and tourism	***Pricing system***	Importance of water scarcity	4 1: very imp. 5 not at all
		Average household budget for domestic water (pa)	*No data available*
		Average household budget for agricultural water	*No data available*
		Average household income (for a year)	11,243€
		Contribution of agriculture to island economy	2.4%
		Water prices	Drinking water: 2.57€ Irrigation: *0.05€*
		Energy prices for used water technology	*No data available*
		Cost recovery	*No data available*
		Price elasticity	*No data available*
	Social capacity building	Public participation in decisions	medium
		Public education on water conservation issues	medium
		Acceptability in using treated waste water	Very weak
Decision making process	***Water resources management***	Water ownership	
		Decision making level (municipal, regional, national) **regarding:** • Water supply for each sector • Water resources allocation for each sector	- For drinking water and wastewater treatment :municipal decision - Others sectors: regional (CTC) National / Regional
	Water policy	Local economy basis	Services / tourism
		Development priorities	Tourism / agriculture

**Surface and ground water from other Water Regions.*

Chapter II: Selection of a representative catchment – The GOLO watershed

2.1 Location of the GOLO catchment

One catchment was selected in Corsica. It is located in the North of the island, south of Bastia. The location of the watershed is shown in the figure 52.

Figure 52: *Location of the GOLO catchment.*

The Golo River goes down from the Monte Cinto mountain and emerges in the plain of Marana, bordering the east by the sea. This plain is situated south of Bastia, close to the Biguglia Pond. The corresponding watershed is the largest of the island with a surface of about 1,000km². This catchment gathers 56 communes (see Appendix 2).

The Golo River is affluent (figure 53) and its valley separates the plain in two parts: one catchment with a size of 43km² and another with about 52km².

2.2 Physical characteristics

2.2.1 Geology and relief

2.2.1.1 Relief and altitude

The selected watershed is the largest of Corsica and it is also characterized by various altitudes: 0 m to 2,710m (for the Monte Cinto).

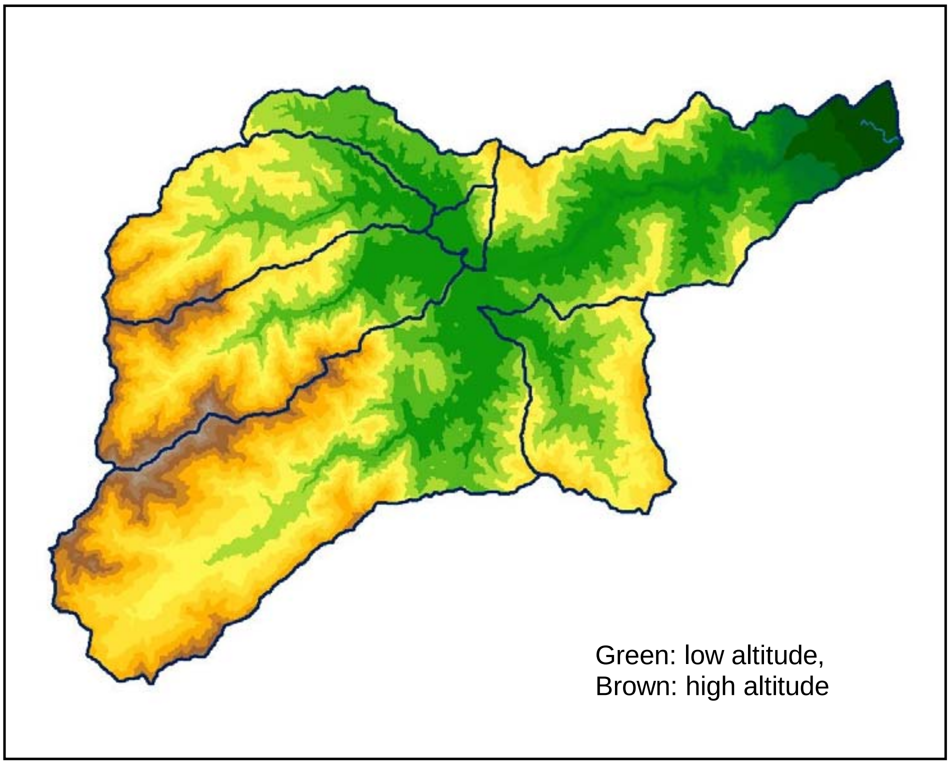


Figure 53: *Altitude of the GOLO catchment, (OEC/BRGM).*

There are plains and mountains in the same catchment. This configuration is responsible for the different activities developed in the region.

2.2.1.2 Geology

Regarding its geology, the GOLO watershed belongs to the two main geological zones of the island at the same time (figure 54).

The GOLO catchment crosses Alpine Corsica (in blue on the map) as well as Crystalline Corsica (in red on the map). Consequently, the part of the catchment that is located in plain is essentially composed by shistes and sediments, whereas the part located in altitude consists of granites and secondary and tertiary sediments. In the plain, different zones with sediments can be distinguished.

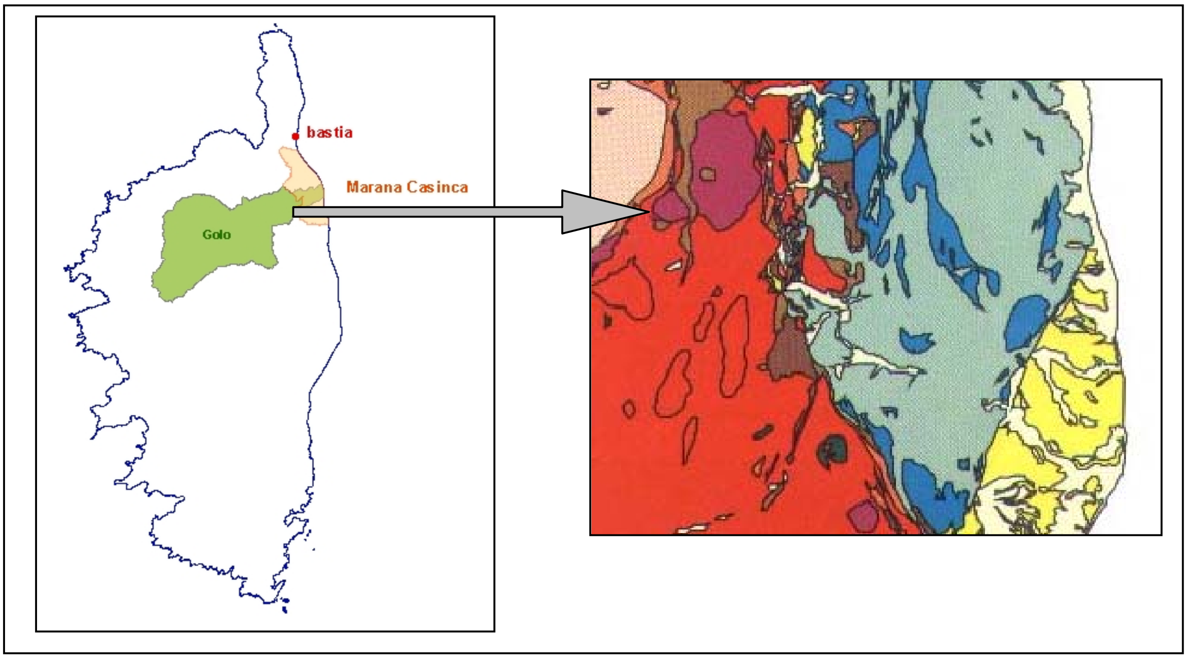


Figure 54: *Geology of the watershed, (BRGM).*

2.2.1.3 Soil characteristics

The catchment soils are essentially made up of:

- Alluvial soils on the coasts (in green on the map),
- washed grounds in the plain of Marana Casinca and Oriental Plain (in red on the map) *and*
- brown soils and limestone in mountain (in clear brown on the map).

The remainder of the island is mainly constituted by Podzols (number 11 on the map, green) and peaty soil (number 10 on the map, blue). In the very south, for example in Bonifacio, we calcareous soil (number 4 on the map, yellow).

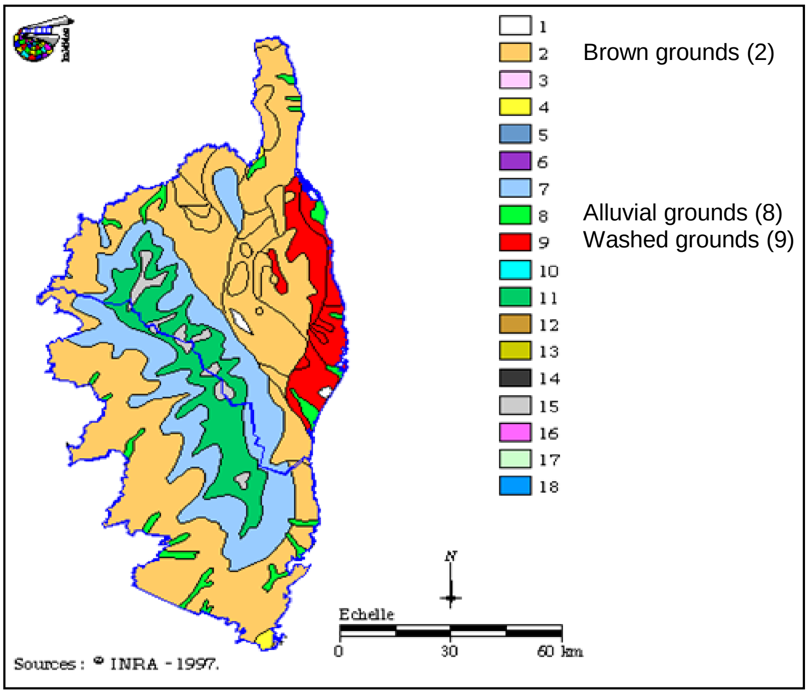


Figure 55: *Soil characteristics of the island, (INRA, 1997).*

2.2.1.4 Vegetation

The species of the Corsican vegetation are arranged with regard to the altitude. Three characteristic zones can be distinguished:

- *Mountains (from 1,500m to 1,900m),*

  Mainly covered with forests (throughout the island with pine forests in the Niolu the Restonica, in the Rotondu and Renosu massifs).
- *High Valleys (from 500m to 1,500m) and*

  They bear the hand print of man such as the Castagniccia (in the south of Bastia) and meaning the Corsican language "chataigneraie".
- *The Low Regions (up until 500m).*

  The seaside is on the deepest slopes and extends from the zone where the maquis and the "garrigue" areas meet.

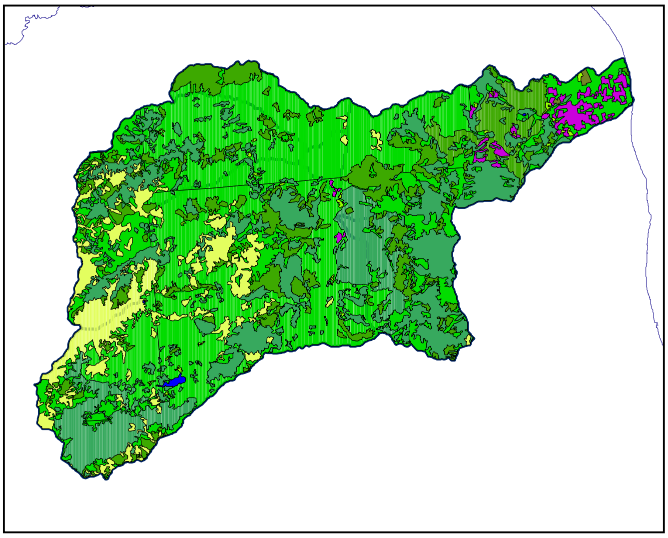


Figure 56: *Watershed vegetation, (OEC/BRGM).*

2.2.2 Climate and hydrology

2.2.2.1 Climate and precipitation

In the Golo catchment, the heads of basin have significant rainfall which gives rise to several rivers. These rivers have not been affected by pollution and have a good quality. However, they are often modified because of the presence of artificial reserves and dams. These zones contain an important potential for an economical development linked to water, but they are not exploited. On the contrary, plains in downstream areas have to face difficulties regarding their water supply during summer. Moreover, the economic development has caused perturbations and pollution. The Marana plain is characterised by an annual average precipitation level of 800mm, with an average temperature of around 15°C. In the mountainous regions of the watershed the temperatures are lower than in the plain, and precipitations are more extensive. Meteo France runs several meteorological stations in the watershed. The results found by the Calacuccia station are presented below (figure 57).

This graphic represents the real rainfall fallen in the Calacuccia station, which is located in a mountainous zone of the centre of the island, between 1971 and 1999. The data is neither estimated nor values from modeling.

- On the *curve*, each point (total: 29 points) corresponds to the annual sum of precipitation, throughout the hydrological year (September to august). The unit used is l/m². For example, in 1992, the total annual amount of rainfall was about 1200 l/m², in 1994, the total annual amount of rainfall was about 700 l/m² *and*

- the *line* represents the "yearly norm".

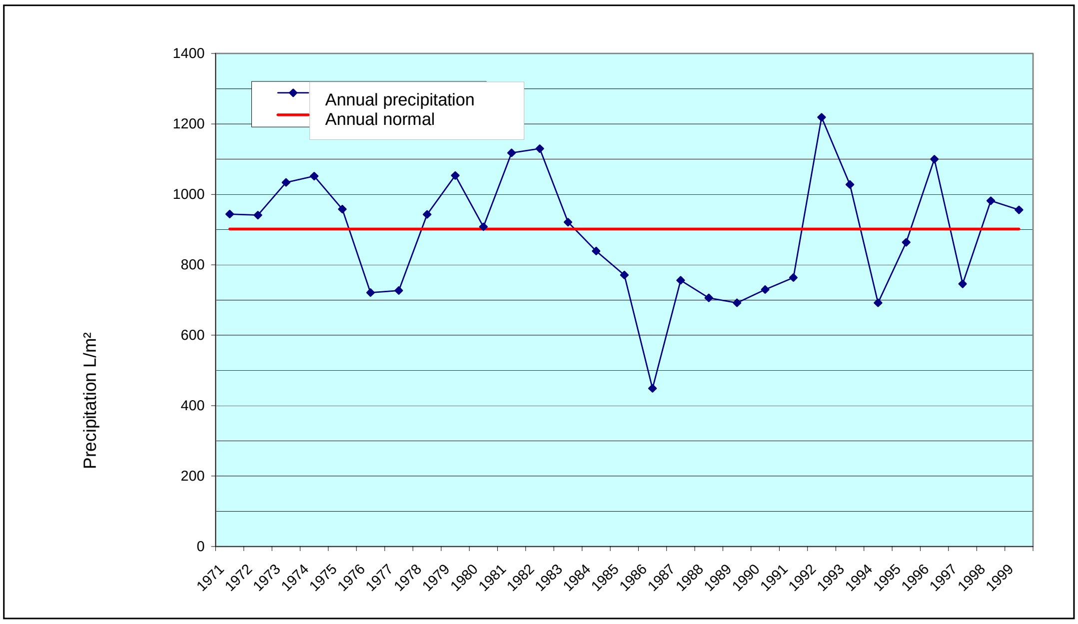


Figure 57: *Annual precipitation in Calacuccia 1971-1999, hydrological year Sept-August, (Meteo France, CDRom "Synthesis Convention on Water", OEHC, 2003).*

In climatology, this parameter corresponds to an average based on values of several years. Traditionally, this average covers a period of over 30 years (htpp://www.meteo.be/francais/pages/klimatologis/rr_2001_fr.htm). Meteo France has measured these values for over 30 years, in order to establish this "yearly norm". In doing that one value has been obtained for the considered period: from 1971 to 1999 the average of precipitation per year was about 900 l/m².

Observations

On the graphic the red line represents a reference which permits to see the variation of precipitation, every year, for 30 years. For example, we can note a significant decrease below the yearly norm from 1984 to 1991 in Calacuccia, whereas from 1991 to 1992, there has again been an increase.

Conclusion

After 1984, the number of blue points located above the red line has decreased: only 5 points against 10 between 1971 to 1983. Precipitation has decreased in this station since 1984.

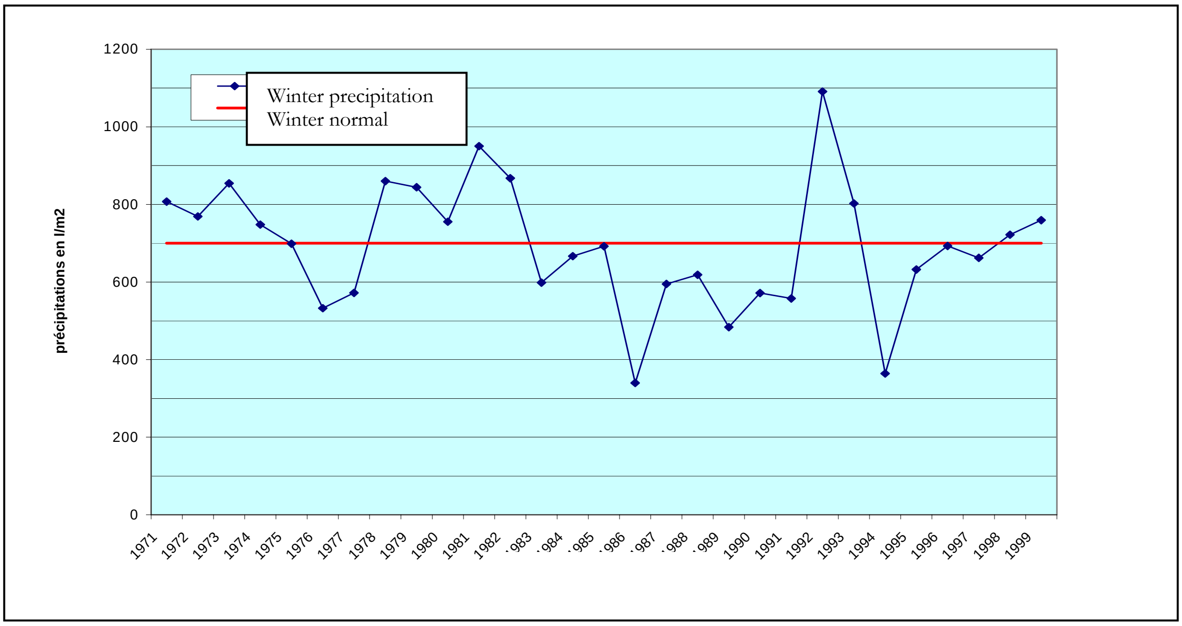


Figure 58: *Winter precipitation in Calacuccia, October – April, (Meteo France, CDRom "Synthesis Convention on Water", OEHC, 2003).*

The following figure presents the winter rainfall in the Calacuccia station. In this mountainous region snow represents a significant potential of water especially for the summer (figure 59).

2.2.2.2 Hydrology

Surface water

The Golo is the main river of the watershed, measuring 84km of length with its source being located at an altitude of 2,000m. It has an average discharge of 110m^3/s and a lot of affluents (figure 60). The two main affluents are Tartagine and Asco.

Several stations control the flow of the Golo (monitoring by DIREN SEMA). The following figure presents its flow in the Volpajola station in August and November 2001, showing that August corresponds to a dry period.

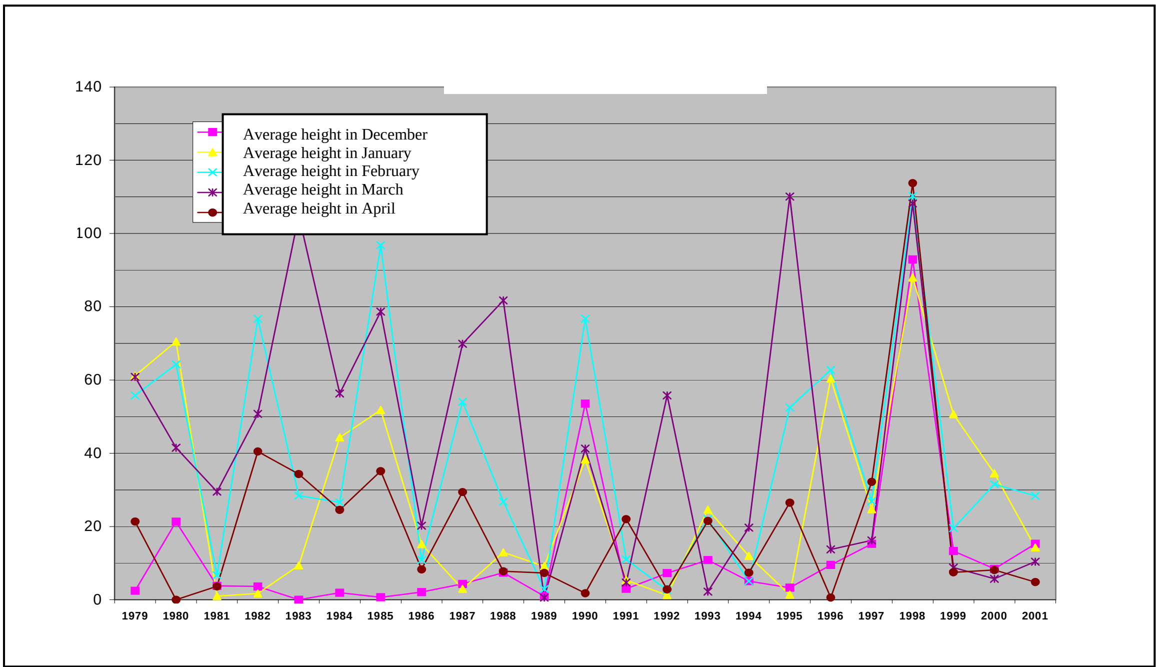


Figure 59: *Thickness of the layer of snow on Ghisoni station (1500m) during winter (December-April), (Meteo France, CDRom "Synthesis Convention on Water", OEHC, 2003).*

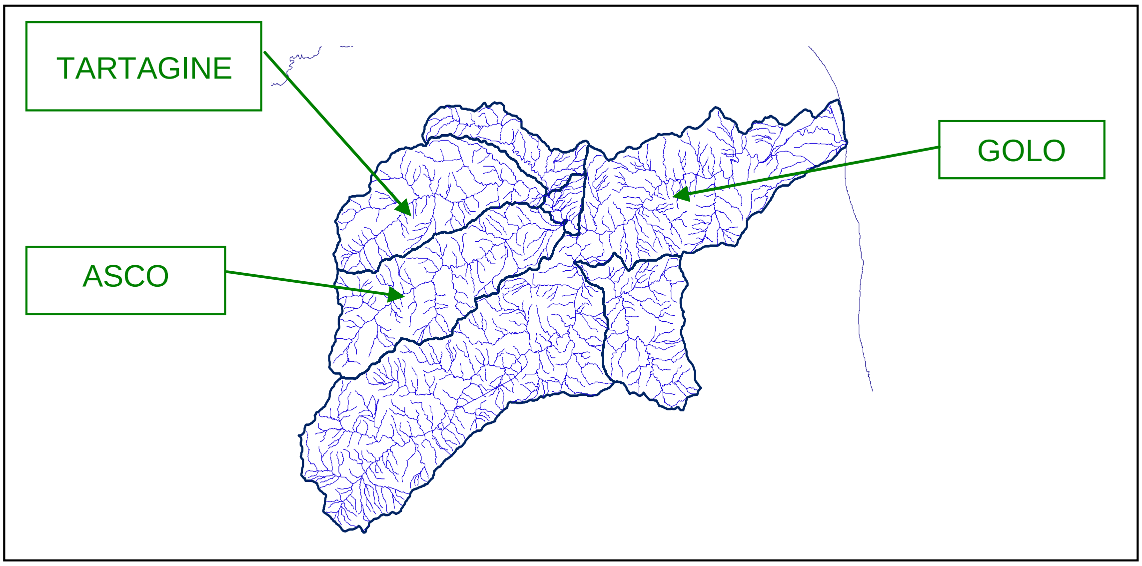


Figure 60: *The GOLO river affluent, (OEC/BRGM).*

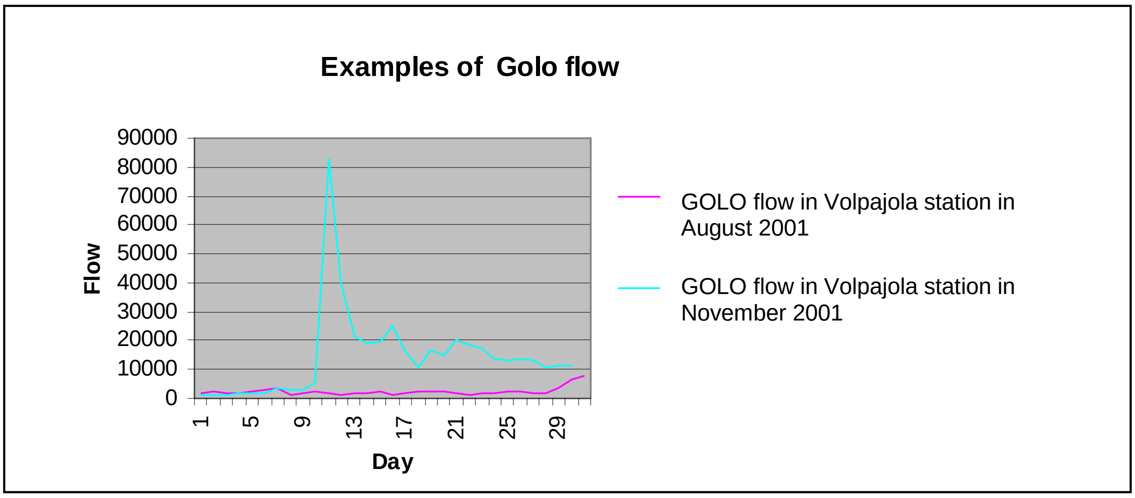


Figure 61: *GOLO flow in August and November 2001 in Volpajola, (DIREN SEMA).*

Figure 62 presents the annual average inflow of the river, according to the LOIEAU model. Figure 64 shows a bending of the Golo flow, since 1982. This change corresponds to the decrease of rainfall at the same period (see figure 58).

Ground water and aquifers

In the Marana Plain there is an important alluvial aquifer which supplies drinking water to 8 municipalities (figure 64). This reserve is managed by the Marana SIVOM which is a trade union of these eight municipalities.

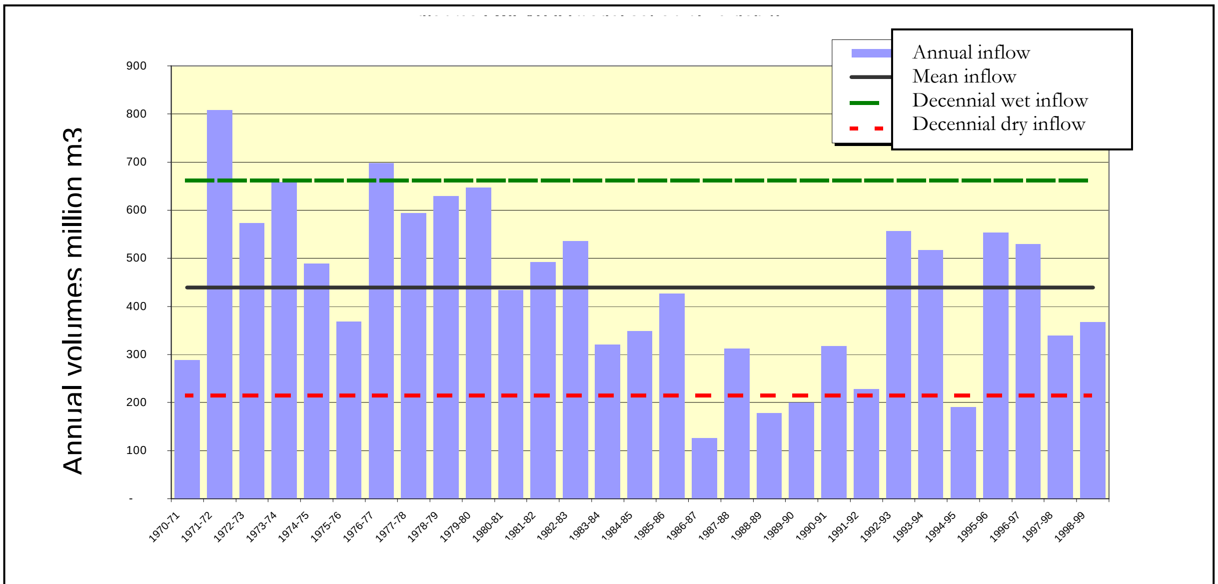


Figure 62: *Development of the annual average inflow of the GOLO (Sept-August 1970/1999) from LOIEAU, (DIREN SEMA).*

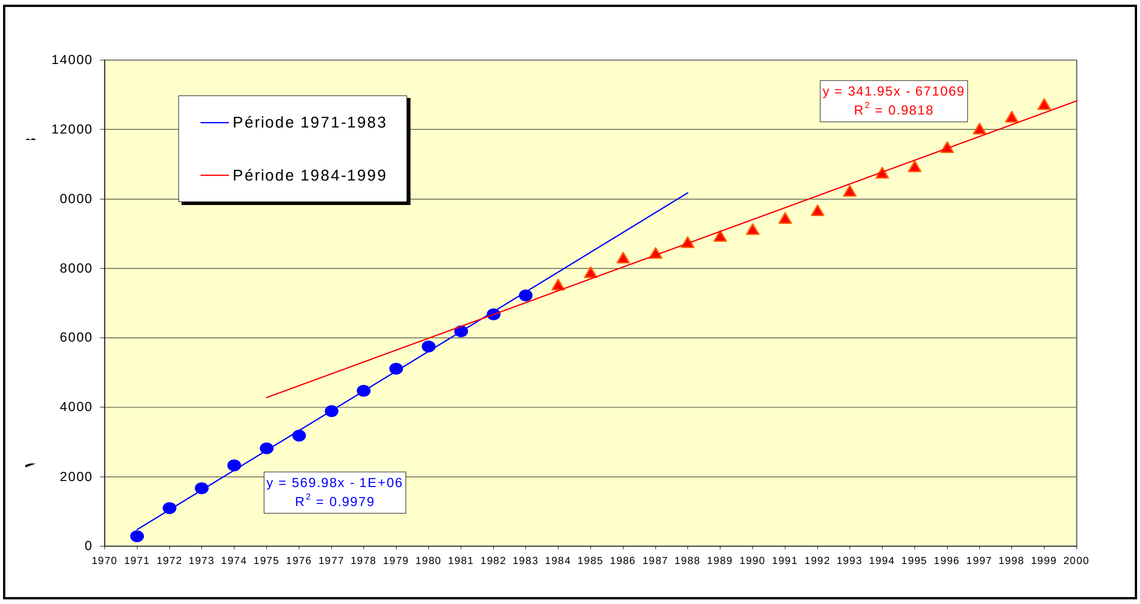


***Figure 63**: Cumulated annual average inflow of the Golo (1970/1999) from LOIEAU (Sept-August), (DIREN SEMA).*

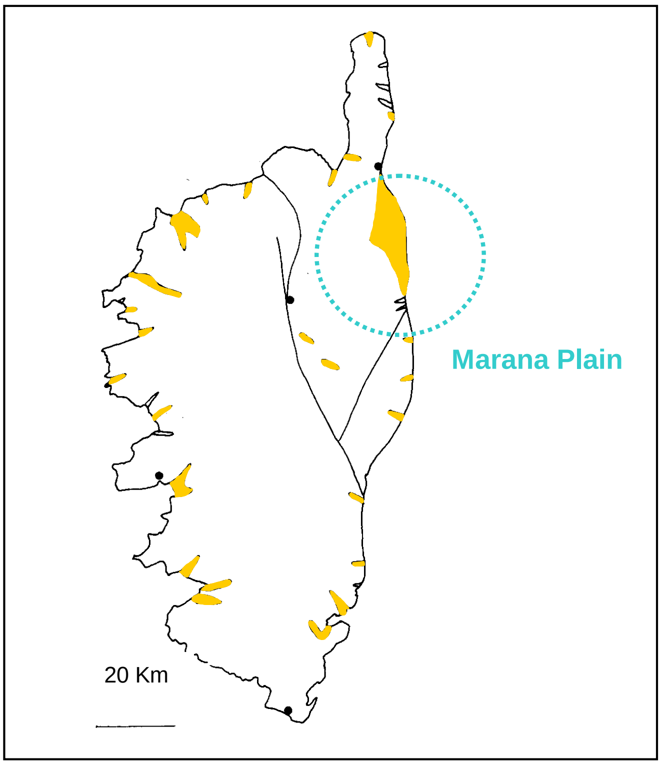


***Figure 64:** Alluvial aquifer of the Marana Plain, (DIREN SEMA).*

2.3 Population and water supply

The regions represented in figure 65 are located on the Golo catchment. They have experienced a demographic growth of 1% and more per annum. The population density is unevenly distributed between the upstream and the downstream of the watershed. The size of the household confirms this partition: 2.5 persons and more in the downstream area are opposed to less than 2 persons in upstream area.

Regarding the patterns of domestic water supply, it can be noted that the domestic sector is the only one in Corsica with a supply provided by surface water and groundwater. Indeed, 60% of the water used come from groundwater, which represents a volume of 18 million of m^3. 40% come from surface water with a corresponding volume of about 12 million of m^3.

As it is presented in chapter 2.2.2 Climate and hydrology, in the plain of the Golo watershed, there is an alluvial aquifer which ensures the water supply of eight communes (Biguglia, Borgo, Furiani, Lucciana, Monte, Olmo, Vignale, see "1.8.4 water price"), for drinking water only. All these municipalities do not belong to the watershed. This aquifer is exploited by the SIVOM of the Marana, with 9 wells and 14 pumps. In 2001, these wells provided 2,616,244m^3 of water. The drinking water supply of the others municipalities of the catchment, is ensured by springs, direct collecting in the river and drillings. DDASS and DIREN SEMA follow the implementation and the water quality of drillings made by the municipalities (see Appendix 3).

The private drillings made by private persons are not declared, so that no data are available.

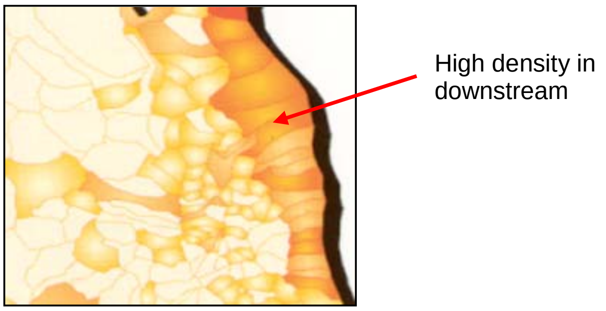


Figure 65: *Population density in the Golo catchment, (INSEE).*

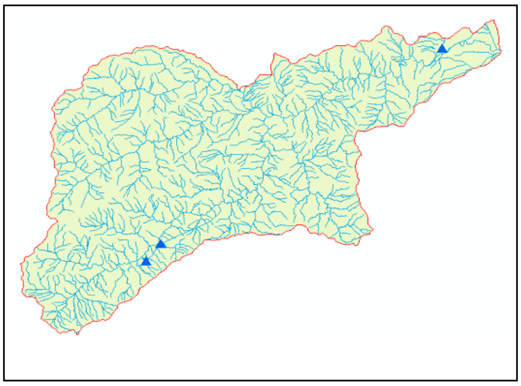


Figure 66: *Dams and reserves for surface water storage in the GOLO watershed.*

2.4 Agricultural situation

2.4.1 Location

The agricultural area is essentially located in the Marana Casinca plain. The corresponding TAS covers 97.72km², which represents 3% of the total SAU. Animal husbandry is concentrated in mountains (Agricultural Census AGRESTE 2000, April 2002). There are of about 600 farmers in the watershed (see Appendix 4).

2.4.2 Irrigation and water consumption

Regarding irrigation the water resources used primarily come from the GUAZZA reserve. The water is taken out of the GOLO River and comes from the EDF dam, located in Calacuccia.

Indeed, the OEHC is authorized to use a defined amount of the EDF water for irrigation and drinking water (see chapter I) the maximal capacity of the dam of Calacuccia is 25Mm^3 and the OEHC can use 15Mm^3, from May to the end of October.

Figure 67: *Location of the Calacuccia dam and the Guazza reserve.*

Irrigation systems

Traditionally, Drip irrigation and mini sprinkler were used for the irrigation of citrus trees, orchards and vegetables with a small surface. The Marana Casinca Plain followed the general tendency of the island and uses micro irrigation and irrigation by aspersion. As a result, gravitating irrigation has disappeared. But recently, farmers of this region have chosen to use the total cover for the irrigation of fruit trees like Kiwi or Clementine.

The municipalities of the Marana Casinca Plain present the most important equipped and irrigated area of the watershed (see Appendix 5).

Table 42: *Description of the Marana Casinca region: API, SE, volumes and perspectives, (OEHC, Hydraulic Development of the Eastern Plain, 2003).*

Regions	**Perimeters**		**Current situation** (Mean consumption, during the irrigation period, from May to October)		**Perspectives**		
	Area potentially irrigable API (km²)	Area equipped for irrigation SE (km²)	Volumes of raw water used for agriculture, industry and amenities (Mm³)	Volumes of raw water used for drinking water (Mm³)	Area equipped for irrigation SE (km²)	Volumes of raw water used for agriculture, industry and amenities (Mm³)	Volumes of raw water used for drinking water (Mm³)
Marana	47	37	4.1	1.5	40	5.5	1.75
Casinca	53	51	5.5	0.15	53	7.3	0.20
Total	**100**	**88**	**9.6**	**1.6**	**93**	**12.8**	**2.2**
			≈ 11			**≈ 15**	

The following table gives the repartition of the 9Mm³ of raw water consumed.

Table 43: *Repartition of raw water consumption in the Marana Casinca Plain, (Estimations OEHC, 2004).*

Crops	**Water consumption (m³)**
Non agricultural use (garden, swimming pool …)	2,983,325
Kiwi	1,193,297
Market gardening	1,079,461
Meadow	903,424
Citrus tree	886,547
Peach	447,509
Fodders	323,114
Corn	287,550
Pulm	232,053
Vine	139,554
Sheds	138,125
Nurseries	133,861
Pomelos	132,644
Watering place	63,641
Almonds	27,989
Apricots	25,706
Olives	17,599
Apple	5,101
Total	**9,020,500**

The losses in the irrigation network (drainings and leaks) are estimated to 4Mm^3 (OEHC). The irrigation network of the Marana Casinca Plain is divided into 3 sectors and comprises several points of water alimentation. We can distinguish two kinds of these points:

- Alimentation for non agricultural uses (BP) *and*
- Alimentation for agricultural uses (BO).

Each terminal possesses four arms of connexion.

Table 44: *Repartition of the terminals for the agricultural water supply in the Marana Casinca Plain, (OEHC, 2004).*

Sectors	Arms of connexion used/terminal		Terminals		Number of terminals/ sectors
	BO	BP	BO	BP	
08-001: South of MARANA CASINCA (Figaretto)	58	27	48	27	75
09-001: CASINCA	1019	904	904	904	1,808
10-001: MARANA	657	478	630	478	1,108
Total number of terminals (BO + BP) in the whole sector of MARANA CASINCA					**2,991**

The following table presents the flows of the taking out of GOLO River, to ensure the Marana Casinca water supply.

Table 45: *Most important flows of the taking out of GOLO (from May to October), (OEHC, 2003).*

Region	Current situation		Perspectives	
	Raw water for irrigation m/s	Raw water for DW m/s	Raw water for irrigation m/s	Raw water for DW m/s
Marana	0.70	0.25	1	0.35
Casinca	1	0.03	1.30	0.05
Total	**1.70**	**0.3**	**2.30**	**0.40**
	2		**2.70**	

2.4.3 Main crops and animal husbandry

Unlike in the Eastern plain, a cultural plan does not really exist in this zone. The following table presents the main agricultural activities and the corresponding areas in this zone.

Table 46: *Agricultural data regarding the Marana Casinca Plain in 2000: Main crops and corresponding areas and farms, (AGRESTE).*

Agricultural area used TAS		Area of grass STH		Vine		Vine AOC Controlled name		Orchards	
Number of Farms	Area km²	Number of Farms	Area km²	Number of Farms	Area km²	Number of Farms	Area km²	Number of Farms	Area km²
402	97.72	134	46.81	69	7.38	17	1.61	190	18.50

Table 47: *Agricultural data regarding the Marana Casinca Plain in 2000: animal husbandry, (AGRESTE).*

Bovine		Sheep		Caprine		Porcin		Hives	
Number of Farms	Number of animals	Number of Farms	Number of animals	Number of farms	Number of animals	Number of Farms	Number of animals	Number of Farms	Number of animals
25	1,342	70	20,411	15	1,926	13	1,182	16	1,247

These values are only concerning the plain. To have a global vision of the agricultural activity in the whole catchment, we have to take into account the breeding practised in the mountains of the interior.

Regarding the Kiwi production, 56% of the product comes from the Marana-Casinca, the remainder is grown in the Eastern Plain and Fiumorbu.

In the Marana Casinca plain, the area for fodder production has risen from 1 to 5km² since 1988. As far as animal husbandry is concerned, sheep breeding has increased in the plains of High Corsica:

For example, in Marana Casinca production has increased by +40% (about 10,000 ewes), but simultaneously there has been a significant decrease in south Corsica.

One reason for that could be the epizooty of Catarrhale fever in 2000.

2.5 Tourism

In the upstream area of the Golo watershed, tourism plays a more important role than in the downstream area with more than 4 tourist beds per inhabitant, against 0 or 1 for the downstream area (see Appendix 6).

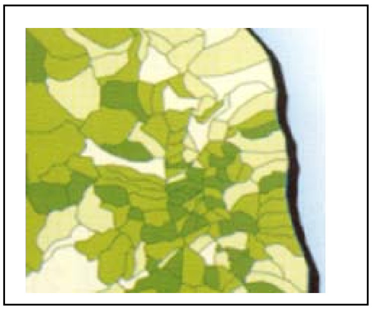


Figure 68: *Tourist pressure in the Golo catchment, (INSEE, 2000).*

2.6 Industry

The Golo catchment houses a very important EDF dam in Calacuccia which is used for the production electricity, human consumption and the irrigation. In Corsica all the works are multi functional as the watershed contains also several micro-hydropower stations.

2.7 Conclusions

The GOLO catchment was selected because it offers significant economical opportunities and thus contributes to the island's economical.

Indeed, the catchment possesses an airport, an important dam in Calacuccia, several micro hydropower stations as well as several hotels. This zone is also characterised by agricultural activity, even though it is not the most important for the island.

Finally, the existence of a SAGE on the Biguglia pond near to the catchment selected should be also mentioned.

Yet it is a first step in the establishment of a common water management in High Corsica which might serve as good example to be emulated by other watersheds in Corsica.

Appendix 1

Main crops: Surface and Number of Exploitation (DDA/AGRESTE regional census 2000).

Main Crops		**Corse**	**Southern Corsica**	**High Corsica**
Cereals (total)	Farms	87	6	81
Cereals (total)	**Area ($10^{-2}km^2$)**	**1.689**	**29**	**1,660**
Corn, fodder and ensilage	Farms	12	4	8
Corn, fodder and ensilage	Area ($10^{-2}km^2$)	59	12	48
Weeded fodder crops	Farms	1	0	1
Weeded fodder crops	Area ($10^{-2}km^2$)	1	0	1
Other annual fodders	Farms	121	66	55
Other annual fodders	Area ($10^{-2}km^2$)	806	321	486
Artificial meadows	Farms	323	64	259
Artificial meadows	Area ($10^{-2}km^2$)	3,068	262	2.805
Graminaceous meadows sown since autumn 1994	Farms	191	62	129
Graminaceous meadows sown since autumn 1994	Area ($10^{-2}km^2$)	1,981	429	1,552
Other meadows sown since autumn 1994	Farms	85	41	44
Other meadows sown since autumn 1994	Area ($10^{-2}km^2$)	1,117	287	830
Fodders (total)	Farms	563	191	372
Fodders (total)	**Area** ($10^{-2}km^2$)	**7,032**	1,310	5,721
Natural meadows or sown before 1994	Farms	1,334	777	557
Natural meadows or sown before 1994	**Area** ($10^{-2}km^2$)	**28,673**	15,425	13,248
Potatoes (total)	Farms	48	29	19
Potatoes (total)	**Area** ($10^{-2}km^2$)	**46**	21	24
Fresh vegetables in open air or in low shelter except rotation	Farms	139	53	86
Fresh vegetables in open air or in low shelter except rotation	Area ($10^{-2}km^2$)	317	64	254
Fresh vegetables of full fields or intented for the market	Farms	69	10	59
Fresh vegetables of full fields or intented for the market	Area ($10^{-2}km^2$)	222	50	172
Fresh vegetables of full fields or intented for the transformation	Farms	6	3	3
Fresh vegetables of full fields or intented for the transformation	Area ($10^{-2}km^2$)	5	3	2
Fresh vegetables under greenhuose or high shelters	Farms	55	25	30
Fresh vegetables under greenhuose or high shelters	Area ($10^{-2}km^2$)	22	14	8

Appendix 1 continued.				
Main Crops		**Corse**	**Southern Corsica**	**High Corsica**
Fresh vegetables (with. Stawberries and melons) (total)	Farms	199	65	134
Fresh vegetables (with strawberries and melons) (total)	**Area ($10^{-2}km^2$)**	**565**	130	435
Vines (total)	Farms	448	93	355
Vines (total)	**Area ($10^{-2}km^2$)**	**7,182**	907	6,276
Apricot tree	Farms	45	16	29
Apricot tree	Area ($10^{-2}km^2$)	39	3	35
Cherry tree	Farms	31	8	23
Cherry tree	Area ($10^{-2}km^2$)	8	1	8
Peach tree and nectarine tree	Farms	66	21	45
Peach tree and nectarine tree	Area ($10^{-2}km^2$)	219	20	198
Pear tree for table	Farms	34	17	17
Pear tree for table	Area ($10^{-2}km^2$)	14	3	11
Apple tree for table	Farms	72	40	32
Apple tree for table	Area ($10^{-2}km^2$)	48	23	25
Plum tree	Farms	74	15	59
Plum tree	Area ($10^{-2}km^2$)	500	2	498
Orchards 6 species	Farms	182	55	127
Orchards 6 species	**Area ($10^{-2}km^2$)**	**827**	52	775
Citrus tree	Farms	309	35	274
Citrus tree	**Area ($10^{-2}km^2$)**	**2,334**	49	2,286
Kiwi	Farms	154	4	150
Kiwi	**Area ($10^{-2}km^2$)**	**946**	1	944
Olive tree	Farms	500	248	252
Olive tree	**Area ($10^{-2}km^2$)**	**1,816**	603	1,213
Walnut	Farms	10	6	4
Walnut	**Area ($10^{-2}km^2$)**	**3**	3	0
Other fruits with shells	Farms	286	75	211
Other fruits with shells	**Area ($10^{-2}km^2$)**	**2,021**	401	1,621
Other orchards	Farms	52	16	36
Other orchards	**Area ($10^{-2}km^2$)**	**44**	9	35
Little fruits	Farms	10	8	2
Little fruits	**Area ($10^{-2}km^2$)**	2	2	0

Appendix 2

List of the municipalities of the Golo catchment.

Name	POPU (INSEE 1999)	Surface (km²)	Density
Aiti	24	12	2
Albertacce	200	97	2
Asco	134	123	1
Bigorno	78	9	9
Bisinchi	173	13	14
Borgo	5,002	38	132
Calacuccia	340	19	18
Campile	199	10	20
Campitello	103	8	13
Canavaggia	98	35	3
Casabianca	68	4	18
Casamaccioli	100	36	3
Castello-di-Rostino	277	12	22
Castiglione	25	23	1
Castineta	53	9	6
Castirla	186	24	8
Corsica	155	59	3
Corte	6,329	149	42
Cristinacce	49	20	2
Crocicchia	50	4	12
Francardo	Belongs to Omessa		
Gavignano	51	11	5
Lano	21	8	3
Lento	91	24	4
Letia	122	36	3
Loreto-di-Casinca	234	8	29
Lozzi	132	31	4
Lucciana	3,794	29	130
Manso	130	121	1
Moltifao	549	55	10
Monte	444	15	30
Morosaglia	1,008	24	41
Olmo	168	4	38
Omessa	537	24	22
Ortiporio	113	5	22
Penta-Acquatella	40	3	13
Piano	54	3	18
Piedigriggio	124	10	12
Pietralba	244	39	6
Ponte Leccia	Belongs to Morosaglia		
Ponte Novo	Belongs to Castello di Rostino		

Appendix 2 conitniued.			
Name	**POPU (INSEE 1999)**	**Surface (km²)**	**Density**
Popolasca	36	10	4
Prato-di-Giovellina	40	12	3
Prunelli-di-Casacconi	162	6	27
Rutali	247	17	14
Saliceto	47	13	4
Scolca	62	7	9
Silvareccio	77	5	15
Soveria	68	12	6
Tralonca	64	16	4
Valle-di-Rostino	83	16	5
Venzolasca	1333	16	83
Vescovato	2316	18	132
Vignale	165	11	15
Volpajola	366	13	28

Appendix 3

List of the water collecting points of the Golo river (only these with a flow > 100 m³ / day), (DDASS 2B).

Municipality	Name of the collecting point	Origin*	Flow m3/J
Albertacce	Viru	ESU	113
Calacuccia	Galerie du Tavignano	ESU	375
Silvareccio	Corona	ESO	216
Corsica	Ruda	ESU	125
Corte	Restonica	ESU	2,200
Lento	Forage de L'Occhiu	ESO	100
Lozzi	Ercu	ESU	150
Moltifao	Puits de Capanaccia	ESO	304.1
Morosaglia	Forage et Puits Ponte Rossu	ESO	250
Moltifao	Asco 1 (Tranchée)	ESO	900
Prunelle di Casaconi	Golo-Reserve de Guazza	ESU	20,000
Omessa	Drain Golo	ESU	125
Vescovato	Forage Saint Just	ESO	877.4
Loreto di Casinca	Murmurio	ESO	310.5
Manso	Cavicchia	ESU	230
Lucciana	Puits de Casanova	ESO	12,000
Valle di Rostino	Forage Chergolo	ESO	100
Loreto di Casinca	Berbogliula	ESO	163
Volpajola	Piola	ESO	100

**ESU = Surface water*
ESO = Groundwater

Appendix 4

Number of farmers per municipalities in the GOLO watershed.

Municipalty	Farms
AITI	0
ALBERTACCE	20
ASCO	10
BIGORNO	29
BISINCHI	7
BORGO	67
CALACUCCIA	26
CAMPILE	8
CAMPITELLO	6
CANAVAGGIA	9
CASABIANCA	0
CASAMACCIOLI	16
CASTELLO DI ROSTINO	11
CASTIGLIONE	0
CASTINETA	0
CASTIRLA	11
CORSCIA	9
CORTE	26
CRISTINACCE	4
CROCICCHIA	0
EVISA	6
FRANCARDO	
GAVIGNANO	4
LANO	3
LENTO	0
LETIA	9
LORETO DI CASINCA	11
LOZZI	15
LUCCIANA	40
MANSO	0
MOLTIFAO	29
MONTE	13
MOROSAGLIA	17
OLMO	4
OMESSA	21
ORTIPORIO	0
PENTA ACQUATELLA	4
PIANO	0
PIEDIGRIGGIO	5

Appendix 4 continued.	
Municipalty	**Farms**
PIETRALBA	22
PONTE LECCIA	
PONTE NOVU	
POPOLASCA	6
PRATO DI GIOVELLINA	3
PRUNELLI DI CASACCONI	6
RUTALI	5
SALICETO	0
SCOLCA	3
SILVARECCIO	0
SOVERIA	0
TRALONCA	7
VALLE DI ROSTINO	3
VENZOLASCA	42
VESCVATO	59
VIGNALE	6
VOLPAJOLA	13
	615

Appendix 5
Source Agricultural Chamber of High Corsica

Irrigation of the watershed municipalities (in grey, the Marana Casinca Plain municipalities), (DDAF).

Municiaplity	TAS of the Municipality 2000 [$10^{-2}km^2$]	Irrigated area $10^{-2}km^2$ 1979	Irrigated area $10^{-2}km^2$ 2000
AITI	158	3	0
ALBERTACCE	1,962	2	c*
ASCO	1,242	0	0
BIGORNO	372	7	0
BISINCHI	215	6	0
BORGO	1,305	314	406
CALACUCCIA	1,532	c	c
CAMPILE	168	0	0
CAMPITELLO	136	0	0
CANAVAGGIA	823	12	0
CASABIANCA	52	0	0
CASAMACCIOLI	1,108	0	0
CASTELLO DI ROSTINO	534	40	16
CASTIGLIONE	19	0	0
CASTINETA	79	c	0
CASTIRLA	711	5	c
CORSCIA	1,963	1	0
CORTE	2,278	45	81
CRISTINACCE	55	0	0
CROCICCHIA	53	0	0
EVISA	165	c	c
GAVIGNANO	150	24	c
LANO	164	5	c
LENTO	682	16	0
LETIA	954	c	c
LORETO DI CASINCA	367	8	c
LOZZI	1,252	c	c
LUCCIANA	1,243	487	547
MANSO	433	0	0
MOLTIFAO	1,905	16	c
MONTE	563	54	22
MOROSAGLIA	1,447	21	0
OLMO	140	0	0
OMESSA	1,273	10	c

Appendix 5 continued.			
Municiaplity	**TAS of the Municipality 2000 (Ha)**	**Irrigated area Ha 1979**	**Irrigated area Ha 2000**
ORTIPORIO	184	c	0
PENTA ACQUATELLA	194	0	0
PIANO	108	0	0
PIEDIGRIGGIO	274	7	0
PIETRALBA	1,779	c	c
POPOLASCA	1,159	0	c
PRATO DI GIOVELLINA	410	c	0
PRUNELLI DI CASACCONI	209	c	17
RUTALI	402	4	c
SALICETO	53	15	0
SCOLCA	130	c	0
SILVARECCIO	130	c	0
SOVERIA	294	c	0
TRALONCA	992	13	0
VALLE DI ROSTINO	268	3	0
VENZOLASCA	763	430	568
VESCVATO	965	446	626
VIGNALE	413	9	c
VOLPAJOLA	1,004	8	0

* *c = confidential*

Appendix 6

List of the touristic accommodations in the municipalities of the GOLO watershed, (INSEE, 2000).

Municipalities	**Hotels**	**Name**	**Campings**	**Name**	**Vacation villages**	**Name**	**Hosts rooms**	**Lodgings**	**Name**
AITI	0		0		0		0	0	
ALBERTACCE	0		0		0		0	0	
ASCO	1	Hôtel le Chalet	0		0		0	0	
BIGORNO	0		0		0		0	0	
BISINCHI	0		0		0		0	0	
BORGO	1	Isola Hotel	0		1	Pineto Grand Confort	0	7	Baffico JB Botte Madelaine Cinquini D Pacelli Marcel Vinciguerra PL Vivarelli Madelaine
CALACUCCIA	3	Hôtel Acqua Viva Hôtel des Touristes Hôtel Casa Balduina	0		0		0	0	
CAMPILE	0		0		0		0	0	
CAMPITELLO	0		0		0		0	0	
CANAVAGGIA	0		0		0		0	0	
CASABIANCA	0		0		0		0	0	
CASAMACCIOLI	0		0		0		0	0	
CASTELLO DI ROSTINO	0		0		0		0	0	
CASTIGLIONE	0		0		0		0	0	
CASTINETA	0		0		0		0	0	
CASTIRLA	0		0		0		0	0	
CORSCIA	0		0		0		0	0	

Appendix 6 continued.									
Municipalities	**Hotels**	**Name**	**Campings**	**Name**	**Vacation villages**	**Name**	**Hosts rooms**	**Lodgings**	**Name**
CORTE	9	Hôtel ARENA Hôtel CYRNOS COLONNA Hôtel DE LA PAIX Hôtel de la Poste Hôtel Colonna Hôtel du Nord Hôtel HR Hôtel Jardin de la Glacière Hotel Sampiero Corso	0		7	Albadu Alivetu Chez Bartho Santa Barbara Rstonica Sognu Tuani	0	4	Giovanni Jean (x4)
CRISTINACCE	0		0		0		0	0	
CROCICCHIA	0		0		0		0	0	
EVISA	5	Hôtel Aitone Hôtel Chataigneraie Hôtel Pozzu Hôtel Scopa Rossa Hôtel Acciola	0		0		0	2	Leca Andre (x2)
FRANCARDO	0		1	Campita	0		0	3	Luciani Baptiste (x3)
GAVIGNANO	0		0		0		0	0	
LANO	0		0		0		0	0	
LENTO	0		0		0		0	0	
LETIA	0		0		0		0	0	
LORETO DI CASINCA	0		0		0		0	0	
LOZZI	0		2	Arimone Monte Cintu	0		0	0	

Appendix 6 continued.									
Municipalities	**Hotels**	**Name**	**Campings**	**Name**	**Vacation villages**	**Name**	**Hosts rooms**	**Lodgings**	**Name**
LUCCIANA	8	Hôtel Les Oliviers Hôtel Castellu Rossu Hôtel Chez Walter Hôtel Colibri Hôtel La Lagune Hôtel La Madrague Hôtel Poretta	0		1	Maraninca	0	0	
MANSO	0		0		0		0	0	
MOLTIFAO	0		3	Cabanella Tizarella Tra Mare e Monte	0		0	0	
MONTE	0		0		0		0	0	
MOROSAGLIA	0		0		0		0	2	Luciani François (x2)
OLMO	0		0		0		0	0	
OMESSA	0		0		0		0	5	Regnoult Lucciani (x4) Valli françois
ORTIPORIO	0		0		0		0	0	
PENTA ACQUATELLA	0		0		0		0	0	
PIANO	0		0		0		0	0	
PIEDIGRIGGIO	0		0		0		0	0	
PIETRALBA	0		0		0		0	0	
PONTE LECCIA	2	Hôtel des Touristes Hôtel Las Vegas	1	Domaine de Griggione	0		0	0	
PONTE NOVU									
POPOLASCA	0		0		0		0	0	
PRATO DI GIOVELLINA	0		0		0		0	0	
PRUNELLI DI CASACCONI	0		0		0		0	0	
RUTALI	0		0		0		0	0	
SALICETO	0		0		0		0	0	
SCOLCA	0		0		0		0	0	
SILVARECCIO	0		0		0		0	0	
SOVERIA	0		0		0		0	0	

Appendix 6 continued.									
Municipalities	**Hotels**	**Name**	**Campings**	**Name**	**Vacation villages**	**Name**	**Hosts rooms**	**Lodgings**	**Name**
TRALONCA	0		0		0		0	0	
VALLE DI ROSTINO	0		0		0		0	0	
VENZOLASCA	0		0		0	Cap Sud village Confort	2	0	
VESCVATO	0		0		0		0	0	
VIGNALE	0		0		0		0	0	
VOLPAJOLA	0		0		0		0	0	
TOTAL	29		6		7		2	23	

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Report on Sicily

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Abstract

Sicily is the largest island in the Mediterranean Sea. With a surface of about 25,700km^2, a permanent population of 5,076,700 inhabitants and a total of about 3,720,000 tourists a year, especially in the summer season, Sicily is one of the most densely populated Mediterranean islands. Its GDP is about 67.5 billion Euro (13,266 Euro per capita) divided as follows: 6.1% agriculture, 20.5% industry, and 73.4% commercial and non-commercial service.

The climate is Mediterranean, with dry summers and rainy winters. The mean annual precipitation is 625.3mm, ranging from a maximum of about 1600mm in the mountainous areas of the Etna massif and a minimum of about 300mm in the southern coastal part. Precipitations are strongly related to the seasonally changes with 80% of the precipitations occurring in the period from September to April. The mean yearly temperature is about 16.5°C with a minimum value of –13°C on the top of the Etna massif in January and a maximum value of 34°C along the south eastern coast in July.

The island is bounded by the Tyrrhenian Sea to the north, the Ionian Sea to the east, and the Sicilian Sea to the south-west; the Strait of Messina separates it from Calabria. The island is mountainous and hilly, with only one big plain near Catania. The most important massif is the Etna in the eastern part of Sicily, rising majestically between the Catania plain and the Alcantara and Simeto river valleys. The 3,340m high volcano is active, and the biggest one in Europe. Along the northern coast, from east to west, there is a stretch of the Peloritans. The Nebrodi Mountains stretching from the Strait of Messina to the Torto valley are the continuation of the Calabrian Apennines whose peaks go up to 2,000m. Just west of the river Torto, the Madonie with peaks of up to 2,000m give way to irregular calcareous formations, isolated or in groups, dominating roundish low hills. To the east, between Messina and Etna, the Peloritans continue, wholly similar to the mountains of Calabria. The middle of the island is a broken succession of rolling hills, the Erei and the so-called Altopiano Solfifero (the sulphur-bearing upland), low rounded hills of Cenozoic sulphurous chalk rock. The west of the island has a similar landscape of predominantly Cenozoic clay and sandstone, alternating in some places with Mesozoic limestone formations: the nearby Egadi Islands have the same geological and morphological structures, while Ustica, the Aeolians and Pantelleria areof predominantly of volcanic origin. From a hydro-geological point of view, a high ground water flow circulation is present in all carbonatic-sandstone mountains (Trapani, Palermo, Sicani, Nebrodi, Peloritani, Iblei, Erei) and in the Etna volcano with a high presence of springs and wells in their lower part. Sandy aquifers are characteristic of the Trapani-Belice area with a medium level of groundwater flow circulation.

The total renewable water resources for Sicily are 6,443.9Mm^3/yr; distributed as follows between ground water: 1994.4Mm^3/yr and surface water: 4,449.5Mm^3/yr; however, part of the surface water flows into the sea due to the absence of artificial water regulation.

The total available water for use in the island is 2,472.4Mm^3/yr divided by source as follows: groundwater: 1,766.2Mm^3/yr; surface water: 664.4 10^6m^3/yr; desalinated water: 41.8Mm^3/yr. The water consumed is about 1874.8Mm^3/yr divided by source as follows: groundwater: 1,457.4Mm^3/yr (78%); surface water: 394.0Mm^3/yr (21%); desalinated water: 23.4Mm^3/yr (1%) and by use: irrigation: 989.8Mm^3/a (53%); domestic: 720.9Mm^3/yr (38%); industrial: 164.1Mm^3/yr (9%). The major water use in Sicily is for irrigation in agriculture with a water demand of 989.8Mm^3/yr (which is 53% of the total consumption) while domestic use, including tourism, is 38%. Interestingly, the contribution of agriculture to the Gross Domestic Product of the island is only 6.1% and the contribution of services is 73.4% (including tourism). The demand for irrigation water is high, although only 14% of the cultivated land is irrigated. 15,640km^2 are used for agriculture, 2,189.6km^2 of which are irrigated with 989.8Mm^3/yr of water originating from groundwater and surface water. The main crops grown in Sicily are wheat, vineyard, olive grove, citrus trees (orange, mandarin, and lemon), fruit, vegetables and forage.

National and European laws are applied on Sicily. As a result of this legislative context, administration of water is managed by too many institutions in Sicily: 3 regional authorities, 3 municipal enterprises, 19 private enterprises, 11 draining consortium, 284 municipal authorities, and a certain number of associations (around 400).

For the purposes of the MEDIS project, one catchment was chosen: the Belice catchment. The Belice catchment is located in the central-western part of Sicily. Its size is about 949.5km^2, with a typical Mediterranean climate. The main reasons why this catchment was chosen were:

- Complex water resources demand and purposes (irrigation, drinking, industrial, etc.),
- conflicts between users of water resources (farmers, tourist resorts, urban uses, etc.),
- numerous previous studies and projects *and*
- the presence of several gauging sites with a long term recording period: three thermometric gauging stations, sixteen rain gauging stations recording, five flow gauging stations with N>40 years).

Water for domestic and agricultural usage comes from wells, dams and small detention ponds. A large amount of this water is distributed from the basin especially for domestic use however at the moment no data is available to quantify it.

As a matter of fact, periodic droughts which are linked to climate features, a high population presence and intense agricultural activities are factors which present a serious problem for the social communities and economic forces of the region. In this framework conflicts often arise between agricultural and drinking uses, i.e. between city and country. Yet the principal problem resides in the bad management of the water resources.

Chapter I: Overview of the island

1.1 Climate

The climate is Mediterranean, with dry summers and rainy winters. The mean annual precipitation is about 625.3mm, ranging from a maximum of about 1,600mm and a minimum of about 300mm. Precipitation is strongly related to the seasonally changes with 80% of the precipitations occurring in the period from September to April. The chart in figure 1 shows mean monthly precipitation values in Sicily, while figure 3 illustrates the mean annual precipitation values.

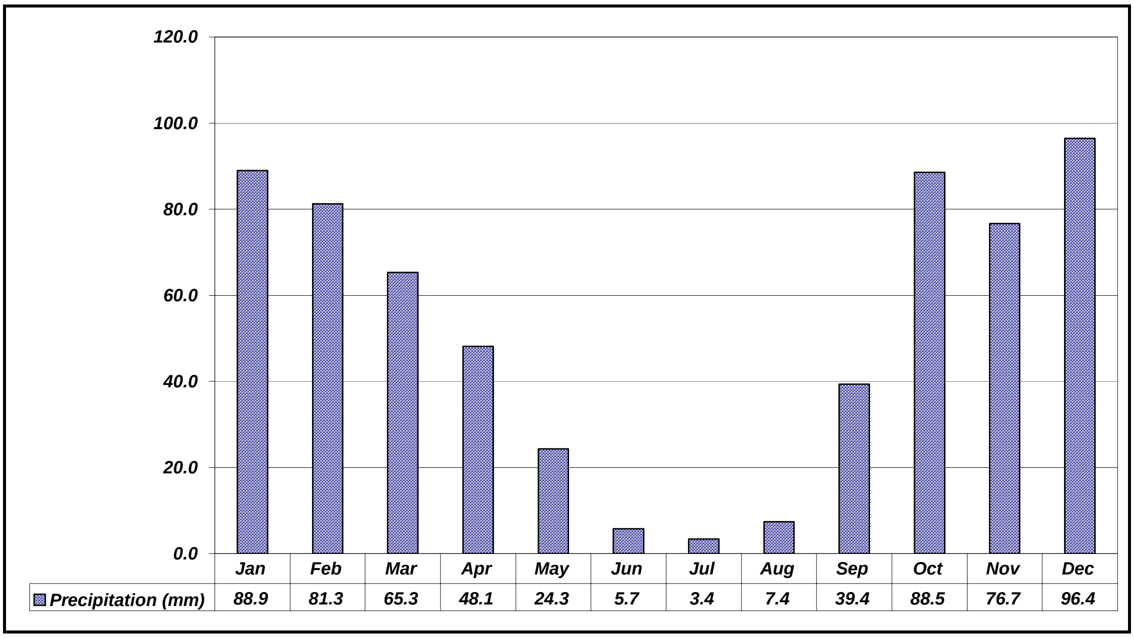


Figure 1: *Mean monthly precipitation (1965-1994), (Regional Climatological Atlas).*

The mean temperature is about 16.5°C. Figure 2 shows mean monthly temperature values, while figure 4 illustrates mean annual temperature.

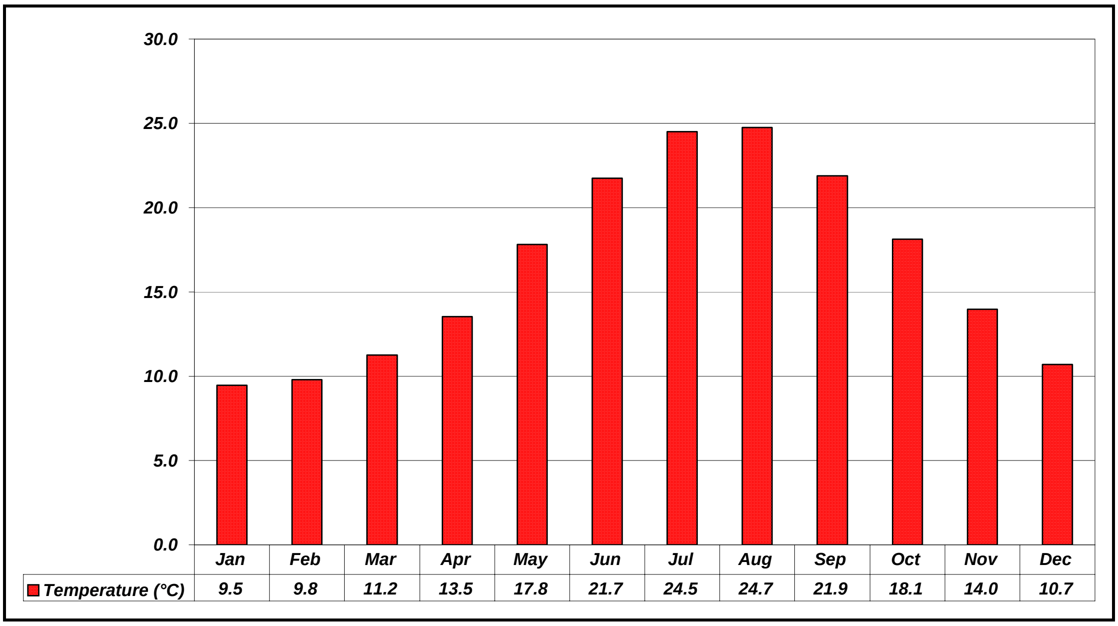


Figure 2: *Mean monthly temperature (1965-1994), (Regional Climatological Atlas).*

Table 1 shows general values of temperature in Sicily.

Table 1: *Regional climatic data.*

Climate data	
Mean temperature per year	16.5°C
Coldest month	January
Minimum temperature in January	-13 ÷ 12°C
Warmest period [w.p.]	July ÷ August
Maximum temperature in w.p.	20 ÷ 34°C
Annual thermic range	13 ÷ 26°C

According to the Thorntwaite model, the mean yearly potential evapotranspiration for Sicily is about 831.9mm, as shown in figure 5.

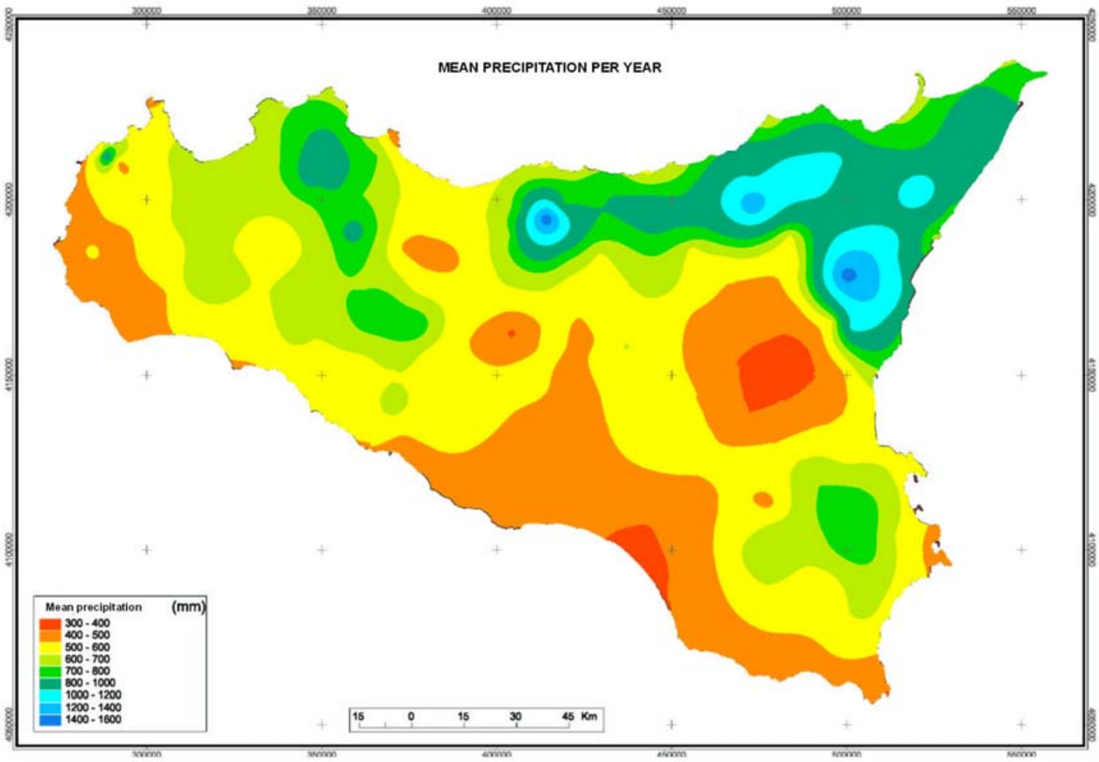


Figure 3: *Mean annual precipitation (1965-1994), (Regional Climatological Atlas).*

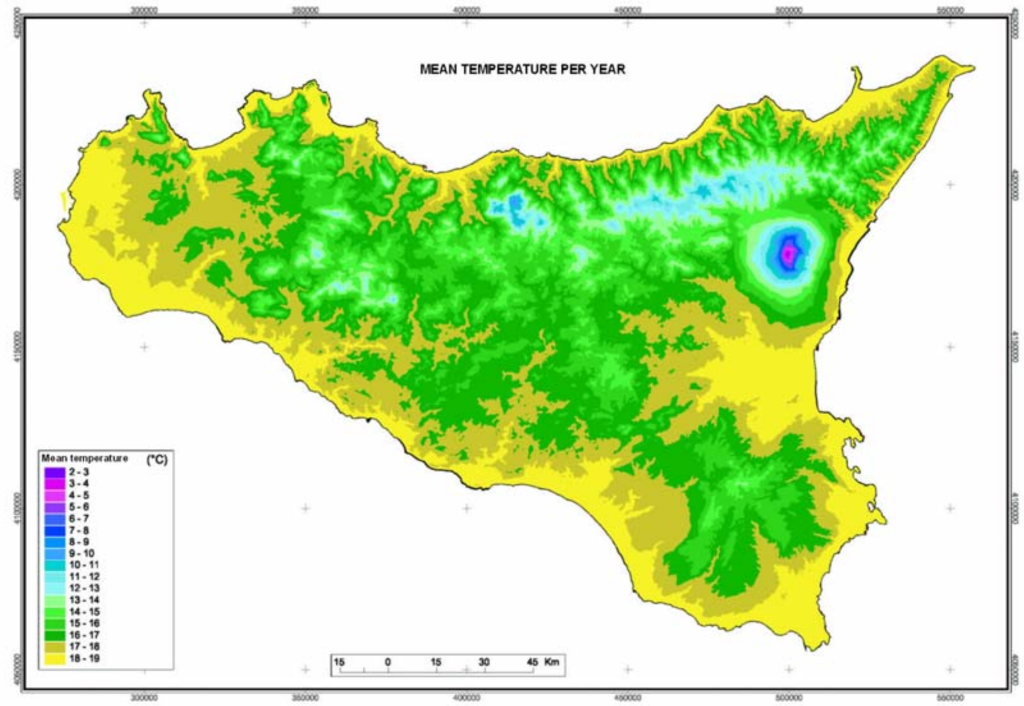


Figure 4: *Mean annual temperature (1965-1994), (Regional Climatological Atlas).*

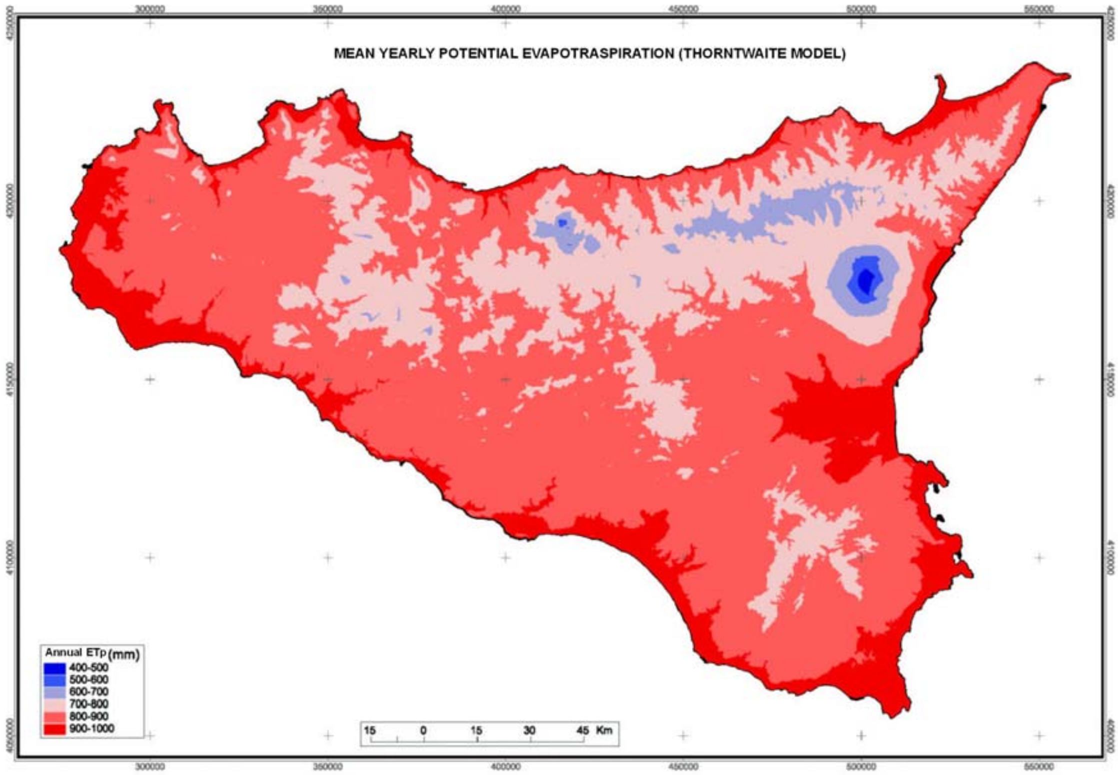


Figure 5: *Mean annual evapotranspiration (1965-1994), (Regional Climatological Atlas).*

1.2 Humidity index

The mean yearly precipitation is 625.3mm and the mean yearly potential evapotranspiration is 831.9mm.

The Humidity index, following the Thorntwaite model, can be expressed as follows:

$$HI = \frac{P - ETp}{ETp} x100$$

P is the mean yearly precipitation and ETp the mean yearly evapotranspiration.

Table 2: *Thorntwaite Aridity index ranges and classification.*

Classification	Humidity index ranges
Hyper humid	>100
Humid	100 ÷ 20
Subhumid - Humid	20 ÷ 0
Dry – Subhumid	0 ÷ -33
Semiarid	-33 ÷ -67
Arid	-67 ÷ -100

The spatial distribution of this index is shown in figure 6.

On Sicily Island the Humidity Index (spatially averaged) is –24.8, for which it reverts in the type of climate dry – sub-humid.

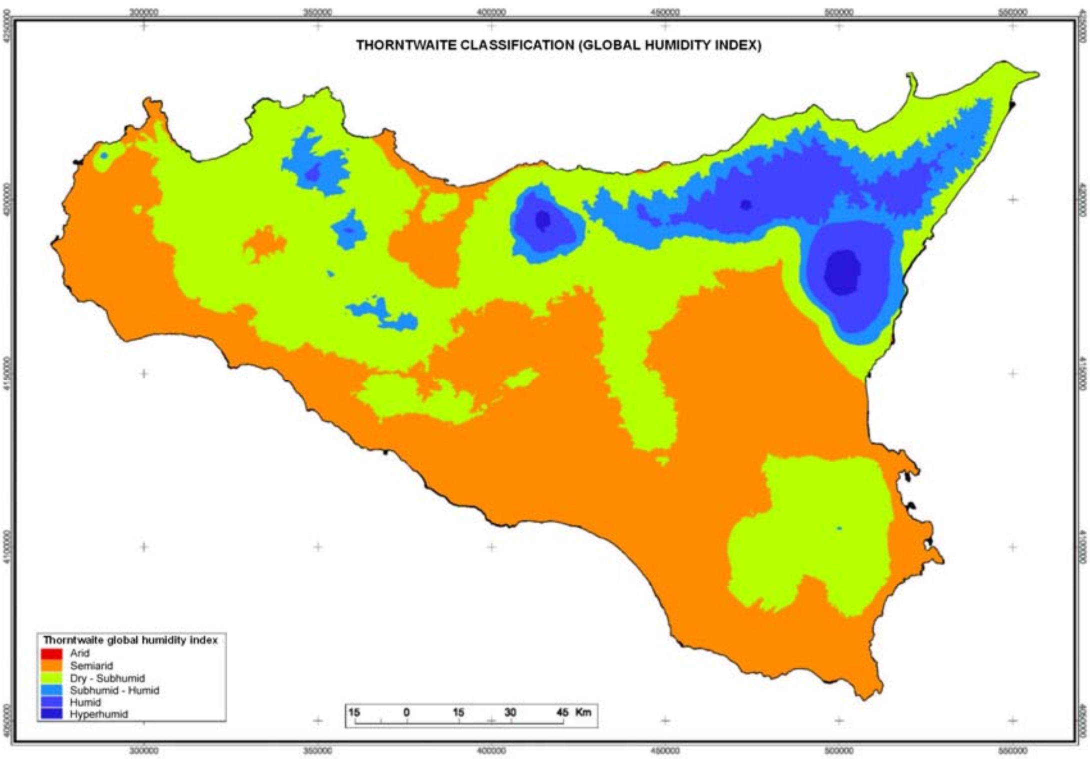


Figure 6: *Thorntwaite classification (1965-1994), (Regional Climatological Atlas).*

1.3 Geology and geomorphology

Placed at the centre of the Mediterranean, Sicily is the biggest island in this region (25,706km^2). Surrounded by a series of smaller islands: to the north the Aeolian Islands and Ustica, to the west the Egadi, to the south the Pelagie and Pantelleria. Its coast, predominantly rocky to the north, and sandy to the south, is 1,000km. long. The island is bounded by the Tyrrhenian Sea to the north, the Ionian Sea to the east, and the Sicilian Sea to the south-west. The Strait of Messina separates it from Calabria.

There is great variety within the Sicilian landscape: the island is mountainous and hilly with only one big plain near Catania. The most important massif is the Etna in the eastern part of Sicily rising majestically between the Catania plain and the Alcantara and Simeto river valleys. The whole area around the Etna is protected by a big national park. The 3,340m high Etna Volcano is active and it is the biggest one in Europe. Along the northern coast, from east to west, there is a stretch of the Peloritans. The Nebrodi mountains stretch from the Strait of Messina to the Torto valley and clearly are the continuation of the Calabrian Apennines across the water whose peaks go up to 2,000m. Just west of the river Torto, the Madonie, whose peaks go up to 2,000m, give way to irregular calcareous formations, isolated or in groups, dominating the roundish low hills. To the east, between Messina and Etna, the Peloritans continue, similar to the mountains of Calabria.

At the foot of the south slope of the Etna lies the Catania plain, limited to the south by the Iblei Hills, a wide expanse of high ground culminating in Mount Lauro (986m). The middle of the island is a broken succession of rolling hills, the Erei (lying among the Catania plain, the Iblei and the Salso valley) and the so-called Altopiano Solfifero (the sulphur-bearing upland), low rounded hills of Cenozoic sulphurous chalk rock. The west of the island has a similar landscape of gentle hills and wide rolling uplands, predominantly Cenozoic clay and sandstone, alternating in some places with Mesozoic limestone formations: the nearby Egadi Islands have the same geological and morphological structures, while Ustica, the Aeolians, and Pantelleria are prevalently of volcanic origin. Other active volcanoes in the area are the Stromboli and Vulcano in the Aeolians. The rivers are fast flowing with an irregular volume of water, flash flooding in winter and long periods of drought during the summer. 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, the Belice, Platani, and Salso which flow into the Sicilian Sea.

Spontaneous vegetation on the coastal areas consists of evergreen shrubs of the typical Mediterranean scrub, dominated by citrus and fruit orchards, with vines and olive trees higher up. Woodlands, covering barely 8% of the territory, grow in a few hilly areas only.

The richest and most interesting forest environment in western Sicily is the Ficuzza-Rocca Busambra, south of Palermo, dominated by the majestic limestone Rocca Busambra (1,613m), with a quantity of karst phenomena, marshes and small lakes, pastures and meadows, with an ecological variety unique in that part of Sicily.

From a hydro-geological point of view a high groundwater flow is present in all carbonatic-sandstone mountains (Trapani, Palermo, Sicani, Nebrodi, Peloritani, Iblei, Erei) and in the Etna volcano with innumerable springs and wells in the lower parts. Sandy aquifers are characteristic of the Trapani-Belice area with a medium level of groundwater flow circulation.

Table 3: *Altimetrical description of Sicily.*

Classification	**Extension [km^2]**
lowland (0÷300m)	3,640
hill (300÷800m)	15,780
mountain (> 800m)	6,290
Sicily	25,706

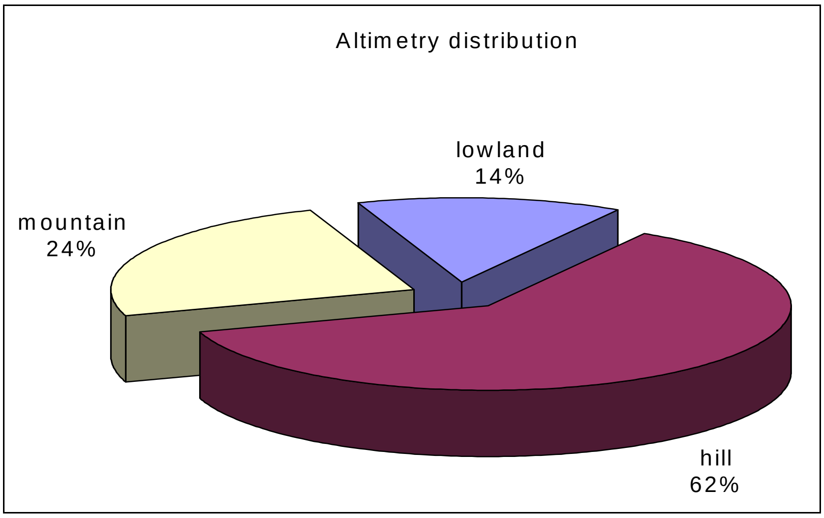


Figure 7: *Altimetry distribution.*

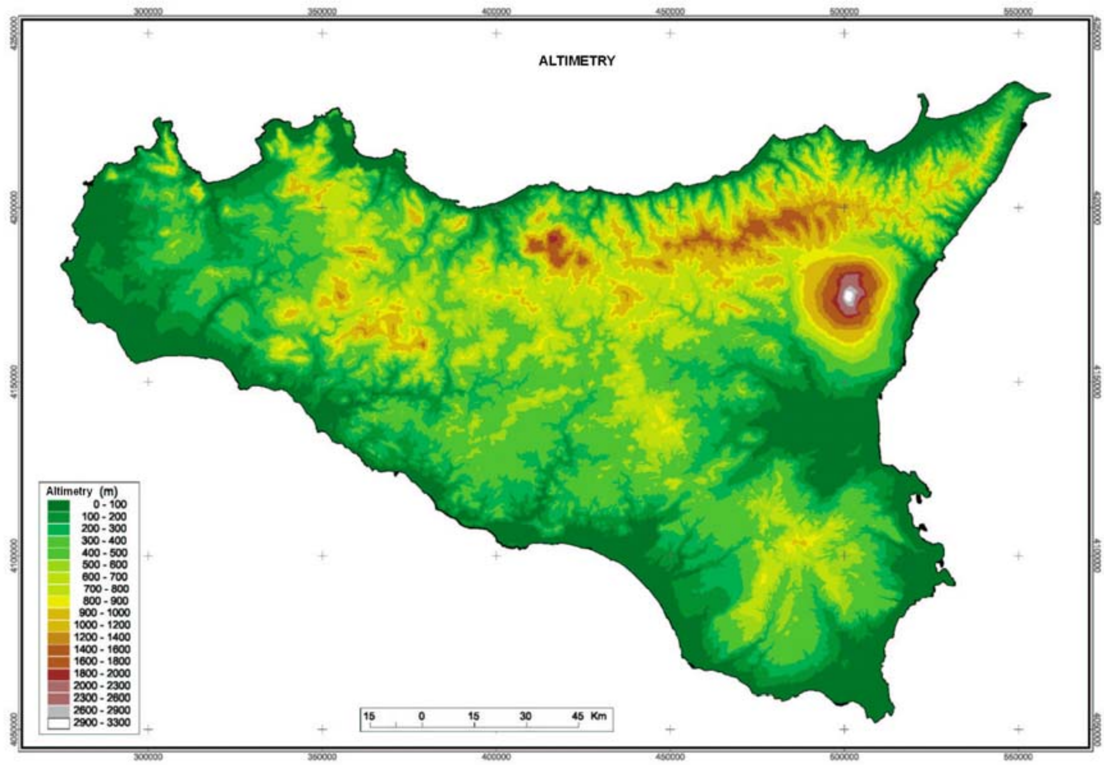


Figure 8: *Altimetry map of Sicily, (Source: Regional Climatological Atlas).*

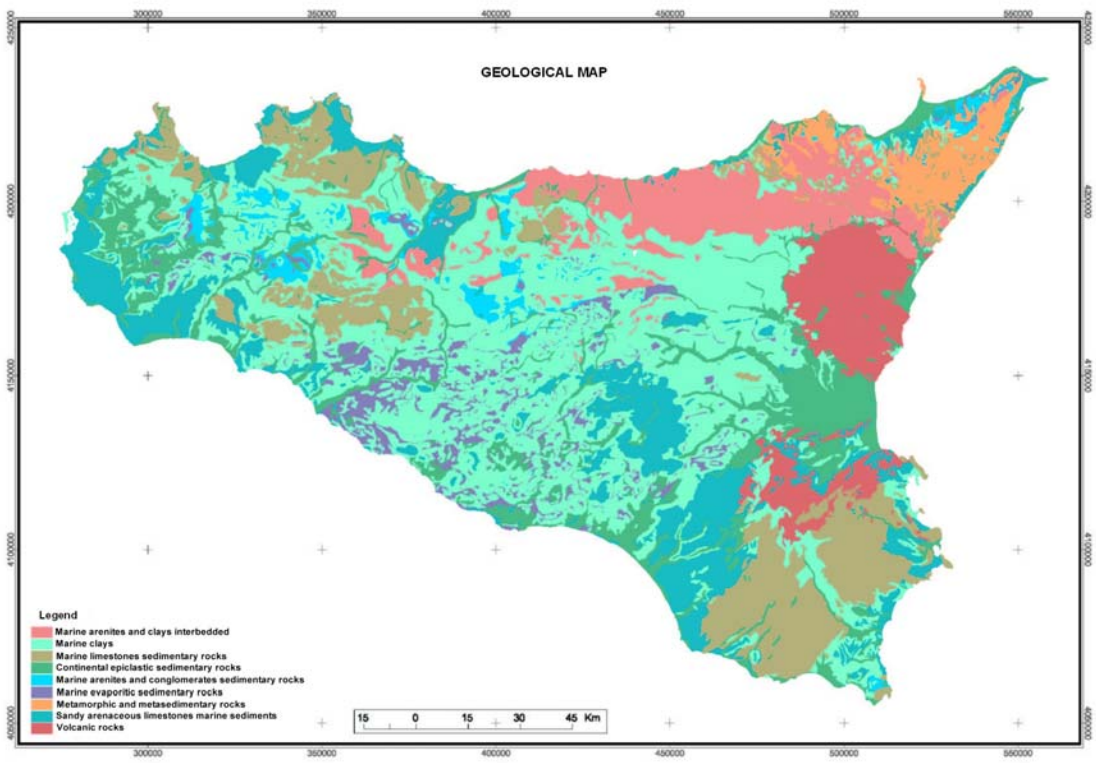


Figure 9: *Geological map of Sicily.*

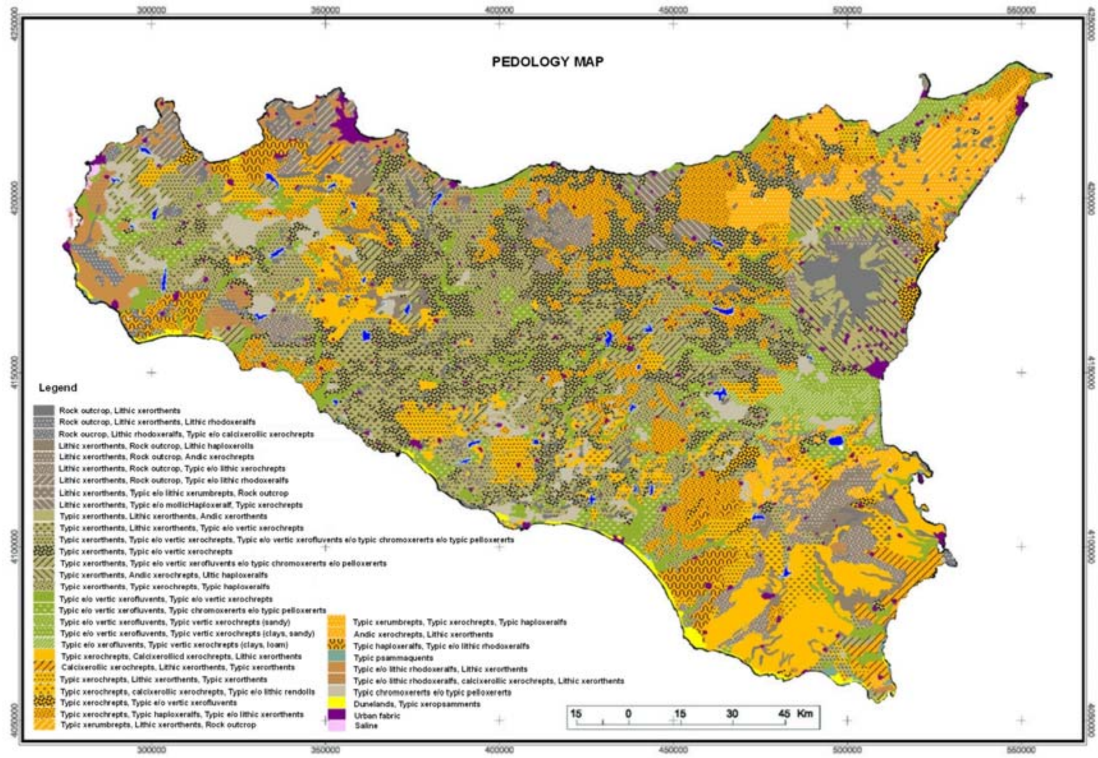


Figure 10: *Pedology of Sicily.*

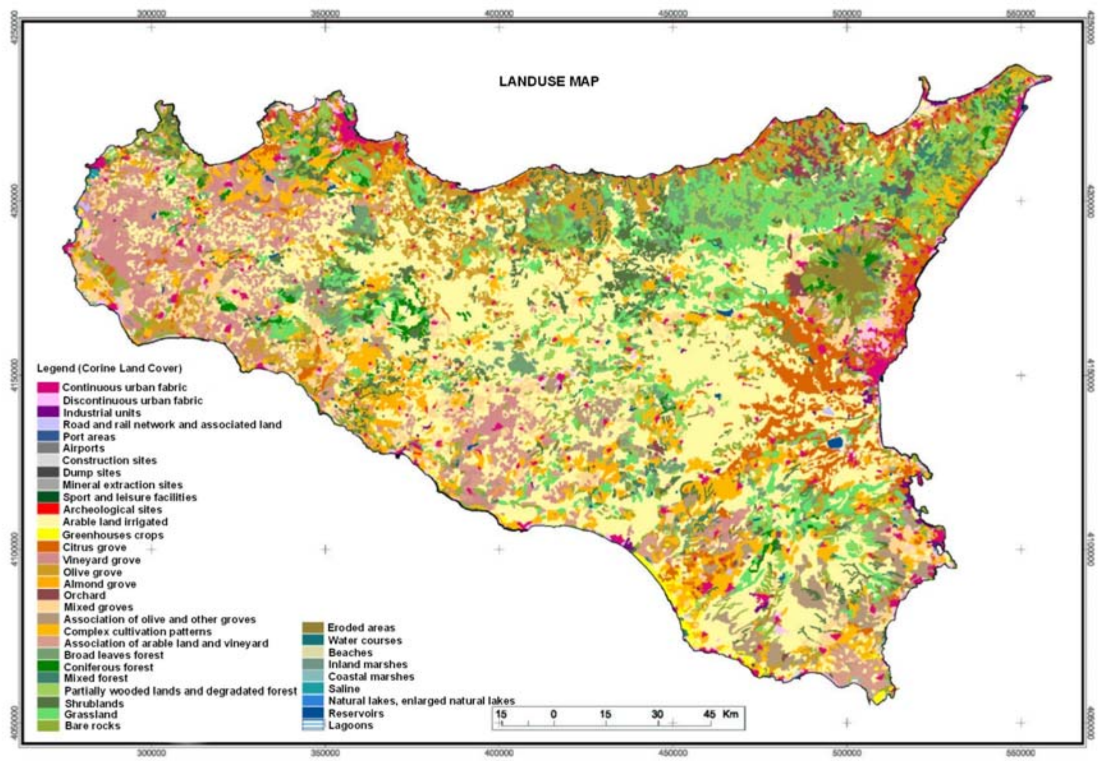


Figure 11: *Land use map of Sicily.*

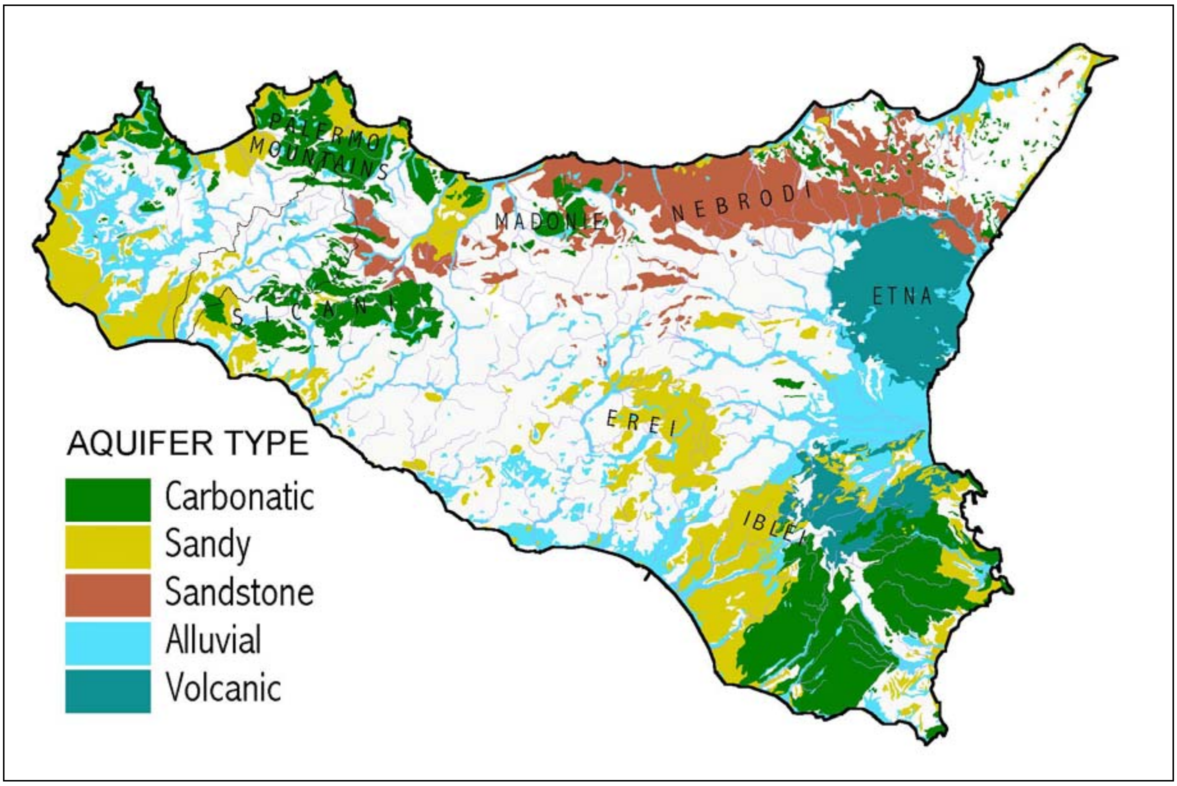


Figure 12: *Regional aquifers of Sicily.*

1.4 Water Resources

The evaluation of the available water resources for the entire island was carried out by analysing the global water balance. The hydrological analysis started with the calculus of the total water volume coming from the precipitations, mainly rainfall, in the period 1965-1994, equal to 15,890.9Mm^3/yr.

The surface component was defined by simply multiplying this value for the mean runoff coefficient for the entire island, which is equal to 0.28. The groundwater component comes from an analysis of regional aquifers presented in the Water Resources Survey of the Sicilian Regional Government, 2000.

The total available water resources in Sicily are therefore 6,443.9Mm^3/a divided in:

- Surface water = 4,449.5Mm^3/yr *and*
- Groundwater = 1,994.4Mm^3/yr.

As a matter of fact, 85% of the surface water flows into the sea due to the absence of civil works for water regulation. The total exploitable water resources in Sicily are 2,472.4Mm^3/yr, as presented in the Sicilian Regional Government – Water Resources Survey, 2000 and divided in:

- Groundwater: 1,766.2Mm^3/yr,
- Surface water: 664.4Mm^3/yr *and*
- Desalinated water: 41.8Mm^3/yr.

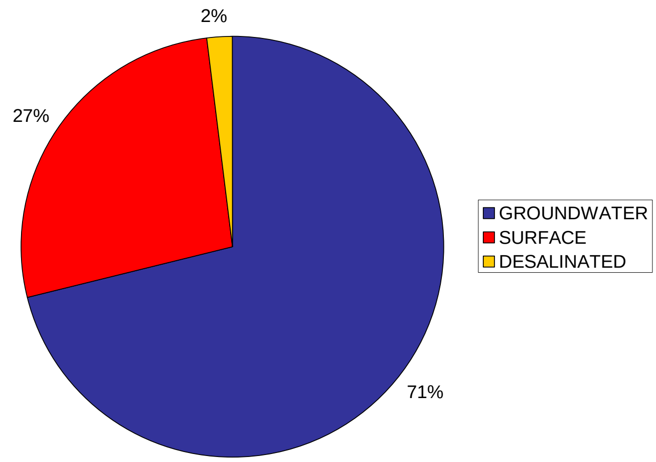


Figure 13: *Total potential water resources (2,472.4Mm^3/yr).*

The surface resources are recharged by 39 reservoirs and 23 barrages with a total exploitable capacity of 664.4Mm^3.

However, the exploitable water resources are not wholly available for use due to several reasons; (i) some aquifers are not (in some cases can not) entirely exploited; (ii) some dams are still under construction or still need an appropriate hydraulic infrastructure (pipelines, channels, treatment plant) in order to deliver the water to the destinations of final use; (iii) for economic reasons, desalination plants do not work at maximum capability. As final result, the total consumed water resources in Sicily is 1,874.8Mm^3/yr, as stated in the Sicilian Regional Government – Water Resources Survey, 2000 and divided by source as follows:

- Groundwater: 1457.4Mm^3/yr,
- Surface water: 394.0Mm^3/yr *and*
- Desalinated water: 23.4Mm^3/yr.

and by sectors:

- Irrigation: 989.8Mm³/yr,
- Domestic: 720.9Mm³/yr *and*
- Industrial: 164.1Mm³/yr.

Table 4: *Water consumption in Sicily by source.*

Water consumpation [Mm^3/yr]	Irrigation	Domestic	Industry	Total
Groundwater	673.9 (46%)	619.4 (43%)	164.1 (11%)	1457.4
Surface water	315.9 (80%)	78.1 (20%)	0	394.0
Desalinated water	0	23.4 (100%)	0	23.4

Table 5: *Water consumption in Sicily by sector.*

Water consumption [Mm^3/yr]	SW	GW	DW	Total
Irrigation	315.9 (32%)	673.9 (68%)	0	989.8
Domestic	78.1 (11%)	619.4 (86%)	23.4 (3%)	720.9
Industrial	0	164.1 (100%)	0	164.1

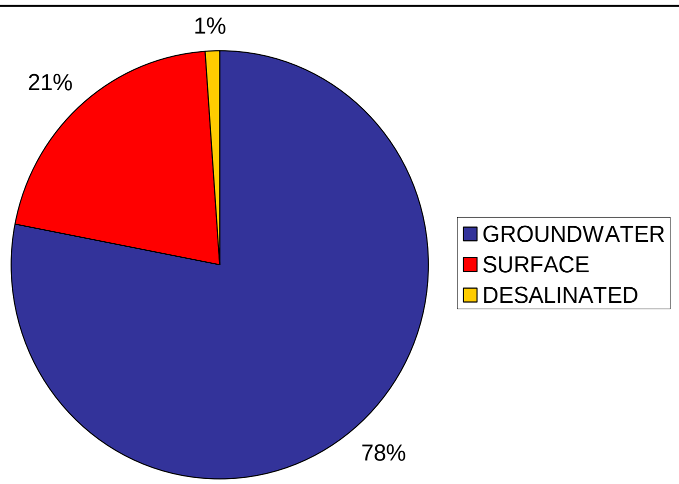


Figure 14: *Water consumption by source (1874.8Mm^3/yr).*

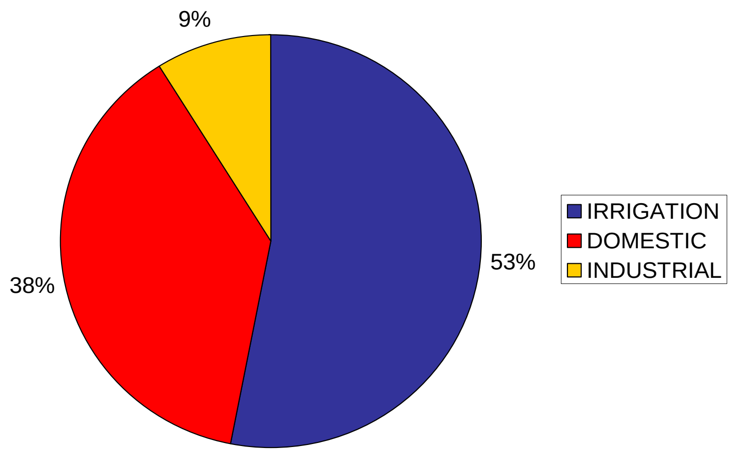


Figure 15: *Water consumption by sector (1874.8Mm^3/yr).*

Consumption index %:

Water consumed (1,874.8Mm^3/yr)/ total water resources (2,472.4Mm^3/yr)= 0.76

Water consumption per capita (real water resources: 1,874.8Mm^3/yr):

- On a yearly basis is 369.3m^3 *and*
- on a daily basis 1.01m^3.

1.5 Agricultural situation

Table 6: *Surface utilisation*

Surface utilisation	
S_{Sicily} [km²]	25,706
N of farms	329,000
Agricultural Surface, AS [km²]	15,648.04
Agricultural Surface per farm [km²]	0.48
Irrigable surface [km²]	2,190.72 (14%)

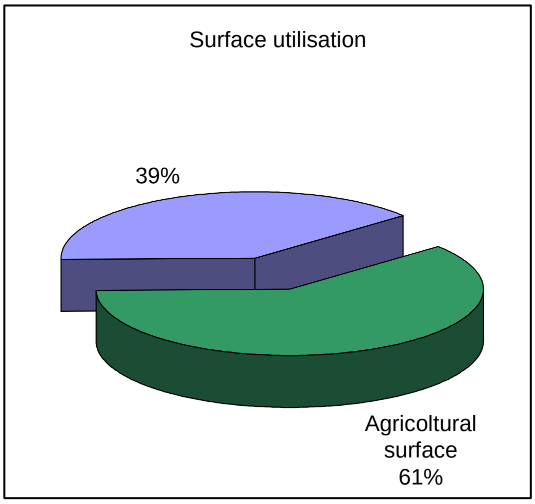


Figure 16: *Surface utilisation.*

Table 7: Main crop distribution.

Land use	Surface [km²]	%
Grass crop	7.66	50.0
Meadow and pasture	3.06	20.6
Permanent crop	4.60	29.4

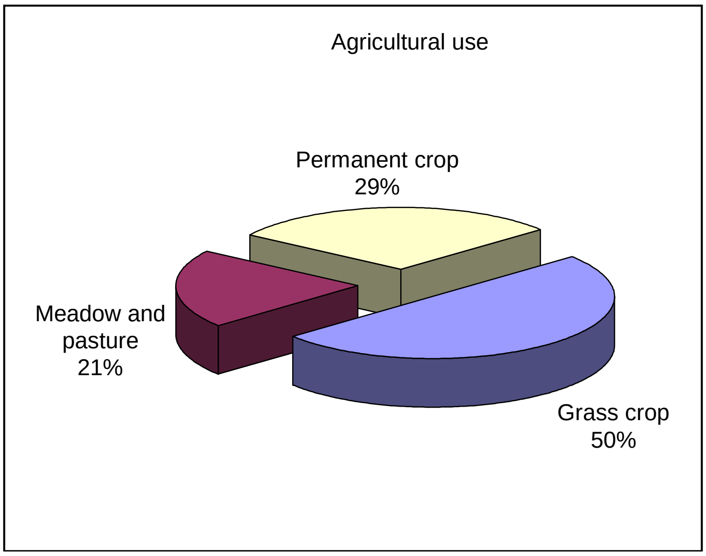


Figure 17: Agricultural use.

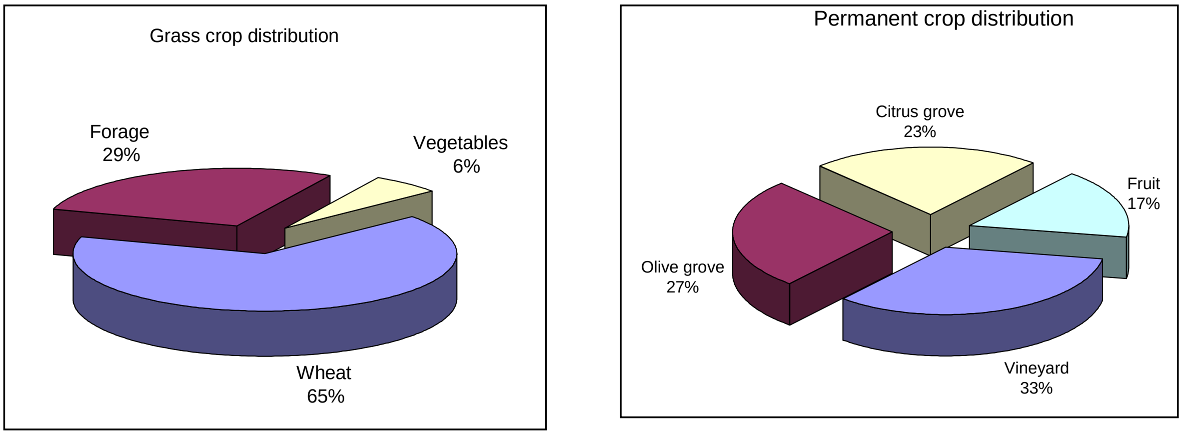


Figure 18: *Main crop distribution.*

The total cultivated land excluding meadow and pasture is 12,262.55km². The distribution of the various permanent and grass crops in this area are shown in figure 18, the main cultivars in figure 19.

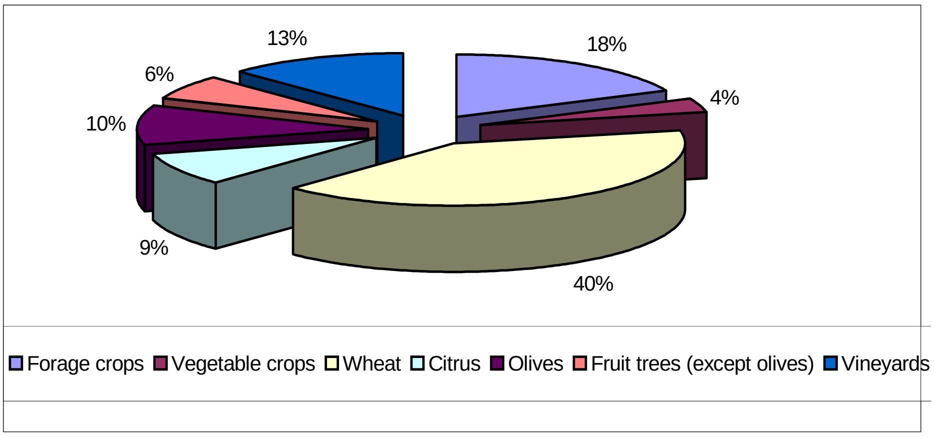


Figure 19: *Main cultivars of Sicily.*

The various forms of fertilisers presently being used are shown in table 8.

Table 8: *Fertiliser use in Sicily per crop.*

Crops	N [kg/10^{-2}km^2]	P [kg/10^{-2}km^2]	K [kg/10^{-2}km^2]
Olive groves	30	10	20
Vineyard	180	90	120
Fruit trees	180	130	100
Vegetables	80	120	150
Artichoke	200	100	100

1.6 Irrigated area and irrigated crops

The total water used for agriculture is 989.8Mm³/yr, which is 52.8% of the total water used. 68% of the water used for irrigation comes from groundwater and 32% form surface water.

The administration of water sources is based on four main laws. First of all the law RD n.1775/1933, which was applied to water management on a national scale for almost 60 years. This normative law was modified by three new legislative measures (see chapter 1.7).

According to L. 45/95, 11 associations called "Consorzi di Bonifica" (CdB from now on) are exclusively in charge of irrigation. These associations, however, do not administer the entire irrigable surface which is predominantly in private hands.

These associations are:

1. CdB Trapani 1,
2. CdB Palermo,
3. CdB Agrigento,
4. CdB Caltanissetta,
5. CdB Gela,
6. CdB Enna,
7. CdB Caltagirone,
8. CdB Ragusa,
9. CdB Catania,
10. CdB Siracusa *and*
11. CdB Messina.

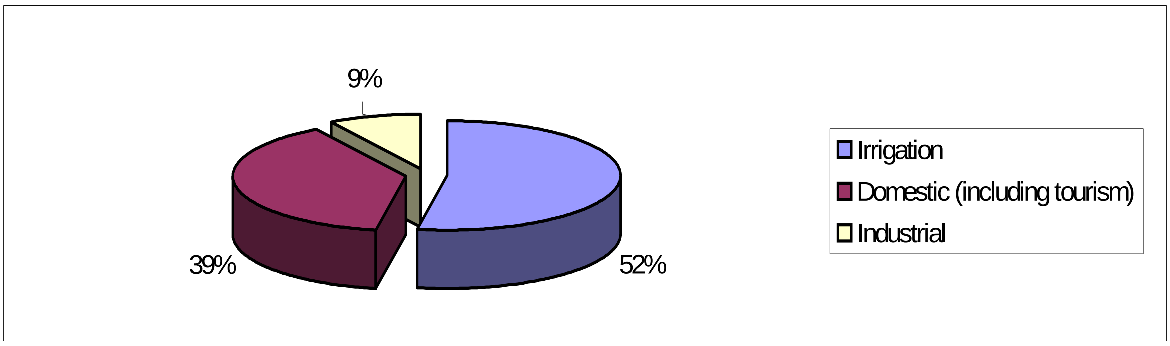


Figure 20: *Water use in Sicily.*

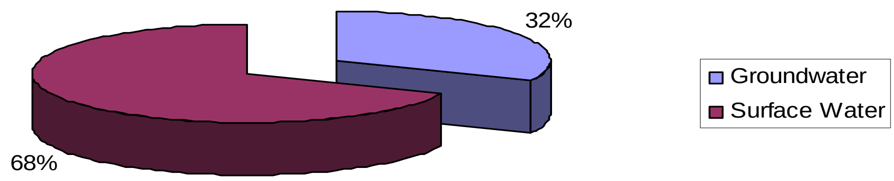


Figure 21: *Origin of irrigation water in Sicily.*

Every association manages a surface that extends almost to the respective provincial boundaries. This surface is divided into subareas called districts. Although not the entire surface of the districts is irrigated, the whole area is equipped for irrigation.

Table 9: *Equipped and irrigated area in districts.*

Irrigation consortia [CdB]	Equipped surface [km²]	Irrigated surface [km²]
Trapani	-	58.74
Palermo	94.79	64.17
Agrigento	212.84	212.84
Caltanissetta	-	-
Gela	24.69	24.69
Enna	77.75	14.07
Caltagirone	70.07	31.90
Ragusa	108.49	108.49
Catania	477.69	200.20
Siracusa	154.65	18.71
Messina	2.27	2.27

The following map (figure 22) shows regional equipped areas (districts) – see next page.

The used irrigation systems in Sicily are:

- for olive groves: drip irrigation,
- for fruit trees: micro-sprinkler *and*
- for vegetables: micro-irrigation.

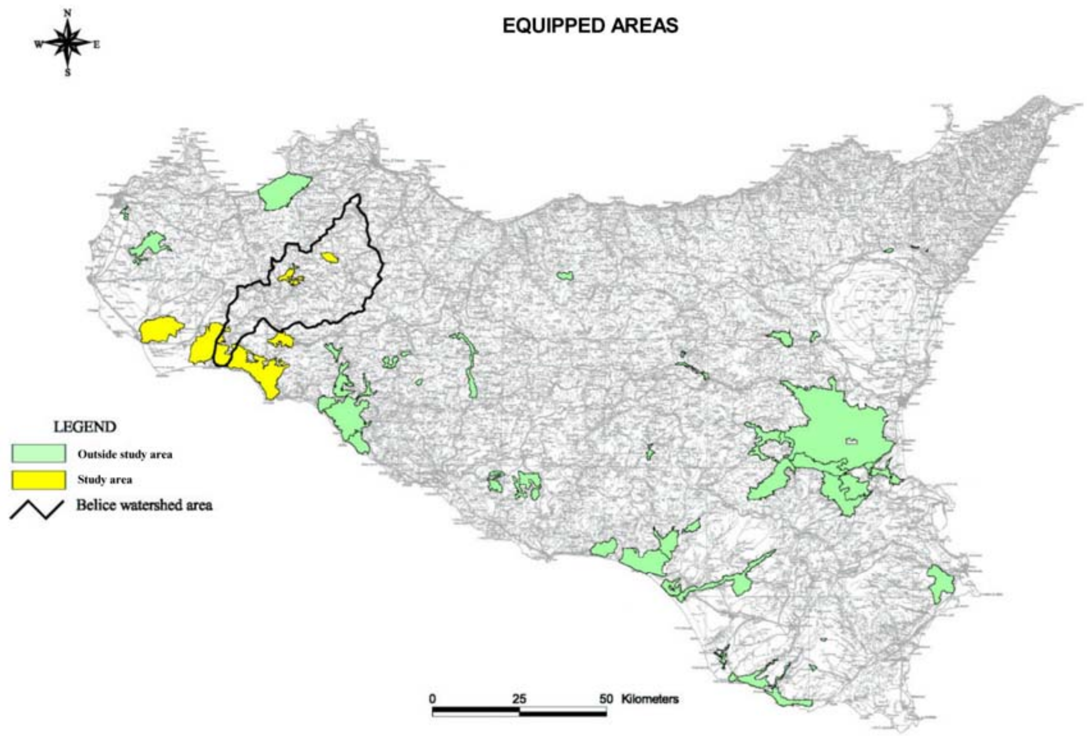


Figure 22: *Regional equipped areas.*

1.7 Socio-economic situation

1.7.1 Social profile

1.7.1.1 Population

There is an unevenly distribution of population, the almost uninhabited inland zone clearly contrasting with the largely populated coastal areas. The population is concentrated mostly along the coast zones and here as well as in other southern regions people prefer to live in country-side cities while the little farmers' settlements are scattered and can only be found in Piana di Catania and on the northern coast. It needs to be said that this trend is offset by a negative migration trend: today many young people keep leaving Sicily to work abroad, thus causing a loss of human capital. There is still considerable migration from the mountains and hills where the economy is predominantly agriculture to the larger towns and industrialised areas along the coast, where both earning prospects and living conditions are better. The most densely populated areas are the coastal belt near Catania and Messina, around Palermo, Siracusa and the hinterlands of Agrigento and

Licata; the underpopulated areas of the inland include the highlands of the Sicilian Apennines, the Etna, the Erei, Iblei and other high ground in the west. Languagewise Sicilian is divided into a number of Italian sub-dialects, those of Messina, Catania-Siracusa, south-east Sicily, Nissa-Enna, Agrigento, Palermo and Trapani. There is still a significant linguistic enclave at Piana degli Albanesi (Palermo) where Albanian is spoken. The quality of life in Sicily is conditioned by a generally poorly developed economy, characterised by a high unemployment rate, frequently leading to exploitation and crime. Nevertheless, in at least several industrialised areas the situation has greatly improved in recent years. As to the environment, the ecological equilibrium has been disturbed in a number of zones where petrochemical plants have been installed (Gela, Augusta, Siracusa) but the real danger lies in indiscriminate speculative housing construction with no respect for natural surroundings. Sicily is a very populated country thanks to birthrate higher than the deathrate.

Table 10: *Resident population and demographic change by region (2002), (ISTAT).*

<table>
<tr><th colspan="3">Region</th><th>Sicily</th><th>Italy</th></tr>
<tr><td colspan="2" rowspan="3">Natural changes</td><td>Live Births</td><td>51,234</td><td>538,198</td></tr>
<tr><td>Deaths</td><td>46,068</td><td>557,393</td></tr>
<tr><td>Natural increase</td><td>5,166</td><td>-19,195</td></tr>
<tr><td rowspan="7">Migration changes</td><td rowspan="3">Registration</td><td>From other Municipalities</td><td>78,972</td><td>1,275,339</td></tr>
<tr><td>From other Countries</td><td>9,517</td><td>222,801</td></tr>
<tr><td>For other reasons</td><td>16,637</td><td>152,821</td></tr>
<tr><td rowspan="3">De-registration</td><td>To other Municipalities</td><td>93,088</td><td>1,210,752</td></tr>
<tr><td>To other countries</td><td>7,094</td><td>49,383</td></tr>
<tr><td>For other reasons</td><td>3,655</td><td>44,303</td></tr>
<tr><td colspan="2">Net migration</td><td>1,289</td><td>346,523</td></tr>
</table>

Table 11: *Development of the population of Sicily, (ISTAT).*

Year	Population in Italy	Population in Sicily	divided into	
			Men	Women
01.01.1999	57,612,615	5,098,234	2,478.594	2,619,640
01.01.2000	57,679,895	5,087,794	2,471,247	2,616,547
01.01.2001	57,844,017	5,076,700	2,464,554	2,612,146

Table 12: *Development of the population distribution by age, (ISTAT).*

Population by age (%)	01.01.1999	01.01.2000	01.01.2001
0 - 14 years	931,898	925,324	898,943
15 – 64 years	3,358,094	3,340,629	3,343,500
65 years and over	808,242	821,841	834,257

Table 13: *Life expectancy at different ages by sex and region (1999), (ISTAT).*

Region	Ages					
	0	1	15	45	65	75
	Males					
Sicily	75.8	75.4	61.6	32.9	16.0	9.5
Italy	76.0	75.4	61.6	33.1	16.2	9.7
	Females					
Sicily	80.9	80.5	66.6	37.3	19.1	11.4
Italy	82.1	81.5	67.7	38.4	20.2	12.3

Table 14: *Percentage of urban population by region (1998-2000), (ISTAT, Environment Unit).*

Region	1998	1999	2000
Sicily	77.1	77.2	77.2
Italy	78.8	78.9	79.1

1.7.1.2 Family structure

Table 15: *Total fertility rate per 1.000 women aged 15-49 by region of residence (1984-1996, 1999-2000), (ISTAT).*

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1999	2000
Sicily	1.96	1.94	1.85	1.834	1.83	1.84	1.85	1.778	1.79	1.67	1.55	1.46	1.47	1.44	1.41
Italy	1.48	1.45	1.37	1.35	1.38	1.35	1.36	1.33	1.33	1.26	1.22	1.19	1.21	1.22	1.24

Marriages

In 1998 the number of marriages in Sicily was 26,441 while 272,138 people got married throughout Italy, i.e. 5.2 persons per 1,000 inhabitants got married in Sicily in 1998, 4.7 persons per 1,000 inhabitants throughout Italy.

Table 16: *Average number of members per household and percentage of households by number of members (Average 1999-2000), (ISTAT).*

Region	Average number of members	Percentage of households by number of members						
		1	2	3	4	5	6 and over	Total
Sicily	2.8	20.6	24.9	19.2	24.3	9.1	1.9	100.0
Italy	2.7	19.9	23.8	20.4	24.9	8.9	2.2	100.0

Table 17: *Demographic balance: live births, deaths, increase rate, birth and mortality rates by region of residence - Year 2000, (ISTAT).*

Region	Live births (P)	Deaths	Increase rate (x1.000)	Natality rate (x1.000)	Mortality rate (x 1.000)
Italy	543,039	560,241	-0.3	9.4	9.7
Sicily	53,152	46,863	1.2	10.5	9.2

1.7.1.3 Education

The educational level in Sicily is generally low. However, the *high school* enrolment rate showed a positive trend in the last years, growing from the 68.2% in 1994 to the 79.6% in 2001.

Table 18: *Resident population aged 6 + by educational level, Average 2001, (ISTAT).*

	Educational level						
	Primary school leaving certificate or no certificate of education	Junior secondary school leaving certificate	Vocational qualification	Senior secondary school leaving certificate	Short first university degree	University degree or Ph.D.	Total
Sicily	2,219	1,503	83	970	26	245	5,046
Italy	22,957	16,554	2,541	11,749	357	3,189	57,348

1.7.1.4 Health

Table 19: *Health indicators by region and economic function, (2000).*

Health indicators		Sicily	Italy
Health expenditure directly provided	Million €	2,627	37,834
	Expenditure per capita	517	655
Total health expenditure	Million €	4,951	66,728
	Expenditure per capita	974	1,155
General practitioners	Number	3,914	47,148
	People per general practitioner	1,298	1,225
	Patients per general practitioner	1,111	1,092
Ambulatories and laboratories per local health unit		211.1	70.5
Doctors and Dentists		8,869	96,313
Nurses		16,831	251,343
hospital beds		18,633	259,601
hospital beds per 1,000 inhabitants		3.67	4.49

1.7.2 Economic Profile

Sicily has long been noted for its fertile soil, pleasant climate, and natural beauty. It has a long, hot growing season, but summer droughts are frequent. Agriculture is the chief economic activity but has long been hampered by absentee ownership, primitive methods of cultivation and inadequate irrigation. The establishment (1950) of the now-defunct *Cassa per il Mezzogiorno* (Southern Italy Development Fund) by the national government led to land ownership reforms, an increase in the amount of land available for cultivation, and the general development of the island's economy. The Mafia, which is still influential, has hindered governmental efforts to institute reforms in the region, and Sicily continues to have an extremely low per capita income and high unemployment, although many workers have "black," or unreported, jobs. Among the economic sectors the primary one is still of great importance both in quality and output, though characterised by a net distinction between the low-productivity inland areas where wheat is extensively cultivated, and the coastal belt, with its specialised cultivation of citrus fruit, orchards and vineyards. The land is divided into a large number of very small holdings, with the result that incomes are rather low. The most important crops are wheat, carrots, aubergines, peppers, artichokes and courgettes. Citrus fruit (oranges, lemons and mandarins) are typical of the region, which is undeniably the leading citrus fruit producer in Italy. Its international markets, however, are no longer safe from the keen competition of other Mediterranean countries such as Spain. There are numbers of plantations, especially of almonds and hazel nuts, as well as olive groves and vineyards (table and wine grapes). There are still large numbers of sheep but the fishing industry, though in difficulty as a consequence of over-fishing Mediterranean waters, is still one of the most important sectors in the regional economy (tunny and swordfish fishing are traditional). There is a certain amount of exploitation of underground resources, petroleum (Ragusa and Gela areas) as well as potash and sulphur though the latter is now declining. In the industrial sector, petrochemicals (near Gela, Ragusa, Siracusa and Augusta) are crucial, followed by other developed industries including construction and the transformation of agricultural and fish products. The principal industrial areas lie around Catania (engineering, pharmaceuticals, electrotechnical industry, food, building materials). Of the service industries, the commercial sector is fragmented into smaller units, while the proportion of employment in the public sector is excessive, especially in Palermo. Banking and finance are active, booming especially in the larger centres. Tourism is clearly a major source of income, though still partly suffering from the lack of adequate hotel and other facilities. Regional communications are still unsatisfactory, though the construction of new roads and highways has partially eased the situation. Links with mainland Italy are maintained by sea (Palermo, Messina and Catania) and air (Palermo-Punta Raisi, Catania-Fontanarossa and Trapani-Birgi airports); the bridge across the Strait of Messina is intended to be constructed by the end of this century.

1.7.2.1 Gross Domestic Product (GDP)

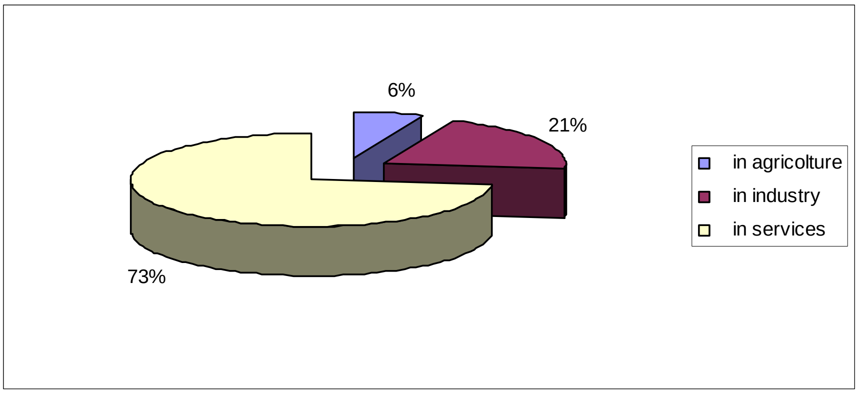


Figure 23: *Sicilian GDP by sectors.*

Table 20: *GDP by regions, (1999).*

Region	GDP Million €	%
Trapani	4,182	8
Palermo	13,736	25
Messina	8,473	16
Agrigento	4,062	7
Caltanissetta	2,588	5
Enna	1,778	3
Catania	11,191	21
Ragusa	3,728	7
Siracusa	4,361	8
Total	54,100	100

Table 21: *GDP data in Sicily.*

GDP-data	
National Gross Domestic Product (GDP)	921,370,000,000€
on the island	67,494,000,000€
per capita (island)	13,266€
divided in agriculture (%) (contribution)	6.1
in tourism (included in services)	(The available data is included in services)
in industry	20.5
in services	73.4
declared income per inhabitant	12,000€/yr
average household income	1,395€
contribution of agriculture to the island economy	Total € 3,819,800,000

1.7.2.2 Employment

Table 22: *Percentage of people employed by economic sector, sex and region of residence (2001), (ISTAT).*

	Employed				Employees			
	Agriculture	Industry	Other activity	Total	Agriculture	Industry	Other activity	Total
Sicily	9.5	19.9	70.5	100.0	59.6	72.7	74.7	100.0
Italy	5.2	31.8	63.0	100.0	41.2	77.6	71.9	100.0

Table 23: *Labour force in Sicily per province/region, (1999).*

Province/Region	Employed	%
Agrigento	114,057	8.60
Caltanissetta	75,756	5.71
Catania	292,505	22.05
Enna	40,146	3.03
Messina	188,607	14.22
Palermo	291,581	21.99
Ragusa	92,679	6.99
Siracusa	112,909	8.51
Trapani	118,017	8.90
Sicily	1,326,257	100.0
ITALY	20 ,691,619	

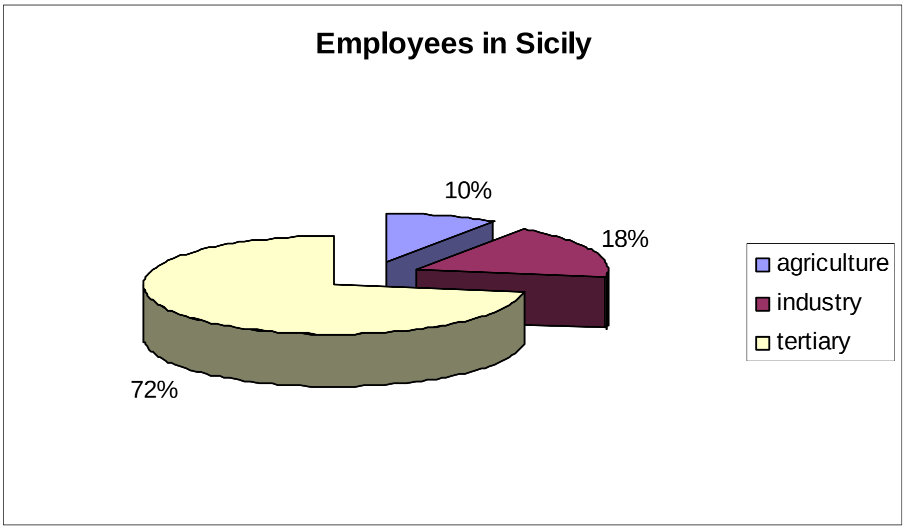


Figure 24: *Employees in Sicily.*

Table 24: *Unemployment rate of young people and total labour force by sex and region of residence (2001), (ISTAT - Unit "Formazione e lavoro").*

Region	Males		Females		Total	
	Age group 15-24	Total	Age group 15-24	Total	Age group 15-24	Total
Sicilia	47,2	16,8	66,0	31,2	54,7	21,5
Italy	25,0	7,3	32,2	13,0	28,2	9,5

1.7.2.3 Working sectors

Agrigento´s wine industry has an ancient tradition, dating back to the earliest Greek colonisation of the area. The province has two wine outputs a year in Sicily. Tourism has been one of the province's main resources thanks to a myriad of beautiful and diverse attractions. A number of sea resorts along the shoreline are major tourist goals, let alone the breath-taking Valley of the Temples.

Wine-making is likewise a leading economic industry in *Caltanissetta*. Unlike other Sicilian provinces, this domain particularly flourished in the Middle Ages. Craftsmanship of equal importance, having brought forth such traditional activities as pipe-making (made Erica Arborea briar), confectionery (notably the torrone), glass processing, decoration, wood works, restoration, and embroidery. An intense mining activity was recorded in the past century, notably related to sulphur extraction. Oil – mostly drilled off Marina di Ragusa's shore – is refined at the petrochemical plant in Gela, its output accounting for a considerable percentage of the internal consumption. Agriculture remains a traditional realm with the province's large estates mainly cultivating vines, corn, olive and almond trees.

The harbour has been a fundamental resource for *Catania*'s economy. Tourism is remarkably developed thanks to natural resources like the Etna volcano, offering opportunities for excursions or sky vacations, and the splendid Ionian shore, comprising amazing spots, resorts and fishing villages. The province territory is largely covered by vineyards, divided into groups according to their geographical position and type of production. The first group refers to the Etna wines, further split into three sub-groups according to the different quality produced. The second group refers to the Caltagirone's grape varieties. The third and last group concerns the production of bodied and highly alcoholic wines.

Enna's tourism has developed a lot in the last decades, taking full advantage of the province's numerous historical, cultural and natural riches. Mainly conducted in the Floristella-Grottacalda district sulphur mining, was a major source of income up to the early 1980s.

Thanks to its strategic location and to its highly developed harbor, *Messina* has played an outstanding role in the Mediterranean commercial routes. Its harbor is still a fundamental resource for its economy. The last decades have seen the growth of the wine industry that Phoenicians, in their day, introduced to the Aeolian archipelago and Messina area. The Romans continued refining its quality. Among the major wine labels are the *Mamertino*, the

Malvasia of the Aeolian Islands and the *Faro*. Tourism is an equally important field, largely relying on the province's natural and historical riches.

Farming is still a major economic resource for *Palermo* province. Thanks to the plenty of natural, historical and cultural sites across the province, tourism has much developed in the past decades. Today the wine industry is as important. Boasting an old tradition rooted in the Phoenecians impact on the area in remotest times, it entered a period of alternating decline and revival under the Spanish. Most vineyards are located in the hilly hinterland, notably in the San Cipirello and Ficuzza districts where the production of *table* wines prevails.

Despite its not very propitious climate and grounds, the province of *Ragusa* is primarily an agricultural area. The hard work of generations of peasants and farmers, intense works of deforestation and reclamation over the centuries have resulted in a modern agriculture with high output and income levels. The technological development of the last years has also been fundamental to economy. The Valley of the Ippari River is a major agricultural area, important for the output of early fruit, vegetables, citrus fruit and flowers, and for the presence of the agricultural market of Vittoria, a valuable support for the trade and marketing oflocal products., Mostly located on the coast, the hothouse cultivation is also worth mentioning.

Since 1950 the province of *Siracusa* has slightly changed its main economic activity, moving from farming to industrialising, witnessing a particular development of chemical implants and oil refineries. This change has attracted manpower from the inland. Agricultural activities are still important, specially focusing on citrus in the north and on "ciliegino" tomato, vineyard and almonds in the south-east of the province. Other typical products are wines (Marsala di Noto, Moscato di Siracusa and Nero d'Avola), the olive oil and, as regards fishing some varieties of tuna fish. Finally, even tourism is a great economic resource for Siracusa, attracting people both for its archaeological sites and beautiful landscapes.

Trapani's economy is based largely on fishing and wine making along withsalt-mining, with tourism growing annually. The main fishing centre is the town of Mazara del Vallo (mainly tuna fish and swordfish). As regards wine-making the province of Trapani alone produces more wine than the entire regions of Tuscany or Piedmonts; the wine production is focused on table wine (Bianco d'Alcamo, Moscato di Pantelleria for example). Over the centuries the salt pans and salt industries have created a unique environment of great culture and economic relevance. This route is called "via del sale" (salt-road). Tourism plays a marginal role within the local economy, despite the region's numerous natural beauties and rich archaeological and cultural testimonies.

1.7.2.3.1 Primary sector

The mild climate and fertile soil of the seaside plains has created favourable conditions for one of most successful agricultural economies in Italy. The main products are corn, wine grape, wheat, barley, olive and olive oil, citrus fruits, almonds, fig, artichoke, pea-green, pistachio, caper, carob, and cotton (greatest production in Italy). Cattle, mules, donkeys, and sheep are raised, although animal husbandry as such does not have a big importance, while fishing especially tuna and sardines yield very good profits.

1.7.2.3.2 Secondary sector

The *industry*, which has only recently taken off in Sicily in comparison with the rest of Italy, is playing an increasingly important role offering a considerable source of income and employment. The main industrial activities fall into two sectors: 1.those involved in the processing and marketing of agricultural products, thus accounting for a great number of oil and flour mills, cheese, confectionery and wine factories are spread throughout the entire territory; 2. the construction (notably stone, asphalt, and black-stone factories), and mining industry (oil is extracted in the area of Marina di Ragusa), have been growing rapidly. There is also a distinction between modern industrial activity in the provinces of Siracusa, Caltanissetta, Agrigento, Messina and Catania, and the traditional one spread throughout the territory. The new industries are petrochemicals, mechanics, chemistry, electronics, etc. The old industries are mostly in food producing and exporting to other other Italian regions. It should also be mentionedthat Sicily belongs to those regions of Italy where the land still contains some mineral resources, which account for the production of rock-salt, potassic salts, methane and petrol.

Sicily's *manufacturing* industry includes food processing, chemicals, refined petroleum, fertilisers, textiles, ships, leather goods, wine and forest products. There are petroleum fields in the southeast, with natural gas and sulphur also being produced. Improvements in Sicily's road system have helped to promote industrial development. The chief ports of the island are Palermo, Catania, and Messina.

1.7.2.3.3 Tertiary sector

Apart from agricultural and industrial activities there is also a thriving commerce (export of wine) and tourism (Palermo, Taormina, Siracusa, islands).

1.7.2.3.4 Trade

Table 25: *Sicily's in- and export by region, (1999).*

	Agrigento	Caltanissetta	Catania	Enna	Messina
Imports million €	73	460	725	16	1,011
% value	0.92	5.81	9.16	0.20	12.77
Exports million €	55	145	643	11	329
% value	1.61	4.25	18.91	0.34	9.67

	Palermo	Ragusa	Siracusa	Trapani	Sicily	Italy
Imports million €	431	114	3,114	1,970	7,912	**203,446**
% value	5.45	1.44	39.36	24.89	100	
Exports million €	507	93	1,414	203	3,400	**215,980**
% value	14.91	2.74	41.59	5.98	100	

1.7.2.3.5 Tourism

Following Rome, Milan and Venice, Sicily is the most sought tourist destination by foreign visitors and is surely on first place among the regions of the Peninsula with a 16% consensus of tourists surpassing even that of Tuscany. Notably, the last decade has seen an outstanding growth, with the construction of new tourist facilities. In terms of percentage tourists accounted for 3.9% of the national total in 2001, a slight downturn with respect to the 4%in 2000, with while another slight decrease to be expected for the year 2002 (cf. 2nd Sicily Tourism Report, 2003 by the Mercury Srl of Florence in collaboration with the Sicilian Tourism Observatory coordinated by Professor Emilio Becheri).

A first balance of overnight stays for the 2003 summer season shows 296,546 overnight stays in all the holiday villages in Sicily and Sardinia and in the Paris structures in the months of June and July, thus an increase of 3.8% in comparison with the 285,788 overnight stays in 2002. The following data give some tourist-indicators:

- tourist arrivals (2001): 3,719,214,
- tourists total (2001): 4,068,623,
- tourist residents (2001): 12,016,880,
- mean tourist stay (2001): 3.4 days *and*
- average permanence (2001): 3.2 days.

1.8 Water laws and regulations

The *administration of water sources* is based on four main laws. First of all, law RD n.1775/1933, which was applied to water management on a national scale for almost 60 years. This normative law was modified by three new legislative measures.

L. 183/89 – Law for soil defence, establishing the institutional role of the "Basin Authority" responsible for water administration of a single geographic area.

L. 36/94 – Galli law fostering the conservation, maintenance and reuse of water.

D.L. 152/99 – New dispositions on water guardianship in order to prevent it from pollution and to absorb directive 91/271/CEE that relates to the treatment of urban refluent water as well as to implement directive 91/676/CEE which is related to the protection of water polluted with nitrates from agriculture. This decree focuses on three main elements:

a) quantitative guardianship of water sources (planning of the basins' water balance, recycling of used water, and water sources conservation),

b) qualitative guardianship of water sources (overall protection of water sources under a whole water-cycle perspective) *and*

c) groundwater protection: With this law a larger regional self-government in water politics has been established.

In Italy, the *water management* is under the control of different actors, like the Prime Minister Cabinet, the Surveillance Committee on water usage, the Minister for Public Works, Environment Secretary, Health Secretary and local authorities, such as regions, provinces and municipalities. Moreover the Basin Authorities are also in charge of water administration, regarding the planning of water policies on a basin scale, like the Draining Consortium responsible for the administration of water for irrigation. In 2002 the Prime Minister Cabinet declared Sicily in a dire state of "water emergency" and thus appointed the Sicilian Premier as High Commissioner of water management.

As a result of this legislative context, the administration of water is split up between too many institutions in Sicily: 3 regional authorities, 3 municipal enterprises, 19 private enterprises, 11 draining consortia, 284 municipal authorities and a certain number (approx. 400) of associations.

1.9 Management, institutional and policy options

Table 26: *Policy options in Sicily.*

Activity	Municipal Authority Water Utility	Regional Authorities	Ministry of Health	Ministry of Interior	Ministry of Environment	Ministry of Agriculture	Ministry of Finance
Surface water							
Use	X	X		X			
Storage		X					
Recharge							
Diversion							
Quality monitoring					X		
Assessment					X		
Groundwater		X					
Use					X		
Storage					X		
Recharge					X		
Quality monitoring			X		X		
Assessment					X		
Well/drill permits		X					
Irrigation network							
Rehabilitation		X					
Modernisation							
Reuse							
Drainage water					X	X	
Wastewater					X	X	
Desalination		X					
Introduction of technology		X					

Table 26 continued.

Activity	Municipal Authority Water Utility	Regional Authorities	Ministry of Health	Ministry of Interior	Ministry of Environment	Ministry of Agriculture	Ministry of Finance
Efficient water utilisation							
Domestic		X					
Industrial		X					
Irrigation		X					
Legislation							
Regulation & codes		X		X	X	X	
Standards			X		X		
Policy setting		X					
Water allocation		X					
Project financing		X			X		
Project design		X					
Project implementation		X					
Operation & maintenance							
Pricing	X						
Enforcement							
Water data records		X				X	

1.10 Summary table

Table 27: *Summary table I.*

Natural water conditions and infrastructure	***Regional context***	Area	25706km^2
		Climate Type	Mediterranean
		Aridity Index	Dry-Subhumid
		Permanent Population	5,076,700 inh.
		Tourists (arrivals per year)	4,068,623 inh
	Water availability	Precipitation	300-1,600mm
		Total Water Resources /Availability (Mm^3/a)	2472.4
		Water resources • Surface water • Ground water • Storage/dams/reservoirs • Desalination	 27% 71% (incl in surface water) 2%
		Water availability per capita and year (m^3)	369.3
		Resources to population index	
		Water availability per capita (m^3) • April-September • October-March	1.01 (daily)
		Trans-boundary water	-
	Water quality	Quality of surface water	Good
		Quality of groundwater	Good
		Quality of coastal water	
	Water Supply	Supply coming from: • Groundwater • Surface water • Desalination • Recycling • Importing[1]	 78% 21% 1%
		Network coverage: • Domestic • Irrigation • Sewerage	 - - -

Table 27 continued.				
Economic and Social system agriculture and tourism	***Water use***	Water consumption by category: • Domestic • Tourism • Irrigation • Industrial and energy production	38% (incl tourism) -% 53% 9%	
		Water consumption for domestic use coming from • Groundwater • Surface water • Desalination • Importing	720.9 $10^6 m^3$/yr (incl. tourism) 86% 11% 3%	
		For tourism coming from • Groundwater • Surface water • Desalination • Importing		
		For irrigation coming from • Groundwater • Surface water • Desalination • Recycling • Importing	989.8 $10^6 m^3$/yr 68% 32%	
		For industry coming from • Groundwater • Surface water • Desalination • Recycling • Importing	164.1 Mm^3/yr 100%	
	Water demand	Water Demand trends	Increasing	
		Consumption index:	0.76	
		Exploitation index:	Not available at the moment	
	Agricultural issues	Area used	15,648.04km²	
		Irrigated area	2,190.72km²	
		Cultivated crop types (per area)	Permanent crop	29%
			Meadow and pasture	21%
			Grass crop	50%

Table 27 continued.			
Economic and Social system agriculture and tourism	***Agricultural issues***	Irrigation methods	Olive groves: drip irrigation; Fruit trees: micro sprinkler Vegetables: micro irrigation
		Water used for irrigation (per area)	451,400m³/km²
		Water demand per crop and area	Not available at the moment
		Fertiliser used - average	N [kg/km²] P [kg/km²] K [kg/km²]
		Pesticides used - average	Not available at the moment
	Social and economic situation	Unemployment rate	24.5%
		Employees in • Agriculture • Industry • Services	135,812 persons (9.5%) 253,039 persons (17.7%) 1,040,748 persons (72.8%)
		Importance of water scarcity	high
	Pricing system	Average household budget for domestic water	120 Euro/yr
		Average household budget for agricultural water	
		Average household income	16,740 Euro
		Contribution of agriculture to island's economy	6.1%
		Water prices	0.3-0.85 Euro/m³ for domestic use not available for agriculture use
		Energy prices for used water technology	Not available at the moment
		Cost recovery	Not available at the moment
		Price elasticity	Medium
	Social capacity building	Public participation in decisions	Bad
		Public education in water conservation issues	Bad
		Acceptability of using treated waste water	There is not use of treated waste water

Table 27 continued.			
Decision Making Process	***Water Resources Management***	Water ownership	State
		Decision making level (municipal, regional, national) regarding • Water supply for each sector • Water resources allocation for each sector	National Regional Intra-Regional Municipal
	Water Policy	Local economy basis	Agriculture, tourism
		Development priorities	Agriculture, tourism

[1] *Surface and ground water from other Water Regions.*

Chapter II: Selection of a representative catchment

For the purposes of the MEDIS project, just one catchment was chosen. The Belice catchment is located in the central-western part of Sicily. Its size is about 949.5km^2, with a typical Mediterranean climate. The main reasons why this catchment was chosen were:

- Complex water resources demand and purposes (irrigation, drinking, industrial, etc.),
- Conflicts among water resource users (farmers, tourist resorts, urban uses, etc.),
- Numerous previous studies and projects *and*
- The Presence of several gauging sites with a lon-term recording period: three thermometric gauging stations, sixteen rain gauging stations, five flow gauging stations with N>40 yrs.

Water for domestic and agricultural usage comes from wells, dams and small detention ponds. A large amount of this water is distributed from the basin, especially for domestic use; however, at the moment no data is available to quantify it.

As matter of fact, the periodic droughts are linked to climate features, a high population presence and intensive agriculture, are factors which present a serious problem for the social communities and economic forces. In this framework conflicts often arise between agricultural and drinking water users, i.e. between city and countryside. Yet the principal problem can be put down to the bad management of the water resources.

2.1 Catchment description

The Belice catchment (figure 25) is located in the central-western part of Sicily. Its size is about 949.5km^2, with a typical Mediterranean climate. The altimetry of the basin is predominantly undulated (figure 36), hilly with level areas constituted by the floodplain of the principal river bed. The maximum quota is 1,333m s.m. in the mountains of Sicani. In the basin numerous water-bearing springs and wells exist; these are intensely exploited for irrigation purposes and drinking water. According to their hydro-geologic characteristics, they can be distinguished as: formations carbonate, permeable for shear and karst phenomenon; alluvial formations extending to the valley zone of the basin. Of great importance are the aquifers that have their centre in the geologic formations. In the river network, it is possible to distinguish three great branches that fall into three under - principal basins: the Belice right (for 227km^2) and the Belice left (for approx. 407km^2) and the Belice resulting from the confluence of these two branches.

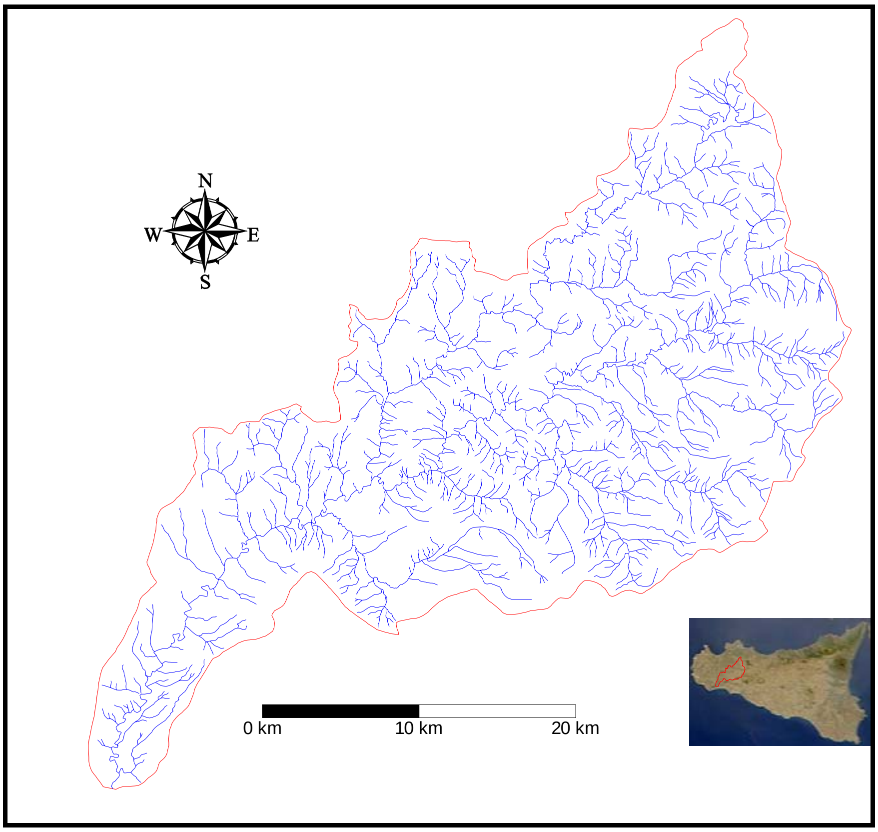
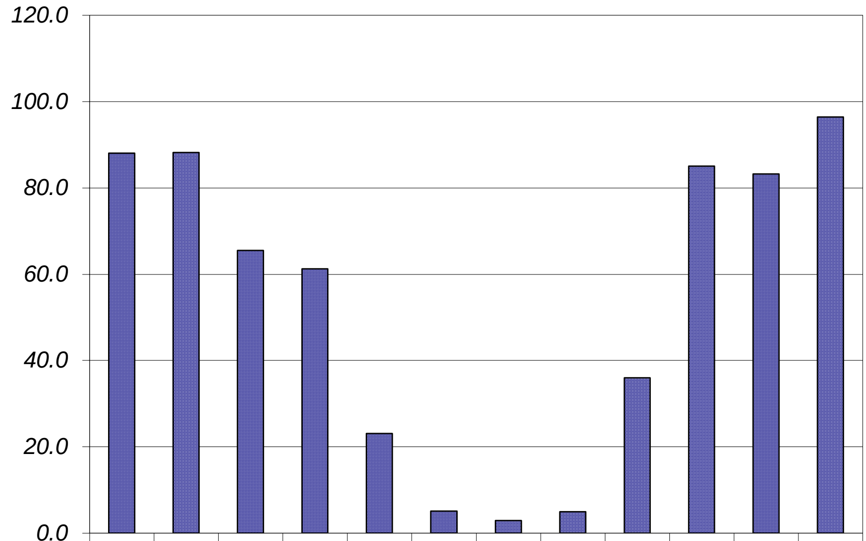


Figure 25: *Layout of the Belice catchment.*

2.2 Climate

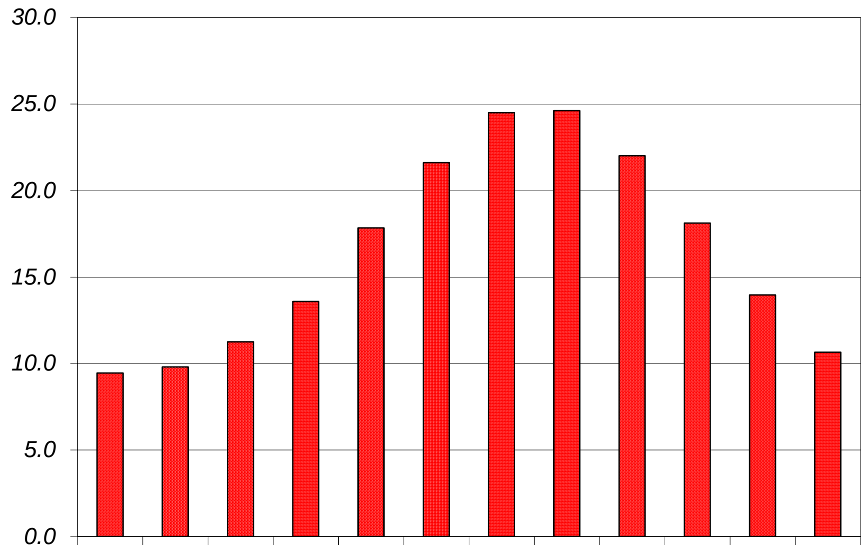
The climate is Mediterranean with dry summers and rainy winters. The mean annual precipitation is 639.7mm, ranging between a maximum of about 1,000mm and a minimum of about 500mm. Precipitations are strongly related to seasonal changes with 80% occurring in the period from September to April. The chart in figure 26 shows mean monthly precipitation values in the Belice catchment.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation (mm)	88.1	88.2	65.5	61.2	23.1	5.2	2.9	5.0	36.0	85.0	83.2	96.4

Figure 26: *Mean monthly precipitation (1965-1994), (Regional Climatological Atlas).*

The mean temperature is about 16.4°C. The chart in figure 27 shows mean monthly temperature values, while figure 30 presents mean annual temperatures.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	9.4	9.8	11.2	13.6	17.8	21.6	24.5	24.6	22.0	18.1	14.0	10.7

Figure 27: *Mean monthly temperature (1965-1994), (Regional Climatological Atlas).*

Table 28 shows general values of climatic data in the Belice catchment.

Table 28: *Regional climatic data.*

Climate data	
Mean temperature per year	16.4°C
Coldest month	January
Minimum temperature in January	-2°C
Warmest period [w.p.]	July ÷ August
Maximum temperature in w.p.	38°C
Annual thermic range	40°C

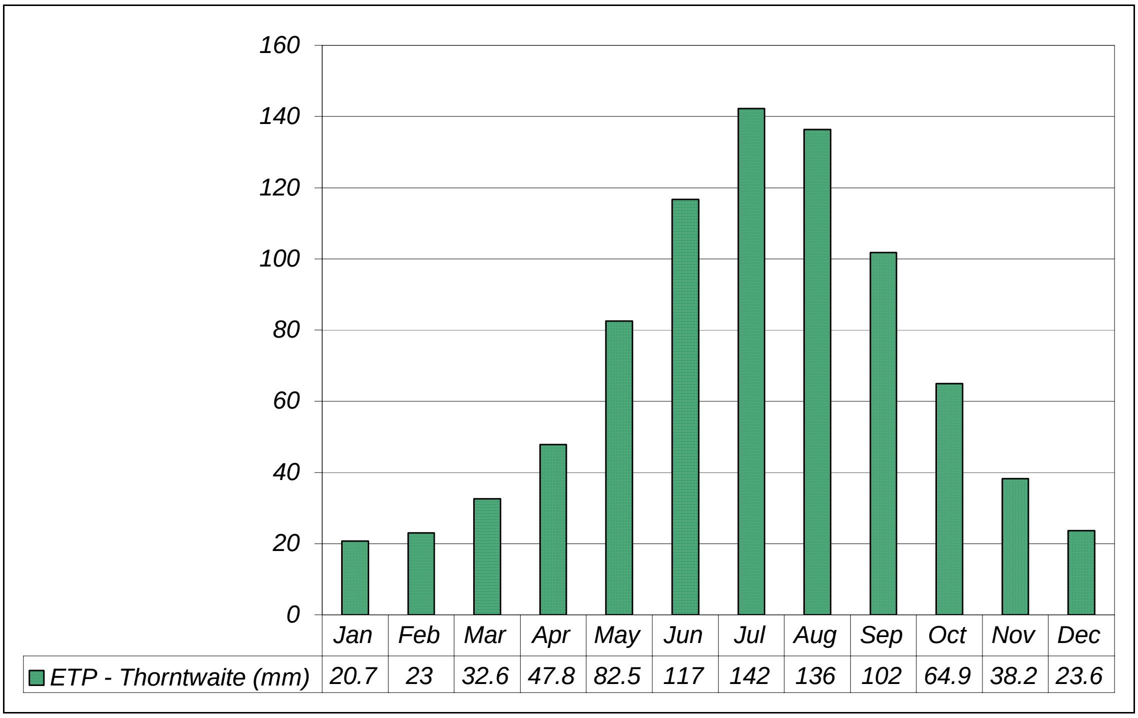


Figure 28: *Mean monthly potential evapotranspiration (1965-1994), (Source: Regional Climatological Atlas).*

The mean yearly potential evapotranspiration for Sicily is, according to the Thorntwaite model, 828.4mm, as shown in figure 31. The chart in figure 28 shows mean monthly potential evapotranspiration values.

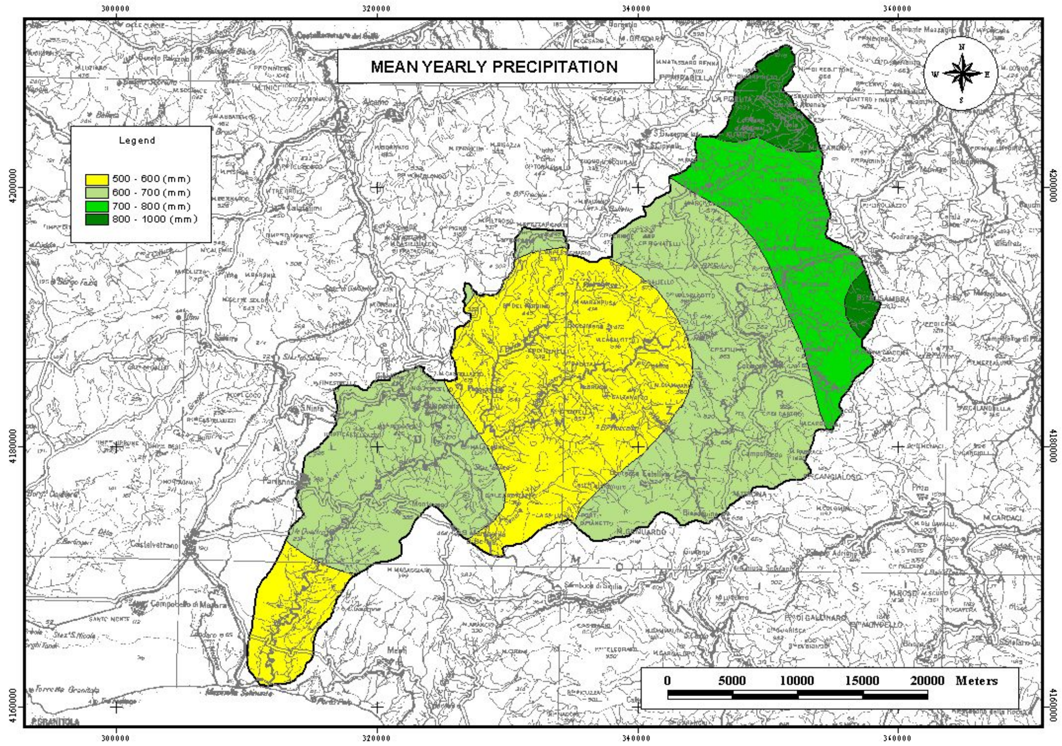


Figure 29: *Mean precipitation per year, (1965-1994).*

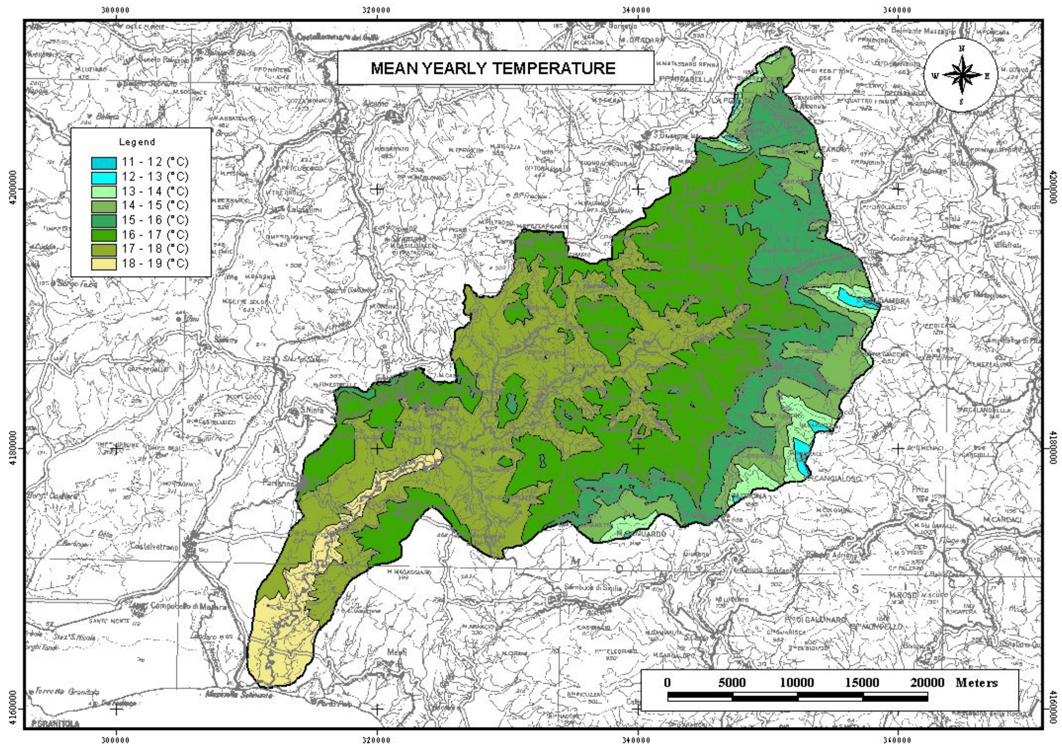


Figure 30: *Mean temperature per year, (1965-1994).*

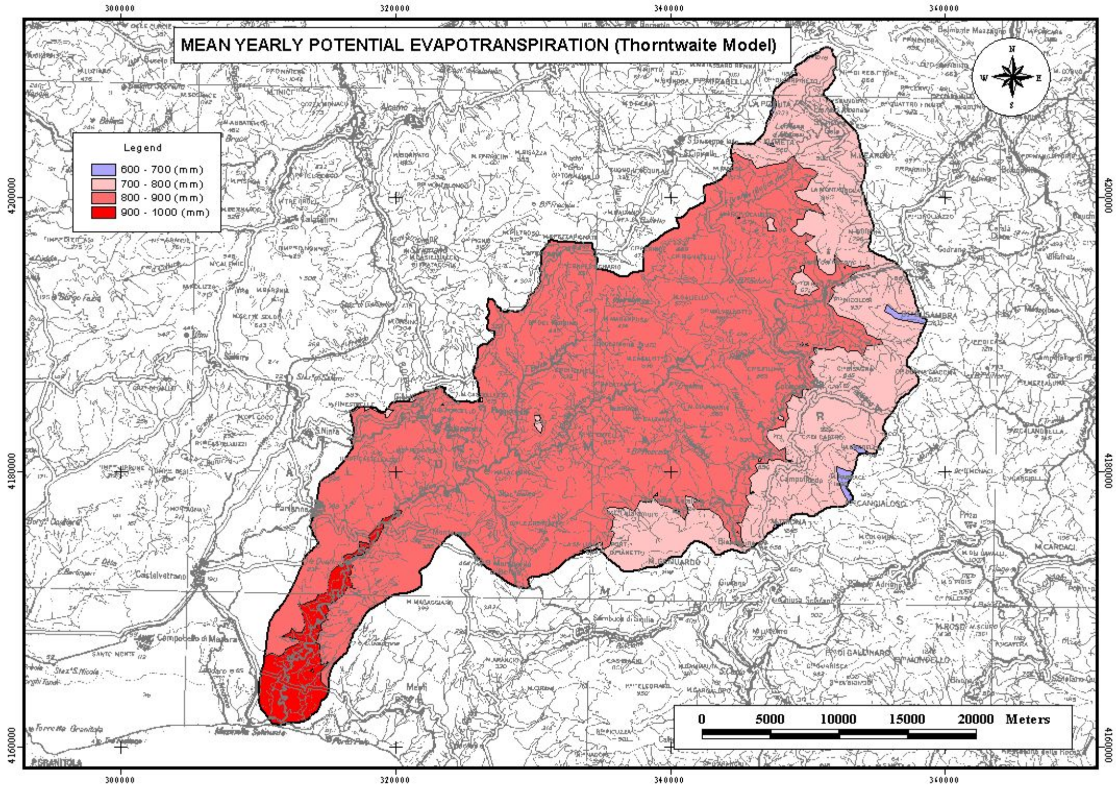


Figure 31: *Mean evapotranspiration per year, (1965-1994).*

2.3 Humidity Index

The mean annual precipitation is 639.7mm and the mean annual evapotranspiration is 828.4mm.

The Humidity Index, following the Thorntwaite model, can be expressed as follows:

$$HI = \frac{P - ETp}{ETp} x100$$

P is the mean yearly precipitation and ETp is mean yearly evapotranspiration.

Table 29: *Thorntwaite: Aridity index ranges and classification.*

Classification	Humidity index range
Hyper humid	>100
Humid	100 ÷ 20
Subhumid - Humid	20 ÷ 0
Dry – Subhumid	0 ÷ -33
Semiarid	-33 ÷ -67
Arid	-67 ÷ -100

In the Belice catchment the Humidity Index (spatially averaged) is –22.8, for which it reverts in the type of climate dry – sub-humid.

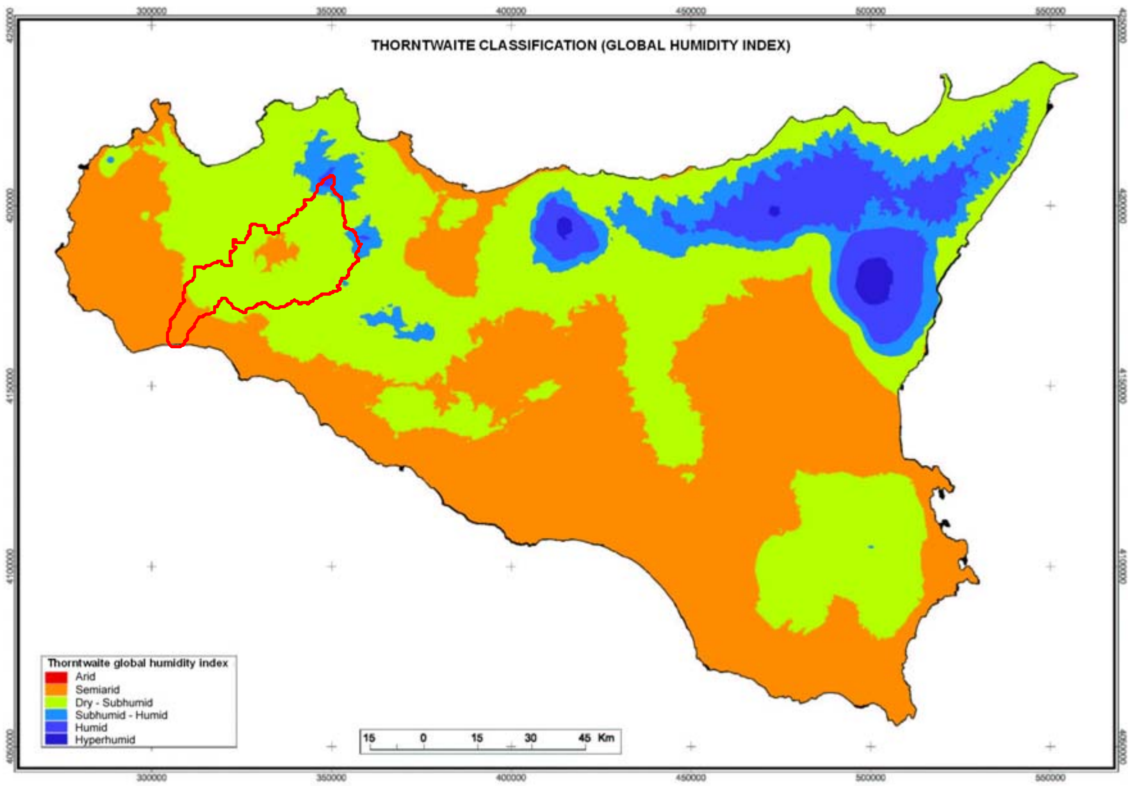


Figure 32: *Thorntwaite classification, (1965-1994), (Regional Climatological Atlas).*

2.4 Geology and geomorphology

The geology and hydrogeology of the Belice basin is typical ofthe central-western part of Sicily. In the basin numerous water-bearing formations are present; these are intensely exploited for irrigation purposes and drinking water supply. According to their hydrogeologic characteristics, they can be distinguished as carbonate formations, permeable for shear and karst phenomenon; alluvial formations that extending into the valley zone of the basin; the calcareous formation, permeable for porosity and flaw, which is present in the southern zone with the classical structure of tilted plain layers.

Along the north-eastern border from north to south lies a stretch of the Palermo Mountains (Piana degli Albanesi and Rocca Busambra at 1613m osl) and of the Sicani Mountains (Barracù 1,420m osl, Titona, 1,245m osl, Genuardo 1119m osl, Maggiaro 399m osl). The latter are carbonatic-dolomitic fractured rocks with a high level of groundwater. A lot of springs are present exist owing to their contact with the clay formations. In the valley the geology is characterised by an alternation of clay and calcarenite (sandy) formations, with big banks close to the outlet of the basin. These formations are characterised by a medium groundwater flow circulation pointed out by many natural springs. Sandy aquifers are intensely exploited by wells with a low flow rate (less than 1l/s), used especially for irrigation. The evaporitic formations (chalk, sulphur) are also very important which are placed in the central part of the basin in the surroundings of Montevago with thermal springs. Alluvial aquifers are located along the stream of the river in the valley of the basin.

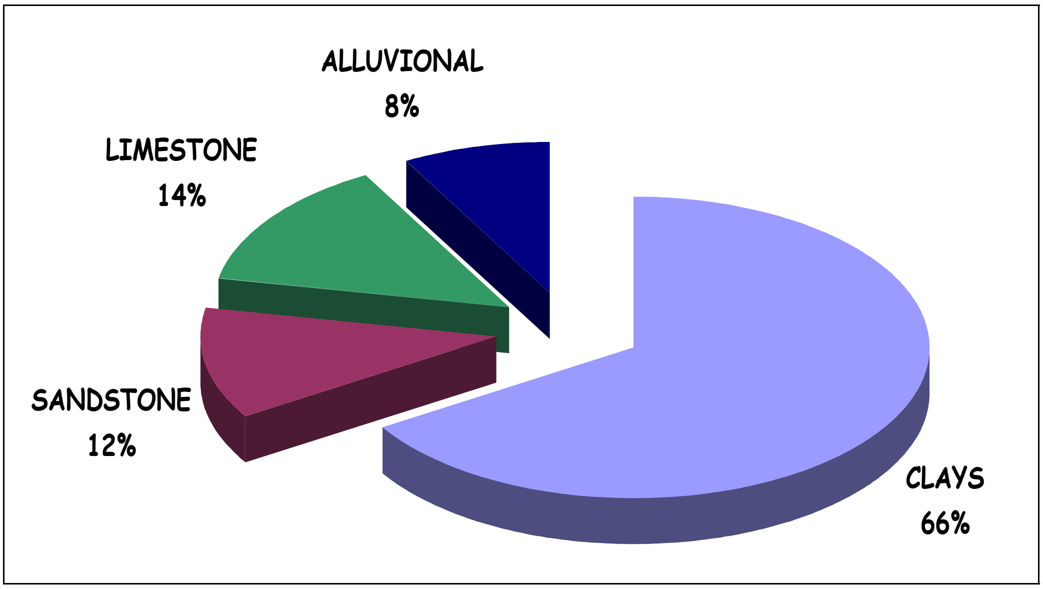


Figure 33: *Geological features of the Belice catchment.*

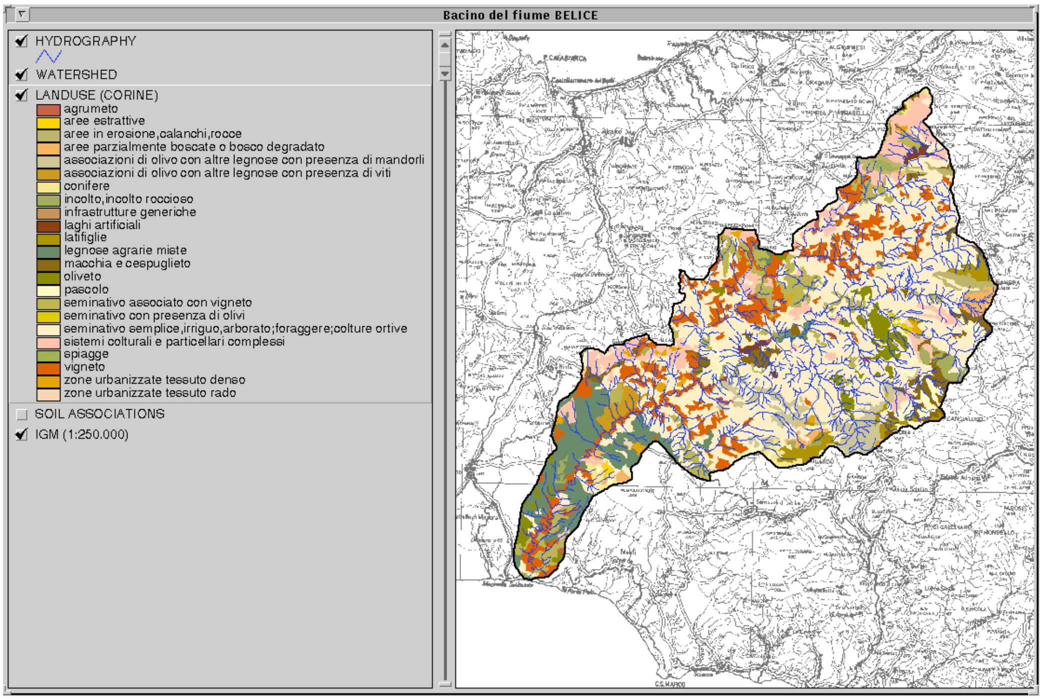


Figure 34: *Land use map of the Belice catchment.*

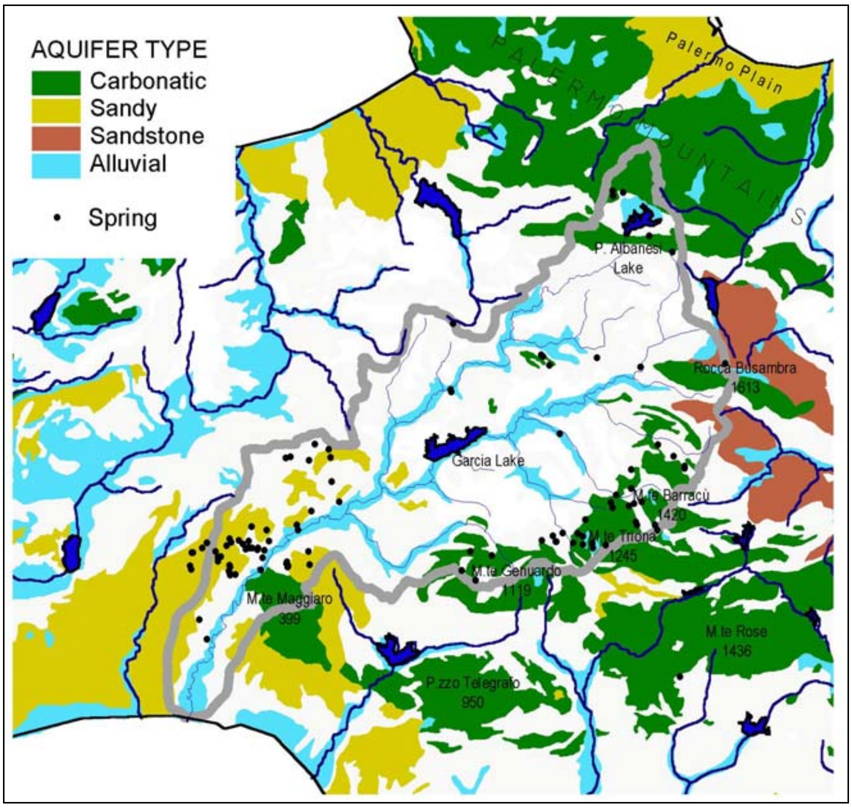


Figure 35: *Acquifers of the Belice catchment (100m res.).*

The altimetry of the basin is predominantly undulated, hilly with level areas constituted by the floodplain of the principal river bed. The greatest reliefs are those to the north and northeast, constituting the southern slope of the Palermitani Mountains (quota max 1.333m s.m.) and the western slope of the Sicani Mountains; the greatest quota is verifiable on the top of the Rocca Busambra with 1,613m s.m. To the west and south the reliefs are less accented, varying between 526m s.m. and 1,180m s.m.

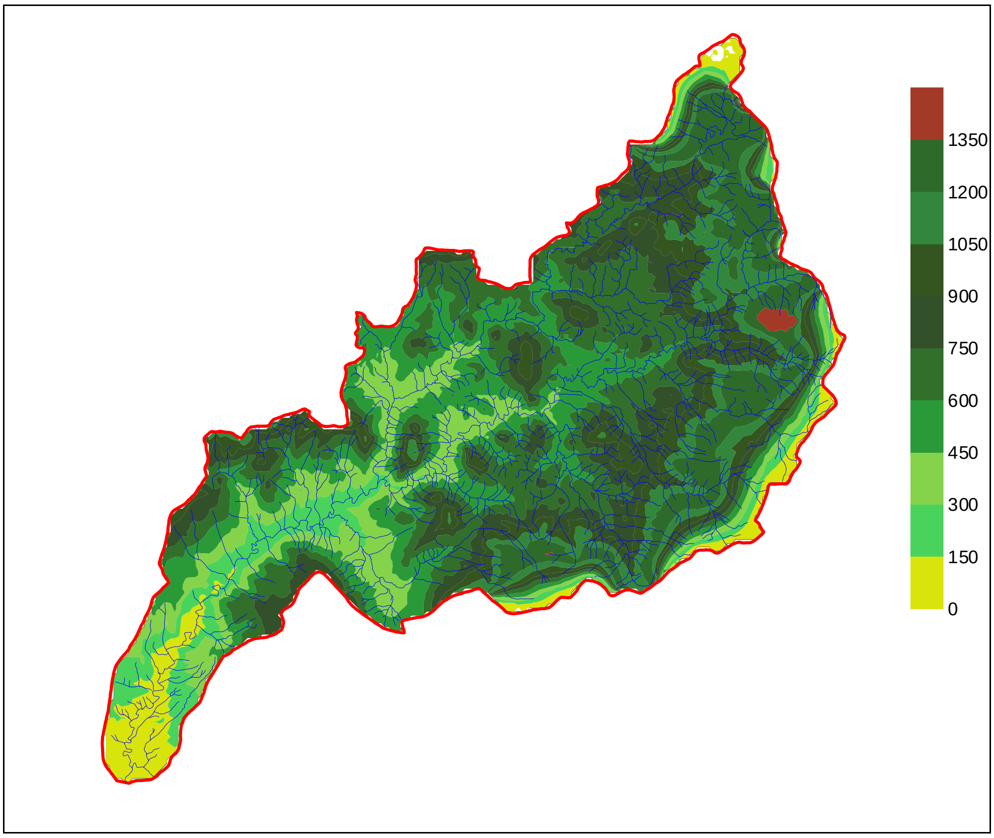


Figure 36: *Catchment DEM (100m res.).*

2.5 Water resources

The evaluation of water resources for the catchment was carried out by analysing the global water. The hydrological analysis started from the calculus of the total water volume coming from precipitation, mainly rainfall, in the period 1965-1994 equal to 607,5Mm^3/yr.

The surface component was defined by simply multiplying the total precipitated water volume for a mean runoff coefficient for the entire island. This coefficient is equal to 0.22. The groundwater component comes from an analysis of regional aquifers presented in the Water Resources Survey of Sicilian Regional Government, 2000.

The total available water resources in the Belice catchment are 167.4Mm^3/yr divided in:

- Surface water: 133.6Mm^3/yr *and*
- Groundwater: 33.8Mm^3/yr.

As a matter of fact, part of the surface water flows into the sea, mostly due to the absence of civil works for water regulation.

The total exploitable water resources in Belice catchment are (Sicilian Regional Government – Water Resources Survey, 2000) 104.5Mm^3/yr divided in:

- Groundwater: 24.8Mm^3/yr,
- Surface water: 79.7Mm^3/yr *and*
- Desalinated water: 0.0Mm^3/yr.

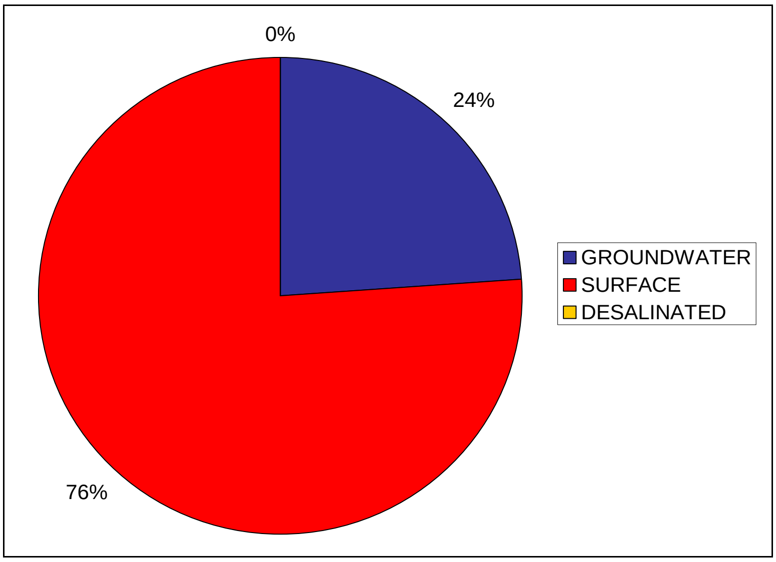


Figure 37: *Exploitable total water resources in the Belice catchment (104.5 Mm^3/yr).*

The total consumed water resources in the Belice catchment are 39.0 10^{6}m^3/yr divided by source in:

- Groundwater: 9.0 Mm^3/yr,
- Surface water: 30.0Mm^3/yr *and*
- Desalinated water: 0.0Mm^3/yr.

And by use:

- Irrigation: 18.9Mm³/yr,
- Domestic: 19.8Mm³/yr *and*
- Industrial: 0.3Mm³/yr.

(Source: Sicilian Regional Government – Water Resources Survey, 2000)

Table 30: *Water consumption in the Belice catchment by source.*

Water consumption [Mm^3/yr]	Irrigation	Domestic	Industry	Total
Groundwater	6.2 (68.9%)	2.5 (27.8%)	0.3 (3.3%)	9.0
Surface water	12.7 (42.3%)	17.3 (57.7%)	0.0	30.0
Desalinated water	0.0	0.0	0.0	0.0

Table 31: *Water consumption in the Belice catchment by use.*

Water consumption [Mm^3/yr]	SW	GW	DW	Total
Irrigation	12.7 (67.2%)	6.2 (32.8%)	0.0	18.9
Domestic	17.3 (87.4%)	2.5 (12.6%)	0.0	19.8
Industrial	0.0	0.3 (100%)	0.0	0.3

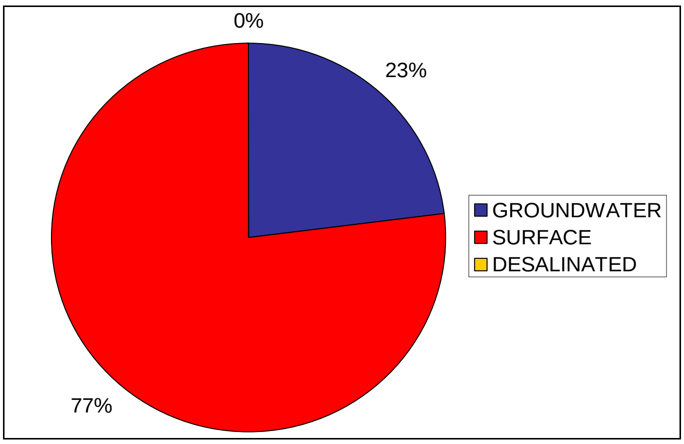


Figure 38: *Water consumed by source in the Belice catchment (39.0Mm^3/yr).*

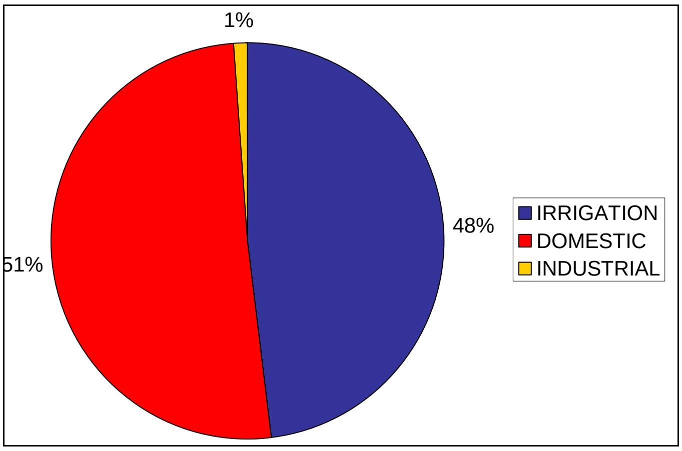


Figure 39: *Water consumption in the Belice catchment by use (39.0Mm^3/yr).*

Consumption index %:

Water consumed (39.0Mm^3/yr) / total water resources (104.5Mm^3/yr): 0.37.

Water consumption per capita (Real water resources: 39.0Mm^3/yr - 120000 inhabitants):

- On yearly basis is 325.0m^3 *and*
- on daily basis is 0.89m^3.

Currently, the potential water resources are not wholly available for use due to several factors; (i) the aquifers are not entirely exploited; (ii) some water resources are taken from this catchment and supplied to other end users.

In order to clarify the latest concept, the water distribution scheme of the study area was investigated and defined. It can be recognised easily by observing figure 40 that the system is rather complex and shows many sources of conflicts between the three main users on the domestic, industrial and agricultural levels.

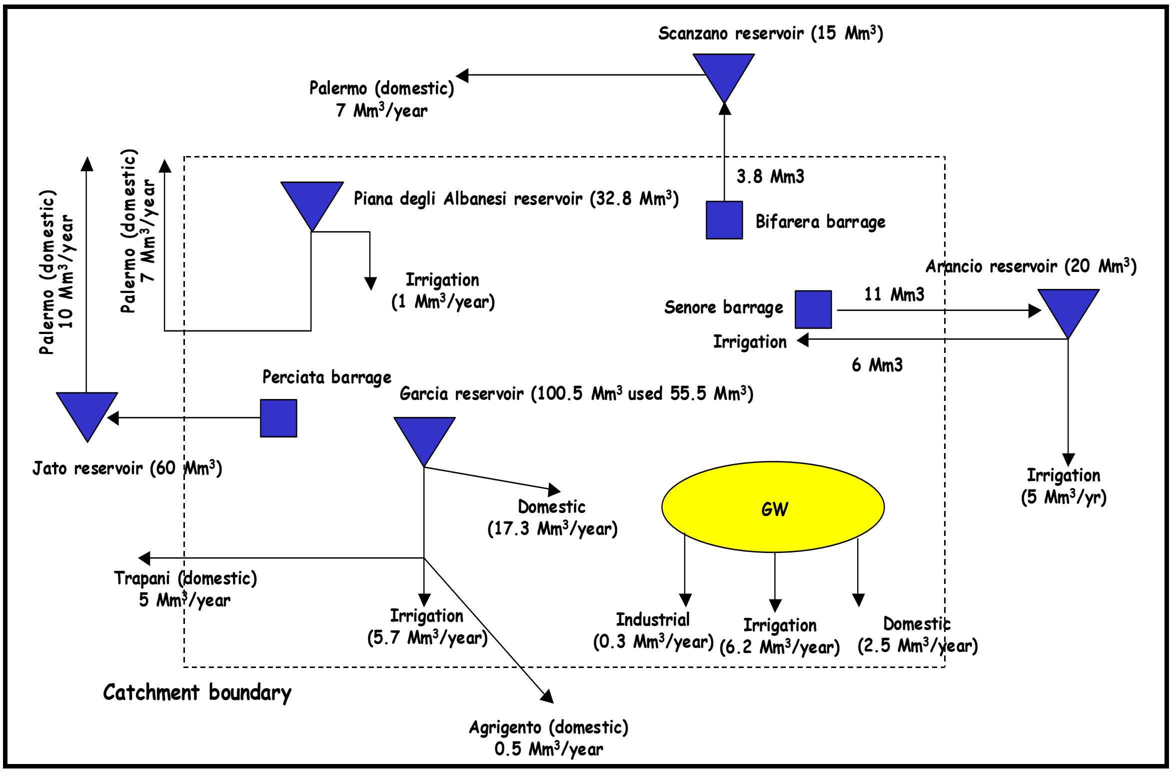


Figure 40: *Water distribution scheme.*

2.6 Agricultural situation

Table 33 shows the land use classes (according to the Corine classification) distribution in the irrigated area. The different irrigation techniques used (drip irrigation, micro sprinkler, micro-irrigation), facilitate water on demand, allow a first estimation of crop water requirements as shown in table 34.

Table 32: *Surface utilisation.*

Surface utilisation	
S_{Belice} [km²]	949.53
N of farms	16,800
Agricultural surface, AS [km²]	850.00
Agricultural surface per farm [km²]	0.051
Irrigable surface [km²]	316.85 (35%)

Only 28% of the Belice basin is irrigated (269.32km²) and the main crops found there are vegetable, forage crops, cereal, orchard, vineyard, olive crops, citrus crops.

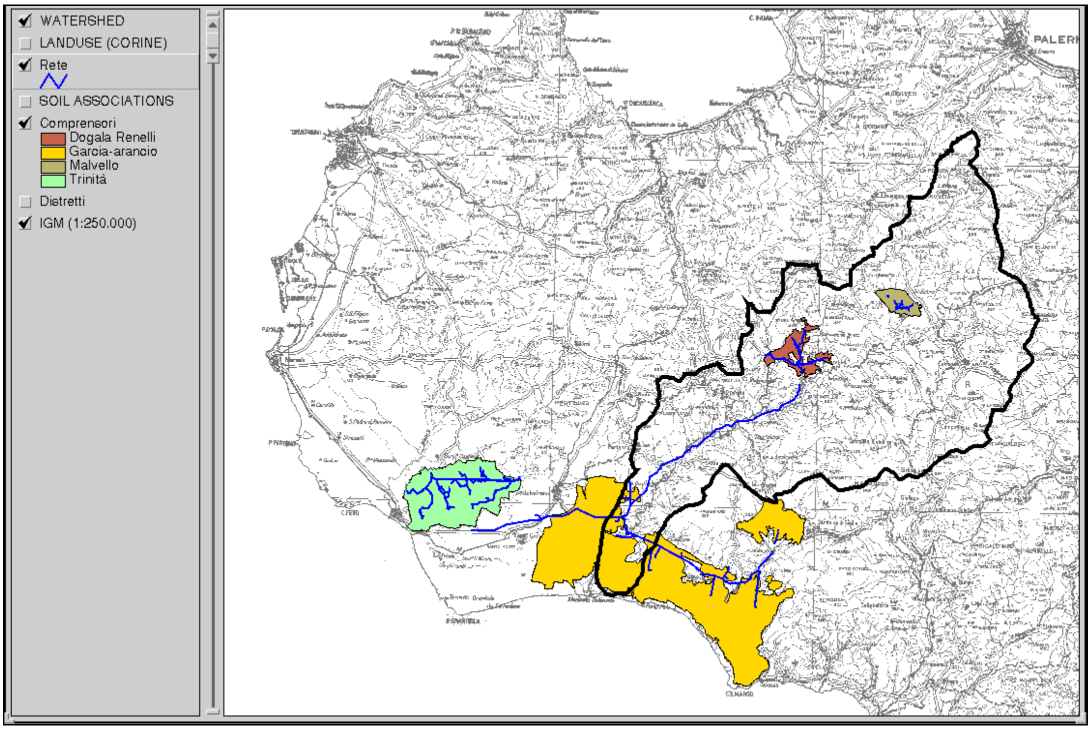


Figure 41: *River basin, irrigation districts and pressurised pipelines.*

Table 33: *Land use distribution in the Belice.*

Land use	Percentage
Type 2: moors and heath land	0.22%
Type 3: area with no vegetation, bare rocks	0.50%
Type 4: permanently irrigated arable land, vegetables	12.34%
Type 5: discontinuous urban fabric	0.52%
Type 6: vineyard	33.89%
Type 7: complex cultivation patterns	1.15%
Type 8: mixed forest	21.07%
Type 9: mineral extraction sites	0.09%
Type 10: arable land and vineyard	12.07%
Type 11: continuous urban fabric	0.17%
Type 16: olive groves	16%
Type 21: mine, dump and contraction sites	0.45%
Type 22: citrus grove	1.33%
Type 41: artificial water bodies	0,003%
Type 47: open spacies with no vegetation, bare rocks und scrub vegetation	0.20%

Table 34: *Water used for irrigation.*

Crop	Water used for irrigation [m^3/km^2]
Vineyard	13.85
Artichoke	26.30
Olive grove	3.48
Vegetables	22.59
Citrus Grove	13.48
Other	13.85

2.7 Socio-economic situation

The following socio-economic data apply to the Belice catchment:

- gross domestic product GDP in the catchment in 1996: 14,040 Millions €,
- gross domestic product GDP per capita: 11,700€,
- gross domestic product GDP divided in percent into *and*
  - Agriculture: 3.8%,
  - Industry: 19.7% *and*
  - Services: 76.5 (including tourism).
- Permanent population: (2002) 120,000 inhabitants.

Employees:

- Agriculture: 24%,
- Industry: 23% *and*
- Services: 53%.

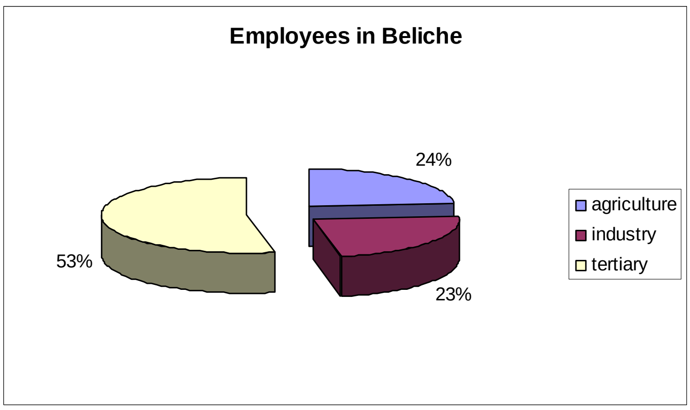


Figure 42: *Employees in the the Beliche catchment.*

Unemployment rate (also seasonally)

Rate of unemployment (2002) 21.0%

The economy of the Belice catchment is structurally rather weak, characterised by a lack of enterprise culture, atomisation of a corporate culture, geographical and strategic remoteness from major markets of the island, heavy financial bonds. In 1996, for example, the regional GDP recorded a nominal variation of 5.7%, witnessing a general lowering of the local economy (GDP growth rate at 0.3%); the added value is represented as follows: 530 millions € in the agricultural sector, 2.76 billions € in industrial production, 7.41 billions € in commercial services sector and 3.34 billions € in uncommercial services. Nowadays, the local enterprise system is divided into a set of micro-enterprises, mostly focused on commerce (39.36% U.L.) and manufacturing (24.87% U.L.). Regarding the agricultural field, the most representative sectors are the viniculture, the cereal-growing, the olive-growing, the orchard one and the zootechnic one.

A small part of the local economy is linked to tourism. The influx of tourists is mainly directed toward the Greek site of Selinunte, the sea town of Menfi, the artistic city of Gibellina and the thermal baths of Montevago.

2.8 Summary table

Table 35: *Summary table II.*

<table>
<tr><td rowspan="22">Natural water conditions and infrastructure</td><td rowspan="5">Catchment context</td><td>Area</td><td colspan="3">949.5 Km²</td></tr>
<tr><td>Climate Type</td><td colspan="3">Mediterranean</td></tr>
<tr><td>Aridity Index</td><td colspan="3">Dry- Subhumid</td></tr>
<tr><td>Permanent Population</td><td colspan="3">120000</td></tr>
<tr><td>Tourists (arrivals)</td><td colspan="3"></td></tr>
<tr><td rowspan="8">Water availability</td><td>Precipitation</td><td colspan="3">500-1000 mm</td></tr>
<tr><td>Total Water Resources/ Availability (hm³)</td><td colspan="3">104.5 Mm³</td></tr>
<tr><td>Water resources
• Surface water
• Ground water
• Storage/dams/reservoirs
• Desalination</td><td colspan="3">76%
24%</td></tr>
<tr><td>Water availability per capita and year</td><td colspan="3">870m³</td></tr>
<tr><td>Resources to population index</td><td colspan="3">Not available at the moment</td></tr>
<tr><td>Water availability per capita
• April-September
• October-March</td><td colspan="3">325m³ (yr)</td></tr>
<tr><td>Trans-boundary water</td><td colspan="3">see scheme</td></tr>
<tr><td rowspan="4">Water quality</td><td rowspan="2">Quality of surface water</td><td>Belice Destro</td><td>Belice Sinistro</td><td>Belice dopo la confluenza</td></tr>
<tr><td>poor</td><td>good</td><td>poor</td></tr>
<tr><td>Quality of groundwater</td><td colspan="3">Good</td></tr>
<tr><td>Quality of coastal water</td><td colspan="3">Good</td></tr>
<tr><td rowspan="2">Water Supply</td><td>Supply coming from:
• Groundwater
• Surface water
• Desalination
• Recycling
• Importing[1]</td><td colspan="3">23%
77%</td></tr>
<tr><td>Network coverage:
• Domestic
• Irrigation
• Sewerage</td><td colspan="3"></td></tr>
</table>

Table 35 continued.				
Economic and Social system agriculture and tourism	**Water use**	Water consumption by category: • Domestic (incl. tourism) • Tourism • Irrigation • Industrial and energy prod.	51% - 48% 1%	
		Water consumption for domestic coming from (incl. tourism) • Groundwater • Surface water • Desalination • Importing For tourism coming from • Groundwater • Surface water • Desalination • Importing For irrigation coming from • Groundwater • Surface water • Desalination • Recycling • Importing For industry coming from • Groundwater • Surface water • Desalination • Recycling and importing	19.8 Mm³/yr 12.6 % 87.5 % - - 18.9 Mm³/yr 32.8 % 67.2% 0.3 Mm³/yr 100%	
	Water demand	Water Demand trends	Increasing	
		Consumption index :	0.37	
		Exploitation index :	Not available at the moment	
	Agriculture issues	Area used	316.85km²	
		Irrigated area	269.32km²	
		Cultivated crop types (per area)	Shrubs	0.22%
			untilled	0.50%
			vegetable, forage crops, cereal orchard	12.34%
			sparse urbanisation	0.52%
			vineyard	33.89%
			complex cropping systems	1.15%
			mixes orchard	21.07%
			mining areas	0.09%
			vineyard-cereal intercrop	12.07%
			dense urbanisation	0.17%
			olive crops	16%
			marginal land	0.45%
			citrus crops	1.33%
			artificial lakes	0.003%
			untilled with dwarf palm	0.20%

<table>
<tr><td colspan="7">Table 35 continued.</td></tr>
<tr><td rowspan="29">Economic and Social system agriculture and tourism</td><td rowspan="11">Agriculture issues</td><td>Irrigation methods</td><td colspan="4">Olive groves: drip irrigation;
Fruit trees: micro sprinkler
Vegetables: micro irrigation</td></tr>
<tr><td>Water used for irrigation (per area)</td><td colspan="4">935,550m³/km²</td></tr>
<tr><td>Water demand per crop and area</td><td colspan="4">Not available at the moment</td></tr>
<tr><td rowspan="7">Fertilisers used - average</td><td></td><td>N [kg/ km²]</td><td>P [kg/ km²]</td><td>K [kg/ km²]</td></tr>
<tr><td>Olive groves</td><td>3000</td><td>1000</td><td>2000</td></tr>
<tr><td>Vineyard</td><td>18000</td><td>9000</td><td>12000</td></tr>
<tr><td>Fruit trees</td><td>18000</td><td>13000</td><td>10000</td></tr>
<tr><td>Vegetables</td><td>8000</td><td>12000</td><td>15000</td></tr>
<tr><td>Artichoke</td><td>20000</td><td>10000</td><td>10000</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Pesticides used - average</td><td colspan="4">Not available at the moment</td></tr>
<tr><td rowspan="3">Social and economic situation</td><td>Unemployment rate</td><td colspan="4">21%</td></tr>
<tr><td>Employees in
• Agriculture
• Industry
• Services</td><td colspan="4">24%
23%
53%</td></tr>
<tr><td>Importance of water scarcity</td><td colspan="4">high</td></tr>
<tr><td rowspan="9">Pricing system</td><td>Average household budget for domestic water</td><td colspan="4">190€/yr</td></tr>
<tr><td>Average household budget for agricultural water</td><td colspan="4">Not available at the moment</td></tr>
<tr><td>Average household income</td><td colspan="4"></td></tr>
<tr><td>Contribution of agriculture to catchment economy</td><td colspan="4">3.8%</td></tr>
<tr><td>Water prices</td><td colspan="4">0.85€/m³ for domestic use
not available for agriculture use</td></tr>
<tr><td>Energy prices for used water technology</td><td colspan="4">Not available at the moment</td></tr>
<tr><td>Cost recovery</td><td colspan="4">Not available at the moment</td></tr>
<tr><td>Price elasticity</td><td colspan="4">Medium</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="3">Social capacity building</td><td>Public participation in decisions</td><td colspan="4">Bad</td></tr>
<tr><td>Public education on water conservation issues</td><td colspan="4">Bad</td></tr>
<tr><td>Acceptability in using treated waste water</td><td colspan="4">There is not use of treated waste water</td></tr>
</table>

<table>
<tr><td colspan="4">Table 35 continued.</td></tr>
<tr><td rowspan="4">Decision Making Process</td><td rowspan="2">Water Resources Manage-ment</td><td>Water ownership</td><td>State</td></tr>
<tr><td>Decision making level (municipal, regional, national) regarding:
• Water supply for each sector
• Water resources allocation for each sector</td><td>Intra-Regional
Regional
Municipal</td></tr>
<tr><td rowspan="2">Water Policy</td><td>Local economic basis</td><td>Agriculture, services, industry</td></tr>
<tr><td>Development priorities</td><td>Agriculture, tourism</td></tr>
</table>

[1] *Surface and ground water from other Water Regions.*

Report on Crete

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Dimitris Papamastorakis***, Anastasios Xepapadeas*,
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Abstract

The area of Crete covers 8336km^2; the mean altitude is 460m and the total population is about 600,000 people. The climate is considered to be sub-humid Mediterranean with humid and relatively cold winters and dry and warm summers. The average annual precipitation is about 927mm/yr. The potential renewable water resources are 2,120Mm^3 and the real water used is about 372Mm3/yr. Despite considerable precipitation, it is estimated that from the total precipitation in plains per year about 62% is lost to evapotranspiration, 10% as runoff to sea and only 28% goes to recharging the groundwater. Crete has high per capita water availability, which is slightly lower than that of the country. The major water use in Crete is irrigation for agriculture (83.3% of the total consumption) while domestic use including tourism is 15.6% and industrial use 1%. The demand for irrigation water is high, while at the same time only 31% of the available agricultural land is irrigated. The main vegetable crops grown in Crete are fresh tomatoes, cucumbers, potatoes, eggplants, onions, watermelons, melons, cabbages and peppers, while among fruit crops olive covers more than 89% followed by citrus 3.4%, almonds and avocados.

Crete shows significant regional variations in water availability, especially in coastal, eastern and southern regions due to tourism and agriculture. The rainfall is not uniformly distributed throughout the year, and it is mainly concentrated in the winter months while the drought period is extended to more than six months (May to October) with pan evaporation values ranging from 140 to more than 310mm in the peak months. Long series rainfall data all over Crete does not show any significant change in precipitation. The temperature of the area shows a great variation. Crete lies between the isotherms 18.5-19^{o}C. The annual temperature range is 17-20^{o}C. The south of the island is warmer than the northern part and is the warmest region in Greece.

The geology of Crete can be described in terms of four pre Neogene major nappes and one autochthonous isopic zone with a cumulative thickness of 6.5km. It is estimated that approximately 20% of the groundwater resources of the island, totaling approximately 2.1billion m^3, are associated with Neogene-Quaternary aquifers while the remaining 80% are associated with their deep karstic counterparts. There are no perennial streams on Crete and the total mean annual runoff is estimated to be in the region of 0.74billion m^3. The contribution of the surface water to the potential water resources of Crete is about 35%. The real contribution though is about 5%, which means that almost all the water quantity used in Crete comes from subterranean sources (springs, wells and boreholes).

The main issue in water resources management on the island is focused on the uneven geographical distribution of water resources in relation to the water demand hotspots on the island. The key actions adopted by the Regional Governor of Crete for the implementation of the recommended strategic response to the water resource problems

are the following: Protection of groundwater resources against over-exploitation; restrictions in issuing groundwater abstraction license in areas under pressure; pollution control of surface and groundwater; monitoring of water quality; protection of coastal aquifers from saline intrusion; exploitation of Un(der)Exploited Aquifers such as karstic aquifers; implication of a water plan on a watershed basis for detailed water management; the investigation and implementation of artificial recharge of aquifers; feasibility studies for further introduction of surface reservoirs; the improvement of the information services in rural scale; the application of modern effective irrigation methods; improved freshwater storage and transport; groundwater recharge promotion; reuse of water after treatment; utilisation of untapped surface water sources; interbasin transfer; agricultural, industrial and domestic demand reduction.

It should be noted that water availability in average terms is not the limiting factor. Much more important are the significant regional and seasonal variations in water availability and demand. To overcome the water shortage, especially in the future, several measures should be taken for the conservation of water resources and protection of the environment.

Introduction

The island of Crete may be characterised as having marginal water resources, which, although still adequate at present, are supposed to decline by 2025. Irrigation and tourism create peak demands resulting in a seasonal pattern of water demand with an annual volume of waters abstracted exceeding 50% of the average annual runoff or 35% of the groundwater potential. It is therefore considered essential that the water problems the island faces can be effectively encountered only by strategic policies based on integrated water management systems. The climate is considered to be sub-humid Mediterranean with humid and relatively cold winters and dry and warm summers. The average annual precipitation is estimated to be 927mm; the potential renewable water resources 2120Mm^3 and the real water used about 372Mm^3/yr.

Chapter I: Overview of the island

Crete is the biggest of the Greek islands with an area of 8,336km^2 and is located in the southern area of Greece. Its mean altitude is 460m and the total population is about 600,000 people.The region of Crete consists of four prefectures: Iraklion prefecture whose capital is the city of Iraklion; Chania prefecture whose capital is the city of Chania; Rethymnon prefecture whose capital is the city of Rethymnon; and Lasithi prefecture whose capital city is Aghios Nikolaos. The city of Iraklion is the capital city of both the island of Crete and the prefecture of Iraklion.

The climate is considered to be sub-humid Mediterranean with humid and relatively cold winters and dry and warm summers (Chartzoulakis et al., 2001). The average annual precipitation is estimated to be 927mm; the potential renewable water resources 2120Mm^3 and the real water used about 372Mm^3/yr. The major water use in Crete is irrigation for agriculture (83.3% of the total consumption) while domestic use, including tourism, is 15.6% and industrial use 1%. Crete shows significant regional variations in water availability, especially in coastal, eastern and southern regions due to tourism and agriculture. It has high per capita water availability, which is slightly lower than that of the country. The demand for irrigation water is high, while at the same time only 31% of the available agricultural land is irrigated. The growing water requirements make the rational management of water resources extremely important for development to be sustainable and for the environment to be served (Chartzoulakis et al., 2001).

Figure 1: *Geophysical map of Crete, (Regional Governor of Crete).*

1.1 Physical characteristics

1.1.1 Climate

The present climate of Crete is sub-humid Mediterranean with humid and relatively cold winters and dry and warm summers. The annual rainfall ranges from 300 to 700mm in the low areas and along the coast (Lerapetra 312mm, Iraklio 512mm and Chania 665mm) and from 700 to 1,000mm in the plains of the mainland, while in the mountainous areas it reaches up to 2,000mm (Chartzoulakis et al., 2001). During winter, starting in November the weather is unstable due to frequent changes of low and high pressures. Long timeseries of rainfall data all over Crete does not show any significant change in precipitation (Markou-Iakovaki, 1979; Macheras & Koliva-Machera, 1990).

The rainfall is not uniformly distributed throughout the year and concentrates mainly on the winter months while the drought period is extended to more than six months (May to October with pan evaporation values ranging from 140 to more than 310mm in the peak month (Chartzoulakis et al., 2001).

As noticed, more than one-third of the total precipitation occurs along the northern coast of the island in the three main mountainous terrains (White Mountain, Idi and Dikti).

Spring is short because of the cold fronts often affecting the region in March, whereas May is rather warm, especially due to the appearance of the first south winds and the disappearance of the action of low pressures. North winds are dominant in the island. In summer the north winds predominate, creating very dry conditions, which are additionally enhanced by the diminishing of low pressures in the Eastern Mediterranean and are only interrupted by some local rainfall of tropical origin (Chartzoulakis et al., 2001).

The temperature of the area shows a great variation. On an annual basis, the temperature ranges between 17-20^{o}C. The southern part of the island is warmer than the northern part and it is the warmest area of Greece. During the cold period, temperature increases with decreasing latitude, whereas in the warm period and especially in the period from May to August, temperature increases from the coast to the mainland and particularly in the plains. In winter the lowest temperatures scarcely fall below 0^{o}C in the plains. During the summer temperatures higher than 40^{o}C may occur in the lowlands of Crete. The annual temperature has increased by 0.3^{o}C over the last two decades (Chartzoulakis et al., 2001).

1.1.2 Geology

The geology of Crete can be described in terms of four pre Neogene major nappes and one autochthonous isopic zone with a cumulative thickness of 6.5km. The nappes were transported from the north along E-W trending thrusts and were emplaced between Late Eocene and early Miocene times. Shortly after nappe emplacement during the Middle Miocene an N-S extensional regime was established in the region due to the initiation of subduction in the Hellenic trench. The extensional tectonics has resulted in the development of numerous E-W grabens with offsets of up to 5km. This period was associated with the deposition within the grabens of Miocene to Quaternary sediments, which consist mainly of red beds, sandstones, marls, limestones and evaporites (Regional Governor of Crete, 2002). It is the nappe emplacement and post emplacement tectonic and depositional history of the island, which formulated its present day hydrogeological structure. The Neogene-Quaternary sediment filled grabens host shallow aquifers whereas the carbonates of the pre Neogene nappes host the deep karstic aquifers. Furthermore, the major fault systems play a central role in the ground water flow regime and spring discharge by imbedding or facilitating flow, depending on their relative structural positions. It is estimated that approximately 20% of the groundwater resources of the island (totaling approx. 2.1billion m^3) are associated with the Neogene-Quaternary aquifers, whereas the remaining 80% represent the groundwater potential of deep karstic counterparts (Regional Governor of Crete, 2002).

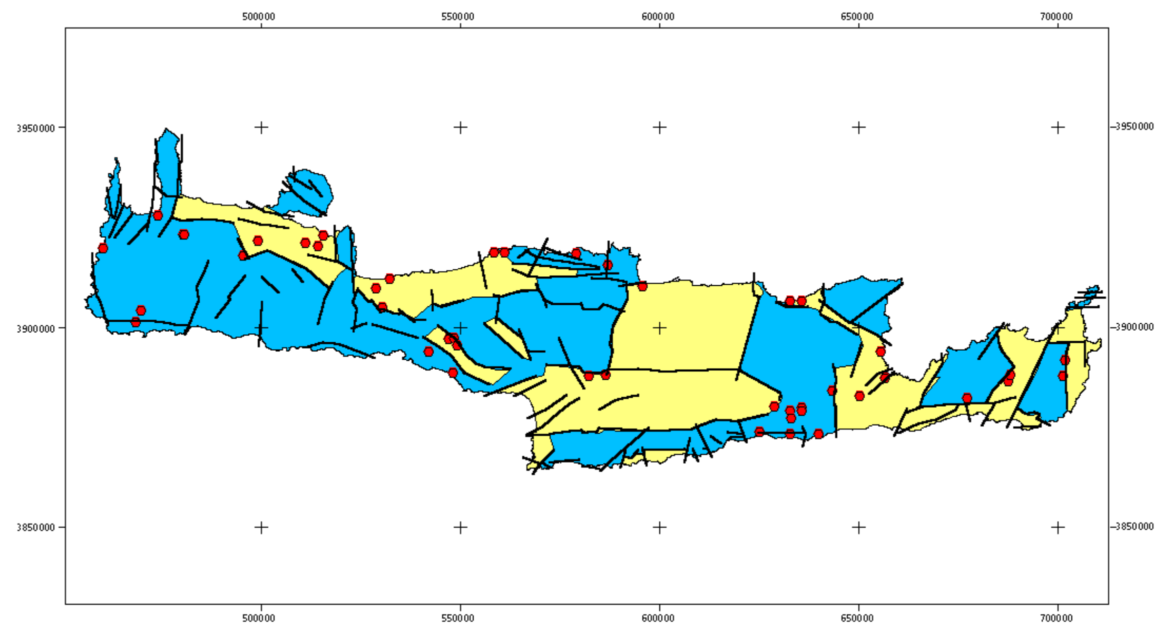


Figure 2: *Spatial distribution of Neogene – Quaternary sediment. Filled grabens hosting shallow, mainly alluvial aquifers (yellow) and pre Neogene formations hosting deep karstic aquifers (blue). Also depicted are the major fault systems (black lines) and the most important karstic springs (red dots), (Regional Governor of Crete).*

karstic aquifers occupy an area of 3,200km^2 (39% of the total area of the island) and are characterised by negligible runoff and high infiltration rates. It is estimated that 40 to 55% of the mean annual precipitation infiltrates into the ground, in these formations, creating a renewable annual groundwater potential of approximately 1.25 billion m^3, 80% of which is discharged from karstic springs the majority of which are unfortunately disposed along the coast, thus contaminated by intruding seawater (Regional Governor of Crete, 2002). The Neogene and Quaternary sediment filled grabens occupy an area of 3,000km^2 (36% of the total area of the island), include the major plains and are commonly characterised by a rich network of streams due to the presence of surface marly deposits and shallow aquifers hosted by quaternary alluvial and/or older sandstone-conglomeratic deposits with a renewable annual groundwater potential of approximately 0.25billion m^3. These plains are the focus of intense agricultural activity with cultivation of olives, grapes, fruits and vegetables. The alluvial aquifers, which are among the most productive on the island, have undergone severe overexploitation (Regional Governor of Crete, 2002).

The remaining 25% of the island comprises aquitards of impermeable geological formations such as phyllites and flysch, characterised by a rich network of streams. It should be noted that there are no perennial streams on Crete and the total mean annual runoff is estimated to be about 0.74 billion m^3 (Regional Governor of Crete, 2002). There are three main mountainous terrains in Crete (White mountain, Idi and Dicti). These three mountains extend over an area of 1,900km^2 and consist mainly of limestone masses intensely karstic.

1.1.3 Hydrology

1.1.3.1 Precipitation

The average annual precipitation in Crete is estimated to be 927mm. Rainfall decreases from west to east and from north to south and is higher at high elevation areas than in the lowlands. As mentioned above, the annual rainfall ranges from 300 to 700mm in the low areas and along the coast (Ierapetra 312mm, Iraklio 512mm and Chania 665mm), and from 700 to 1,000mm in the plains of the mainland, while in the mountainous areas it reaches up to 2,000mm (Chartzoulakis et al., 2001). More than one third of the total precipitation occurs along the northern coast of the island in the three mountainous terrains (White Mountains, Idi, Dikti). Figure 3 shows the monthly variation of rainfall at the Askifou rainfall station (White Mountains), which has an elevation of 740m and a mean annual rainfall of 2085mm.

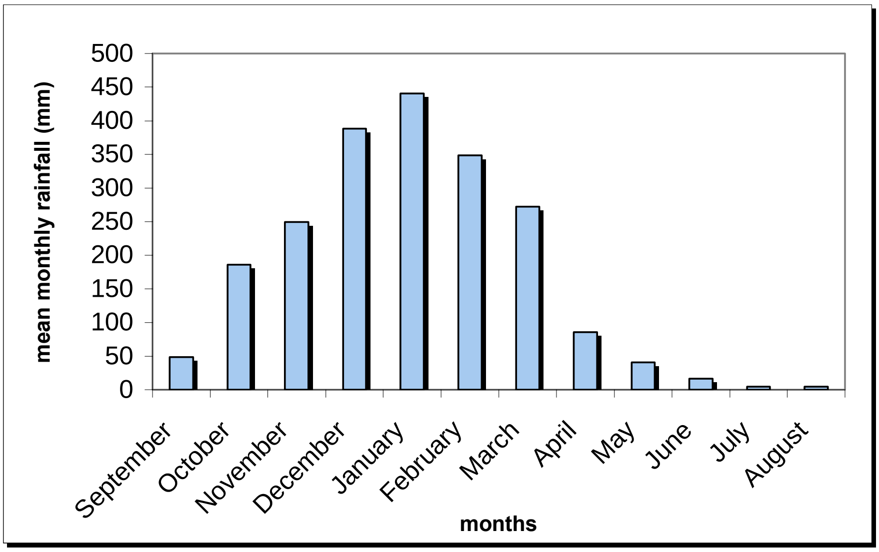


Figure 3: *Monthly variation of rainfall at the Askifou rainfall station, (White Mountains).*

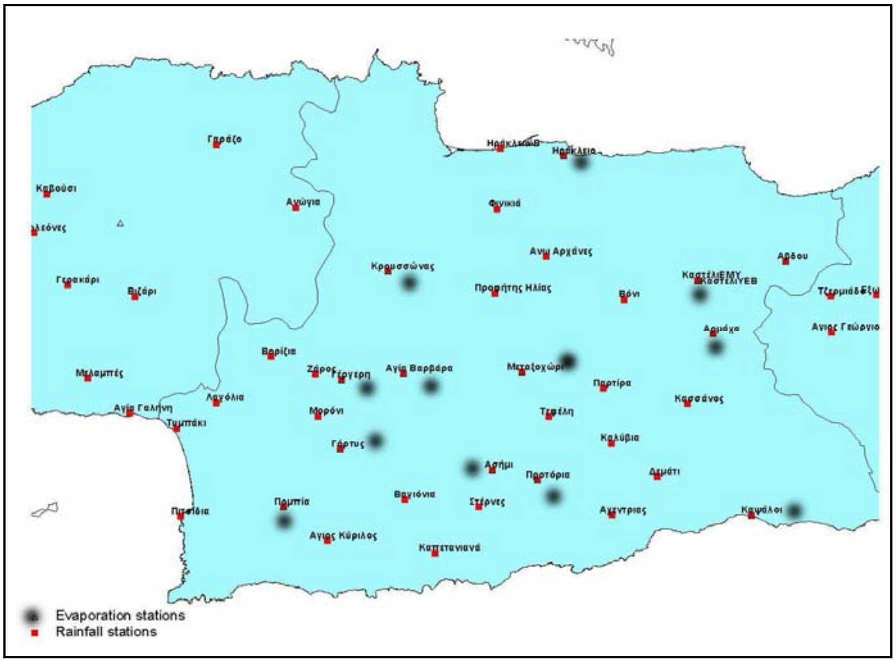


Figure 4: *Rainfall and evaporation stations in the prefecture of Iraklion, (Regional Governor of Crete).*

There are 56 stations in Crete measuring rainfall. Of those stations 28 are situated in the Iraklion prefecture, 10 in the Rethymnon prefecture, 12 in the Lasithi prefecture and 6 in the Chania prefecture. The spatial distribution of the rainfall stations in Iraklion prefecture is shown in figure 4. There is a fairly even spatial distribution of stations in the prefecture. Figure 5 shows the distribution of rainfall stations and their height for Iraklion prefecture. Most stations are found in heights between 200 and 500m while there are only three stations between 500 and 800m and five stations in heights lower than 200m. Figure 6 shows the correlation between rainfall and height in the prefecture of Iraklion. The highest precipitation is observed at Borizia station with an elevation of 520m and a mean annual rainfall of around 1,100mm, while the lowest precipitation is observed at Kapsaloi station with an elevation of 10m only and a mean annual rainfall of 410mm. The station with the highest elevation in the prefecture (Kapetaniana station at an elevation of 800m) has a mean annual precipitation of 680mm. Borizia station lies in the mainland in West Messara valley and shows higher precipitation than Kapetaniana station, which has a higher elevation, but it lies closer to the south coast in the same valley. Figure 7 shows the mean annual rainfall distribution for the different stations in Iraklion.

According to Macheras and Koliva_Machera (1990) the annual average rainfall in the Iraklion prefecture for the period 1909-1987 was 489m. The seasonal precipitation ranged from 252mm in winter, to 95mm in spring, to 5mm in summer and 138.2mm in autumn Two moist periods were observed, the first one lasting for 16 vears (1917-1932) and the second one for 8 years (1961-1969), and one dry period lasting for 23 years (1938-1960). During the first moist period there was an increase in precipitation of 13% while for the second period the increase was around 28%. It was concluded that the dry season in Iraklion lasts for five months (November to March) and the moist for seven. The dry period was accompanied by a 13% decrease in rainfall (Macheras and Koliva-Machera, 1990).

The profile for mean annual and monthly rainfall for the years 1969 to 1999 of the existing stations in the prefecture of Iraklion is shown in figures 8 and 9. The wettest year for the Iraklion prefecture was 1977-1978, while the driest year appears to have been the hydrological year 1989-1990.

The spatial distribution of rainfall and evaporation stations in the prefecture of Lasithi is shown in figure 1. Figure 11 shows the correlation between rainfall and elevation for the prefecture.

The highest mean annual precipitation is observed at Exo Potamoi station which has an elevation of 800m and mean annual rainfall of 1,360mm, while the lowest mean annual precipitation is observed at Siteia station, which has an elevation of 114m and mean annual rainfall of 490mm.

The station with the highest elevation (Agios Georgios at 850m) shows a mean annual precipitation of 1056mm. Stations with lower elevations than Siteia station (Kalo Xwrio, Palaikastro, Paxeia Ammos) show higher mean annual precipitation.

The driest year for Lasithi was the hydrological year 1989-1990 and the wettest one the hydrological year 1986-1987.

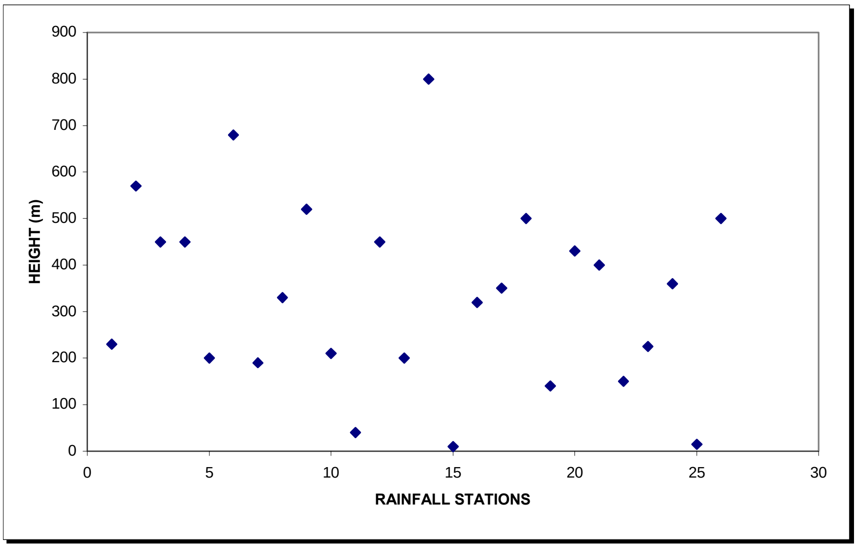


Figure 5: *Rainfall stations height distribution in the prefecture of Iraklion.*

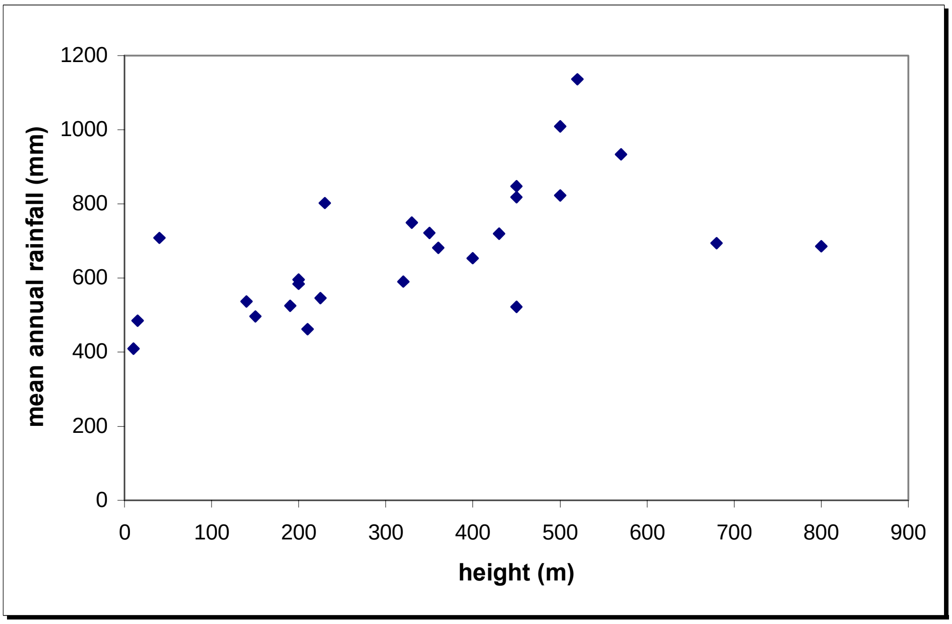


Figure 6: *Rainfall – height distribution in the prefecture of Iraklion.*

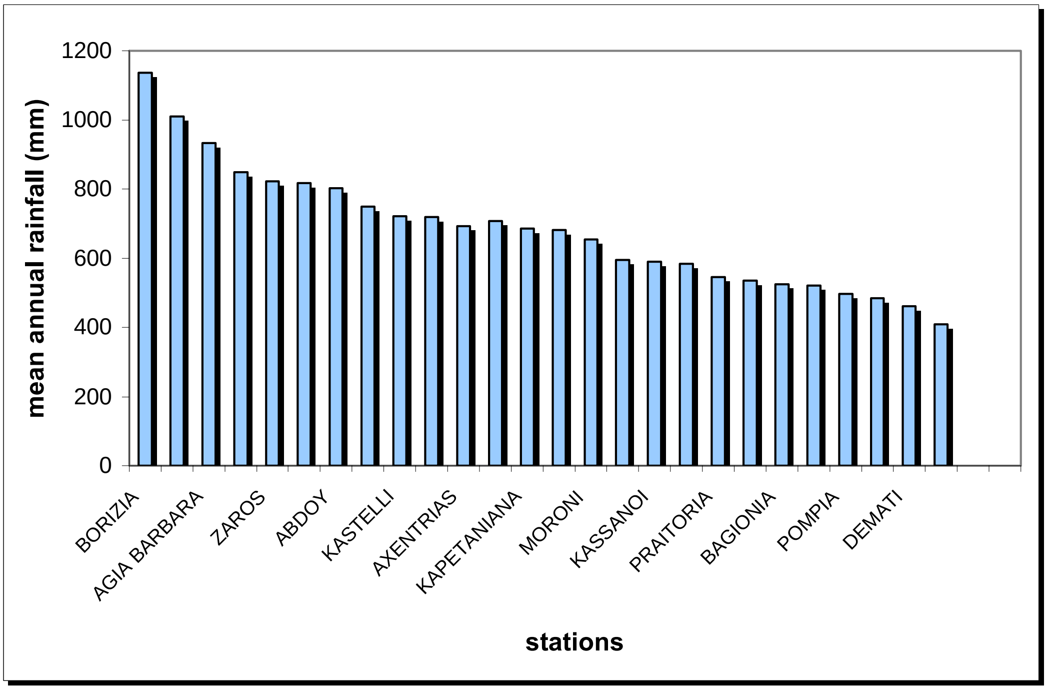


Figure 7: *Rainfall distribution in Iraklion.*

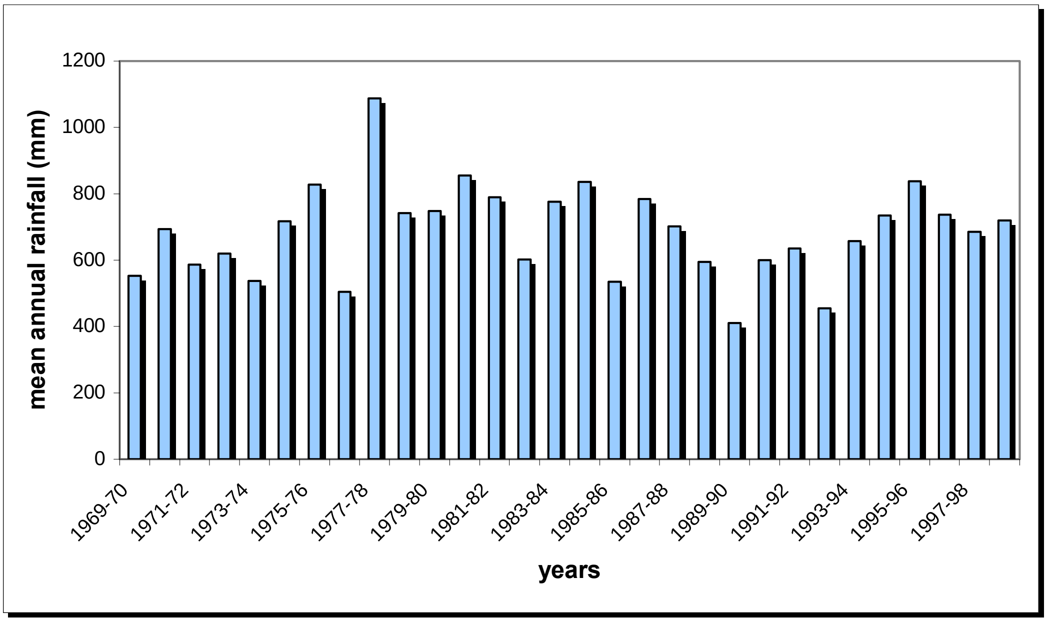


Figure 8: *Mean annual rainfall in the prefecture of Iraklion.*

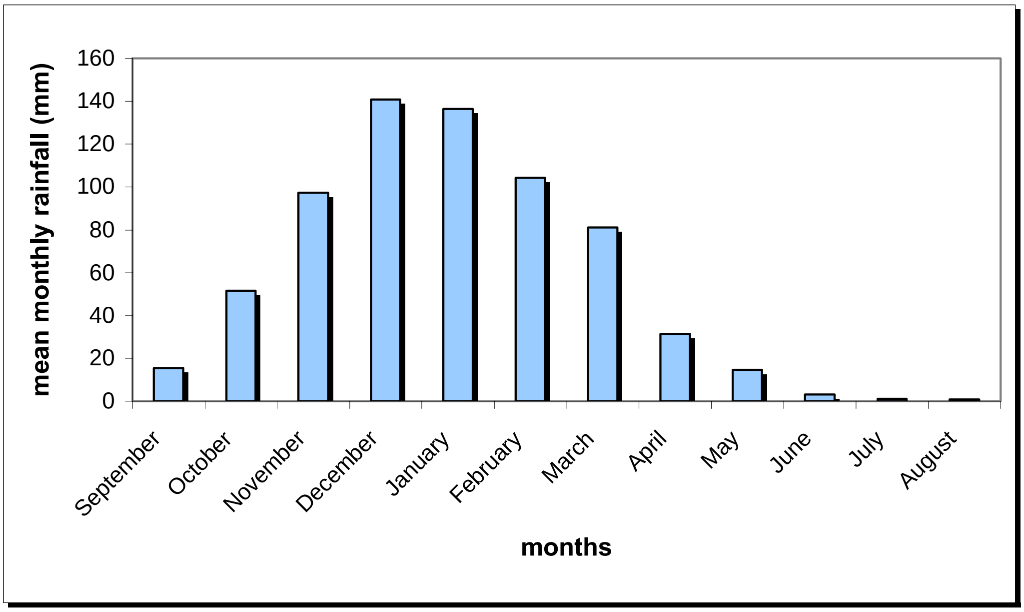


Figure 9: *Mean monthly rainfall pattern in the prefecture of Iraklion.*

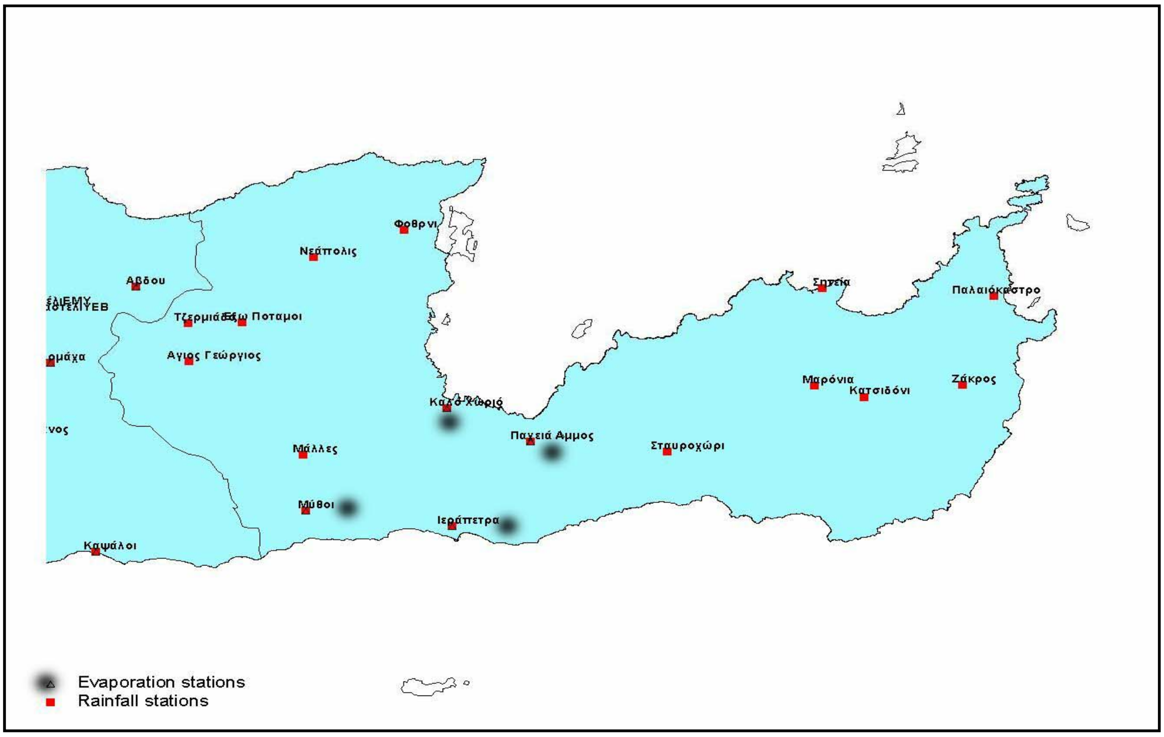


Figure 10: *Rainfall and evaporation stations in the prefecture of Lasithi.*

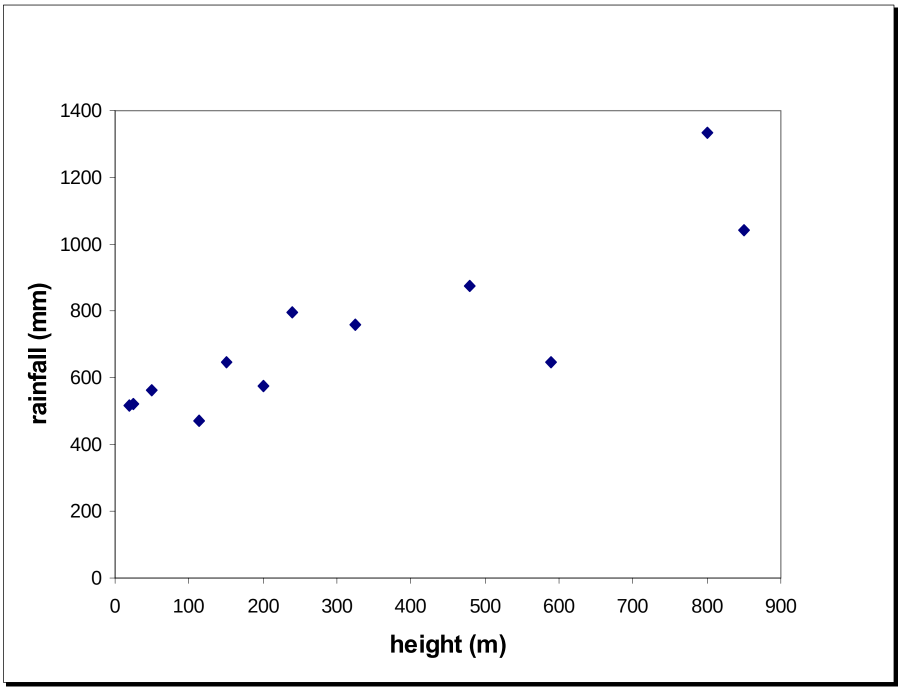


Figure 11: *Rainfall distribution with height in the prefecture of Lasithi.*

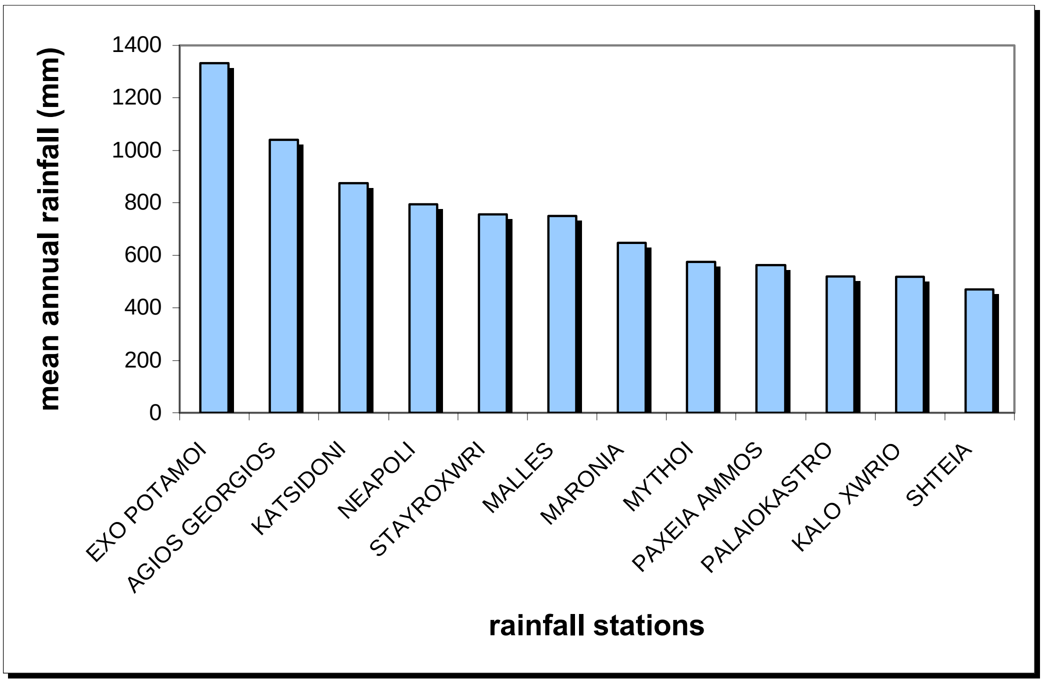


Figure 12: *Rainfall distribution in the prefecture of Lasithi.*

In the Chania prefecture the existing rainfall stations, are set up at elevations between 20 and 740m as shown in figure 14. Figure 15 shows the correlation between rainfall and elevation. The highest precipitation is observed at Askifou station while the lowest precipitation is noted at the island of Gavdos in the very south of the prefecture, which has an elevation of 10m and mean annual precipitation of 330mm (figure 16).

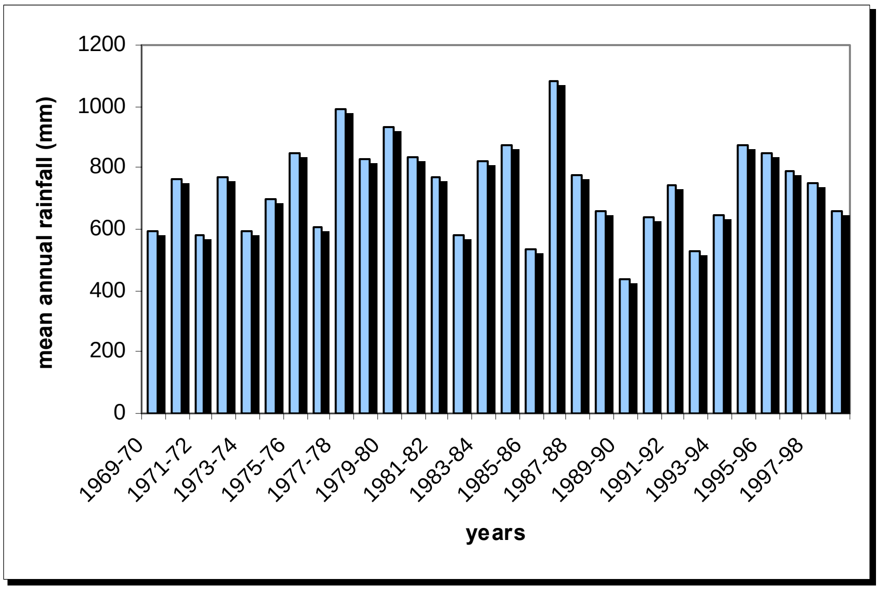


Figure 13: *Mean annual rainfall in the prefecture of Lasithi.*

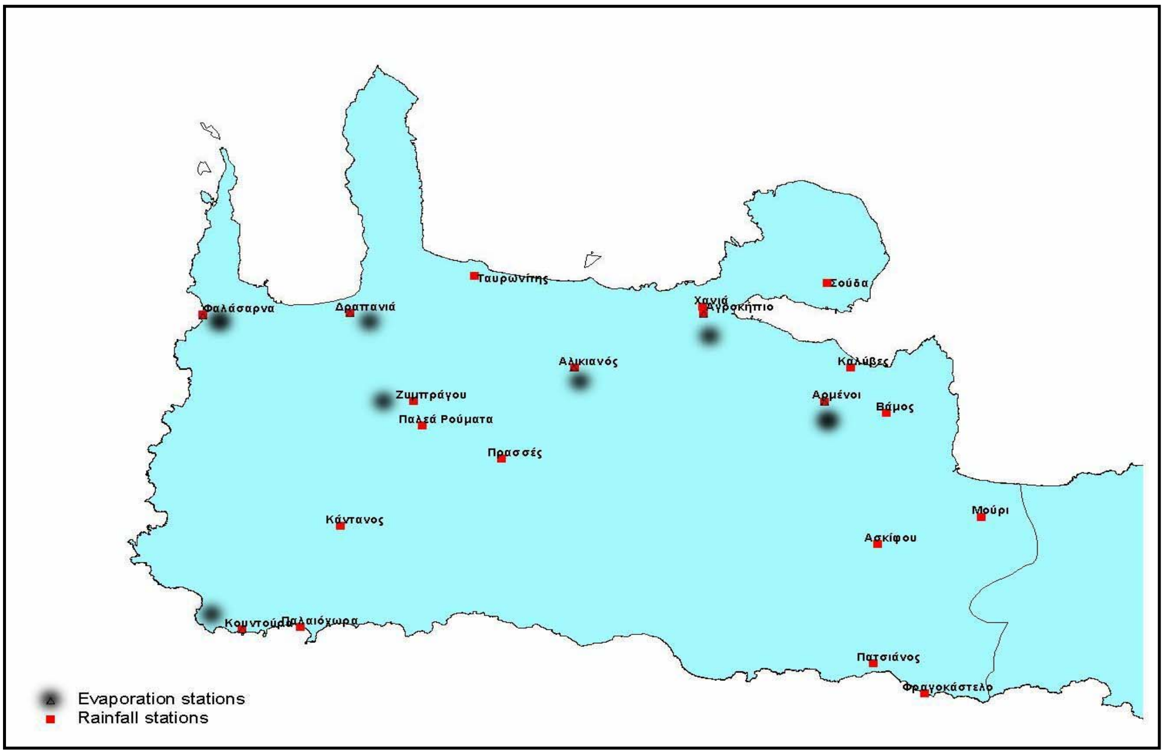


Figure 14: *Rainfall and evaporation stations in the prefecture of Chania.*

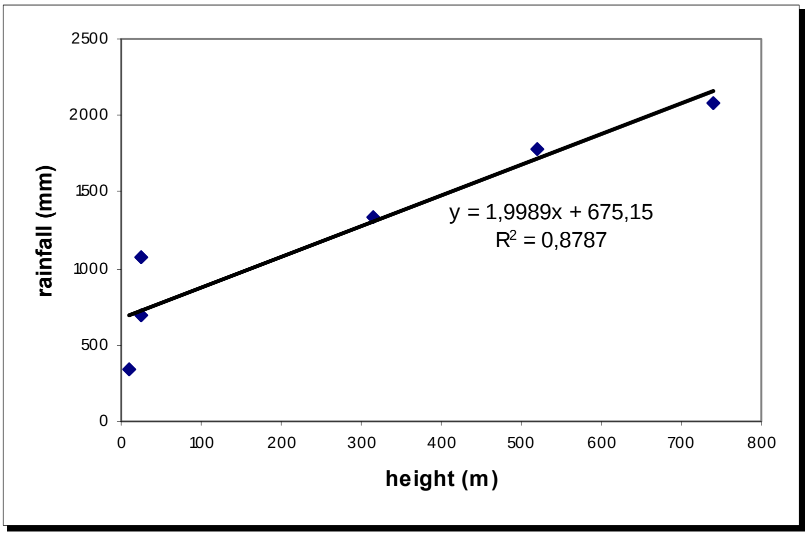


Figure 15: *Rainfall distribution depending on height in the prefecture of Chania.*

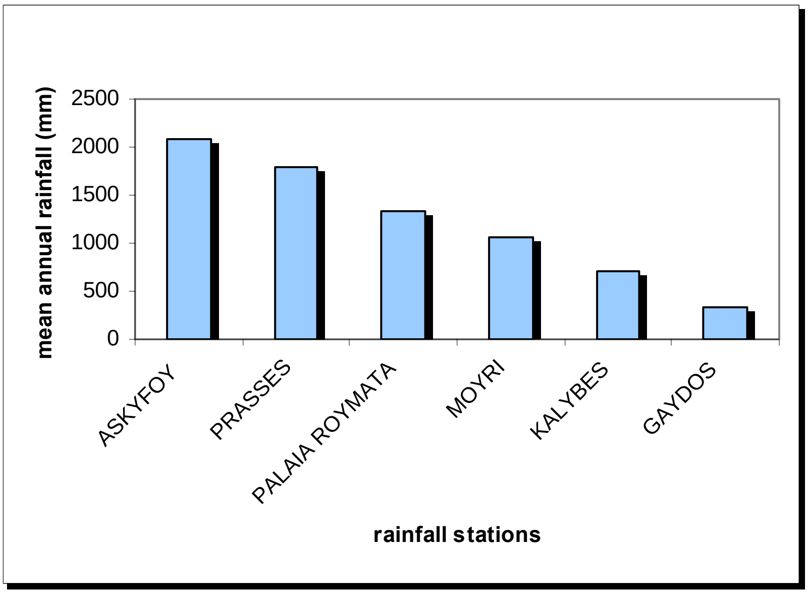


Figure 16: *Rainfall distribution in the prefecture of Chania.*

For Rethymnon prefecture the spatial distribution and the height distribution of the rainfall stations are shown in figures 17 and 18 respectively. The highest precipitation is observed at Garazo station and the lowest at Agia Galini station. Garazo station has an elevation of 260m and shows mean annual rainfall of 1,370mm. Agia Galini station lies in the south of the prefecture near Tympaki and has an elevation of 20m and mean annual precipitation of 570mm. The station with the highest elevation in the prefecture is Anogeia station, which is located 740m ASL. Anogeia station shows a mean annual precipitation of 1,030mm. The rainfall distribution in the prefecture is depicted in figure 19.

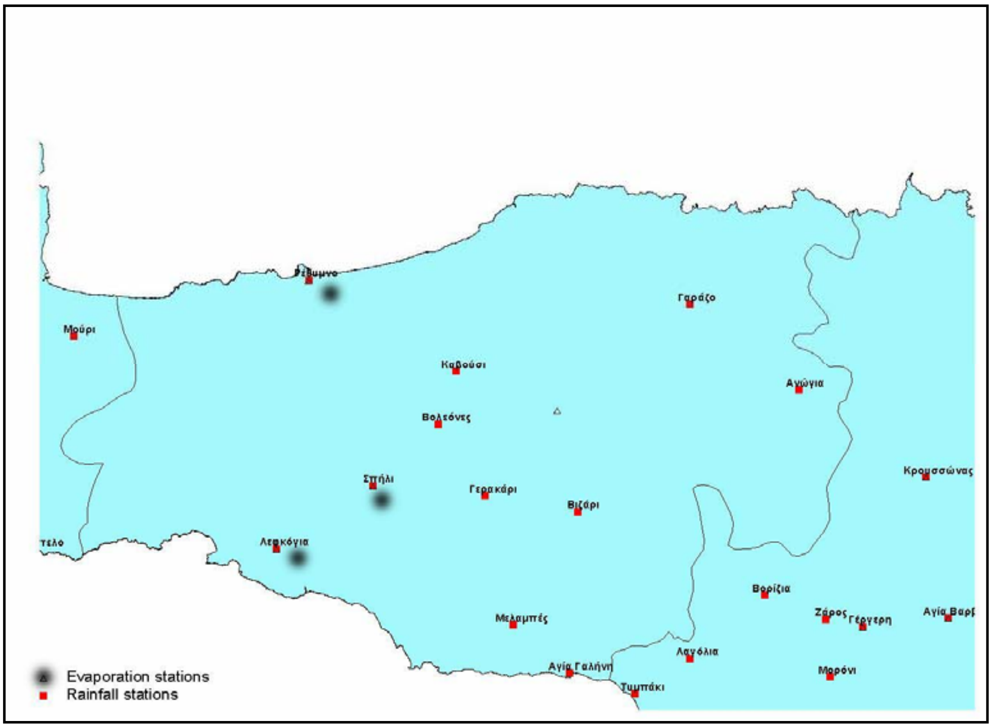


Figure 17: *Rainfall and evaporation stations in the prefecture of Rethymnon, (Regional Governor of Crete).*

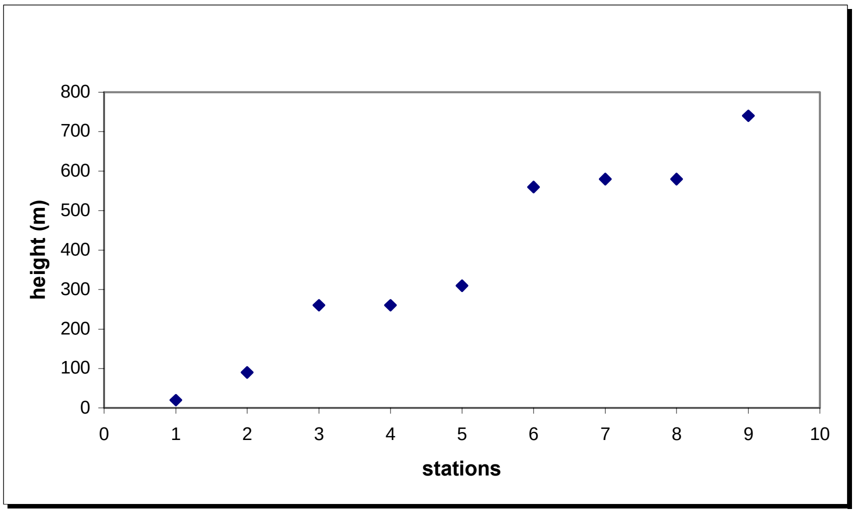


Figure 18: *Height distribution of rainfall stations in the prefecture of Rethymnon.*

The rainfall data of the past thirty years of the stations in Rethymnon show that the driest year for the prefecture was the hydrological year 1977-1978 while the wettest year was 1989-1990. The same situation is observed for the Iraklion prefecture. Figures 20 and 21 show the mean annual and mean monthly rainfall in Rethymnon prefecture.

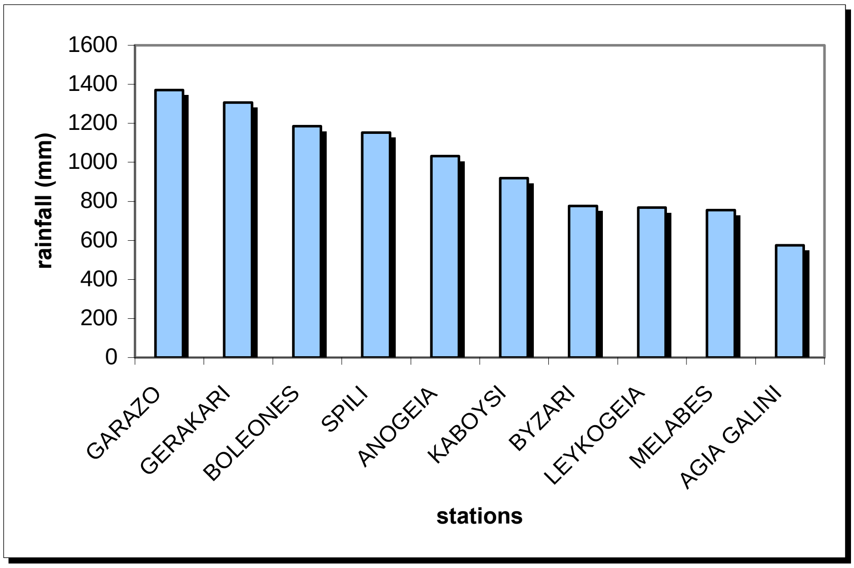


Figure 19: *Rainfall distribution in the prefecture of Rethymnon.*

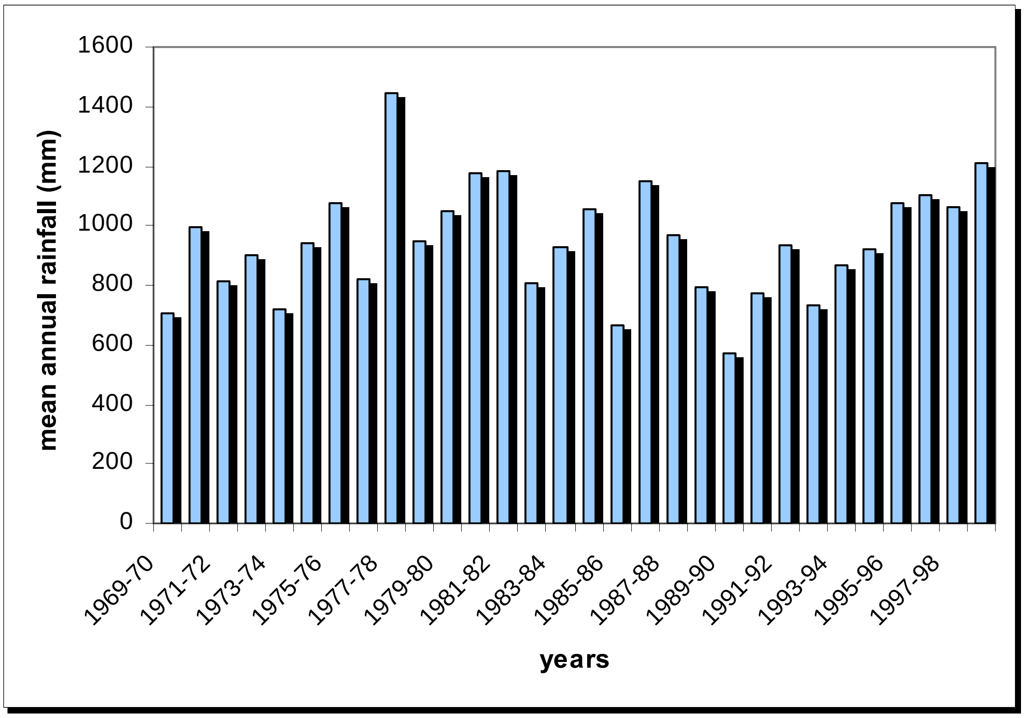


Figure 20: *Mean annual precipitation in Rethymnon.*

Data from the 56 existing rainfall stations in Crete shows that the highest precipitation is observed at Askifou station in the Chania prefecture and the lowest on the island of Gaydos south of the Chania prefecture. This pattern is depicted in figure 22.

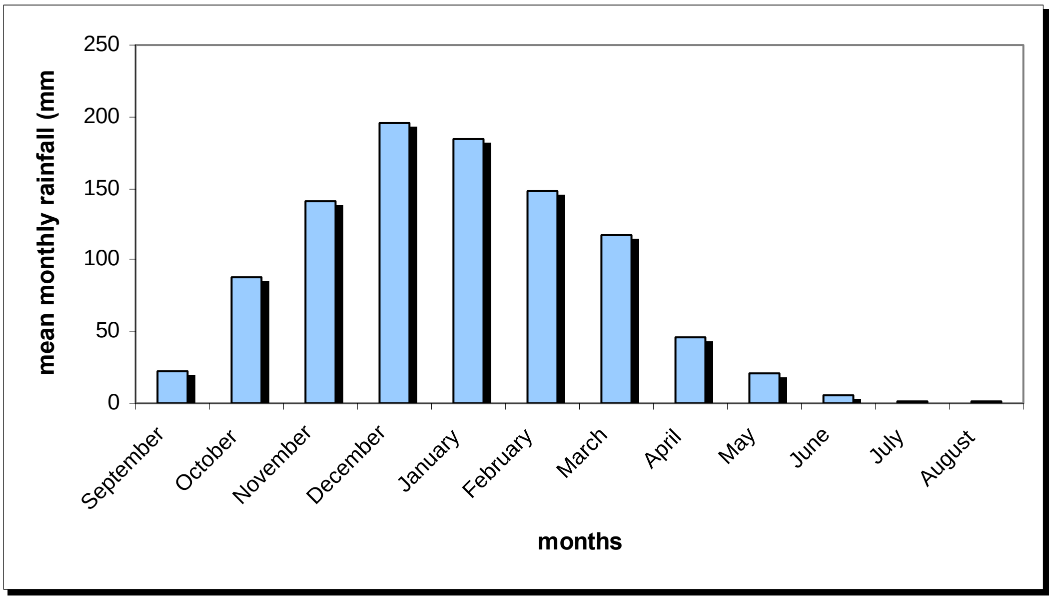


Figure 21: *Mean monthly rainfall in Rethymnon.*

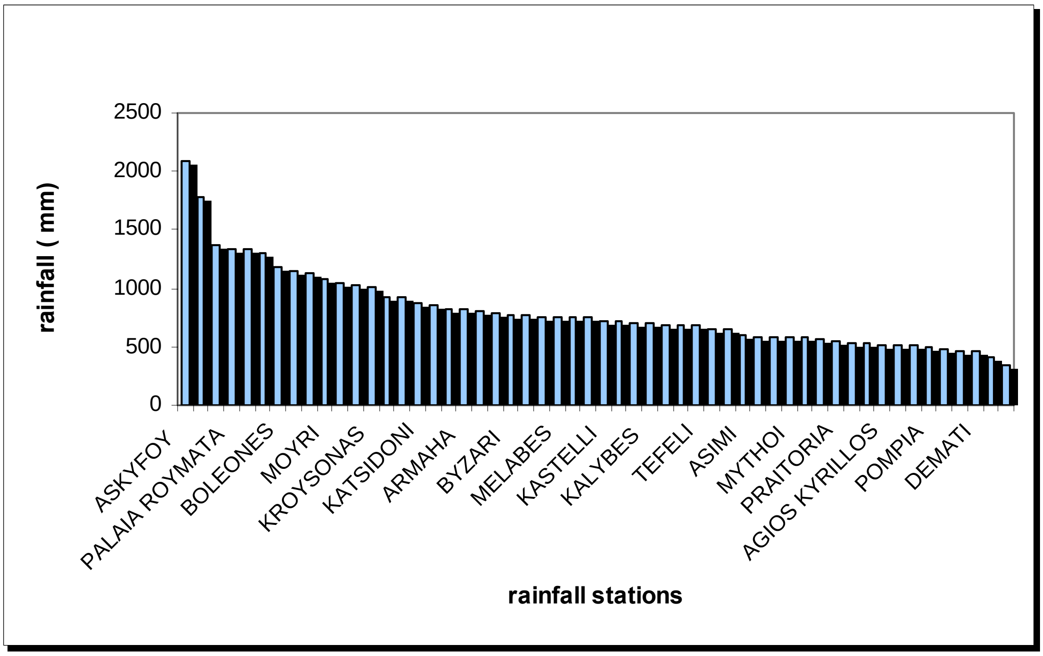


Figure 22: *Rainfall distribution for Crete.*

Rainfall in Crete is not uniformly distributed throughout the year. It concentrates mainly in the period from November to April while the drought period extends to more than six months (May to October). The mean annual precipitation in eastern Crete is 816mm while in western Crete it is 1,052mm. About 60% of the annual precipitation occurs from December to February. On average the number of rainy days ranges from 15 in

December and January to 0.3 in July and August. Snowfall is restricted to the main mountain ranges (Regional Governor of Crete, 2002). Long series rainfall data all over Crete does not show any significant change in precipitation (Markou-Iakovaki, 1979; Macheras & Koliva-Machera, 1990).

1.1.3.2 Temperature

Temperature in the island of Crete shows great variation. Air temperature increases from west (17°C at Alikianos station) to east (18.7°C at Siteia station). The southern part of the island is warmer than the northern and the warmest of Greece (Chartzoulakis et al., 2001). The mean annual temperature at Siteia station (north part of Lasithi prefecture) is 18.7°C while the mean annual temperature at Ierapetra station (south part of Lasithi prefecture) is 19.6°C. The mean monthly temperature range at Siteia station is depicted at figure 23.

During the cold period, temperature increases with decreasing latitude while in the warm period and especially in the period from May to August, temperature increases from the coast to the mainland and particularly in the plains (Chartzoulakis et al., 2001).

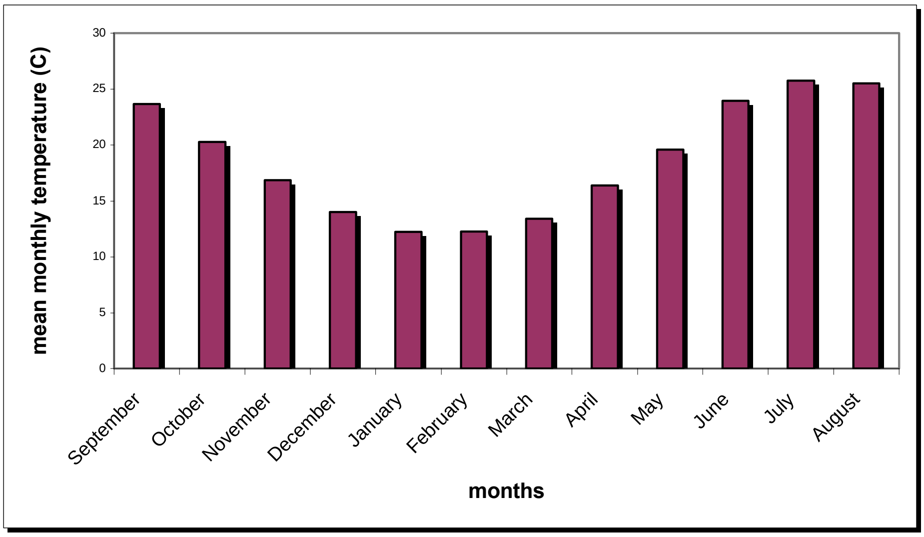


Figure 23: *Mean monthly temperature at Siteia station.*

At Anogeia station in the Rethymnon prefecture, which is located at an elevation of 740m ASL, the mean annual temperature is 15.2°C. The mean annual temperature at Kapsaloi station, in the mainland of the Iraklion prefecture, which is located at an elevation of 10m ASL, is 19.6°C (figure 24).

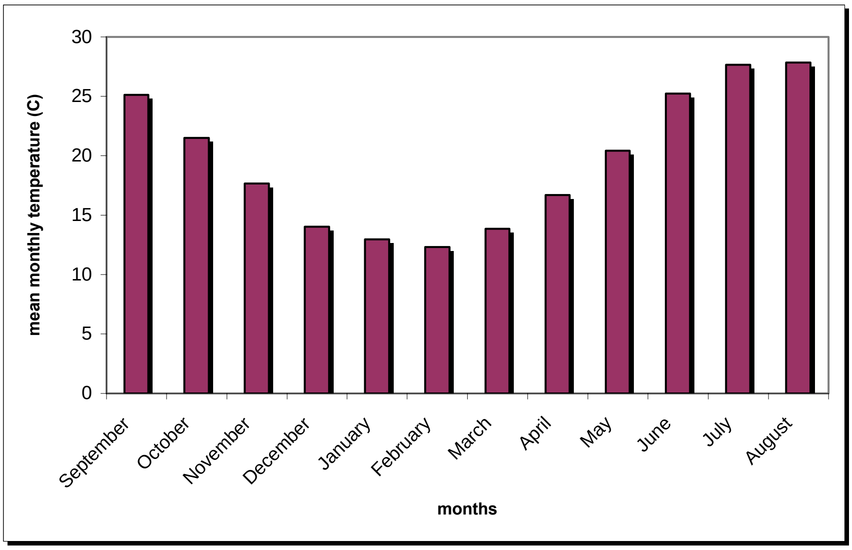


Figure 24: *Mean monthly temperature at Kapsaloi station.*

During the summer, temperatures exceeding 40°C may occur in the lowlands of Crete. In winter, the lowest temperatures scarcely fall below 0°C in the plains. The mean annual temperature range is from 17°C to 20°C. The largest temperature variation within a year is observed at Paxeia Ammos station, where temperature ranges from 10.5°C in February to 26.3°C in August. Generally, the highest temperatures of Crete are observed between July and August and the lowest in January and February. Figure 25 shows the mean annual temperature for different stations in Crete.

1.1.3.3 Evaporation

The potential evapotranspiration in Crete varies from 1,370mm/yr to 1,570mm/yr. The mean annual actual evapotranspiration has been estimated to represent 75% to 85% of the mean annual precipitation in low elevation areas (less than 300m ASL) and 50% to 70% in high elevation areas (Regional Governor of Crete, 2002). There are 24 stations in Crete measuring pan evaporation. Of those stations 11 are located in Iraklion, 3 in Rethymnon, 4 in Lasithi and 6 in the Chania prefecture. The spatial distribution of the stations in each prefecture is shown in figures 4, 10, 14 and 17. The highest mean annual pan evaporation is observed at Kapsaloi station in the mainland of the Iraklion prefecture. Kapsaloi station is located at 10m ASL and shows a mean annual pan evaporation of 2,039mm/yr. The mean annual pan evaporation for different stations in Crete is shown in figure 26.

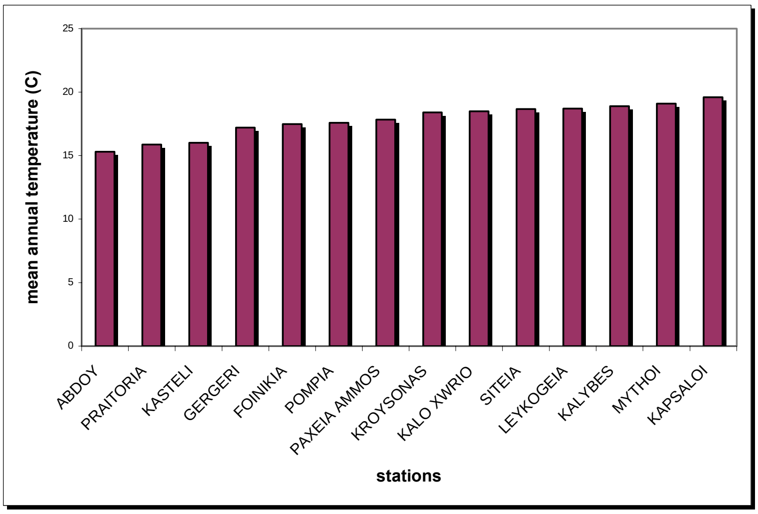


Figure 25: *Mean annual temperature at different stations in Crete.*

Figures 25 and 26 show the mean annual temperature and pan evaporation at different stations in Crete. The mean monthly pan evaporation for Kapsaloi station is shown in figure 27. The highest evaporation values are observed in July while the lowest values are observed in December and January. The mean annual evaporation range is from 40 to 265mm. The highest variation of pan evaporation values within a year is observed at Lefkogeia station in the Rethymnon prefecture. Lefkogeia station is located at 90m ASL and shows a value of mean evaporation of 60mm in January and of 341mm in July.

1.1.3.4 Wind direction

The prevailing wind direction is north and northwestern. High wind speed can occur any time during the year, but is mostly observed in western Crete in February and March and in eastern Crete in July (Regional Governor of Crete, 2002).

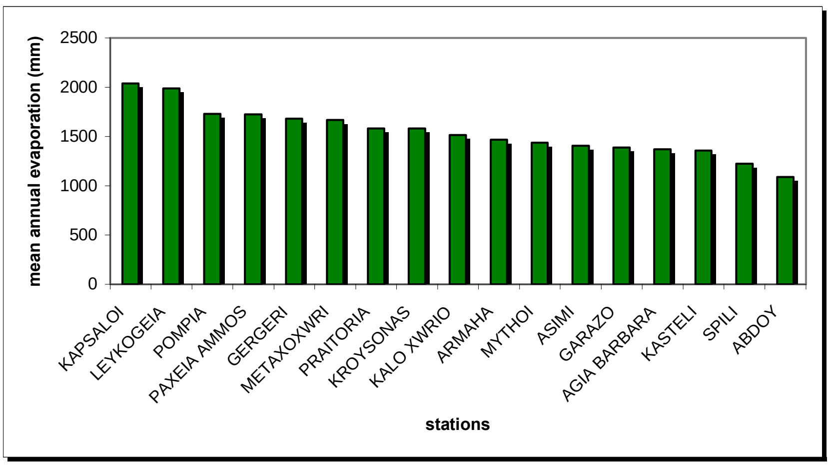


Figure 26: *Mean annual pan evaporation for different stations in Crete.*

1.1.3.5 Humidity

The driest months of the year are June and July with a mean relative humidity of 48.9% at Souda station in Chania prefecture and of 59.88% at Heraklion station. The most humid month is December when the mean relative humidity at Souda station is 72% and 67% at Iraklion station (Regional Governor of Crete, 2002).

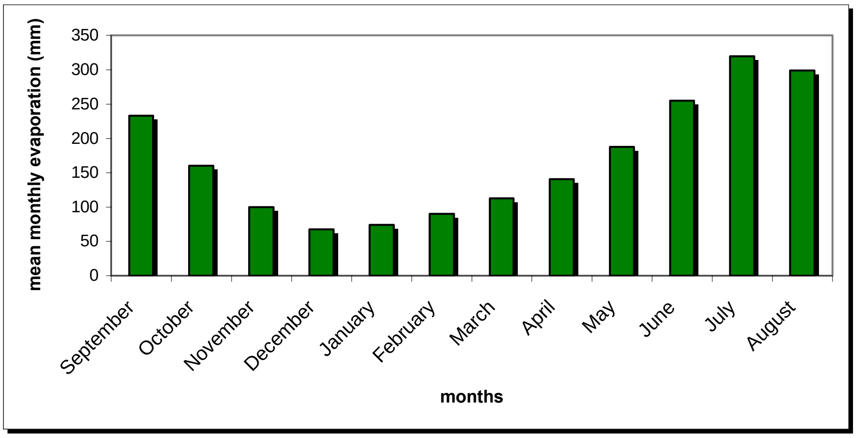


Figure 27: *Mean monthly evaporation at Kapsaloi station.*

1.1.4 Surface water

The contribution of surface water to the potential water resources of Crete is about 35%. The real contribution though is about 5%, which means that almost all the water quantity used in Crete comes from subterranean sources (springs, wells and boreholes).

In Crete there are 25 measured streams, 11 in the Iraklion prefecture, 5 in the Chania prefecture, 3 in the Rethymnon prefecture and 6 in the Lasithi prefecture. There are no perennial streams on Crete and the total mean annual runoff is estimated to be in the region of 0.74 billion m^3. Figure 28 shows the mean annual runoff for measured streams in the prefecture of Iraklion.

The stream with the highest runoff ($236Mm^3/a$) is Almyros (fed by a saline spring) near Iraklion. The stream with the highest mean annual runoff in the Rethymnon prefecture is Platys with mean annual runoff of $50Mm^3$, in the Chania prefecture Sepreniotis with mean annual runoff of $14.9Mm^3$ and in the Lasithi prefecture Katabothres with mean annual runoff of $16.6Mm^3$. Almyros stream in the Iraklion prefecture is also the stream with the highest mean annual runoff in Crete. Figures 28, 29, 30, 31 and 32 show a comparison of the mean annual runoff of streams in the prefectures of Iraklion, Rethymnon, Chania, Lasithi and in Crete in general.

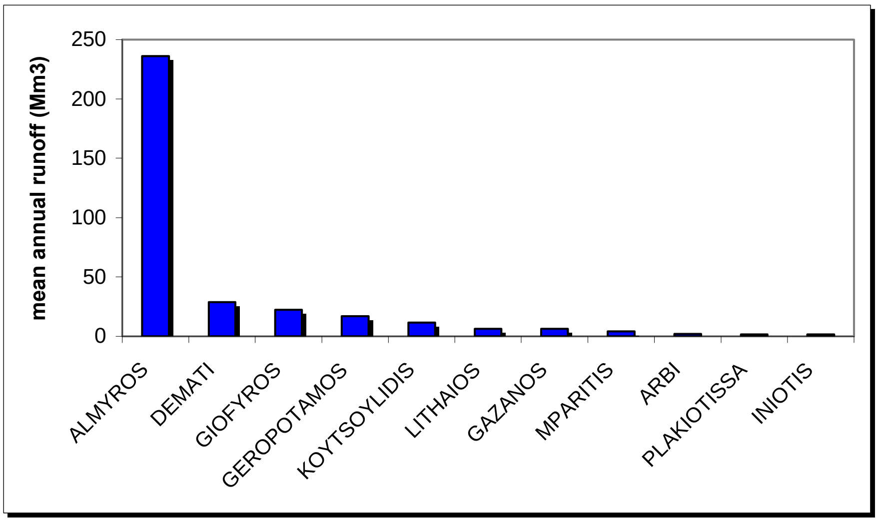


Figure 28: *Mean annual runoff in Iraklion.*

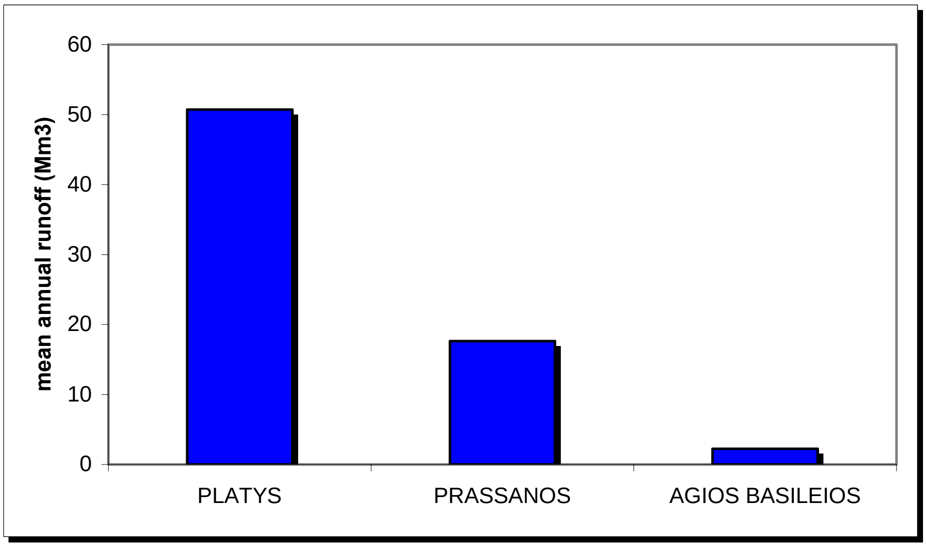


Figure 1.1.4.2: *Mean annual runoff of streams in the prefecture of Rethymnon.*

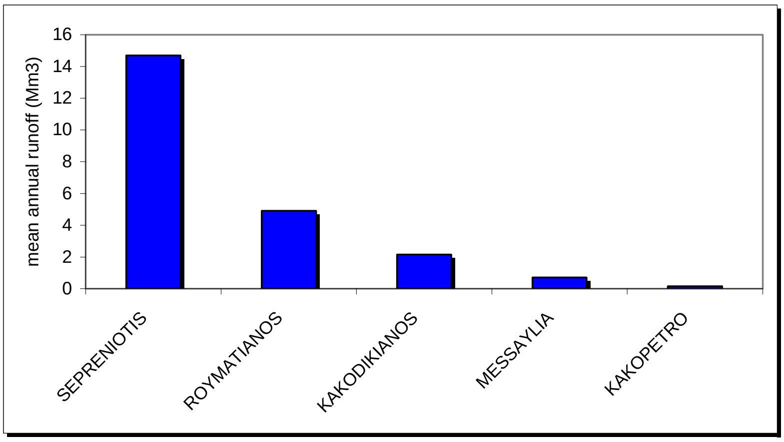


Figure 30: *Mean annual runoff of streams in the prefecture of Chania.*

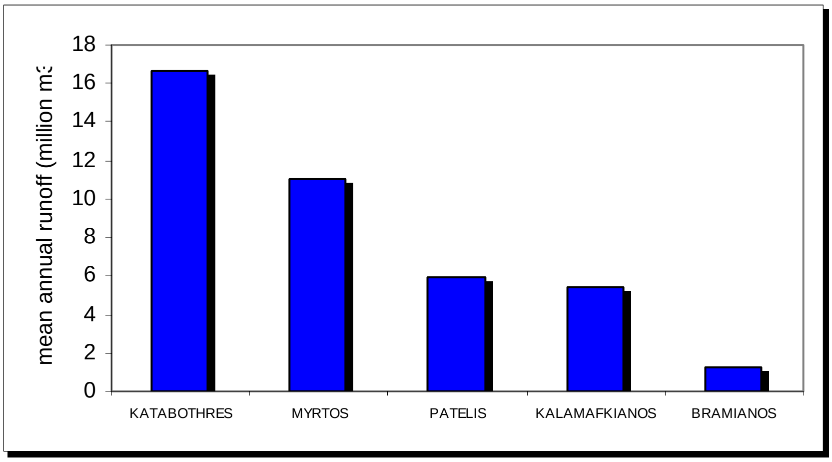


Figure 31: *Mean annual runoff of streams in the prefecture of Lasithi.*

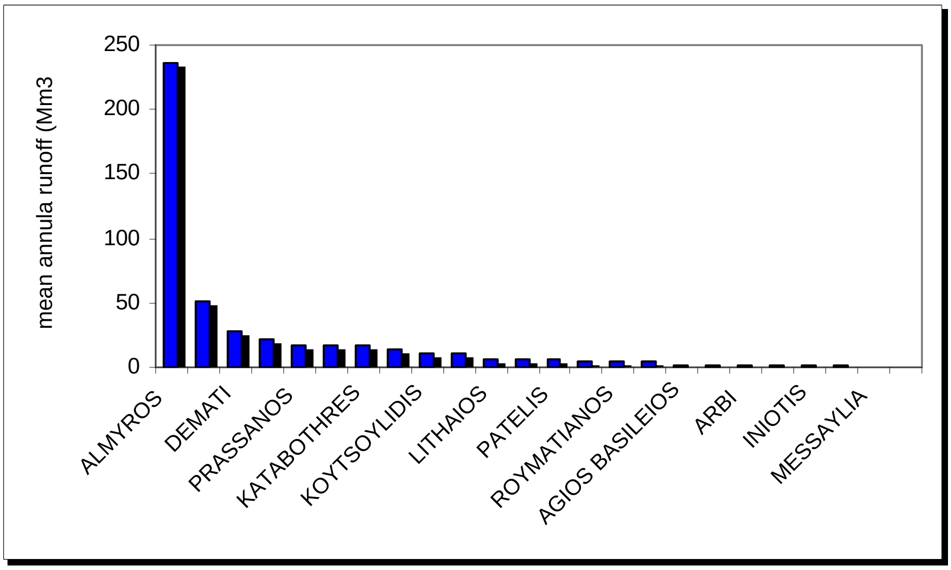


Figure 32: *Mean annual runoff of streams in Crete.*

1.1.5 Groundwater

The contribution of groundwater to the potential renewable water resources in Crete is about 65%. Almost all the water quantity used in Crete comes from subterranean sources. It is estimated that approximately 20% of the groundwater resources of the island, totaling approximately 2.1 billion m^3, are associated with Neogene-Quaternary aquifers while the remaining 80% are associated with their deep karstic counterparts (RGC, 2002). It is estimated that 40 to 55% of the mean annual precipitation infiltrates into the ground in karstic aquifers, creating a renewable groundwater potential of approximately 1.8 billion m^3. Of that groundwater potential 80% is discharged from karstic springs the majority of which are unfortunately located along the coast being thus contaminated by intruding seawater. Shallow aquifers hosted by Quaternary alluvial deposits have a renewable groundwater potential of 0.3 billion m^3. There are several boreholes and pumping wells on the island where the Regional Governor of Crete and other public services measure groundwater levels and chloride concentrations. In overexploited aquifers such as the Messara valley a drop in the groundwater level has been observed. This is mainly due to over pumping of the aquifers for irrigation purposes. In the Iraklion prefecture there is an intense exploitation of the existing aquifers. In 1990 alone, approximately 500 licenses for drilling and wells were issued by the public services in charge. It is certain that many additional unauthorised drillings have also been carried out, intensifying the exploitation of the already exploited underground aquifers.

There are 46 springs in Crete for which measurements of their yields exist. The mean annual yield for various springs in Crete is depicted in figure 33.

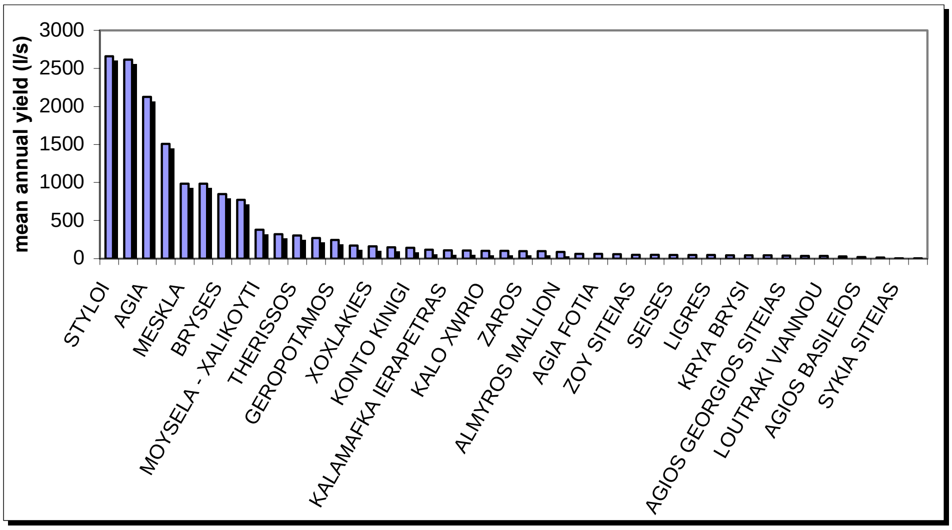


Figure 33: *Mean annual yield for various springs in Crete.*

Generally, the highest yield is observed from January to April. The month with the highest yield is March or April and the month with the lowest yield is August, September or October. This is depicted in figure 34.

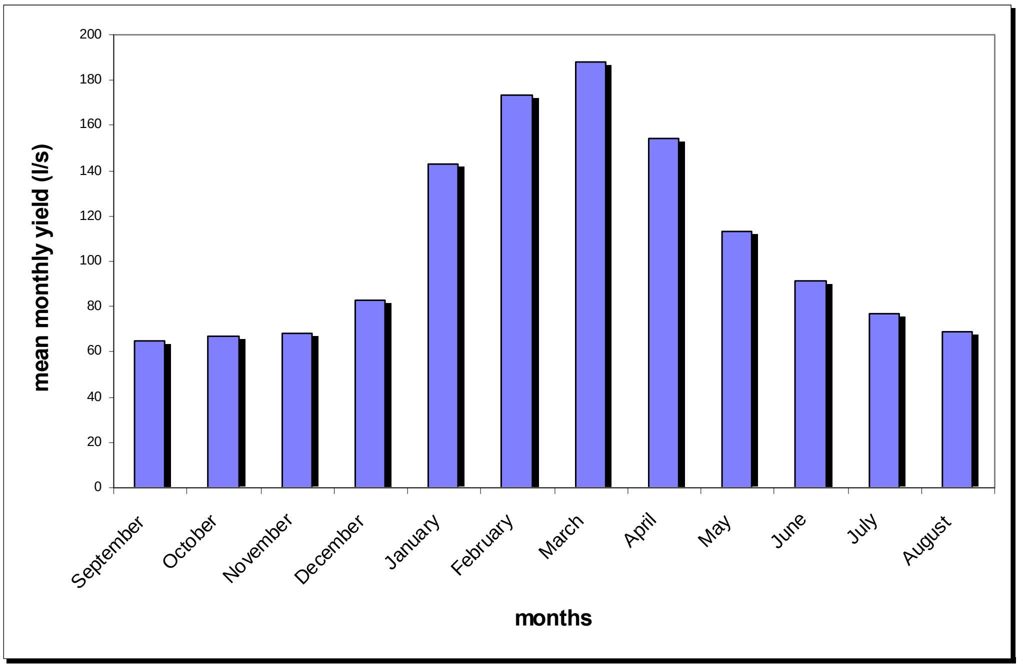


Figure 34: *Mean monthly yield for Kalamafka.*

1.2 Water balance

Despite relatively high precipitation (600mm in the plains and 2,000mm in the mountains), it is estimated that from the total precipitation in plains per year about 62% is lost to evapotranspiration, 10% as runoff to sea and only 28% goes to recharging the groundwater (RGC, 2002). The island of Crete receives approximately 7.7 billion m^3 of precipitation a year. Thus, there is an approximate inflow of 2.1 billion m^3 of water in the underground aquifers of the island.

Table 1 depicts the estimated hydrological balance of Crete in billions m^3 a year for three hydrological conditions namely a normal year with a return period equal to or exceeding 50%, a wet year with a return period equal to or exceeding 10%; and a dry year with a return period equal to or exceeding 90%.

Table 1: *Estimated hydrological balance of Crete (in billion m^3/yr), (Regional Governor of Crete, 2002).*

Hydrologic Conditions	Precipitation	Actual Evapotranspiration	Runoff	Infiltration
Normal year	7.69	4.38 (63%)	0.74 (10%)	12.12 (27%)
Wet year	10.33	6.48 (63%)	0.99 (10%)	2.85 (27%)
Dry year	5.07	3.18 (63%)	0.49 (10%)	1.40 (27%)

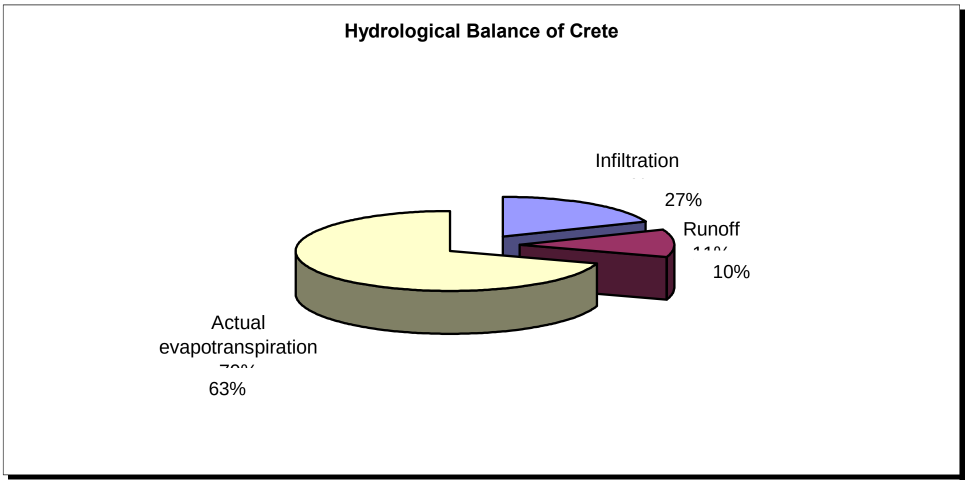


Figure 35: *Hydrological balance of Crete, (Regional Governor of Crete).*

A detailed compilation of the water resources inflows and outflows is presented in table 2, taking into account that agricultural needs are not fully covered. The outflows from springs, pumps and surface water account for 63.4% of the relative water inflows. Also, the outflows from network nodes account for just 2% of the relative inflows in network nodes. On the other hand, it should be noted that the outflows from the aquifers considerably exceed the relative inflows. The outflows for irrigation account for 7.3% of the total outflows, while the relative share for the water outflows for consumption from municipalities is 30.2%.

Table 2: *Supply and demand balance of water resources in Crete (current situation), (Source: http://www.crete-region.gr).*

Categories	Inflows [Mm^3]	Outflows [Mm^3]
Inflows (pumping, springs, surface water)	857.12	543.21
Change in the aquifer storage	0.06	2.27
Rainfalls on aquifer	0.13	1.61
Irrigation (TOEB-OADYK)		63.58
Consumption from Municipalities		265.06
Balances on network nodes	18.73	0.38
Total	**876.00**	**876.00**

Furthermore, as can be seen in figure 36 which depicts the water supply in Crete on a monthly basis for the period 1987–1997, the water resources inflows in springs and surface waters were significantly higher than the outflows for irrigation, in the last four years. Only in the year 1990 do the total amount of water inflows and outflows appear to be symmetric. It is evident that total amount of water outflows for irrigation remains constant over the particular time period and the higher outflows are realised during July and August.

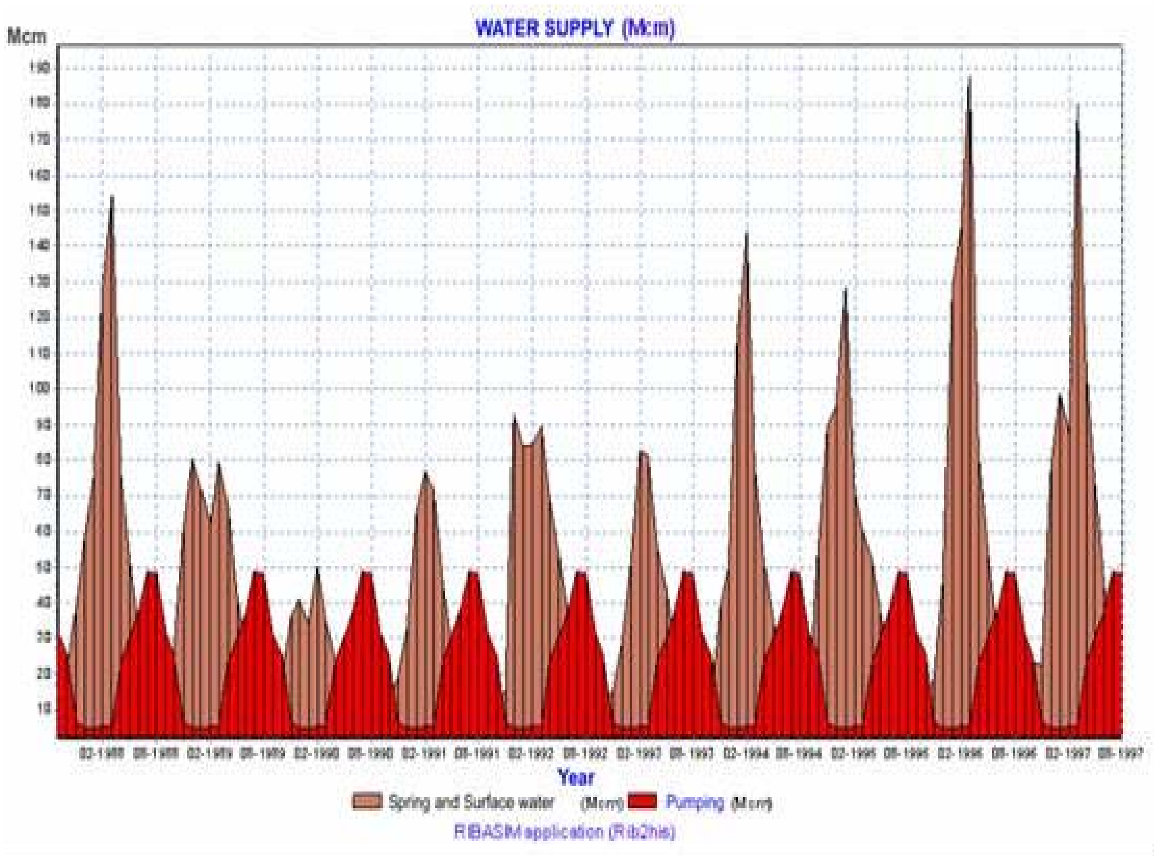


Figure 36: *Water supply on a monthly base for the period 1987-1997, (http://www.crete-region.gr).*

1.3 Water demand and supply

As mentioned above, the average annual precipitation in Crete is estimated at 927mm. The potential renewable water resources 2,120Mm^3 and the real water used about 372Mm^3/yr. Water consumption constitutes only a small percentage, about 5 and 18% of the annual precipitation and water potential respectively. Although the contribution of the surface water to the potential water resources is around 35% (figure 37), the real contribution is about 5%, which means that almost all the water quantity used in Crete comes from subterranean sources.

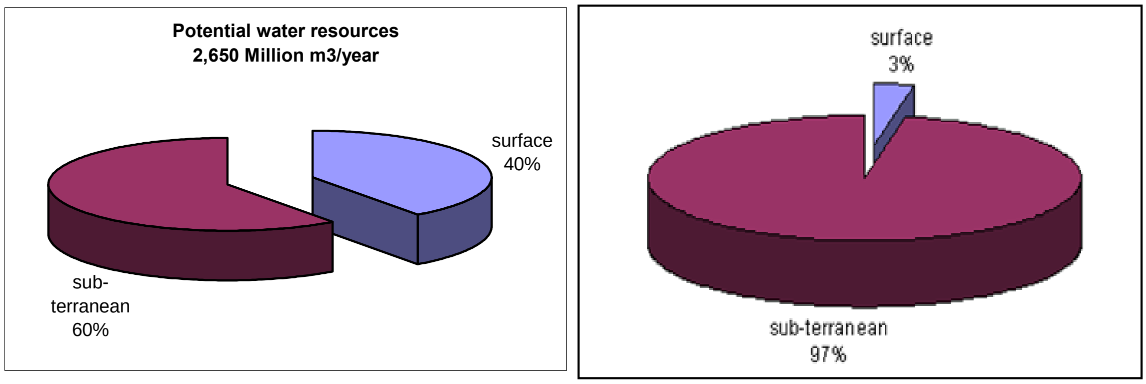


Figure 37: *Water availability (potential water resources) and exploitability on the island of Crete.*

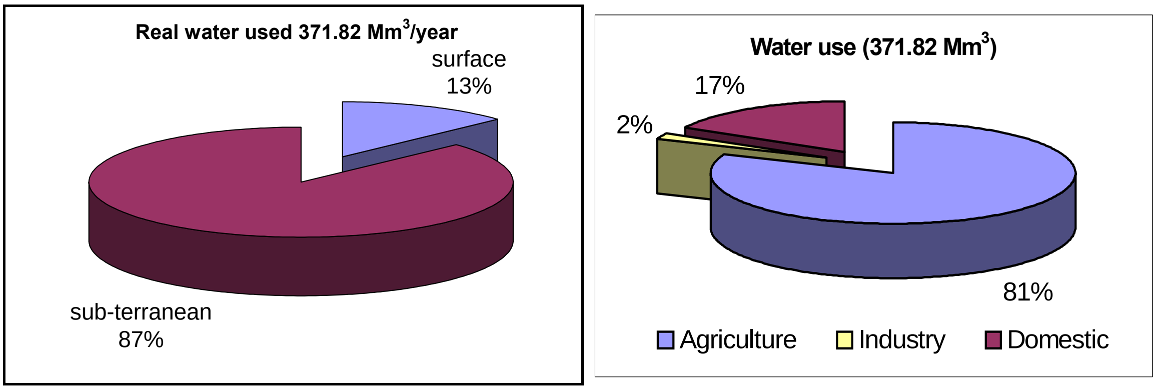


Figure 38: *Water use by sources and sectors on the island of Crete.*

The major water use in Crete is in irrigation for agriculture (81% of the total consumption) while domestic use including tourism is 17% and industrial use only 2% (mainly for olive extraction plants, packaging plants, livestock and water bottling companies) (figure 38). Irrigation covers around 31% of the total cultivated land and uses mainly groundwater from wells or spring outflows. Only a very small percentage of irrigation water comes from surface water impounded in reservoirs. A breakdown of the water use per sector and prefecture is given in table 3.

Table 3: *Breakdown of water use (m^3) in Crete 1995, (http://www.crete-region.gr).*

Administrative units	**Households $10^3m^3/yr$**	**Livestock $10^3m^3/yr$**	**Irrigation $10^3m^3/yr$**	**Olive-oil Production m^3/yr**	**Industries/ Handicrafts $10^3m^3/yr$**	**Total $10^3m^3/yr$**
Chania	17,469	1,707	108,897	236,261	1,459	129,768
Rethymnon	8,427	1,842	39,143	136,214	269	49,818
Iraklion	30,152	1,920	202,914	414,508	1,334	236,735
Lasithi	9,291	704	88,664	142,965	113	98,916
Crete	65,339	6,173	439,618	929,948	3,176	515,236

Water used for irrigation is higher in the interval May-September with peak demand during July and August. Household consumption also shows a peak during July and August.

According to research done by the National Statistical Service of Greece in 1999, 56.5% of the municipalities and communities in Crete, which represent 44.5% of the island's population, had sufficient water supply all year round, while the remaining 43.5%, which represent 55.5% of the population had problems with the water supply (Xepapadeas, 1996).

Another sector related to water use is tourism (domestic and international), an important economic activity in Crete, which is still significantly increasing. In 1999, the total number of tourists in Crete exceeded two million. The tourist industry requires huge quantities of water supply, with peak consumption during the high season (Chartzoulakis et al., 2001).

It should be noted that water availability in average terms is not the limiting factor. Much more important are the significant regional and seasonal variations which Crete shows in water availability and demand. About 70-80% of annual rainfall occurs in three to four months, while summers are usually long and dry. This situation is further worsened by a seasonal and regional variation in water demand. Both agriculture and tourism require increased supplies in late spring, summer, and early autumn, when water is less abundant (table 4). Also, domestic use of water increases during dry and hot periods. On the average, Crete has relatively high per capita water availability, i.e. around 4,800m^3/inh/yr, which is lower than that of Greece (6,700m^3/inh/yr) (Chartzoulakis et al., 2001).

***Table 4**: Water demands and deficit on the island of Crete [Mm^3].*

Water use	Estimated demands	Consumption	Deficit	Cover Percentage %
Irrigation	458.37	302.06	156.31	65.9
Domestic & other	77.34	69.75	7.59	90.2
Total	535.71	371.81	163.90	72.2

**Irrigation demands are the required quantities for optimum crop yield.*

1.4 Environmental protection

1.4.1 Water quality

Hydrogeologic and biological factors affecting water quality in Crete include salinity due to the intrusion of seawater in coastal aquifers and high concentration of sulfuric ions originating from gypsum aquifers. The intense exploitation of existing underground aquifers has increased salinity concentrations. As a result the quality of irrigation water is reduced and this could potentially have negative external effects on the agricultural production (Xepapadeas, 1996). Pollution due to human activities has dramatically increased in recent years. This includes groundwater contamination due to the disposal of untreated domestic and industrial wastewater and the widespread use of fertilisers and pesticides in agriculture. It should be, however, noted that chemical and biological analysis of groundwater has shown that the majority of waters are within drinking standards.

1.4.2 Wastewater treatment and reuse

In today's Greece, there are 270 Municipal Wastewater Treatment Plants (MWTPs) in operation that serve about 60% of the country's permanent population. For the remaining 26% it is estimated that 2,000 MWTPs serving more than 500 population equivalent (P.E.) will be needed (Tsagarakis et al., 2001). 14% of the population lives in villages of less than 500 P.E. for which on site sanitation technologies should be used (Tsagarakis, 1999). In Greece specific technologies for municipal wastewater treatment have been developed. Among these systems, 88% percent are activated sludge systems, 10% are natural systems, and 2% are attached growth systems. Among the activated sludge systems 85% are extended aeration systems, 10% are conventional systems and 5% are sequencing batch reactors. Approximately 44% of the activated sludge systems have nitrogen removal, and 15% have considered phosphorous removal. In Crete it is estimated that at present more than 100,000m^3/d of secondary treated wastewater effluent is produced (Chartzoulakis et al., 2001). There are 23 MWTPs operating in Crete. Among these 22 are activated sludge systems and one is a constructed wetland. Activated sludge systems are currently in operation in the municipalities of Iraklion, Chania, Rethymnon and Agios Nikolaos (Tsagarakis et al., 2001). Conventional wastewater treatment plants also operate in the municipalities of Chersonisos, Archanes, Tympaki and Matala treating municipal wastewater in the prefecture of Iraklion. There is also a small wastewater treatment plant in the industrial area of Iraklion treating industrial effluents. There is a constructed wetland in operation in the community of Pompia in the Iraklion prefecture. Many municipalities and communities in Crete are in the process of designing and building wastewater treatment plants, a number of those having reached the stage of conducting Environmental Impact Assessment studies. Such a case is the construction of a wetland in the community of Episkopi in the Iraklion prefecture. The trend in Crete is towards the construction of wetlands for treating the waste of small communities.

Tsagarakis (1999) has classified the MWTPs in operation in Greece according to their performance, taking into account effluent qualitative parameters and the effluent quality requirements. Of the existing MWTPs in Greece, 42% operate well, 41% moderately and 17% poorly. Qualitative and quantitative values from some large MWTPs of Crete in comparison with others in the rest of Greece are shown in table 5.

Table 5: *Average quantitative and qualitative characteristics of treated effluent from different MWTPs in Greece, (Tsagarakis et al., 2001).*

Parameter	Agios Nikolaos[a]	Heraklion[a]	Rethymnon[a,b]	Chania[b]	Rhodes	Ioannina[a]
P.E.	14,000	110,000	57,500	40,500	120,000	110,000
Q_e (m^3/d)[c]	1,500	15,000	7,500	10,400	8,000	17,089
BOD_5 (mg/L)	16	8	8	4	9	8
COD (mg/L)	54	15	40	29	25	38
TDS (mg/L)	-	950	1,500	-	1,250	-
SS (mg/L)	20	8	13	8	-	13
TKN (mg/L)	-	20.00	2.50	4.50	-	11.50
NH_4-N(mg/L)	2.10	4.50	0.65	0.40	0.50	9.65
NO_3-N (mg/L)	-	-	0.15	0.47	-	0.30
Total P (mg/L)	-	12.50	5.00	7.90	7.60	4.28
FC(MPN/100cm^3)	-	0	1,000,000	275	-	0
TC (MPN/100 cm^3)	1,000	15	23,000,000	-	-	25

[a]Average values for 1999; [b] Without desinfection; [c] Effluent average daily flow rate.

The uneven atmospheric precipitation (spatially and seasonally), the continued growth of the population, the rapid growth of the tourist industry and periodic droughts have forced water services and other agencies to search for new and reliable water sources. The use of reclaimed or recycled wastewater for various non-potable uses has proved to be the most reliable of sources, like in most Mediterranean countries. In Greece, no guidelines or criteria for wastewater reclamation and reuse have yet been adopted. Secondary effluent quality criteria are used for discharging purposes with a Health arrangement action of 1965 (Ministries of Interior and Public Health, 1965) and are independent of the disposal, reclamation and reuse effort. Also, no regulation of wastewater reuse exists on the European level. The only reference to it is Article 12 of the European Wastewater Directive (91/271/EEC) (EU, 1991). Thus the need for establishing wastewater reclamation and reuse standards on both European and national level is obvious (Angelakis et al., 1999). There are a few MWTPs in Greece where effluent is used for direct irrigation of agricultural land. The effluents from four plants are used for the irrigation of forestry and various amenity purposes. There is no industrial reuse of treated effluent apart from some installations that use filtration for treating further effluent that is going to be used in the installation (Tsagarakis et al., 2001). There is no wastewater reuse practiced in Crete. Nevertheless it has been calculated that by reusing the treated effluent of today's existing plants, a 5.3% increase of irrigated area can be obtained (Tsagarakis et al., 2001).

1.5 Water laws and regulations

A new law, 3199/2003, has recently passed from the Greek Parliament, "for the protection and management of water", in agreement with the WFD 2000/60/EC. This law includes articles for the protection and management of surface and ground water, and of transient and coastal waters.

An interim law (1739/81) is also in use, determining the instruments and the processes that should be employed to allow water resources management on a national and regional level. According to this law, water resources management is the set of activities and processes necessary for the best possible cover of water demand for all uses. The main goal of water resources management is coping with problems such as water inefficiency, areas and users of conflict and conservation of the highest possible water quality and quantity according to use, today and in the future. Other goals of water resources management are the orientation of water demand towards uses that comply with research and development programs of the country and the rational development of investigation, exploitation and protection of water resources.

The institutional structure according to the new law 3199/2003 includes:

- The National Water Committee,
- the National Water Council,
- the Ministry of Environment-Directorate of Water,
- the Regional Water Directorates *and*
- the Regional Water Councils.

Parallel to law 3199/03 there is a complimentary law 3010 (for harmonisation of previous law 1650/86 with the EU directives 97/11 and 96/61) for environment protection. In articles 9 and 10 of this law water is defined as a natural element and legislative measures are foreseen for monitoring and evaluation of water resources quality. In the framework of law 1650/86 the Hellenic ministry for the environment, physical planning and public works presented a comprehensive program for water resources protection. This program was part of the "1stEuropean Union support framework (1983-93)", which established the necessary infrastructure for water resources monitoring. The water resources quality-monitoring network was completed with the "2ndEuropean Union support framework".

Apart from these laws there is a number of legislative decrees, joint ministerial decisions, sanitary regulations and articles of the civil code that refer to the investigation, exploitation and protection of water resources.

1.6 Institutional framework and constraints

The institutional framework for water resources management in Greece was shortly described in paragraph 1.5. In more detail the institutional framework in Greece can be seen in figure 39.

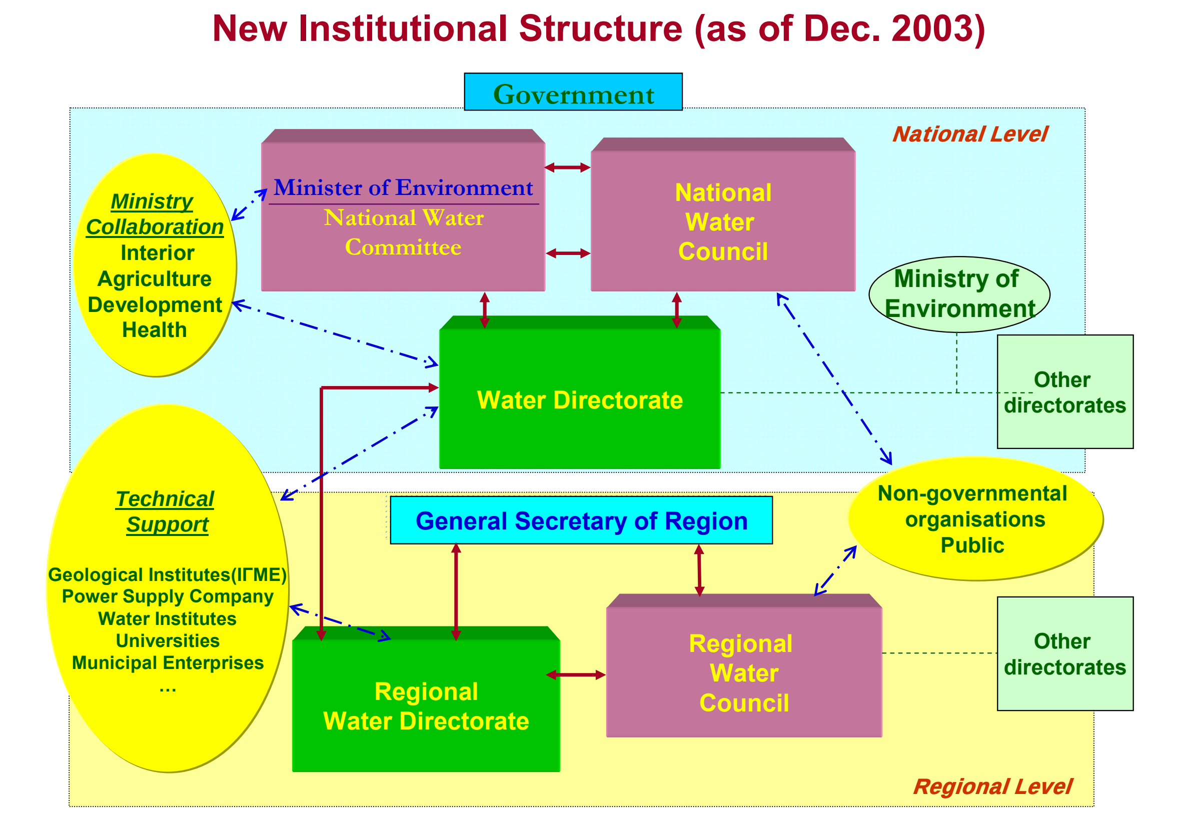


Figure 39: *Institutional framework for water resources management in Greece.*

The ministry in charge of the protection and management of water on national level is the Ministry of Environment. There is also the National Water Committee, which is in charge of National water policy and water protection. The National Water Council is in charge of the water resources condition, the implementation of the water law and the harmonisation with WFD.

On regional level, there are 14 regional water committees, one for each water district constituting Greece. Water districts are areas demarcated by watersheds or islands, which include hydrographic networks with similar hydrological-hydrogeological conditions. The regional water committees function as an advisory and decision-making instrument (on a regional level). The water Directorate of the Regional Government of Crete (RGC) is in charge of water protection and management in the island of Crete, which forms a separate water district. The water resources management policy of RGC is employed by public services. The public service responsible for domestic and public water supply is the regional service of municipalities and communities and users include the municipal service of water supply and sewerage, municipalities and private users.

1.7 Management, institutional and policy options

Water resources management is a key issue on the island of Crete mainly due to the spatial and temporal variation of rainfall in relation to the geological setting of the island and also the intense water uses such as tourism and farming. The main issue in water resources management on the island is focused on the uneven geographical distribution of water resources in relation to the water demand hotspots of the island. In general there is abundance of water resources in the west compared to the east of the island. Furthermore, the demand for tourism and farming activities is increased in the east of the island. This combination of availability and demand places the water resources and their management under pressure.

The main stakeholders on the island can be classified in two categories depending on the scale of their areas and the nature of their responsibilities. On the regional scale the Directorate for Water of the Region of Crete (RGC) constitutes the main stakeholder. Its main duties are water protection, integrated water resources management and identification of water resources problems on the island, as well as suggestion of actions for future sustainable development. On the local scale, the municipal water companies and the local water boards comprise the main stakeholders. They deal with domestic water supply and irrigation water provision and management respectively.

The difficulty of local people in understanding the objectives of a water resources management plan and the misleading belief of the farmers that an increase to the suggested irrigation water volumes would lead to a higher farming production, has created significant frictions on the regional scale. The misconception of water resources ownership status, and the continuously increasing demand and water use are the main reasons for such frictions, leading to a water resources overexploitation, a reduction of the water resources potential, a failure of the existing infrastructure and resulting in a natural water quality deterioration. Human activities also intensify the pressure for a sound water resources management especially in alluvial plain aquifers.

Under the above conditions the section of water management has taken into consideration the following proposals in order to protect and to restore the environment in the view of sustainable development:

- Protection of groundwater resources against over-exploitation,
- restrictions to issue groundwater abstraction licenses in areas under pressure,
- pollution control of surface and groundwater. Monitoring of water quality,
- protection of coastal aquifers from saline intrusion,
- exploitation of un(der)exploited aquifers such as karstic aquifers,
- the implementation of a water plan on a watershed basis for detailed water management,
- the investigation and implementation of artificial recharge of aquifers,
- feasibility studies for further introduction of surface reservoirs,
- the improvement of the information services on the rural scale,
- the application of modern and effective irrigation methods,
- improved freshwater storage and transport, groundwater recharge promotion,
- reuse of water after treatment (grey water),
- utilisation of untapped surface water sources. Interbasin transfer *and*
- demand reduction: agricultural, industrial and domestic.

The implementation of the Water Framework Directive in combination with the application of a strategy that aims at informing local people about the existing issues will assist the regional stakeholders to a geographically balanced water resources management of the island.

1.8 Agricultural situation

1.8.1 Cultivated crops and cultivated land

Agriculture represents an important sector of the local economy in Crete. It contributes 13% to the GDP of the island, while services and tourism represent 77% and industry 10%. Approximately 6.7% of its active working population are in the agricultural sector. Crete is an olive-producing island, with the olive oil production being the most important agricultural sector of the island. 99.8% of the olives produced are used for oil production and only 0.21% of the total production is for edible use (HNSS, 1999). Olives take 38% of the total cultivated land on the island while that percentage is increased in the Iraklio prefecture where it takes 53%. Olives cover more than 90% of the total tree crops, followed by citrus 3.4%, almonds and avocados. Along with olives, citrus (oranges, lemons and mandarins), apricots and cherries are cultivated. Tomatoes, cucumber, potatoes, melons and watermelons are the most widely cultivated vegetable crops, while almost all of the row crops are fodder crops and legumes. The total cultivated land is 3223.2km^2 including fallow land. The main groups of crops and the surfaces covered in Crete are shown in table 6, their development within the last 40 years in figure 40. The production of some groups of crops in the four prefectures of Crete is shown in tables 7, 8 and 9 (HNSS, 1999). The main vegetable crops grown in Crete are fresh tomatoes, cucumbers, potatoes, eggplants, onions, watermelons, melons, cabbages and peppers, while among fruit crops olive covers more than 89% followed by citrus 3.4%, almonds and avocados (Chartzoulakis et al., 2001).

Table 6: *Area and crops cultivated in Crete (km²), (Regional Governor of Crete, 2002).*

Category	Cultivated Area (km²)	Percentage of the total
Row crops	320	9.9
Vegetable crops	80	2.7
Vineyards	309.5	9.6
Fruit crops	1850.2	57.4
Fallow fields	653.5	20.4
Total cultivated land	3223.2	100.0

***Table 7**: Crop production in thousand tons/year: vegetables.*

Vegetables							
Administrative units	**Tomatoes**	**Cauliflowers & Cabbages**	**Onions**	**Egg-plants**	**Potatoes**	**Melons**	**Water-melons**
Iraklio	55.73	8.36	3.53	1.33	33.66	8.41	20.49
Lashithi	38.23	2.41	0.65	6.25	39.19	3.32	0.78
Rethimno	5.39	1.37	0.92	0.22	6.79	0.78	4.37
Chania	30.93	1.07	1.59	0.45	8.20	2.43	8.31
Total	130.27	13.21	6.69	8.25	87.84	14.94	33.94

***Table 8:** Crop production in tons/year: arable land.*

Crops on arable land								
Administrative units	**Wheat**	**Barley**	**Oats**	**Maize**	**Broad beans**	**Beans**	**Chick peas**	**Lentils**
Iraklio	2894	2688	684	16	556	129	72	24
Lashithi	1378	360	600	54	331	142	39	10
Rethimno	629	1031	1595	90	384	216	41	24
Chania	55	124	681	60	216	127	9	2
Total	4956	4203	3560	220	1487	614	161	60

***Table 9:** Crop production in thousand tons/year: tree crops.*

Tree crops									
Administrative units	**Lemons**	**Oranges**	**Mandarins**	**Pears**	**Peaches**	**Apricots**	**Cherries**	**Olives**	**Olive oil**
Iraklio	4.67	11.17	1.95	3.39	1.33	45.89	13.78	307.66	66.21
Lashithi	1.04	3.01	0.80	1.15	6.25	3.88	0.19	64.17	22.63
Rethimno	1.10	3.91	0.38	1.38	0.22	4.29	0.43	80.52	20.76
Chania	3.41	107.55	4.50	1.26	0.45	9.25	0.62	182.10	37.58
Total	10.21	125.64	7.63	7.15	8.25	63.31	15.01	634.45	147.17

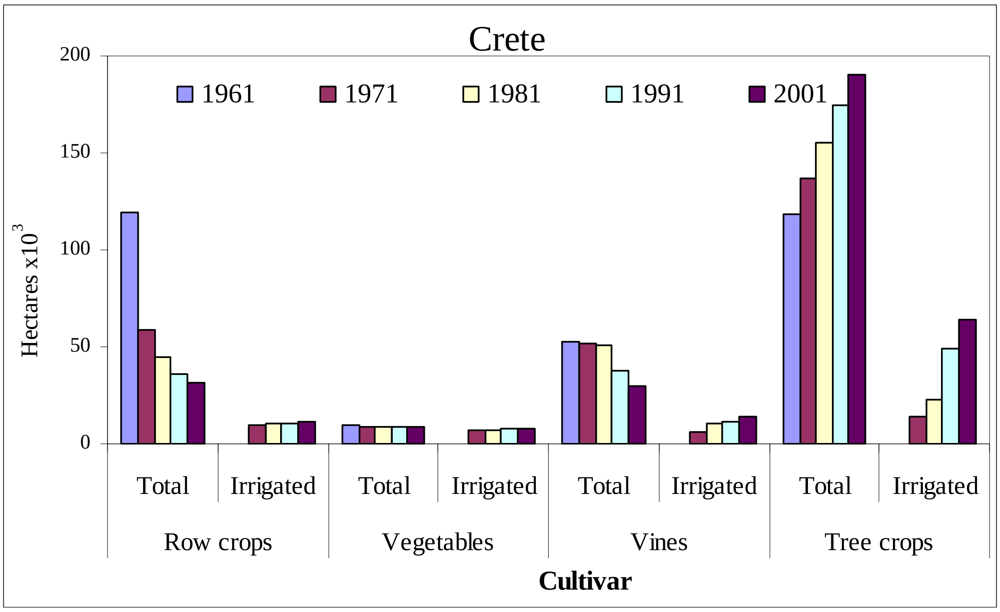


Figure 40: *Area and crops cultivated in Crete in the last 40 years, (Hellenic National Statistical Service).*

1.8.2 Irrigated area and irrigated crops

Demand for irrigation water is high especially in the summer months (agriculture is the major water consumer), adding more pressure on the aquifers, which already suffer from the increased demand for domestic use during those months. In Crete 42% of the available agricultural land is irrigated (RGC, 2002). As shown in figure 41 there has been an increase of irrigated land of more than 55% in the last 15 years in Crete, while the average increase at the same time in the country has been 15% (figure 42).

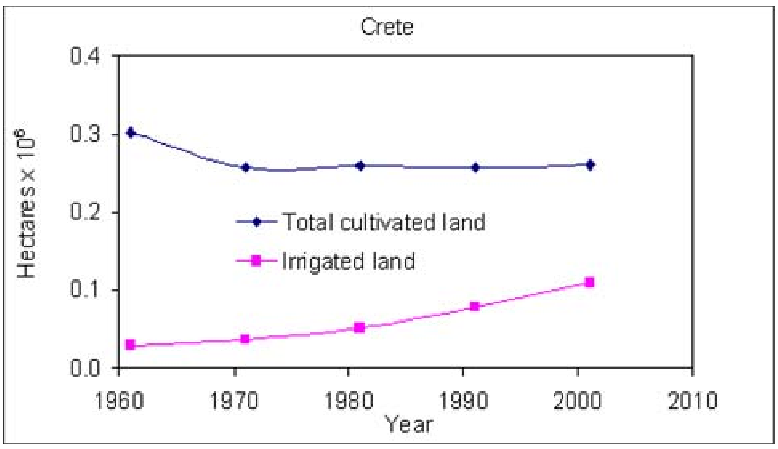


Figure 41: *Total cultivated and irrigated area in Crete, (Hellenic National Statistical Service).*

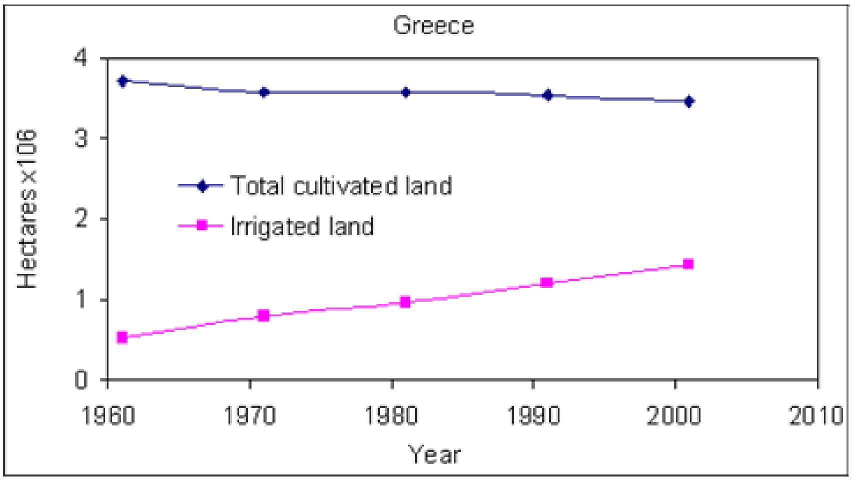


Figure 42: *Total cultivated area and irrigated area in Greece, (Hellenic National Statistical Service).*

The demand for irrigation water is high, while at the same time only 31% of the available land is irrigated, a percentage lower than that of Greece (36.3%). For vegetable crops, more than 92% of the cultivated area is irrigated, while the irrigated percentage in row crops was 36.5%, in fruit trees 38.5% and in vineyards 46.8%. It should be noted that row crops referred to cereals, fodder plants, industrial plants, melons, watermelons and potatoes, while tree crops are olives, citrus, fruit trees, nut and dried fruit trees (figure 43) (Hellenic National Statistical Service). Table 10 depicts the irrigated area for each crop group.

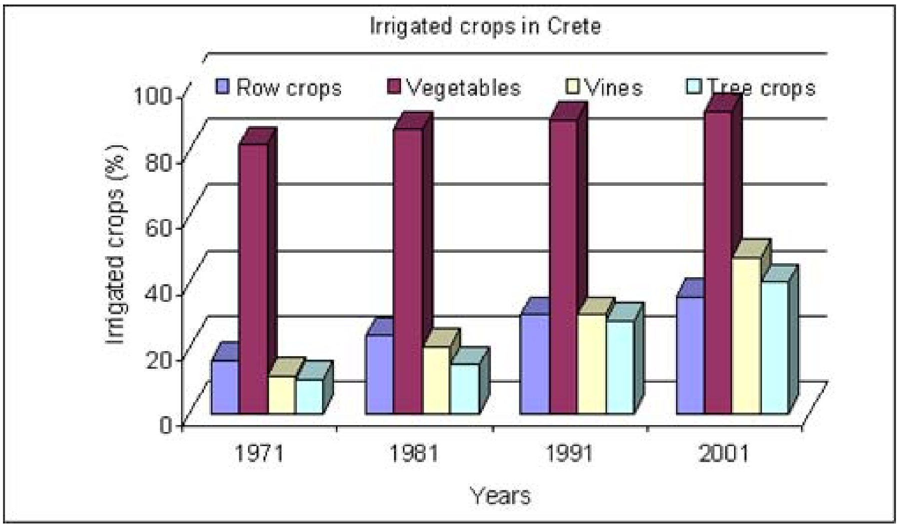


Figure 43: *Irrigated crops (percentage of the total cultivated area in Crete) during the last 30 years.*

Table 10: *Cultivated and irrigated areas in the prefectures of Crete, (Regional Governor of Crete, 2002).*

Type of crop	Cultivated land (km^2)	Irrigated land (km^2)	Percentage of irrigated land	Percentage of irrigated crop
Row crops	322	117.4	11%	36.45%
Vegetables	88	81.7	7.7%	93%
Tree crops	1850	714	67.4%	38.5%
Vineyards	310	145	13.9%	46.8%
Total	2570	1079	42.0%	

Table 11 shows an estimation of the irrigation water requirements for a selection of crops on the island of Crete (RGC, 2002). The last column shows an estimation of the actual water applied per crop, which is usually higher than the recommended amount. Irrigation period varies on the island and depends on the microclimatic conditions of each area, the type of crop and the time of plantation. A mean irrigation period is shown in table 12.

Table 11: *Crop water requirements, (Regional Governor of Crete, 2002).*

Type of crop	Water required (10^2 m^3/km^2)	Water applied (10^2 m^3/km^2)
Vineyards	1780	3000 – 3500
Forage crops	-	7000
Olives	3140	2500
Open field vegetables	5700	4500
Greenhouse vegetables	4350	6500
Orchards	4620	5000
Potatoes	5700	4500
Subtropical trees	-	6000

Table 12: *Irrigation periods per crop type, (Regional Governor of Crete, 2002).*

Type of crop	Irrigation period
Vineyards	1st April – 30th July
Forrage crops	1st April 30 th October
Olives	1st April – 30th October
Open field vegetables	1st Arpil – 30th November
Greenhouses	1st January – 31st December
Orchards	1st April – 30th October
Potatoes	1st April – 30th October
Subtropical trees	1st April – 30th October

Figure 44 depicts the origin of the irrigation water and table 13 where the irrigation water is supplied from. In 1995, the local irrigation organisations TOEB and OADYK, supplied irrigation water to 303,436 and 66,531 $10^{-3}km^2$ respectively. The irrigation needs of the rest of the cultivated area were satisfied by communal, cooperative water projects of smaller size. The share of TOEB in the total irrigated area was estimated to be 28.12%, while the relative share of OADYK was only 6.17% since its activities are located only in the prefecture of Chania. The irrigated area in the prefecture of Lasithi that received water from TOEB was 49.2% of the total area, while the TOEB in the prefecture of Iraklion supplied water to just 14.5% of the irrigated area. In the prefecture of Chania and Rethymnon the corresponding figures are 36.2% and 32.3% respectively. Moreover, the majority of the irrigated areas (62.3%) receive water from these two irrigation organisations.

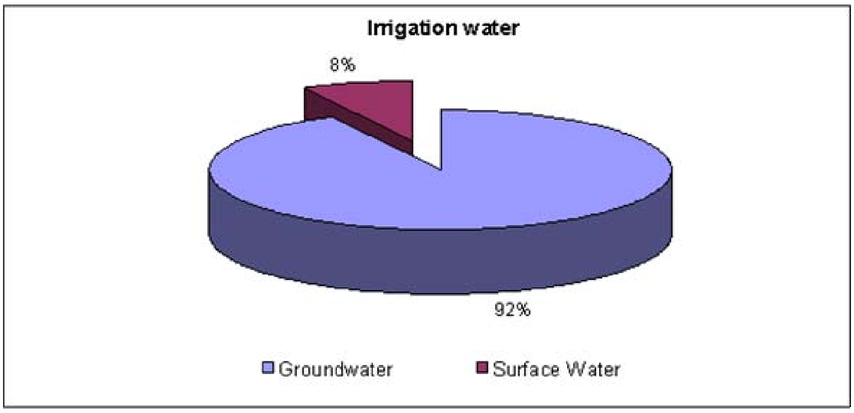


Figure 44: *Origin of irrigation water in Crete.*

Table 13: *Area irrigated by irrigation organisation, (http://www.crete-region.gr).*

Administrative units	Total Irrigated Area	TOEB	OADYK
Chania	251,098	90,906	66,531
Rethymnon	86,783	28,000	
Iraklion	518,810	75,030	
Lasithi	222,402	109,500	
Crete	1,079,093	303,436	
% total area		28.12%	6.17%

1.8.3 Animal breeding

In a study made by the Region of Crete the current water consumption for animal production on the island was estimated to 6,173,463m^3. Small animals (sheep, goats, hens and rabbits) represent 99.3% of the total number of animals and consume 90.5% of the total water used for animal production. In the same study future water needs for animal production were estimated (table 14). The current trends indicate a significant increase in the production of smaller animals (goats, sheep and rabbits) and a steady production of larger animals (pigs and cattle) during the last decade. The number of sheep and goats has increased by 92 and 82% respectively in the Rethymnon prefecture, while the number of rabbits has increased by 42% in the Iraklion prefecture, during a period of 8 years. Based on these trends, the number of small animals is expected to be doubled by 2020, while the production of large animals will remain at present levels. Therefore, the water consumption for animal production is estimated to increase to about 8,500,000m^3/year by 2020 (an 37.7% increase compared to current levels).

Table 14: *Water consumption per animal type in Crete, (Regional Governor of Crete, 2002).*

Animal type	Total population	Water consumption (m^3)
Horses/Asses	13,273	265
Cattle	1,906	113
Breeding Boars	1,235	1,235
Sheep	1,258,254	8,808
Goats	545,449	3,818
Rabbits	769,479	2,308
Chickens	1,219,732	366

1.8.4 Irrigation systems

Depending on the size, irrigation projects are initiated by the government, the local authorities or private individuals. The large scale irrigation schemes, which involve large hydraulic structures such as dams, conveyors, pumping stations, reservoirs and modern distribution systems are constructed by the governmental water resources services and/or agencies. The medium size irrigation schemes of local importance are constructed by the government on behalf of the Local Authority (Prefecture or Community) and usually comprise small dams, stream ponds, boreholes and modern distribution systems. The government finances the cost of large and medium size irrigation schemes and farmers are charged per unit of water consumed. The small scale irrigation schemes comprising a single borehole are constructed by individuals at their own cost and are found mostly in areas overlying aquifers.

The irrigation networks are of modern type made of pressurised distribution systems with delivery of water to the farm outlets carried out on free or modified demand or on rotation with the appropriate pressure for direct use through modern on farm irrigation systems. Although in most cases irrigation water is distributed to fields through closed pipeline networks, there are major losses (seepage, evaporation, leakage, etc.) from water delivered to the agricultural sites for irrigation (Chartzoulakis, Angelakis, & Skylourakis, 1997). It is estimated that on average, only 65% of water diverted or extracted for irrigation is effectively used by the crop (figure 45). In some cases, the losses are estimated to be as much as 50% of the delivered water (Dialynas, Diamadopoulos, & Angelakis, 1995).

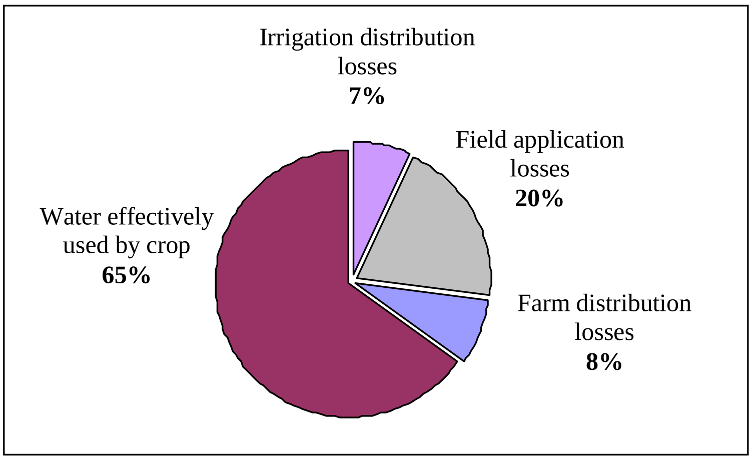


Figure 45: *Average irrigation water losses in the island of Crete.*

Irrigation scheduling is another aspect of utmost importance for the appropriate irrigation of horticultural crops. It consists of a set of procedures which allow to find out when and how much to irrigate a given crop. Irrigation scheduling methods are based on environmental, physiological and soil parameters. For vegetables, especially in greenhouses, the analysis of soil moisture (by tensiometers, gypsum blocks or gravimetrically) is the most common method used for irrigation scheduling in Crete, since it assures low cost, simple operation and reliable estimation of soil water status. For tree crops, irrigation scheduling is mainly based on meteorological parameters (mainly Class A pan evaporation and reference evapotranspiration ETO). Irrigation scheduling is also done empirically by using soil and plant appearance. Drip irrigation systems are used for the irrigation of vegetables, vineyards and tree crops whereas sprinklers are used for forage crops and vegetables and furrow for vegetables.

1.8.5 Price for irrigation water

The price for water per cubic meter varies greatly between catchment areas and even within the same catchment area, depending mainly on the managing agency. Cretean farmers operating in publicly developed irrigation projects still do not fully cover operation and maintenance (O&M) or capital replacement costs. So in the large irrigation project of West Crete the price is as low as 0.07 – 0.08 euros, whereas in community projects it reaches 0.10 – 0.12 euros and in some private projects it is up to 0.23 – 0.35 euros (Chartzoulakis et al., 2001). These prices are much higher than in Portugal or in some regions in Spain (OECD, 1999).

1.9 Socio-economic situation

1.9.1 Social profile

1.9.1.1 Population

Over the last 50 years the total population of Crete has increased by 24.4% and according to the most recent census (2001), is 601,131 residents (table 15). The highest rate of population increase was realised in the prefecture of Iraklion (40%), while the lowest was in the prefecture of Lasithi (3.3%). The largest prefecture in terms of population is Iraklion, whose share of the total population of Crete is nearly 50%. The population of Iraklion is nearly twice that of the next largest prefecture of Chania, which has almost double the population of Rethymnon and Lasithi. Table 15 shows the growth of the population over the past fifty years. In 2001, the island of Crete accounted for 5.5% of the total population of Greece.

Table 15: *Population of Crete, by prefecture, 1961 – 2001, (National Statistical Service of Greece).*

Administrative units	1961	1971	1981	1991	2001	Inhabitants /km^2	1961-2001 %
Crete	483,258	456,642	502,165	540,054	601,131	72.1	24.4
Iraklion	208,374	209,670	243,622	264,906	292,489	111.8	40.36
Chania	131,061	119,791	125,856	133,774	150,387	62.4	14.75
Rethymnon	69,943	60,949	62,634	70,095	81,936	54.7	17.14
Lasithi	73,880	66,226	70,053	71,279	76,319	41.6	3.3

Iraklion is the prefecture with the highest population density and has almost 40 persons more per km^2 than Crete as a whole. Moreover, Iraklion has 28.7 more persons per km^2 than the does the country as a whole (national population density -83.09). The population density in the remaining prefectures is lower, especially in Lasithi that has almost 30.5 inhabitants less per km^2 than Crete as a whole. Finally, in addition to the permanent inhabitants, Crete receives about 2 million visitors during the tourist period from April to October (1999).

Table 16 shows the breakdown of Cretan inhabitants by age group, and the share of each age group to the whole population. Over 33.5% of the population of Crete is in the age group of 20-39, nearly 25% is in the age group of 40-59, and 18.5% is in the "younger" generation of ages 6-19. The population is divided almost equally between males and females. The age groups with the biggest concentration of both male and female population are the 20-39 and 40-59 groups.

Table 16: *Total population distribution by age groups and gender, (National Statistical Service of Greece (2001)).*

Age groups	Total	% in total population	Male	% in total population	Female	% in total population
6-9	102,853	18.5	54,104	9.8	48,749	8.8
20-39	185,751	33.5	96,749	17.4	89,002	16.1
40-59	137,911	24.9	69,948	12.6	67,963	12.3
60-74	88,183	15.9	41,381	7.5	46,802	8.4
75-more	39,643	7.1	17,402	3.1	22,241	4.0
Total	554,341	100	279,584	50.4	274,757	49.6

Figure 46 provides a diagrammatic presentation of the population distribution broken down by both age group and gender.

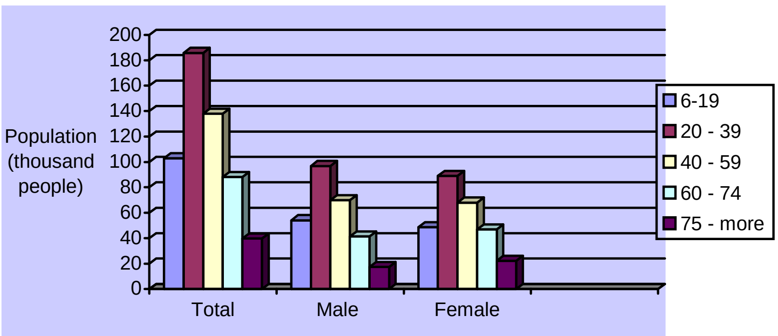


Figure 46: *Population distribution based on gender and age group for 2001, (National Statistical Service of Greece (2001)).*

Table 17 shows the distribution of population by age groups in the prefectures of Crete, as well as the breakdown by gender of their total population. In the prefectures of Iraklion, Chania and Rethymnon the population is divided almost equally between males and females. Only in Chania is the male population slightly higher (2.2%) than the female population. In all the prefectures the age groups with the biggest population concentration are the groups of 20-39 and 40-59.

Table 17: *Population distribution* by age and gender, by prefecture, (National Statistical Service of Greece (2001)).*

Age groups and gender	Population distribution by age and gender							
	Iraklion	%	Lasithi	%	Rethymnon	%	Chania	%
6-19	51,441	18.9	12,039	16.9	14,278	19.5	25,095	18.1
20-39	92,530	34.1	21,129	29.7	25,542	34.9	46,550	33.6
40-59	68,659	25.3	17,729	24.9	16,512	22.1	35,011	25.2
60-74	41,523	15.3	13,367	18.8	11,206	15.3	22,087	15.9
75-more	17,262	6.4	6,826	9.6	5,653	7.7	9,902	7.1
Total	271,415	100	71,090	100	73,191	100	138,645	100
Male	136,242	50.2	35,823	50.4	36,623	50.0	70,896	51.1
Female	135,173	49.8	35,267	49.6	36,568	50.0	67,749	48.9

** These numbers include the population aged 6 years old and above.*

1.9.1.2 Family structure

Table 18 shows the total number of households in Crete and its prefectures, as well as the distribution of households according to their members. The average number of members in the Cretan household is 2.75 persons.

Table 18: *Distribution of households, broken down by number of members, (NSSG (2001) http://www.statistics.gr).*

Administrative unit	Total number		Households, by number of members				
	Households	Members	1	2	3	4	5 or more
Crete	200,299	552,566	43,005	56,625	39,425	39,527	21,717
Iraklion	97,406	273,424	19,838	26,830	19,395	20,453	10,890
Chania	49,235	134,583	10,751	13,826	10,017	9,637	5,004
Rethymnon	26,244	72,857	6,549	6,873	4,673	4,501	3,648
Lasithi	27,414	71,702	5,867	9,096	5,340	4,936	2,175

The households of Iraklion account for 48.6% of the total number of households in Crete, while Chania accounts for 24.6%. Rethymnon and Lasithi account for 13.1% and 13.7% respectively. There is no data available about the average income of a salaried resident of Crete, so the average annual household expenditures can be used as a proxy. On the average a Cretan inhabitant spends 1,094.07€ (1998) per year, while the average annual expenditures at the national level are 1,383.24€. Table 19 shows the total number of childbirths (living) realised in 2001 in Crete and its prefectures. As can be seen in the table, almost half the childbirths in Crete in 2001 took place in the prefecture of Iraklion. The prefecture of Chania followed with 22.8% of childbirths. Moreover, 52.2% of live childbirths took place in rural areas, while 15.6% were in semi-rural areas and 32.1% in agricultural areas of the island of Crete.

Table 19: *Number of childbirths, by prefecture and type of area, (NSSG (2001).*

Mother's Permanent Residence	Total Number	% of total	Childbirths, by type of area		
			Rural	Semi-rural	Agricultural
Greece	102,739		70,764	15,284	15,775
Crete	6,567	100	3,431	1,026	2,110
Iraklion	3,345	50.9	2,075	425	845
Lasithi	754	11.5	-	526	228
Rethymnon	971	14.8	561	20	390
Chania	1,497	22.8	795	55	647

Childbirths in Crete in 2001 account for 6.4% of the country's total childbirths, and 13.4% of the country's childbirths in agricultural areas. In 2001 the total number of childbirths in Crete increased by 8.3%, compared to its total childbirths in 1999. The increased rate of childbirths by prefecture ranged from 4.8% in Iraklion to 14.3% in Chania.

The natural growth of the total population in Crete appears increased and is equal to 1.2 persons per 1000 inhabitants for 1999, in contrast to the natural growth of the national population where there is a decline by -0.25 persons per 1000 inhabitants. In Iraklion and Rethymnon there is an increase by 3.2 and 1.7 persons per 1000 inhabitants respectively. However, this behavior is not observed in the remaining two prefectures, Lasithi and Chania, where there is a decline by -2.5 and -0.9 persons per 1,000 inhabitants respectively. These magnitudes are illustrated in the following figure 47.

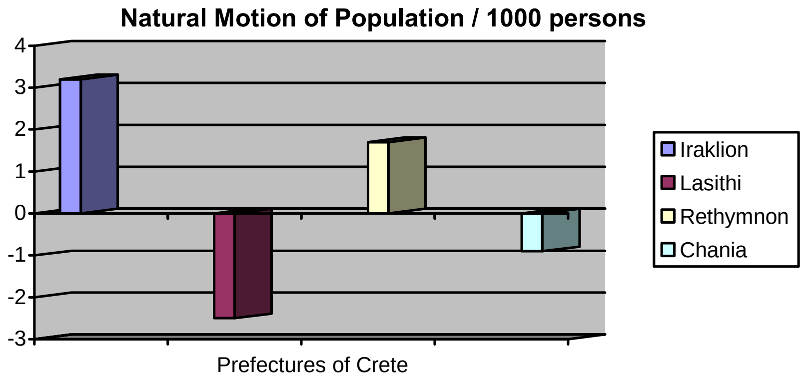


Figure 47: *Natural motion of population, (Prefectures of Greece).*

1.9.1.3 Education

Table 20 shows the total number of students that attended various levels of education (public and private (In Crete only Iraklion and Chania have private schools, which account for 1.7% of the total population of primary and secondary education students) in Greece, and in Crete and its prefectures, in the year 2001. More specifically, the Greek educational system is divided into three levels: primary school (elementary education [6 years]), lower secondary school (gymnasium [3 years]) and upper secondary school (lyceum [3 years]).

Table 20: *Distribution of Greek students, by educational level and geographic location, 2001, (Prefectures of Greece).*

Administrative unit	Primary Education Students	Lower Secondary Education Students	Upper Secondary* Education Students
Greece	695,381	367,539	423,843
Crete	39,999	21,797	21,635
Chania	10,185	4,895	5,584
Iraklion	19,786	11,704	11,011
Lasithi	4,933	2,575	2,488
Rethymnon	5,095	2,623	2,552

**Including vocational training schools*

Table 21 shows the average number of primary and secondary school students per 1,000 inhabitants in Crete and its prefectures, as well as in Greece as a whole, for the years 1992 and 2000. In general terms, the average number of students receiving both primary and secondary education in Greece, is declining. However, in most prefectures of Crete the observed reduction, at both educational levels, is smaller than the national average. Only in the prefecture of Iraklion is the percentage decrease in students higher (by 1.5%) than the decrease in the national average.

Table 21: *Average number of students (per 1,000 inhabitants), (Prefectures of Greece).*

Administrative unit	Average number of Students/ 1000 inhabitants					
	Primary education			Secondary education		
	1992	2000	%	1992	2000	%
Greece	76	60.8	-20.0	80.6	72.1	-10.5
Crete	83	69	-16.9	83	75	-9.6
Chania	81	70	-13.6	77	73	-5.2
Iraklion	88	69	-21.6	91	80	-12.1
Lasithi	77	68	-11.7	72	69	-4.2
Rethymnon	79	69	-12.6	77	70	-9.1

Figure 48 shows the evolution of the average number of secondary school students on the island of Crete from 1981 to 2000. It appears that there is a downward trend in the average number of secondary education students after 1995.

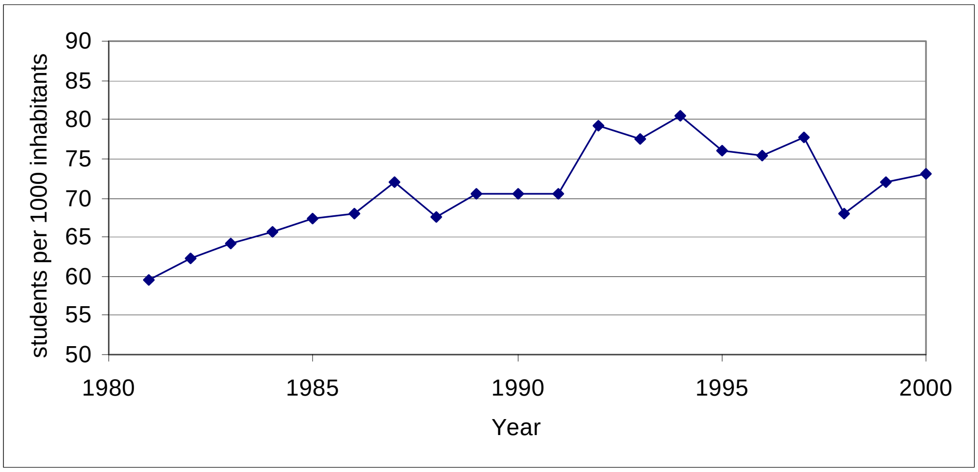


Figure 48: *Average number of secondary school students in Crete (per 1,000 inhabitants), 1981-2000, (The Prefectures of Greece, Epilogi (adapted)).*

Table 22 shows the distribution of the population of Crete and its prefectures based on the level of education completed, for the year 2001. The classification is based on the Certificates, Degrees or Diplomas that document completion of the educational level. It is noteworthy that 34.9% of the population of Crete has only completed elementary education and that 48.9% of this group is located in Iraklion. There is an additional 5.8% that has not finished primary school, but has basic reading and writing skills; 62.7% of this group are women. Only 3% of the population is illiterate, the majority (73.1%) of whom are women. About 23% of the total population possesses a High School Diploma, indicating successful completion of Upper secondary school, while an additional 12.3% has completed Lower secondary school (Gymnasium). About 13% possesses an Undergraduate university degree (B.A.). However, only 0.48% of the total population of Crete has successfully completed Postgraduate Studies.

Table 22: *Population distribution* by educational level and gender, (NSSG (2001)).*

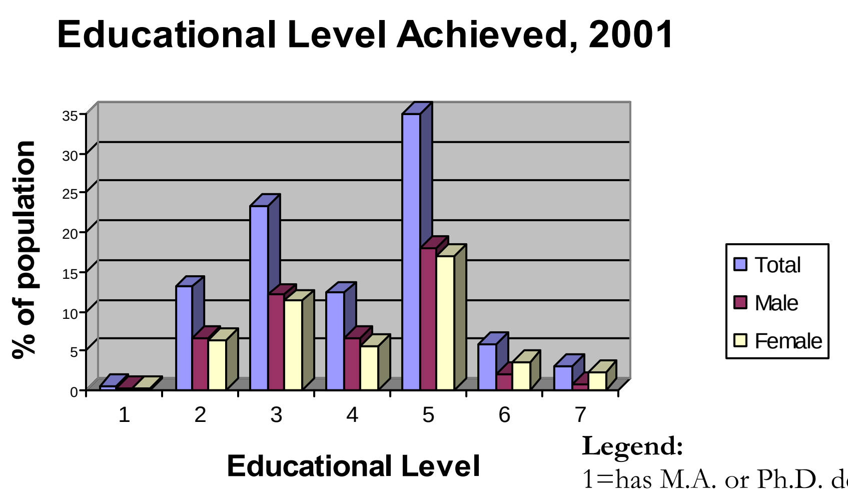
	Post-graduate Studies[a]	Under-graduate Studies[b]	Higher Education Diploma[c]	Gym-nasium Degree	Elementary Education graduates	Elementary Education incomplete	Have not attended School
Gender	**1**	**2**	**3**	**4**	**5**	**6**	**7**
				Crete: 554,341			
Total	2,667	72,342	129,281	67,939	193,404	31,968	17,186
Male	1,690	36,595	66,799	37,421	99,892	11,910	4,621
Female	977	35,747	62,482	30,518	93,512	20,058	12,565
				Iraklion: 271,415			
Total	1,557	36,555	60,323	32,620	94,648	17,036	9,152
Male	986	18,308	30,552	17,840	49,425	6,535	2,451
Female	571	18,247	29,771	14,780	45,223	10,501	6,701

Table 22 continued.

Gender	Post-graduate Studies[a]	Under-graduate Studies[b]	Higher Education Diploma[c]	Gym-nasium Degree	Elementary Education graduates	Elementary Education incomplete	Have not attended School
	1	2	3	4	5	6	7
Lasithi: 71,090							
Total	115	8,181	15,448	8,911	26,828	4,051	2,734
Male	67	4,212	8,101	4,976	13,847	1,444	629
Female	48	3,969	7,347	3,935	12,981	2,607	2,105
Rethymnon: 73,191							
Total	310	8,408	17,501	9,164	26,007	4,052	2,371
Male	181	4,093	8,499	5,117	13,749	1,545	656
Female	129	4,315	9,002	4,047	12,258	2,507	1,715
Chania: 138,645							
Total	685	19,198	36,009	17,244	45,921	6,829	2,929
Male	456	9,982	19,647	9,488	22,871	2,386	885
Female	229	9,216	16,362	7,756	23,050	4,443	2,044

[*]This table contains the population aged 5 years and above. [a]This category includes both Ph.D. and Master's degree holders. [b]This category includes graduates of Universities, Technological Institutions (TEI) and other studies after secondary school. [c]This category includes General High schools, Technological High schools and Technical schools.

Figure 49 provides a diagrammatic presentation of the above breakdown of the educational level of the Cretan population by gender, thus making it easier to compare.



Legend:
1=has M.A. or Ph.D. degree
2=has B.A. degree
3=has high school diploma
4=has gymnasium diploma
5=has completed elementary education
6=has some elementary education
7=has not attended school

Figure 49: *Education level, (NSSG (2001)).*

The University of Crete was established in 1973 and began functioning in the academic year 1977-78. It has five Schools and seventeen Departments in the cities of Rethymnon and Iraklion. It currently has 10,628 students, 8,962 at the undergraduate level and 1,666 at the postgraduate level (U*niversity of Crete Prospectus, 2003*). During the academic year 1981-1982, the University of Crete awarded 42 degrees certificates, while during the academic year 2000-2001 the total number of degrees awarded was 850. The University of Crete has awarded a total of 9,971 degrees.

On the other hand, the Technical University of Crete was established in Chania in 1977 and welcomed its first students in 1984. It has five Departments with an enrollment of 1,750 undergraduate students and 400 postgraduate students (http://www.tuc.gr).

Table 23 shows the total population of students attending Universities and Technological Institutions in Crete, broken down by location and type of department. Crete has 25,300 such students, who constitute 7.7% of the corresponding total student population of Greece (328,100). For the academic year 2002, Crete's Departments accepted 5,970 new students, or 7.6% of the corresponding total population of new students in Greece (78,120). The prefecture of Iraklion has 19 Departments and 14,800 students, while the prefecture of Lasithi has only two Departments and 700 students. The total number of students in the city of Rethymnon is equivalent to 17.8% of its permanent inhabitants, while in the city of Iraklion the corresponding figure is 10.7%.

Table 23: *Students attending universities or technological institutions in Crete, 2002, (http://www.ypepth.gr).*

Town	Number of Departments in		New Students (2002)	Total Students	Permanent inhabitants (2001)	Students/ 1000 inhabitants
	Universities	Technological Institutions				
Chania	4	2	840	4,100	53,000	77
Rethymnon	9	1	1,415	5,700	32,000	178
Iraklion	8	11	3,515	14,800	138,000	107
Aghios Nikolaos	0	1	100	300	20,000	15
Siteia*	0	1	100	400	14,000	29
Crete	21	16	5,970	25,300	-	-

**Siteia is a town located in the prefecture of Lasithi.*

1.9.1.4 Health

Table 24 shows the established health services in Crete and its prefectures for 1992 and 1999. Both the number of hospital beds and the number of doctors appear to be increasing over the last decade. It is noteworthy that the number of doctors in Crete increased by 45.8% during this period.

Data regarding the number of doctors per 1,000 inhabitants in Crete provides additional useful information about the level of health services in Crete. Figure 50 depicts the evolution of the average number of doctors on the island of Crete for the period 1981-1999, indicating an almost continuous increase over this period.

Table 24: *Health care indicators in Crete, (The Prefectures of Greece).*

Administrative units	Public Hospitals	Hospital beds		Doctors	
		1992	1999	1992	1999
Crete	9	2,665	2,989	1,699	2,477
Iraklion	2	1,190	1,494	967	1,450
Lasithi	4	296	283	202	277
Rethymnon	1	215	231	138	229
Chania	2	964	981	392	521

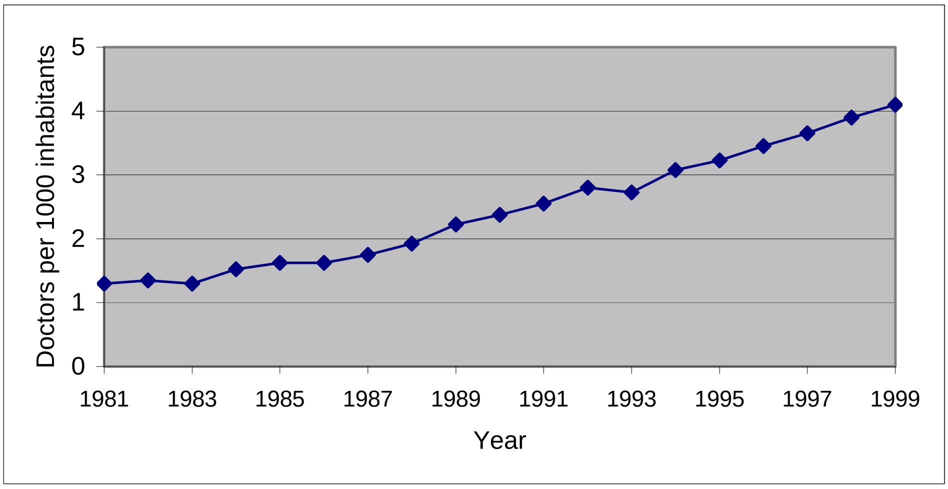


Figure 50: *Average number of doctors in Crete (per 1000 inhabitants), 1981-1999, (The Prefectures of Greece, Epilogi (adapted)).*

1.9.2 Economic profile

1.9.2.1 Gross Domestic Product (GDP)

The Gross Domestic Product (GDP) is the total value of all final goods and services produced in a country and is therefore an indicator of the productivity of the country. Table 25 provides a comparison of the level of certain key welfare indicators for Crete to the corresponding indicators for Greece as a whole. The per capita GDP of Crete is almost 3% lower than the national per capita GDP, while the declared income per inhabitant in Crete is 18.1% lower than the average national figure. The income tax per inhabitant in Crete is 33.3% below the corresponding national figure, while the savings deposits per inhabitant at the local and national levels are the same.

The prefecture of Lasithi has the highest per capita GDP -12.8% higher than the national figure and 16.3% higher than the relevant figure for Crete. The per capita GDP of the rest of the prefectures is slightly lower than the Cretan per capita GDP. Lasithi has also the highest savings deposits per inhabitant compared with the relative national and Cretan figure, followed by Chania. Rethymnon has the lowest declared income per inhabitant of the Cretan prefectures, followed by Lasithi. Finally, in Lasithi the income tax per inhabitant is 45% lower than the national figure and 17.6% lower than the Cretan figure. Rethymnon displays similar behaviour, while the income tax per inhabitant in Iraklion and Chania is 6.4% and 3% higher respectively than the relevant figure for Crete.

Table 25: *Key welfare indicators for Crete as compared to Greece*, (The Prefectures of Greece).*

	Per capita GDP	Saving deposits per inhabitant	Declared income per inhabitant	Income tax per inhabitant
Greece	11,885.54€	4,108.58€	4,695.52€	384.45€
Crete	11,533.38€	4,108.58€	3,844.46€	256.49€
Iraklion	11,093.18€	3,873.81€	3,903.15€	272.93€
Lasithi	13,411.59€	4,636.83€	3,668.38€	211.29€
Rethymnon	11,386.65€	3,756.42€	3,492.29€	220.10€
Chania	11,474.69€	4,548.79€	4,020.54€	264.12€

**Data for all indicators is from the years 1999 – 2001.*

In 2001 the GDP of Crete as a whole was equal to 6,929.04€ and constituted 5.3% of the national GDP in current prices (130,436.08€). This figure closely corresponds to Crete's proportion of the total population of the country. As shown in figure 51, Iraklion comprises the biggest share (47%) of the GDP of Crete, followed by Chania (25%), Lasithi (15%) and Rethymnon (13%).

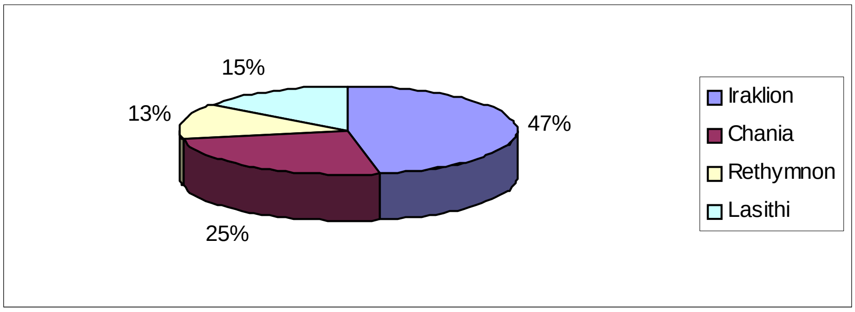


Figure 51: *GDP of Crete, by prefecture, 2001, (The Prefectures of Greece, Epilogi (adapted)).*

The evolution of the per capita GDP of Crete and its prefectures is shown in figure 52. It is clear from this figure that per capita GDP exhibits an almost continuously increasing behavior.

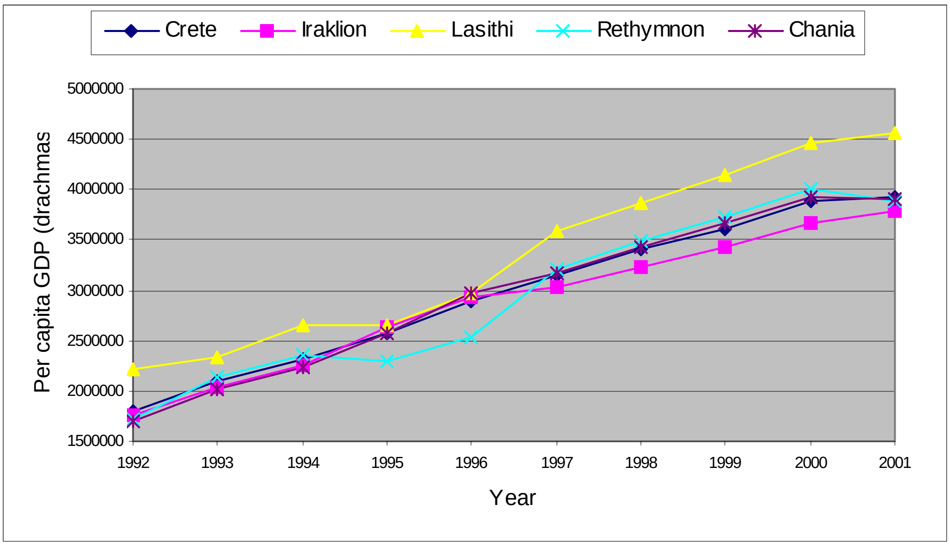


Figure 52: *Per capita GDP of Crete (current drachmas), by prefecture, 1992-2001, (The Prefectures of Greece, Epilogi (adapted)).*

Table 26 shows Crete's percentage share of the national total, for certain welfare indicators. It is worthy of note that the GDP of Iraklion accounts for 47.2% of Crete's contribution to the national GDP, while Chania accounts for 24.5% of that share. Iraklion and Chania account for 50% and 25% respectively of the Cretan share of Greek taxpayers. The percentage contribution of these two prefectures is similar with regard to saving deposits. Iraklion accounts for 56.5% of Crete's percentage share national total direct taxes, followed by Chania that accounts for 21.7%.

Table 26: *Percentage share of Crete to Greek total welfare indicators, (The Prefectures of Greece).*

Percentage share of Greek total					
Welfare indicators	**Crete**	**Iraklion**	**Lasithi**	**Rethymnon**	**Chania**
GDP	5.3%	2.5%	0.8%	0.7%	1.3%
Taxpayers	4.8%	2.4%	0.6%	0.6%	1.2%
Declared income	4.4%	2.2%	0.5%	0.5%	1.1%
Direct taxes	2.3%	1.3%	0.2%	0.3%	0.5%
Savings deposits	4.5%	2.1%	0.7%	0.5%	1.2%

Figure 53 shows the average annual rate of growth of the Cretan economy as a whole and by prefecture, relative to the economy of Greece as a whole. As it can be seen, the average annual growth rate of Crete is 0.38% above the corresponding national figure. Rethymnon displays the highest economic growth in Crete, which is nearly 0.5% higher than the national average growth. Chania follows with a growth rate that is about 0.46%

above the national figure, while the growth rate of the prefectures of Lasithi and Iraklion are slightly less than the average annual rate of Crete.

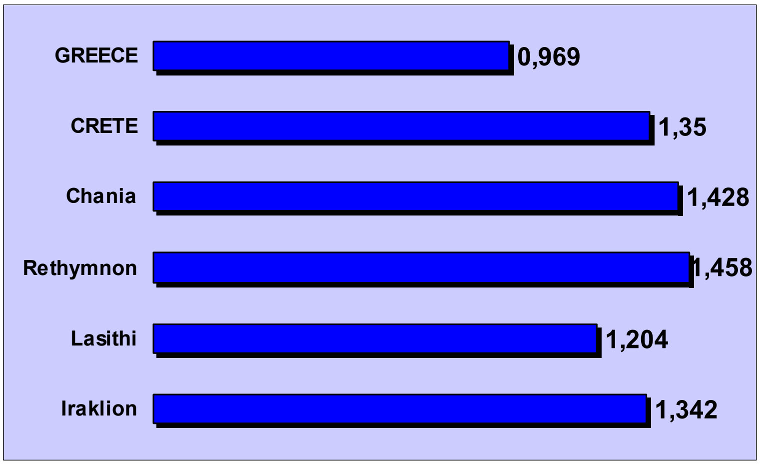


Figure 53: *Average annual rate of economic growth (%) of Greece and Crete (by prefecture), 1981-1998.*

1.9.2.2 Investments

Level of investment, both public and private, is another indicator of development and prosperity in an area. As it can be seen in figure 54, public investment in Greece in constant prices remained at about the same level from 1992 to 2001, while private investment decreased from 1992 to 1994 and then increased steadily until 2001.

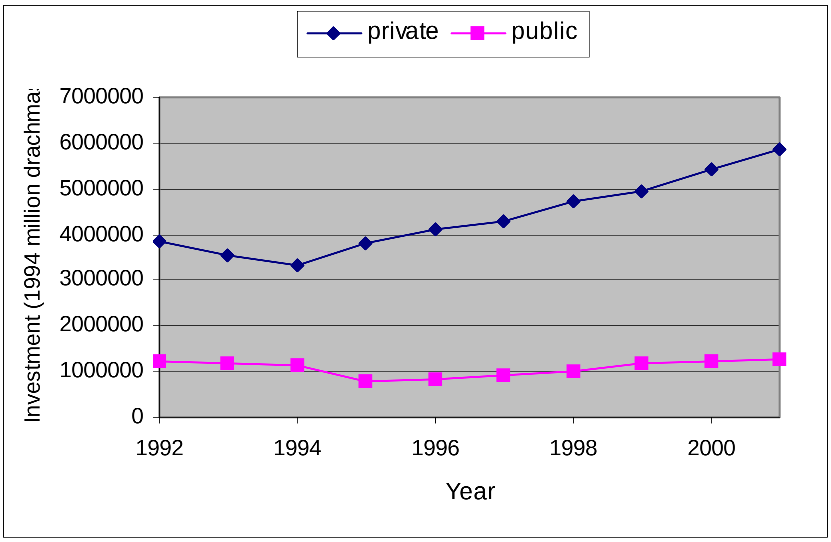


Figure 54: *Public and private investment (in 1994 prices) in Greece, 1992-2001, (100 drachmas ≅ 0.29 €) (Greek Economy in Figures, 2002).*

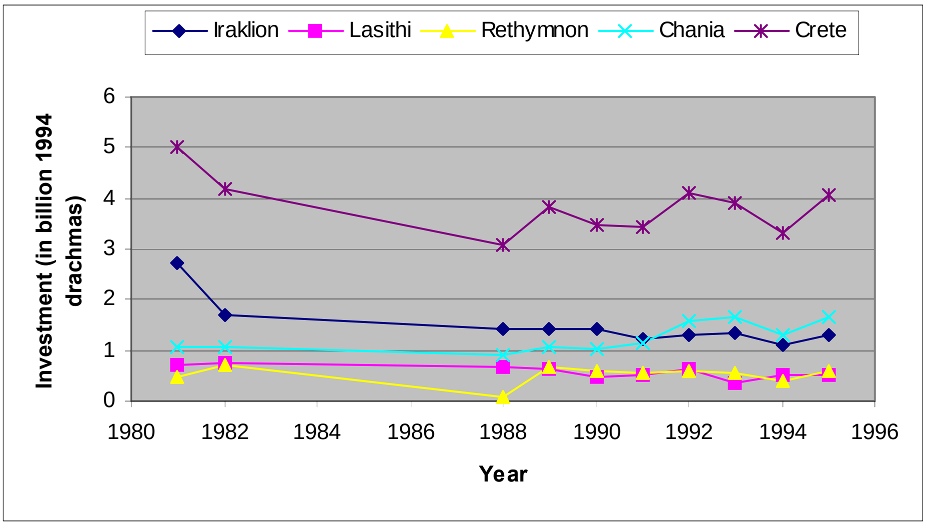


Figure 55: *Public investment in Crete, by prefecture, 1981-1995, (100 drachmas ≅ 0.29 €).*

Figure 56 shows the evolution of private investment in Crete and in its prefectures. During the period 1981 to 1996 private investment in Crete appear to be declining. Private investment in the prefectures of Chania, Lasithi and Rethymnon remains fairly constant, and only in Iraklion do we observe a declining trend similar to the one for Crete as a whole.

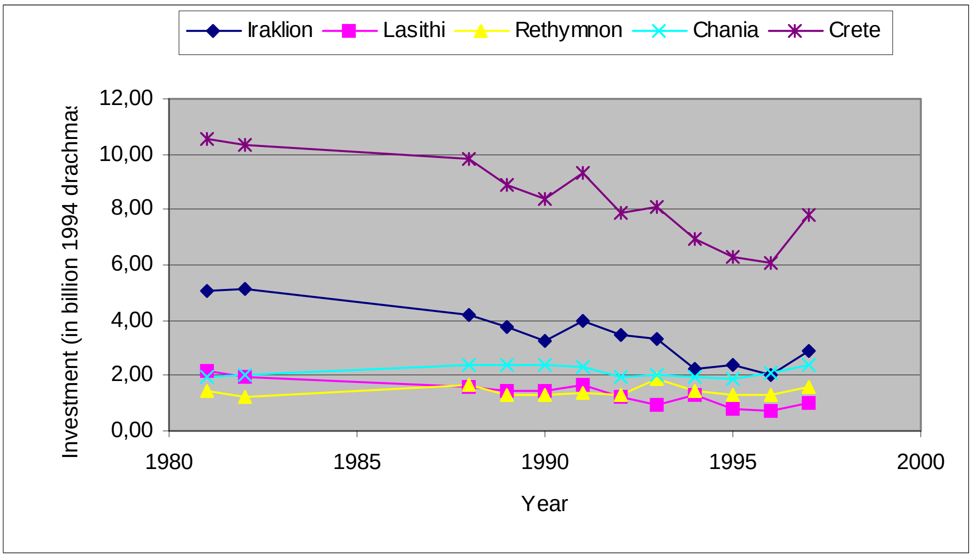


Figure 56: *Private investment in Crete, by prefecture, 1981-1997, (100 drachmas ≅ 0.29 €).*

1.9.2.3 Employment

Table 27 shows the breakdown of the population into financially active and inactive groups in 2001. Almost 42% of the total population of Crete is financially active. This percentage can be further decomposed into the unemployed financially active population (11%) and employed (89%). About 51% of the total active population is located in the prefecture of Iraklion, following by Chania with 25% and Lasithi and Rethymnon with the 13.3% and 13.2% respectively. On the other hand, almost half the population (44.7%) is financial inactive. More than 48% of the total inactive population is located in the prefecture of Iraklion, 25.7% is located in Chania, 12.8% in Lasithi and the remaining 13.5% in Rethymnon. About 38% of the total population (active and inactive) in Crete is employed.

Table 27: *Breakdown of financially active and inactive population*, (National Statistical Service of Greece (2001)).*

Administrative units	Financially Active Population			Financially Inactive
	Total	Employeed	Unemployed	
Crete	252,094	231,333	27,761	268,618
Iraklion	129,088	115,228	13,860	129,198
Lasithi	33,588	30,006	3,682	34,297
Rethymnon	33,301	29,680	3,621	36,178
Chania	63,117	56,419	6,698	68,945

**This table contains the population aged 10 years and above.*

The evolution of the unemployment rate in Greece and in Crete for the years 1989 to 2001 is shown in figure 57. The rate of unemployment in Crete is significantly lower than that of Greece as a whole for the entire period, ranging from 2.0-6.5% lower. In 2001 the unemployment rate in Crete was 6.7%, while at the national level it was 10.5%.

Table 28 shows the distribution of the financially active and inactive populations, broken down by age and gender. About 60% of the financially inactive population of Crete are women. The share of female inactive population in the total population of each prefecture is on the average 27.1%. The 33.2% of the total inactive population belongs to the 40-59 age group, following the age group 10-19 with the 25.5% and the age group 20-39 with the 16.7%. The 60 & more age group accounts only for the 5.6% of the inactive population. On the other hand, the 63.6% of the financial active population of Crete are men while the remaining percentage are women. The 54.3% of the total active population are located in the age group 20-39 and the 37.8% in the 40-59 age group.

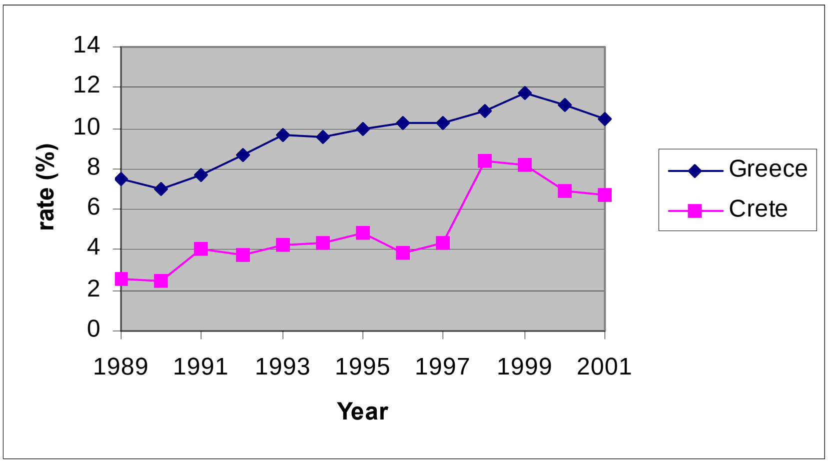


Figure 57: *Unemployment rate in Greece and Crete, 1989-2001, (Greek Economy in Figures, 2002).*

Table 28: *Allocation of active & inactive population in age and sex groups, (National Statistical Service of Greece (2001)).*

Age groups and sex groups	Financial Active Population			Financial inactive
	Total	Employed	Unemployed	
10-19	7,622	4,405	3,217	68,602
20-39	140,816	122,668	18,163	44,935
40-59	95,288	6,001	42,623	89,287
60 & more	15,368	395	112,458	14,973
Male	160,331	145,905	14,426	105,442
Female	98,763	85,428	13,335	163,176

Table 29 shows the distribution of the employed population of Crete in the various production sectors. Obviously the higher employment is concreted in the sector of services, which accounts for the 52.6% of the total employed population in 2001. The agricultural sector corresponds to 32.9% of employed population, followed by the construction and manufacturing sectors that account for the 7.2% and 6.6% respectively. The sector of services is further decomposed to its components and as it can be seen the trade sector and the sector of hotels and restaurants occupy the 26.6% and the 22.2% of the total employed population in the sector of services.

Table 29: *Allocation of employed population*, (The Greek Economy in Figures).*

Production Sector	Total Population	% in Total Population
Total	227,910	100
Agriculture	74,900	32.9
Mines, Quarries	540	0.24
Manufacturing	15,020	6.6
Electricity, Gas, Water	1.140	0.5
Construction	16,340	7.2
Services	119,980	52.6
Trade	31,980	(26.6)
Hotels, Restaurants	26,630	(22.2)
Transport, Communication	10,580	(8.8)
Banking, Insurance	4,230	(3.5)
Real Estate Management	7,260	(6.05)
Public Services	12,890	(10.7)
Education	12,770	(10.6)
Health	7,950	(6.6)
Other Services	5,690	(4.7)

**This table contains the population aged 15 years and above.*

1.9.2.4 Production

Production is divided into three sectors: the primary, secondary and tertiary sectors. As can be seen in figure 58, in 1994 the primary sector in Greece contributed 10% to the GDP, the secondary sector 24% and the tertiary sector 66%. In 1998 the contribution of both the primary and the secondary sector slightly declined (2%), while the tertiary sector grew by 4% to a total of 70% of the total national production.

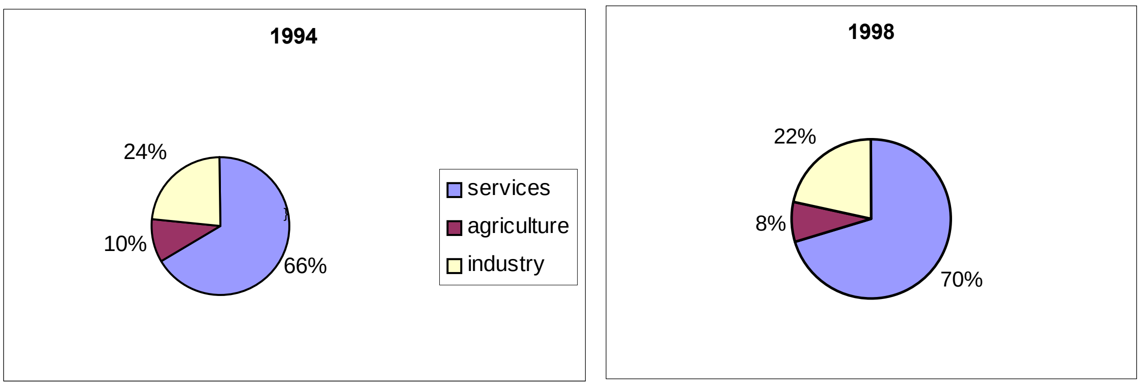


Figure 58: *Production by sector in Greece, 1994 and 1998, (The Prefectures of Greece, Epilogi (adapted)).*

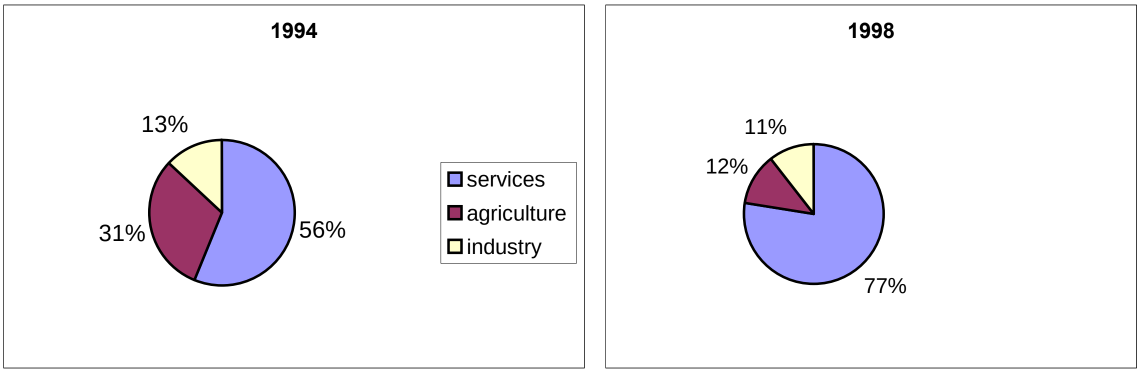


Figure 59: *GDP-contribution by sector in Crete, 1994 and 1998, (The Prefectures of Greece, Epilogi (adapted)).*

In contrast, in 1994 31% of the GDP of Crete came from the primary sector (agricultural activity), which is more than three times the relative percentage for Greece as a whole. The industry and services sectors in Crete were not as developed as in the rest of Greece. By 1998, however, a very striking shift had occurred, with the agricultural sector shrinking dramatically, while the services sector expanded rapidly. The industry sector remained about the same (figure 59).

Table 30 shows the percentage contribution of each production sector to the total GDP of Crete and its prefectures for 1998. The services sector accounts for the biggest share of the total GDP - more than three-quarters - and in Chania services account for almost 82% of GDP. The contribution of the agricultural sector fluctuates from 10% to 15%, while the relative share of the industry sector varies from 9% to 12.3%. Mines and quarries have the lowest share, followed by the energy sector.

Table 30: *Contribution in the total GDP (in %), (The Prefectures of Greece, Epilogi).*

Sector	Crete	Iraklion	Lasithi	Rethymnon	Chania
Agricultural	12.0	12.0	15.0	15.0	10.0
Industry	10.4	11.2	9.0	12.3	8.7
Mines, Quarries	0.1	0.1	0.3	0.3	0.1
Manufacturing	2.9	3.6	1.2	2.9	2.4
Energy	2.0	3.0	2.0	2.0	2.0
Constructions	5.1	4.6	5.9	7.5	4.4
Services	77.4	76.9	75.9	72.7	81.6

1.9.2.5 Tourism

Tourism is an important economic activity in Crete and in Greece as a whole. The total number of tourists in Crete in the year 1999 exceeded two million. Table 31 shows the total number of overnight stays by foreign and local visitors in hotels and similar establishments (including campgrounds) on the island of Crete and in Greece in the years 1981, 1991 and 2001. It is noteworthy that the total number of overnight stays in Crete increased by 110% during the period 1981-2001. Crete's share of the total number of overnight stays in Greece was almost 19% for 2001 and has increased by about 5.5% since 1981.

Table 31: *Number of overnight stays, (The Greek Economy in Figures).*

Number of overnight stays	1981	1991	2001	% change 1981-2001
Total visitors/ Greece	41,032,029	42,585,746	61,556,796	+50%
Total visitors/ Crete	5,553,369	7,321,133	11,671,913	+110%

The evolution of the total number of overnight stays by tourists (both foreign and domestic) in Crete and by prefecture, from 1981 to 2000 is depicted in figure 60. It is evident that the particular figure in Crete as a whole is mostly affected by the number of overnight stays realised in the prefecture of Iraklion and displays a similar behavior over time. The relative figures in the rest of the prefectures display a slightly increasing trend.

Figure 61 shows each prefecture's share of the total number of overnight stays in Crete for 2002. The prefecture of Iraklion accounts for almost half number of overnight stays, while the rest is shared between the other three prefectures.

Figure 62 shows the number of available beds in the four prefectures and in Crete for the period 1981 to 2001. During this period, there was a 270% increase in the number of beds available to tourists, which is a further indication of the ongoing growth of the tourism sector.

Table 32 shows the allocation of hotel establishments and the available number of beds according to the quality of services offered. About 53% of the hotel establishments are of medium quality (C class), nearly 21% belong to the B class category, while 14.5% offer high quality services (AA & A class). Even though 11.4% of hotels offer lower quality services (D & E Class), the corresponding number of beds is only 4.2% of the total. More than 39% of the available beds are in high quality hotel establishments (AA & A class), while 33.5% are in medium quality establishments (C class).

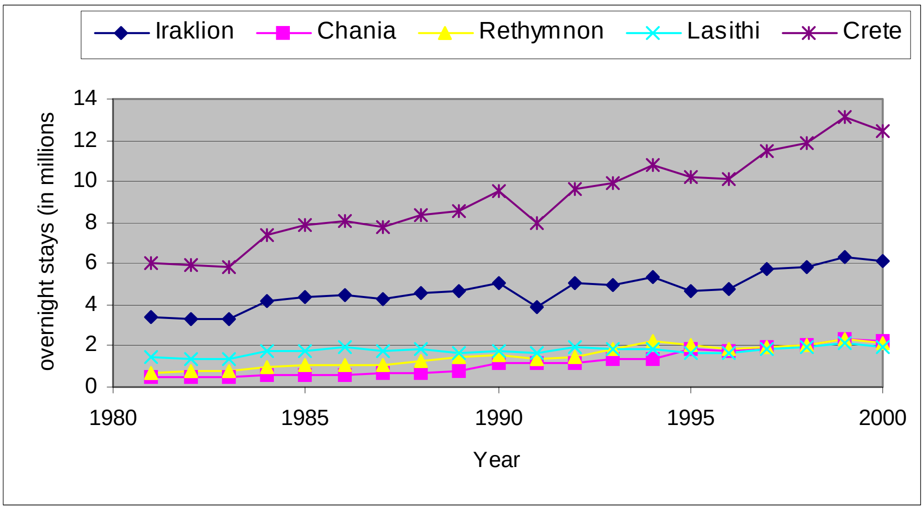


Figure 60: *Number of overnight stays by tourists in Crete, by prefecture, 1981-2000, (The Prefectures of Greece, Epilogi (adapted)).*

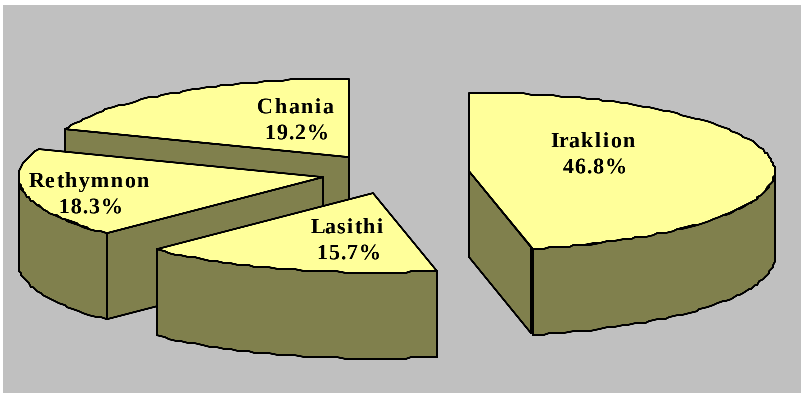


Figure 61: *Distribution of overnight stays in Crete, by prefecture, 2002, (Agency of Tourism of Prefecture of Crete).*

As can be seen in figure 63, in the year 2000 Crete provided 20% of all available beds at the national level, and well as accounting for 20% of all overnight stays by tourists both foreign and domestic, in Greece as a whole. It is worth mentioning that 43.5% of the available beds in Crete are located in the prefecture of Iraklion (52,380 beds).

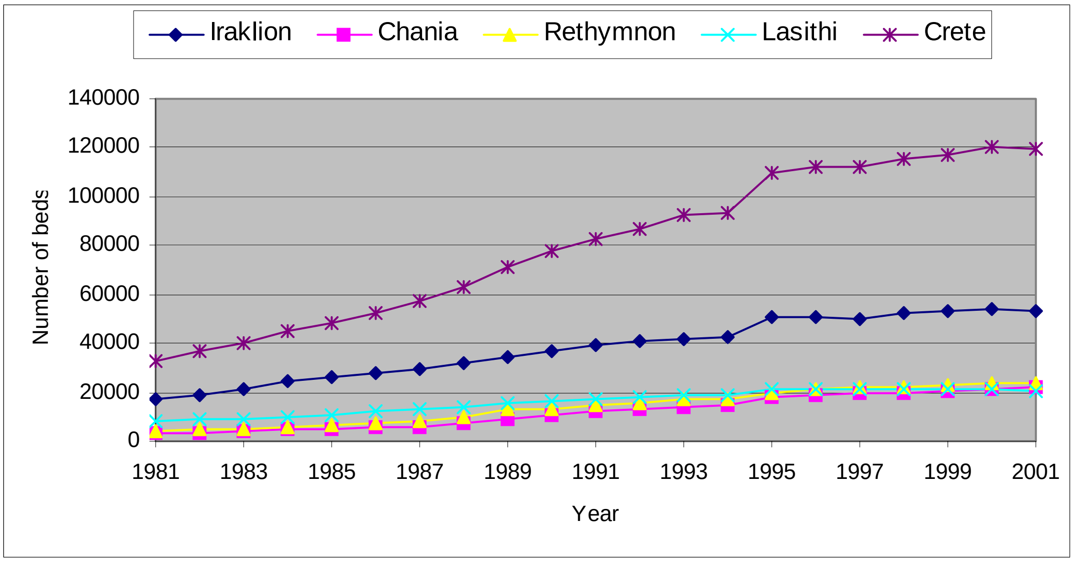


Figure 62: *Number of beds in Crete, by prefecture, 1981-2001, (The Prefectures of Greece, Epilogi (adapted)).*

Table 32: *Breakdown of hotels by number of beds and category, (Agency of Tourism for the Prefecture of Crete).*

	AA Class	A Class	B Class	C Class	D & E Class	Total
Hotels	21	177	284	728	156	1,366
Beds	10,247	36,947	27,880	40,492	5,100	120,666

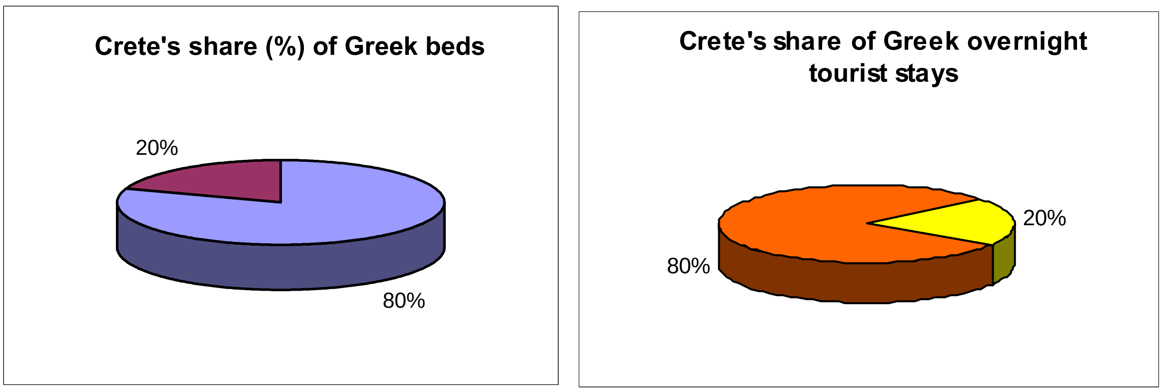


Figure 63: *Crete's share (%) of total beds and overnight stays in Greece, 2000, (The Prefectures of Greece, Epilogi (adapted)).*

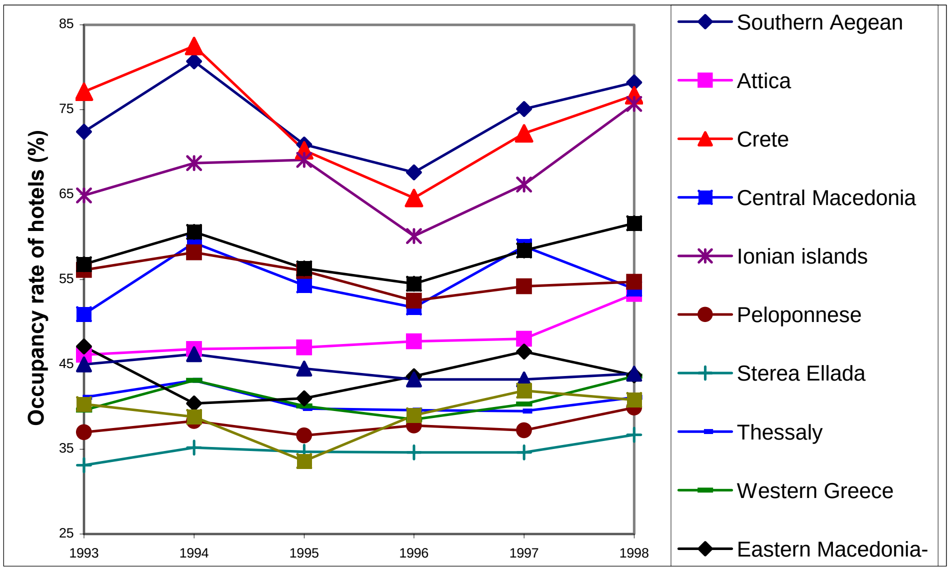


Figure 64: *Occupancy rates of Greek hotels, by region, 1993-1998.*

1.9.2.6 Agriculture

Agriculture continues to be an important economic activity in Crete. Despite the fact that the percentage of the workforce employed in the agricultural sector has dropped slightly, agriculture continues to compose a significantly larger percentage share of GDP than is found in Greece as a whole. Nevertheless in this respect Crete is following the trend, found throughout the country, in which the agricultural workforce is gradually shrinking. Table 33 shows the total number of farms with agricultural production in Crete, their share of the total number of farms on the national level and their area in km². Crete's shares of the total national area used for agricultural production increased by 2.5% over the period 1991-2000. The average size of farms in Crete has increased by 10.7% over the last decade and in 2000 it was 1.5% lower than the national average size while in 1991 the gap was wider and equal to 9.7%.

Table 33: *Farms with agricultural production in Crete, (The Greek Economy in Figures).*

Area with agricultural production	Greece		Crete	
	1991	2000	1991	2000
Total number of farms with agricultural use	852,866	808,602	87,567	90,907
Farms % of Total	100	100	10.2	11.2
Area (in 10^{-3}km²)	35,594.3	35,790.8	2,810.9	3,893.0
Area (% of Total)	100	100	8.4	10.9
Average size of farms (in 10^{-3}km²)	41.8	44.3	32.1	42.8

The total area of cultivated as well as fallow land is a basic indicator of the size of the agricultural sector in Crete for the period 1980-2000. The total cultivated area in Crete is less than the average national cultivated area. Table 34 shows that for the year 1995, 42.2% of total cultivated area is irrigated and the average annual irrigation needs are 439,620,000m^3. Moreover, on the average 418.6m^3 of water are utilised per cultivated 10^{-3}km^2.

Table 34: *Cultivated and irrigated areas in Crete, (http://www.crete-region.gr).*

Administrative units	Total Cultivated Area [10^{-3}km^2]	Total Irrigated Area [10^{-3}km^2]	Irritation Needs [Mm^3/yr]	m^3 per [10 $^{-3}$km^2]
Chania	572,805	251,098	108.90	433.6
Rethymnon	391,950	86,783	39.14	451.0
Iraklion	1,211,974	518,810	202.91	391.1
Lasithi	376,862	222,402	88.66	398.6
Crete	2,553,591	1,079,093	439.62	418.6 (average)

The evolution of the total area with agricultural use, as well as the area of irrigated land is shown in figures 65-68 for each individual prefecture of Crete. In Iraklion the cultivated (and fallow) land displays a constant trend, while the irrigated area appears to be increasing over time.

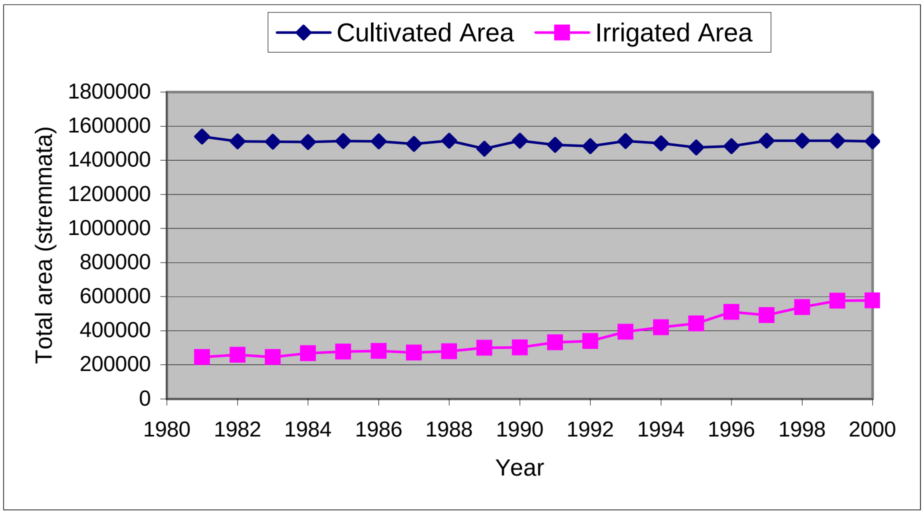


Figure 65: *Cultivated and irrigated land (1stremma ≈ 10^{-3}km^2), Iraklion prefecture, 1981-2000, (The Prefectures of Greece, Epilogi (adapted)).*

The prefecture of Chania displays similar behavior to that of the prefecture of Iraklion. The cultivated area of the prefecture of Lasithi appears to be constant over time. The irrigated area displays a slightly increasing trend, even though during the period 1993-1997 it displays a notable increase. Finally the prefecture of Rethymnon displays similar behavior to that of the prefectures of Iraklion and Chania, where the cultivated (and fallow) land displays a constant trend and the irrigated area appears to be increasing over time.

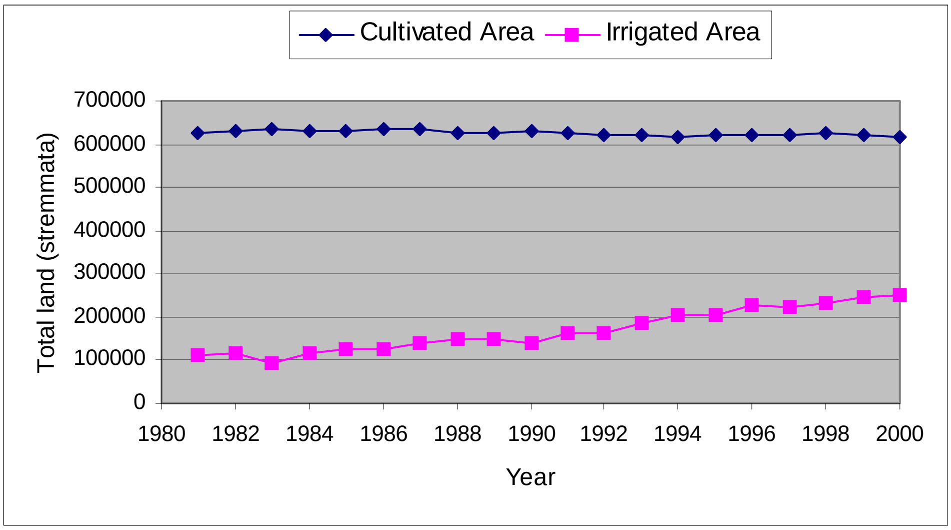


Figure 66: *Cultivated and irrigated land (1 stremma ≈ 10^{-3} km^2), Chania prefecture, 1981-2000, (The Prefectures of Greece, Epilogi (adapted))* .

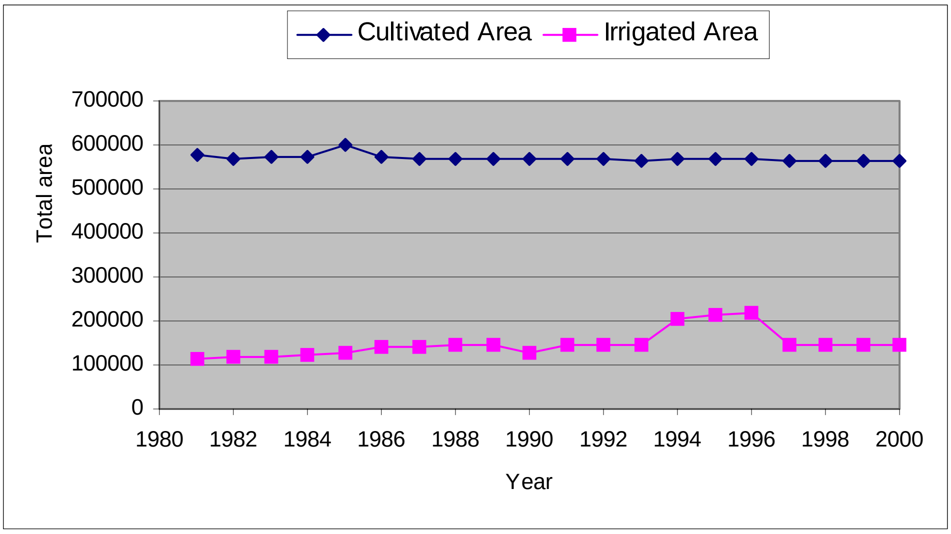


Figure 67: *Cultivated and irrigated land (in stremmata; 1 stremma ≈ 10^{-3} km^2), Lasithi prefecture, 1981-2000, (The Prefectures of Greece, Epilogi (adapted)).*

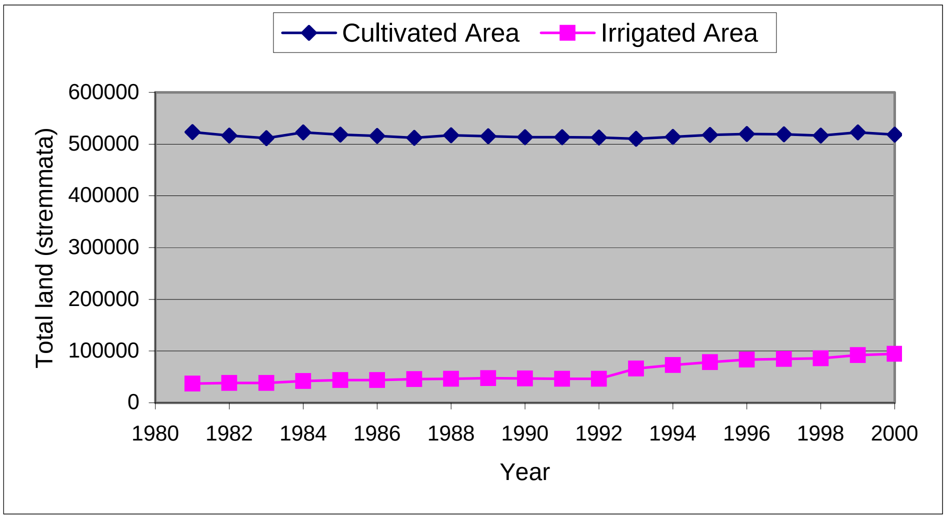


Figure 68: *Cultivated and irrigated land (1 stremma ≈ 10^{-3} km^2), Rethymnon prefecture, 1981-2000, (The Prefectures of Greece, Epilogi (adapted)).*

In general terms the area of cultivated land in the four prefectures of Crete remained stable during the period 1981-2000, while the area of irrigated land increased. Figure 69 presents the evolution of the proportion of irrigated land in each prefecture of Crete. The particular figure clearly illustrates the increasing demand for water for irrigation use in Crete. The observed increase in the proportion of irrigated land over the twenty-year period ranges from 17.6% in Lasithi to 30% in Iraklion.

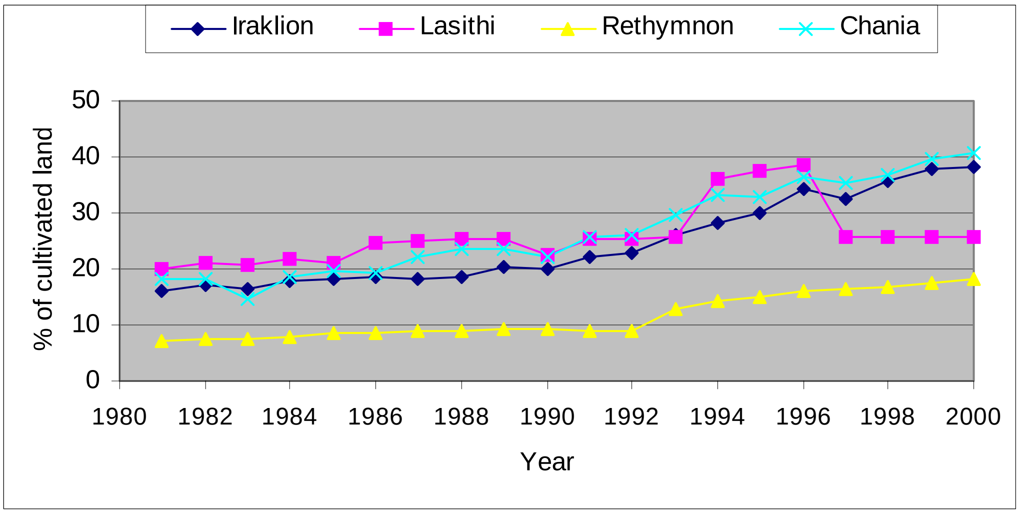


Figure 69: *Proportion of irrigated cultivated land in Crete, by prefecture, 1981-2000, (The Prefectures of Greece, Epilogi (adapted)).*

The specialisation of Cretan farmers in traditional cultivations, such as olive-oil and wine production, is worth noting. Even though the production of vegetables accounts for only 3% of the total cultivated area, Crete accounts for 50% of greenhouses in Greece. Moreover, Crete has a comparative advantage in the production of fresh vegetables and flowers. Even though the livestock production in Crete has an extensive nature, the Cretan production of hard cheese accounts for 25% of the national production. The fishery sector faces various problems (management, innovation and restructuring of fishing fleet and of fishing methods). However, even though the agriculture sector in Crete benefits from the ideal climate conditions and the existing flora, the sector is characterised by a long-term structural weakness due to the small size and the scattering of the farms with agricultural use.

Figure 70 shows the evolution of the Cretan production of five characteristic agricultural products, measured in tons, during the period 1988-2001. In general terms all these products display an increasing trend. Especially noteworthy is the increase in the production of olive oil and tomatoes.

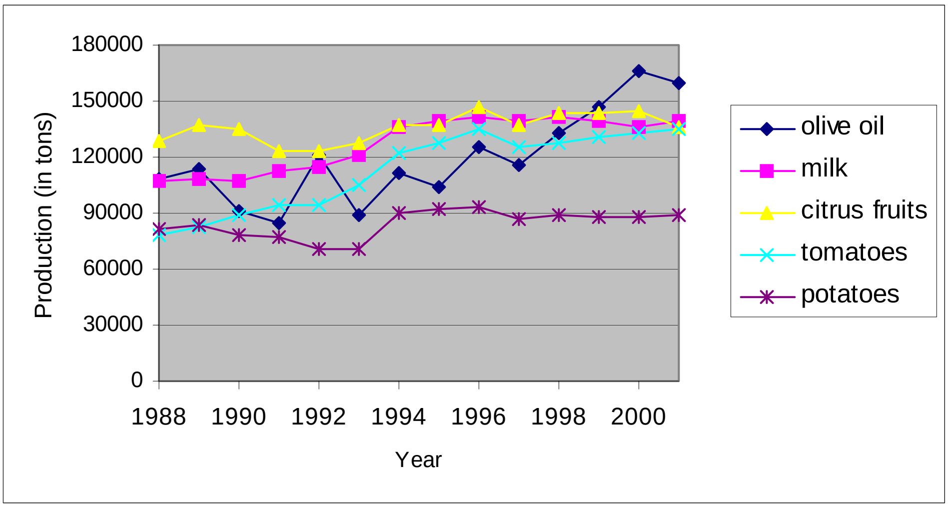


Figure 70: *Production of selected agricultural products in Crete, 1988-2001, (The Prefectures of Greece, Epilogi (adapted)).*

1.9.2.7 Water price

The price for water per cubic meter varies greatly depending on the charging category, the managing agency, the city and catchment. Table 35 shows the water prices that the DEYAH of Iraklion city charged for the different categories of water users in 1999. It is noteworthy that the water price fluctuates from 1.27€ per m^3 for water wagons to only 0.015€ per m^3 for the municipality's services. The majority of water consumers pay proportional prices except for the category of residential consumers with individual metering systems that pay a progressive price. Households, the permanent population of Iraklion city, pay either a progressive or proportional price. On the other hand the hotels, as an indicator of temporary population, pay a proportional price that varies from 0.69€ per m^3 to 1.17€ per m^3.

Table 35: *Water price charged to different categories of water consumers, (http://www.deyah.gr/).*

Water Price List for 1999		
Category of Consumers	**Price**	
Public Schools, Charity Institutions (proportional price)		0.25€/m^3
Public Services and Utilities, Organisations (proportional price)		0.92€/m^3
Residential with individual metering systems (progressive price)	0-27m^3	0.19€/m^3
	28-50m^3	0.35€/m^3
	51-100m^3	0.52€/m^3
	101 & more	0.74€/m^3
Apartment Blocks with volume metering (proportional price)		0.34€/m^3
Municipalities – Communities (proportional price)		0.74€/m^3
Hotels within the administration boundaries of Iraklion city (proportional price)		0.69€/m^3
Industries (proportional price)		0.83€/m^3
Hotels outside the administration boundaries of Iraklion city (proportional price)		1.17€/m^3
Restaurants – Bars – Cafeterias (proportional price)		0.59 €/m^3
Other Professional Precincts – Private Schools – Football clubs (proportional price)		0.23€/m^3
Hospitals – Private Clinics (proportional price)		0.55€/m^3
Construction (proportional price)		0.89€/m^3
Water wagons (proportional price)		1.27€/m^3
Water supply in the Communities of Malevisiu (proportional price)		0.21€/m^3
Municipality Services (proportional price)		0.015€/m^3
Water supply from the source (proportional price)		0.76€/m^3

The final price is increased by additional fees such as construction fees, drainage fees (80% on the value of the water bill) and maintenance fees (3.18€ per quarter). Fixed payments depending on water consumption are determined as follows: 28-50m^3: 0.59€ for water consumption, 0.29€ for drainage; 51-100m^3: 2.05€ for water consumption, 1.03€ for drainage; 101 or more m^3 2.93€ for water consumption, 1.47€ for drainage. There is a further VAT tax of 8%. In 1996 the water price in Iraklion city increased by 11%, in 1997 the price increased further but the increase was less than the inflation rate (4%), while in 1998 the price remained unchanged.

In table 36 the household expenses for water consumption in the DEYA of Iraklion city are compared to the relative prices in the other major cities of Crete, for the consumption of 30, 50 and 100m^3 of water per quarter. In Iraklion city the household expenses for low consumption levels (30m^3) are 36.8% and 32.4% lower than the corresponding expenses in Ierapetra and Rethymnon city, and only 2.8% higher than the water expenses in Aghios Nikolaos. However, these expenses appear to increase as the water consumption increases, compared to the other cities. Particularly, for the consumption of 50m^3 of water in Iraklion city the expenses are 22.1% and 13.8% lower compared to Rethymnon and Ierapetra respectively, while they are 6.4% and 19.1% higher compared to the corresponding expenses in Chania and Aghios Nikolaos respectively. Finally, for 50m^3 of water consumption the household expenses in Iraklion city are 7% and 2.4% lower than in Rethymnon and Ierapetra respectively, but 13.1% and 45.9% higher than in Chania and Aghios Nikolaos city respectively.

It is worth noting that in Rethymnon city the additional consumption of 20m^3 increased the household expenses by 65.2%, while the further consumption of 50m^3 by 128.3%. In Aghios Nikolaos city the water expenses increased by 64.5% for the additional consumption of 20m^3 and by 122.1% for the further consumption of 50m^3. In Chania and Ierapetra the expenses increased by 63.3% and 39.7% respectively for the additional consumption of 20m^3 and the further consumption of 50m^3 increased the relative expenses by 156.2% and 140.6% respectively. Finally, in Iraklion city the relative percentages are 90.5% for an additional 20m^3 and 172.3% for a further 50m^3.

Table 36: *Household expenses for water use in five big towns of Crete, (http://www.deyah.gr/).*

Comparison of Water Prices for Household Consumption (1998 prices)					
Town	**30 m^3(€)**	**Town**	**50 m^3(€)**	**Town**	**100 m^3(€)**
Ierapetra	34.40	Ierapetra	48.06	Ierapetra	115.63
Rethymnon	32.18	Rethymnon	53.18	Rethymnon	121.41
Iraklion	21.75	Iraklion	41.44	Iraklion	112.86
Chania	23.85	Chania	38.94	Chania	99.78
Aghios Nikolaos	21.16	Aghios Nikolaos	34.80	Aghios Nikolaos	77.30

Table 37 shows the different water prices charged by characteristic local organisations TOEB in each prefecture for irrigation use. The TOEBs examined in the prefectures of Rethymnon and Lasithi both charge a proportional price that is common to all the users. It is noteworthy that the irrigation price in Lasithi is 250% higher than the relative price in Rethymnon, since the current administration must cover the debts of the former administration. In the rest of the prefectures the TOEBs examined also charged a proportional price which, however, is differentiated among the users based on established criteria. The irrigated area in Messara and Kissamos is separated into irrigation zones. Particularly, in Messara the irrigation price appears to increase by 30% (0.13€/m^3) when one zone supplies another zone with water, while the price charged increases by a further

100% for farmers who exceed the water consumption limits. Finally, in Kissamo the irrigation price in the second zone is higher by 42.8% compared to the first zone, while the increase from the second to the third zone is only 10%.

Table 37: *Characteristic irrigation prices in each prefecture of Crete.*

Iraklion	**Rethymnon**	**Lasithi**	**Chania**
TOEB in Messara	TOEB in Bizari	TOEB in Siteia	TOEB in Kissamo
0.10€/m^3 inside the irrigation zone 0.13€/m^3 outside the irrigation zone 0.26€/m^3 when farmers exceed water consumption limits	A proportional price: 0.06€/m^3	A proportional price: 0.21€/m^3 Farmers pay 3€ per stremma annually	0.07€/m^3 inside the 1st irrigation zone 0.10€/m^3 inside the 2nd irrigation zone 0.11€/m^3 inside the 3rd irrigation zone

**1 stremma ≈ 10^{-3} km^2*

1.10 Conclusions

Crete is considered a semi-arid region. Although precipitation is high, only 27% of rainfall goes to recharging aquifers and 63% is lost to evapotranspiration. This situation may worsen in the future due to climatic change. The major water use on the island is irrigation for agriculture (83%). Another sector related to water use is tourism (domestic and international), an important economic activity in Crete, which is still growing. The total number of tourists in Crete in 1999 exceeded two million, and this number may double by 2025. The tourist industry requires huge quantities of water supply, with peak consumption during the high season and excess capacity in the low season. Water availability in Crete in general is not the limiting factor. Of the real water used 87% come from subterranean sources accounting to 372Mm^3 per year while the potential water resources are 2,120Mm^3 per year. Much more important are the significant regional and seasonal variations which Crete shows in water availability and demand. Seasonal variations in water availability are created by the seasonal pattern that rainfall exhibits in Crete. About 60-70% of annual rainfall occurs in three to four months, while summers are usually long and dry. In addition, rainfall is not uniformly distributed throughout the island. Precipitation decreases from west to east. This situation is further worsened by a seasonal and regional variation in water demand. Both, agriculture and tourism require increased supplies in late spring, summer and early autumn, when water is less abundant. Also, domestic use of water increases during dry and hot periods. Demand for water for irrigation and tourism is higher in eastern than in western Crete. This results in a situation where western Crete shows higher water availability and lower demand and eastern Crete lower water availability and higher demand.

Spatial and temporal variations of rainfall events combined with seasonal and spatial variation in water demand point towards the necessity of unified water resources management in Crete. The lack of the local people's understanding of the objectives of a water resources management plan and the farmers' belief that the higher the irrigated water volume is, the higher is the resulted farming production respectively, have created significant frictions on the local scale. The misconception of water resources ownership status of local people is the main reason for such frictions. This leads to water resources overexploitation, reduction of the water resources potential and a failure of the existing infrastructure resulting in a deteriorated water quality. Contaminative human activities intensify the pressure on a sound water resources management.

Given the severe limitations of exploiting new water resources, the only solution in meeting water requirements is to use water more efficiently. Although several important advances have been made over the last years, significant challenges still remain in the areas of technological, managerial, policy innovation and adaptation, human resources management, information transfer and social environmental considerations. The issues mentioned concern the Island of Crete, but are applicable to most Mediterranean countries.

They are:

a) Water conservation and efficient use. Since agriculture is by far the largest water user, efficient irrigation management will undoubtedly be a major conservation option for the future. It can be achieved through irrigation requirements and irrigation scheduling techniques, the use of localised irrigation systems, salinity management techniques, and a reduction of losses from water conveyance systems,

b) Water sectorial use. Any prevention of conflict and competition among water users will have positive effects on improving efficiency and productivity. Greater efforts are urgently needed to integrate irrigation planning and management with other sectors of the economy that impinge on water use,

c) Water pricing and cost recovery. The most important recommendation we can make is the adoption of full-cost pricing of water use and services. It will be the basis for promoting conservation, reducing losses and mobilising resources. Furthermore pricing could affect cropping patterns, the income distribution, the efficiency of water management and the generation of additional revenue, which could be used to operate and maintain water projects,

d) Wastewater reuse. Water resources shortage and environmental concerns have already led to wastewater reuse for irrigation. Since wastewater reuse has multidisciplinary interlinkage with different sectors such as environment, health, agriculture, water resources etc., it is necessary that the administrative responsibility for reuse activities is taken and reuse regulations are being well defined,

e) Water quality management and use of saline water. The issue is becoming increasingly as important as water quantity, and is a far more complex task than quantity monitoring. Research has provided much knowledge on the specific interactions of saline waters on soil and plant and various strategies and criteria have been developed for the safe use of such waters for crop production,

f) Other cost-effective technologies. Apart from technologies in current use such as reclamation and reuse of marginal waters, other cost-effective technologies such as artificial recharge of groundwater should be considered,

g) Technology transfer. The availability of improved technologies or techniques is however, is no guarantee for their application. Farmers will play a key role in adopting more efficient and sustainable water management practices. Factors that provide favorable conditions under which farmers may accept and adopt better and more efficient water use practices are: clear benefits from efficient water use, investment support, adequate legislation, simple, practical and cost-effective technologies, guidance and advice in introducing new and more efficient technologies,

h) Education and training. Extensive educational programmes should be instituted at all levels of society to promote a prudent use and conservation of water as one of our indispensable natural resources. The institutional framework to support services and the training of the staff involved in irrigation development will be the key to introducing new technologies in irrigation *and*

i) Application of an integrated water resources plan. It is of high importance to apply a policy for water resources management, which will cover the present requirements, however ensuring future needs.

Chapter II: Selection of representative catchments

Four representative catchments were selected in Crete, one in each prefecture. The location of these catchments is shown in figure 71. West Messara valley catchment is located in the southern part of the Iraklion prefecture and represents the most important agricultural region on the island. Kissamos catchment lies in the northwestern part of Crete and constitutes another very important agricultural region on the island. Platys catchment lies next to Messara valley in the Rethymnon prefecture and is mostly cultivated with olives. Patelis catchment in the northeastern part of Crete is mostly cultivated with vines. It is an important catchment because 90% of the area is cultivated and irrigation creates peak demands in the summer in an area where precipitation is low and water demand is high, especially during the summer.

Figure 71: Main hydrological basins of Crete.

2.1 West Messara valley catchment – Physical characteristics

The Messara valley catchment covers an area of 398km² and is located in the central-southern part of Crete, about 50km south of the city of Heraklion (figure 72). The valley constitutes the most important agricultural region of Crete. It is also the site of the Minoan palace of Phaistos and the Roman city of Gortys. About 250km² of the total valley area of 398km² are cultivated. The main land use activities are olive-growing and grape vine cultivation. The remainder of the land is used for growing vegetable, fruit and cereal. The Messara valley has remained rural with a small population of about 40,000 inhabitants. The main source of irrigation water is groundwater as there is little surface water flow outside the winter months.

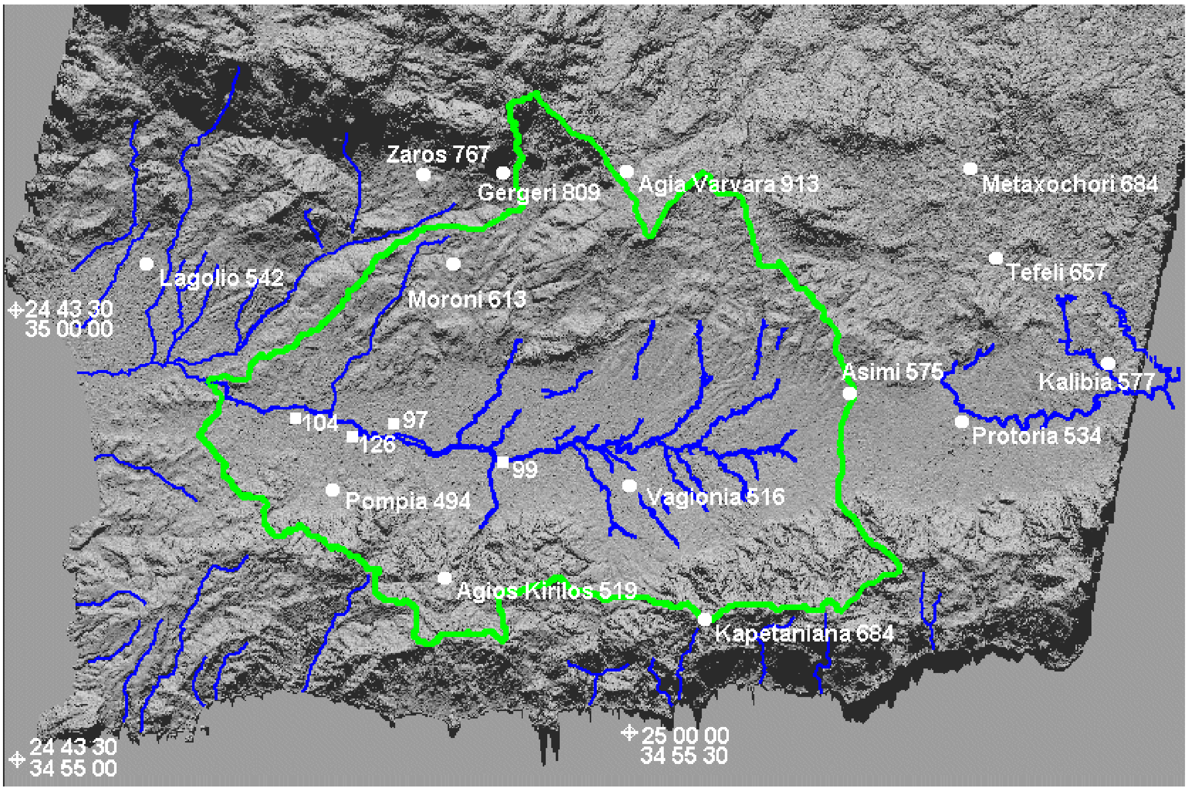


Figure 72: *The Messara valley of Crete.*

The valley's river outlet is at the Phaistos constriction in the west, beyond which is the small coastal Timbaki plain. Boreholes 97, 99, 104 and 126 are near the Geropotamos river (Vardavas et al., 1996).

Groundwater is the key resource controlling the economic development of the region; it is also a component of the environment under siege as water demand has increased dramatically within the last ten years. The groundwater level is thus an important index to assess both anthropogenic and climatic causes of desertification in the valley.

Following the detailed agricultural development study conducted by the UN Food and Agriculture Organisation in 1972 (FAO, 1972) regarding the exploitation of the valley's water resources, an extensive network of pumping stations has been installed since 1984, which has converted what used to be dry cultivation of olive trees to drip-irrigated cultivation, thus leading to a rise in productivity and a dramatic drop of 20m on the groundwater level, where for the extremely wet years 2002-2003, the aquifer was recharged.

2.1.1 Relief and geology

The west Messara valley catchment covers an area of 398km^2 comprising an east-west plain of 112km^2 about 25km long and about 3km wide with steeply rising mountains on the north and the south side. To the north, the divide varies from 1,700m to 600m from west to east, with the highest point being part of the Idi mountain range (peak at 2,540m), which is a limestone massif. To the south there is the Asterousia mountain chain, which rises from 600m in the west to 1,200m in the east and constitutes the most southern mountain range of Europe. At the Phaistos constriction in the west, the catchment outlet of the Geropotamos river is at 30m above sea level (ASL).

The catchment area of the northern slopes covers 160km^2 while the southern slopes constitute a catchment area of 126km^2.

Mainly quaternary alluvial clays, silts, sands and gravels with of a few meters to 100m or more thick, cover the plain. The inhomogeneities of the plain deposits give rise to great variations in the hydrogeological conditions even over small distances. The northern slopes are mainly silty-marly Neogene formations while the southern slopes are mainly schists and limestone Mesozoic formations. The outlet of the catchment is narrow, confined to a channel cut into an impermeable barrier of lower Tertiary near Phaistos. The geology of the catchment is shown in figure 73.

The study area encompasses the Mires basin and the up thrown Vayionia block. The major groundwater basins and surface water catchments are depicted in figure 74. The Mires basin is a down faulted trough roughly 14km long and an average of 3km wide. The trough is filled with alluvial sediments of Quaternary to recent age, which form an extremely variable and complex inter-bedded sequence of gravels, gravely sands, sands, silts, silty sands and clays. This has given rise to a multi-aquifer system in which permeable sand and gravel horizons are locally separated both laterally and vertically by less permeable clays and silts. An area of particularly coarse gravel is present in the trough at the point where the Litheos river discharges into the valley. Material derived from adjacent sandstone (Flysch) has been deposited as a fan, 3km long and 1.5km wide. These gravels are productive aquifers. Other smaller fan deposits occur in several bay-like depressions at the foot of the Asterousia Mountains to the south, but these are not as extensive or important as the Litheos fan.

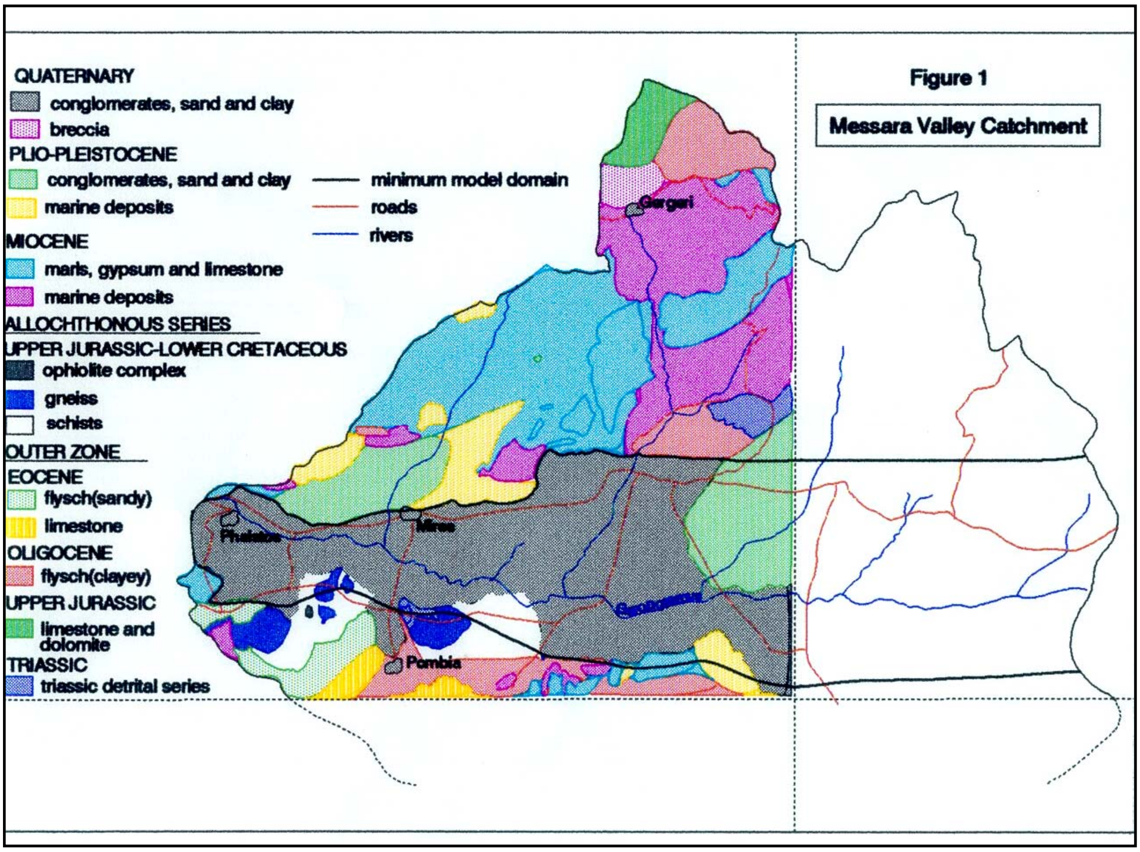


Figure 73: *Geological map of the Messara valley.*

Geophysical surveys have revealed the flanks of the Mires basin to be steep-sided, which may reflect the presence of E-W trending step faults, or the bank of an erosional channel cut into the underlying lower Pleistocene sediments. Whatever is the true nature of the trough boundaries, extensive faulting parallel to and across the valley is present and has resulted in a variable thickness of alluvium throughout the basin. The elevation of the base of the alluvium-lower Pleistocene aquifer ranges from –50 to +100m A.O.D., the lowest points of the elongated trough being to the NE of Petrokefali and N of Koustouliana. This surface is based on the elevation of the lowest permeable unit identified from borehole logs. The saturated thickness ranges from less than 20 m to over 100m in the lowest part of the trough. The aquifer unit as a whole comprises an alternating sequence of clays, silts, sands and gravels; the thickness will inevitably include a substantial proportion of impermeable material (An Integrated Monitoring and Modelling Study of Desertification and Climatic Change Impacts in the Messara valley of Crete, final scientific report, 1996).

The Vayionia block is an up-faulted block of lower Pleistocene-upper Pliocene age, which extends eastward from the longitude of Agioi Deka to the surface water divide near Asimi. The block is 12km long and 5km wide. In this region the ground surface is much more undulating than the Mires basin, and the gradient of the valley floor increases from 1:150 to 1:75. The lithology is complex and comprises a variable sequence of fluvial and lacustrine conglomerates, sandstones, siltstones and silty clays with a thin mantle of alluvial sediments covering the southern half of the region. Drilling and pumping tests showed the region to be poorly productive. The lithology is dominantly clayey or marly with sandstone and conglomerate horizons being thin and few in numbers. Moreover, surface cementation is widespread and infiltration is severely inhibited. Nevertheless, under natural conditions there is sufficient water in storage to supply a number of perennial springs, which provide some base flow to the Geropotamos river in the dry season. The base of aquifers in the Vayionia block is difficult to determine, partly because borehole records are scant and partly because in some cases it is difficult to recognise any aquifer at all. Saturated aquifer thickness ranges from less than 20m to over 70m (An Integrated Monitoring and Modelling Study of Desertification and Climatic Change Impacts in the Messara valley of Crete, final scientific report, 1996). A simplified geology of the west Messara catchment is shown in figure 75.

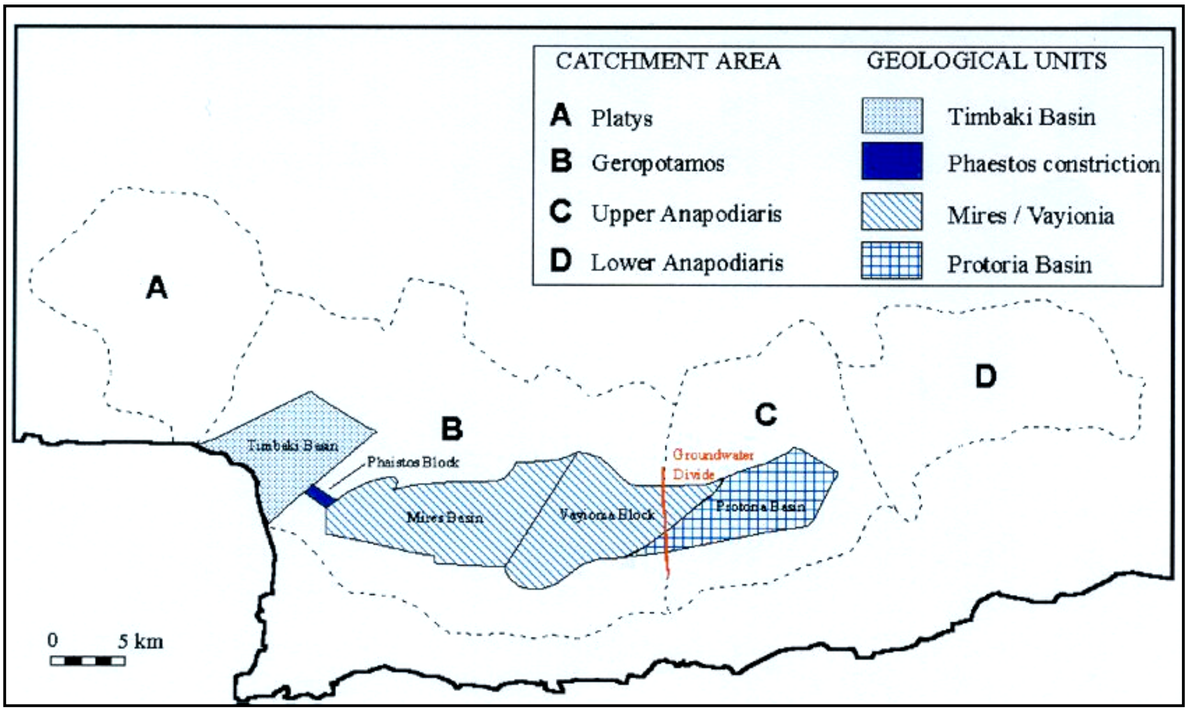


Figure 74: *The major groundwater basins and surface water catchments, (An Integrated Monitoring and Modelling Study of Desertification and Climatic Change Impacts in the Messara Valley of Crete, final scientific report, 1996).*

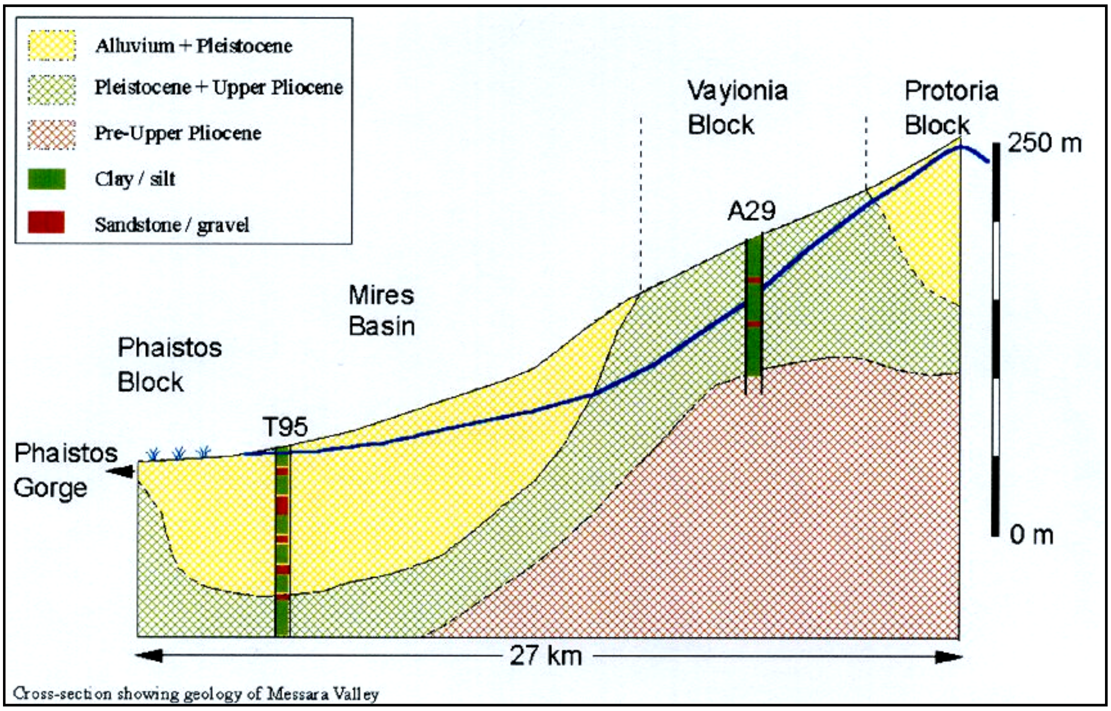


Figure 75: *Simplified geology cross-sectors of the west Messara catchment. (An Integrated Monitoring and Modelling Study of Desertification and Climatic Change Impacts in the Messara Valley of Crete, final scientific report, 1996).*

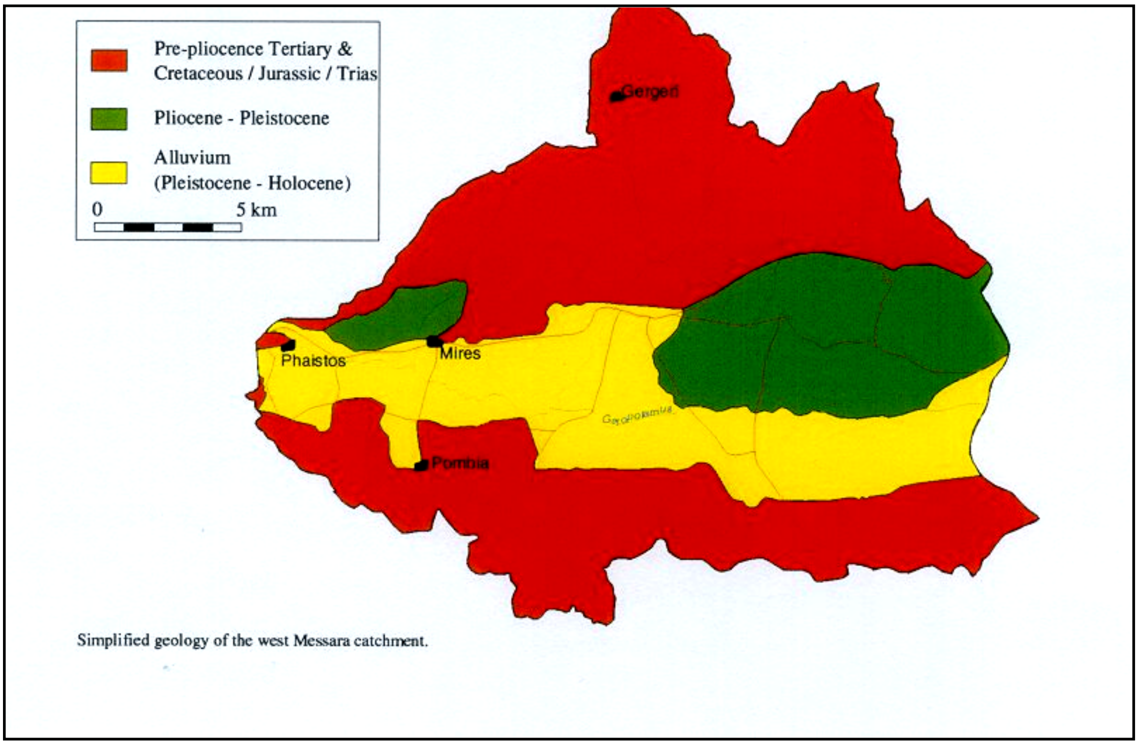


Figure 76: *Simplified geology of the West Messara catchment. (An Integrated Monitoring and Modelling Study of Desertification and Climatic Change Impacts in the Messara Valley of Crete, final scientific report, 1996).*

2.1.2 Climate und hydrology

The climate of the valley is sub-humid with mild, moist winters and dry, almost cloudless, hot summers. The hydrological year may be divided into a wet and dry season. About 40% of precipitation occurs in the months of December and January, while from June to August there is negligible rainfall. Although the valley receives an average of 600mm of rainfall per year, it is estimated that about 65% are lost to evapotranspiration, 10% as runoff to the sea and only 25% go to recharging the groundwater store. Pan evaporation is estimated at 1,500 ± 300mm per year while the winds are mainly westerly. The potential evaporation is estimated at 1,300mm per year (Vardavas, 1994) and so the ratio of mean annual rainfall to potential evaporation for the valley is about 0.5 and is hence classified as dry sub-humid according to UNCED (1994) definitions. The average winter temperature is 12°C, while for the summer it is 28°C. Relative humidity in winter is about 70%, while in summer it is about 60%.

The Department of Agriculture in Crete has monitored the valley's water resources for around thirty years. There are daily measurements of rainfall from 15 stations. The mean annual rainfall for the different stations in Messara valley is shown in figure 77.

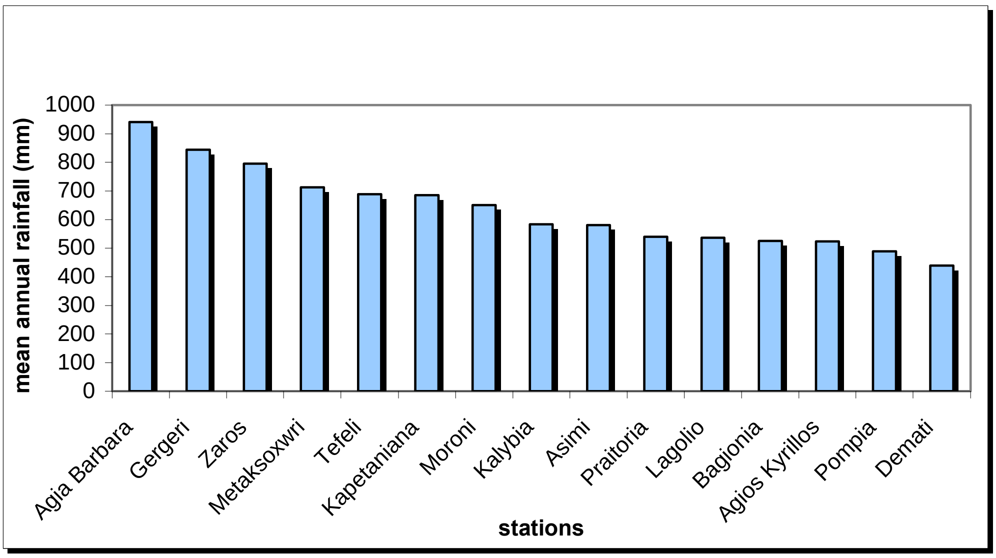


Figure 77: *Rainfall distribution in the Messara valley.*

Rainfall increases with elevation from about 500mm on the plain to about 800mm on the valley slopes and 1,100mm on the Asterousian mountains. There is a variation in the measured rainfall with increasing elevation. Figure 78 shows the total rainfall for 1970 for the 15 stations plotted against their elevation. The south side of the catchment clearly has a lesser dependence of rainfall with elevation compared with the north side. For the north and south sides, the rainfall shows a linear trend with elevation, with the fits being respectively:

$P_i = 361 + 0.94z_i$,

$P_i = 470 + 0.19z_i$ *and*

P_i and z_i = rainfall (mm) and the elevation (m) of a particular location in the catchment.

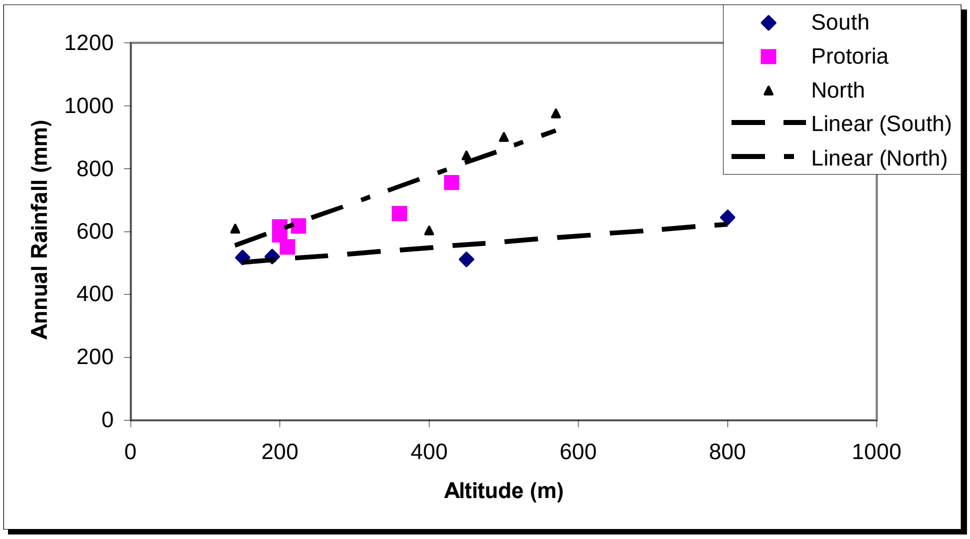


Figure 78: *Rainfall for each of the 15 stations plotted against elevation.*

Data from three regions are shown: north and south of the catchment, and in the neighboring Protoria basin (which closely matches the distribution for the north of the catchment).

Demati is one of the rainfall stations showing the lowest mean annual precipitation of the existing stations in Crete. Figure 79 shows the mean annual rainfall for Messara for the years 1969 to 1998. As shown in the figure, the driest year was the hydrological year 1989-1990 and the wettest year was the hydrological year 1977-1978.

Figure 80 depicts the mean monthly rainfall for the catchment. The wet season lasts from November to March or April, while the dry season extends form June till October.

There are five stations measuring pan evaporation in the Messara valley. For these stations daily pan evaporation values have existed since 1969. The mean annual pan evaporation measured for each of these stations is shown in figure 81. The mean annual pan evaporation for the Messara valley is depicted in figure 82. Pan evaporation is estimated at 1500 ± 300 mm per year.

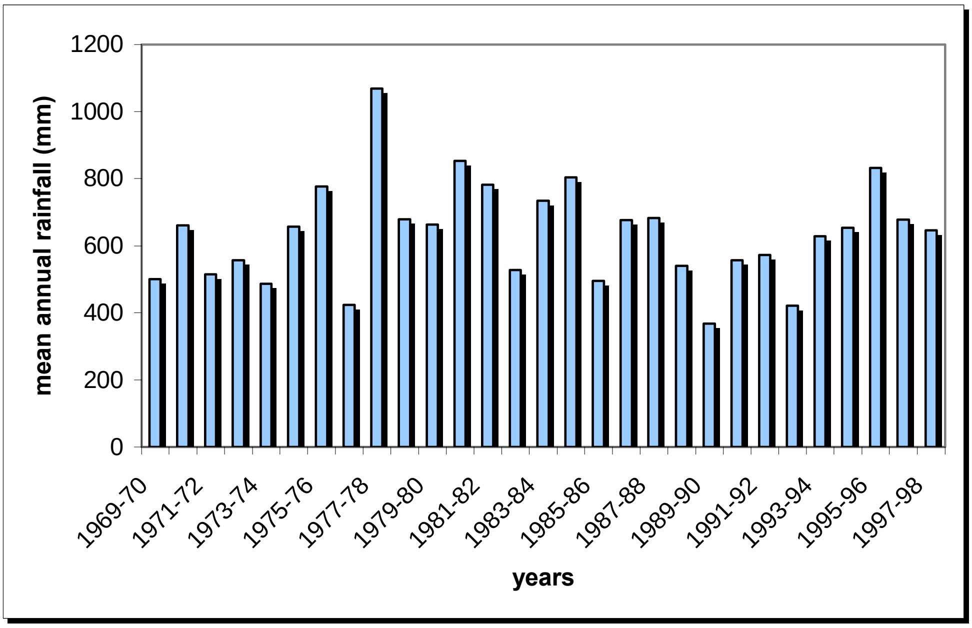


Figure 79: *Mean annual rainfall for the Messara valley.*

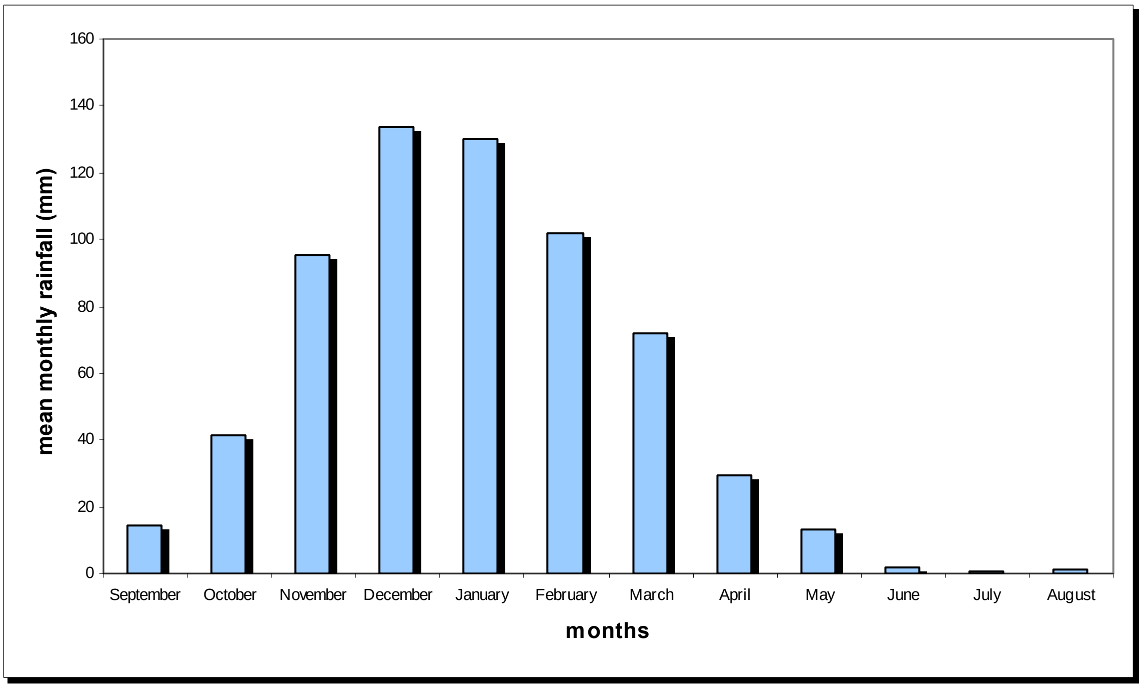


Figure 80: *Mean monthly rainfall for the Messara valley.*

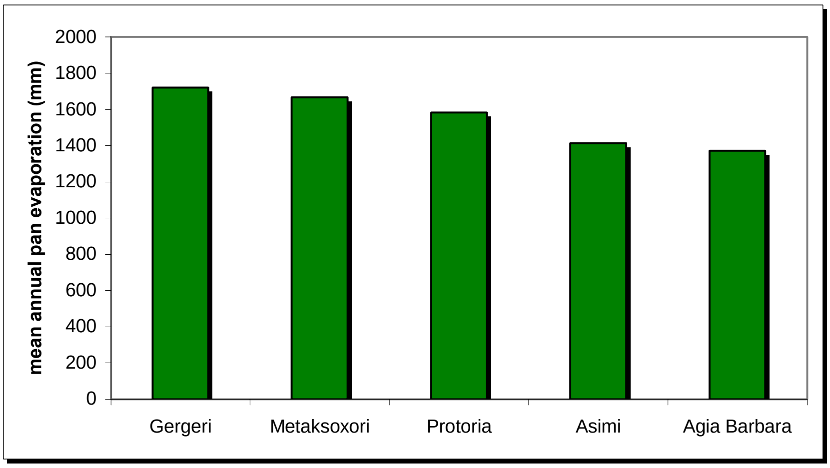


Figure 81: *Pan evaporation for different stations in the Messara valley.*

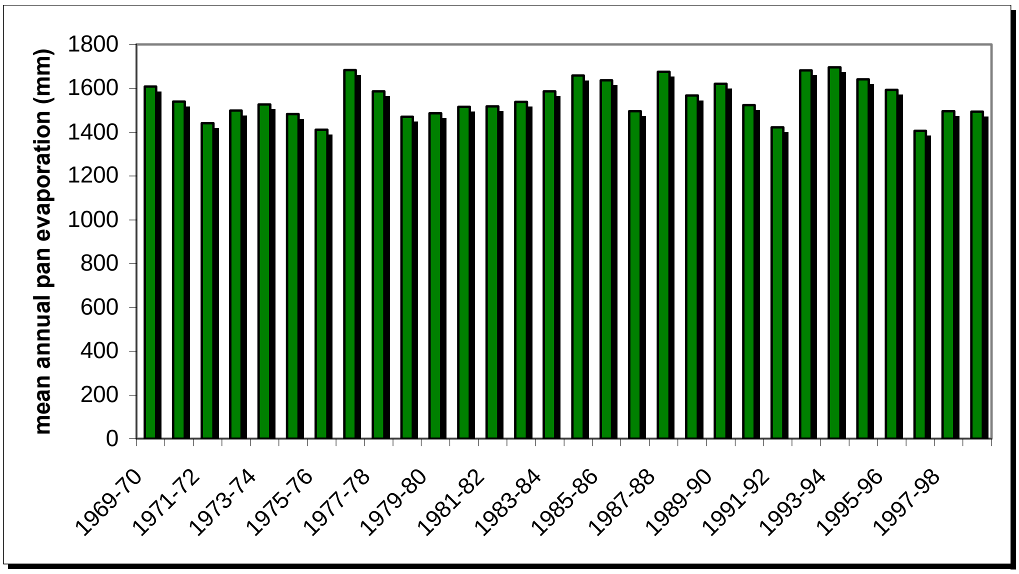


Figure 82: *Pan evaporation for the Messara valley.*

The highest values of pan evaporation are observed in July, while the lowest occur in December and January. Pan evaporation ranges form 38mm in January to 270mm in July. Gergeri station shows the widest range between the lowest and highest pan evaporation values within a year, with an average pan evaporation ranging from 304.5mm in July to 42.3mm in January. Mean monthly pan evaporation for the Messara valley is shown in figure 83.

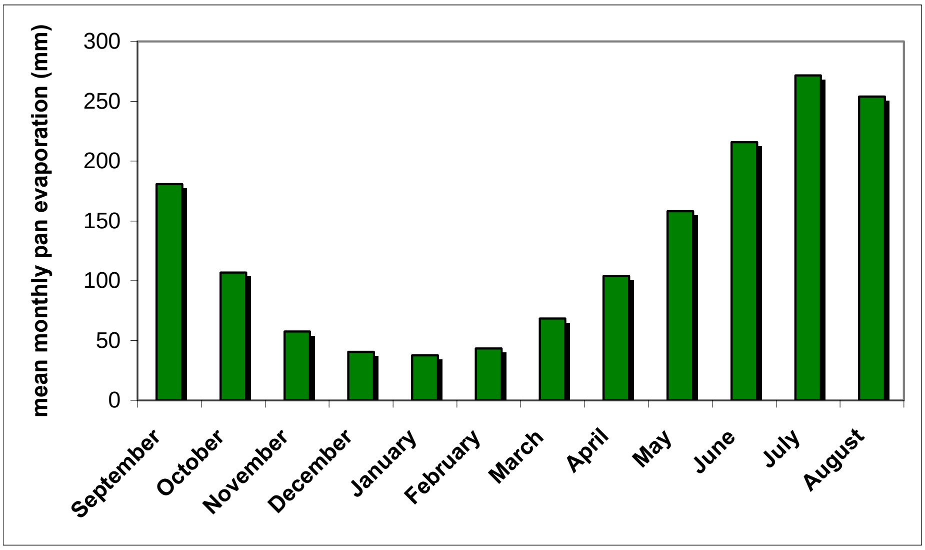


Figure 83: *Mean monthly evaporation for the Messara valley.*

Potential evaporation is estimated from data of the five pan evaporation stations and using monthly mean lake-to-pan coefficients estimated from the potential evaporation via the Penman equation, which requires meteorological and surface radiation budget data. A comparison between the monthly mean Penman evaporation and the mean pan evaporation data available for the catchment gives an estimate of the monthly variation of the pan coefficient. Vardavas et al., 1997, have estimated the mean monthly pan coefficients for the Messara valley (figure 84).

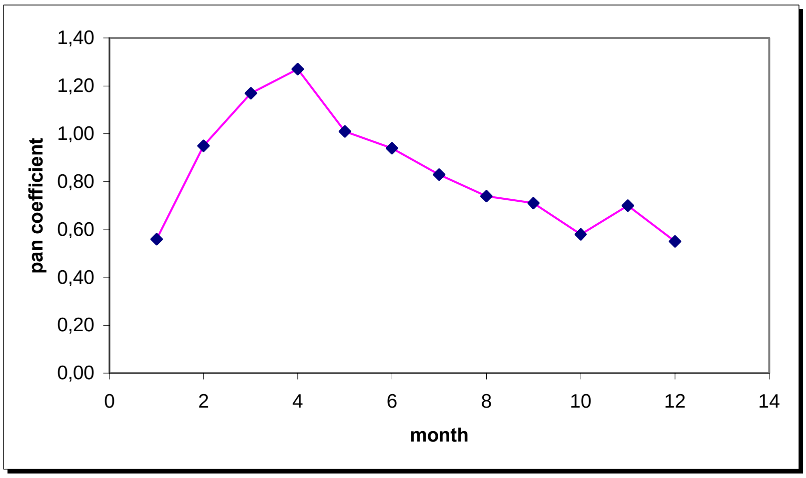


Figure 84: *Mean monthly pan coefficient.*

The mean annual temperature for the Messara valley is estimated at $17 \pm 2^{o}C$. Temperature is measured in three different stations in the valley. The mean annual temperature for the different stations and the valley are shown in figures 85 and 86.

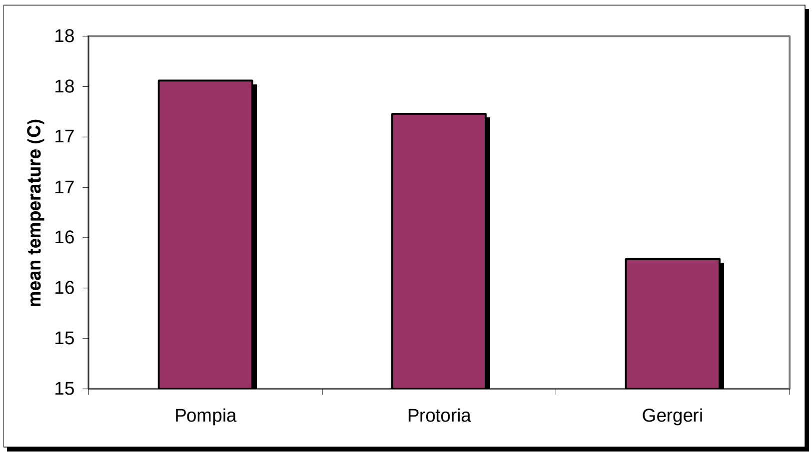


Figure 85: *Mean annual temperature for different stations in the Messara valley.*

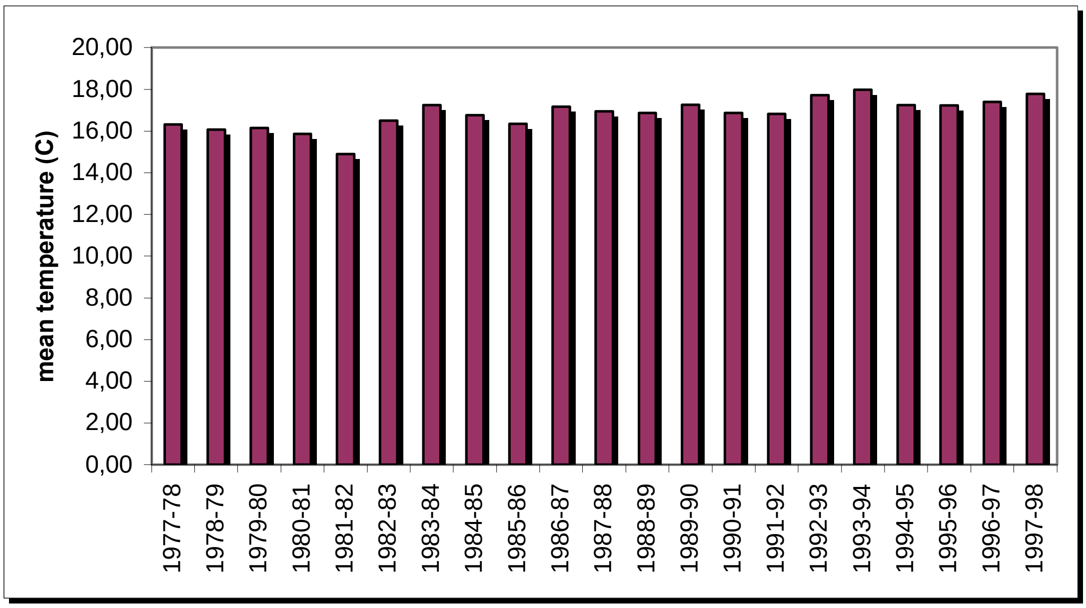


Figure 86: *Mean annual temperature for the Messara valley.*

The lowest mean monthly temperatures are observed in January and February ($9.6^{o}C$) and the highest in July and August ($25\text{-}26^{o}C$). The average winter temperature is $12^{o}C$, while for summer it is $28^{o}C$. The mean monthly temperature for the valley is shown in figure 87.

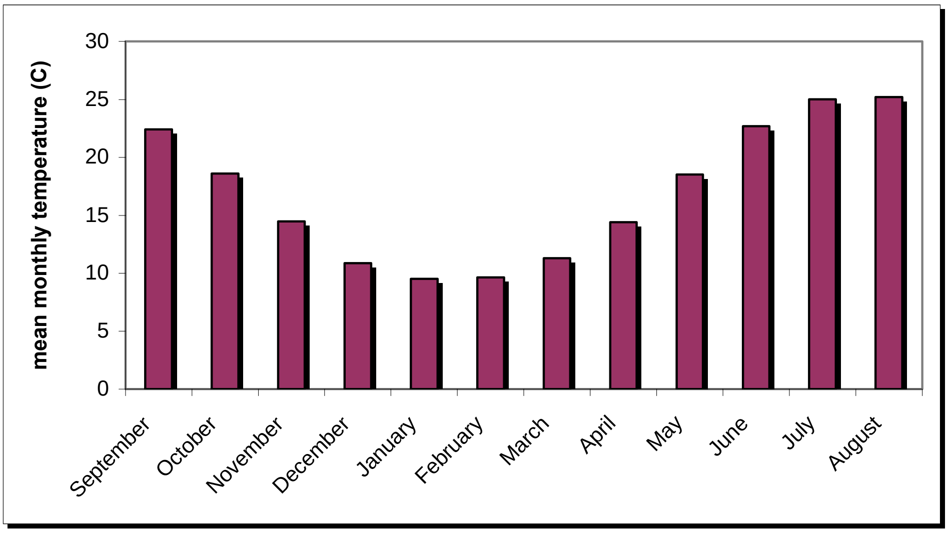


Figure 87: *Mean monthly temperature for the Messara valley.*

2.1.3 Surface water

The main outlet of the catchment is the Geropotamos river at the Phaistos constriction in the west. The catchment outlet of Geropotamos river is at 30m above sea level (ASL). In addition, the outlet of the catchment is narrow, confined to a channel cut into an impermeable barrier of the lower Tertiary near Phaistos. In its natural state, the Geropotamos river of the Messara valley flowed continuously, with a wetland being located near the catchment outlet.

The drop in the groundwater level has resulted in the wetland drying up, with no flow in the river in the dry season through the 1990 and even in the wet season of 1992. During the hydrological year 1992-1993 there was no river flow out of the valley. This was the first time that the main riverbed remained dry according to the records. There are daily measurements of runoff at the valley's outlet at Phaistos. The mean annual runoff is shown in figure 88. The mean annual runoff observed is 16.88Mm^3. The mean monthly runoff for the Geropotamos river, compared to other streams in the Iraklion prefecture is depicted in figure 88. The highest mean monthly runoff is observed in January and February and the lowest in July and August (figure 89).

The mean annual runoff coefficient for the valley is shown in figure 90. The mean runoff coefficient for the valley is 0.07 with a standard deviation of 0.05. This value of a runoff coefficient can be observed in catchments where pumping takes place.

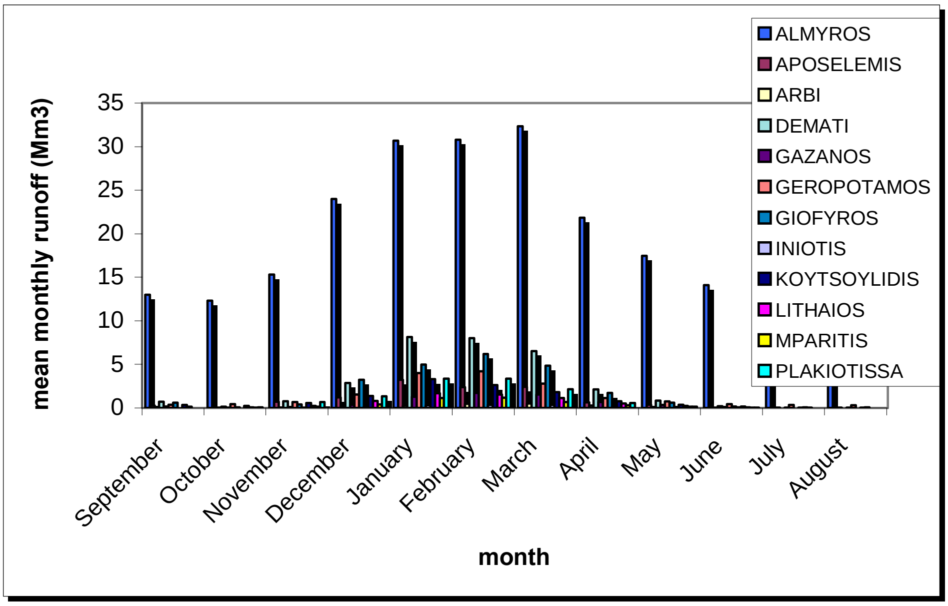


Figure 88: *Geropotamos river compared to other rivers in the Iraklion prefecture.*

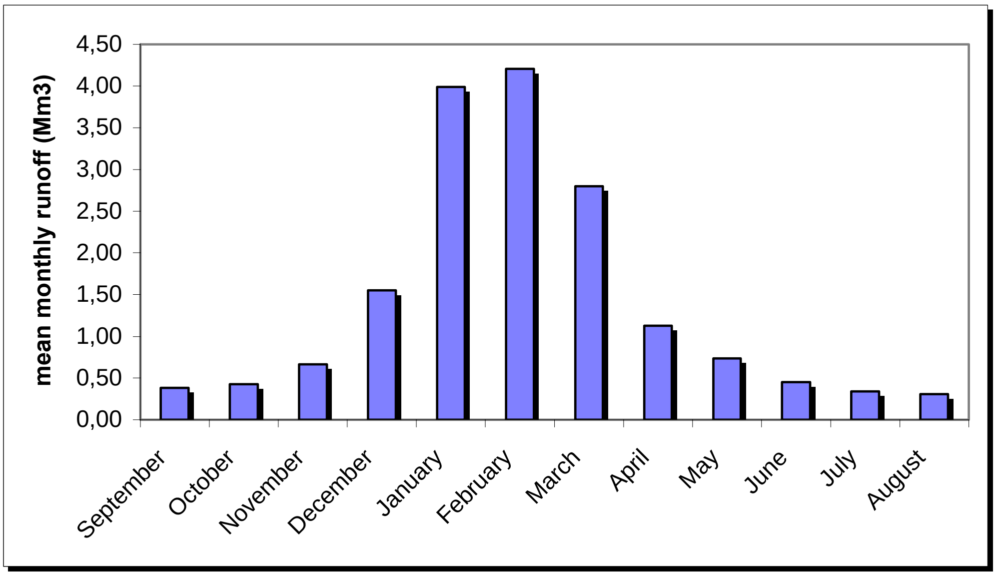


Figure 89: *Mean monthly runoff for the Geropotamos river.*

The plain contains several aquifers and aquicludes of complex distribution and properties. There are monthly measures of groundwater levels for over 25 sites. Groundwater levels are at their highest in March or April with long recessions until recharge occurs in winter. Figure 91 shows the groundwater levels within a year for a selected borehole in the Mires basin. The aquifers were high yielding with discharge rates as high as 300m^3/hr in the early 1970´s but are now reduced to about one tenth of that. From pumping tests, the specific yield ranges between 0.1 and 0.2, while the horizontal transmissivity ranges between 0.1 and 0.01m²/s.

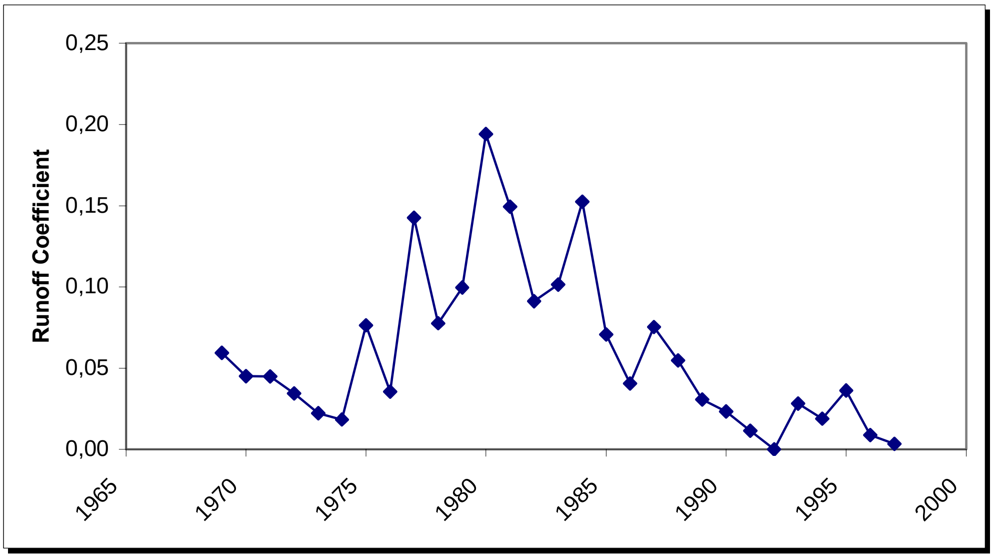


Figure 90: *Annual runoff coefficient for the Messara valley for the period 1969 to 1997.*

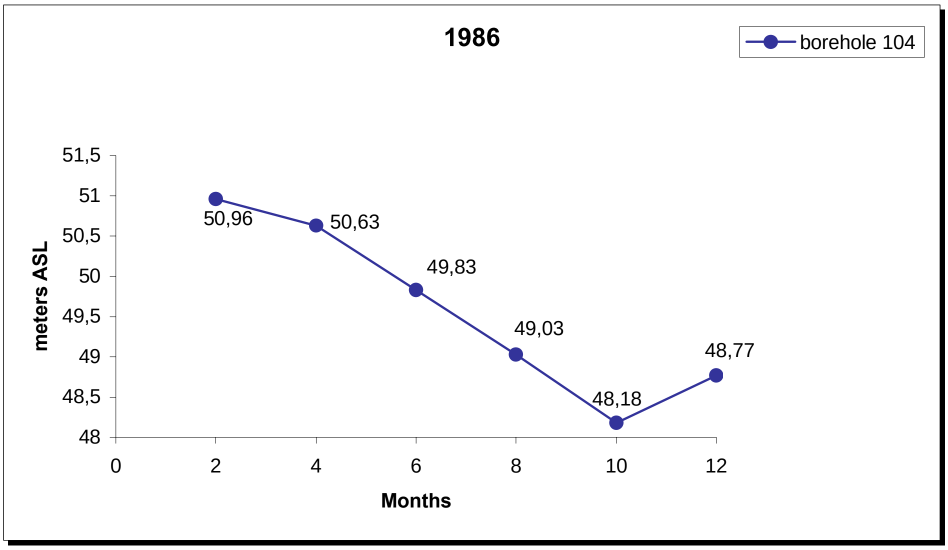


Figure 91: *Annual variation of groundwater levels for borehole 104.*

Lateral groundwater outflow from the valley is small compared with the vertical groundwater outflow. An extensive network of pumping stations has been installed since 1984, which has converted what used to be dry cultivation of olive trees to drip-irrigated cultivation. It is estimated that around 10Mm³ of groundwater were pumped from the aquifer before the installation of the network, while after the installation of the network around $40Mm^3$ are being pumped per year, resulting in a rise in productivity and a dramatic drop of 20m of the groundwater level. At present, there is little surface runoff and the groundwater store is depleted rapidly. Before the installation of the groundwater irrigation system, the average discharge out of the valley was about $20Mm^3/yr$ corresponding to 50mm of the annual rainfall lost as runoff to the sea. It is estimated that the annual recharge of the groundwater store was about $60Mm^3/yr$ (150mm) and evapotranspiration loss was about $160Mm^3/yr$ (400mm). The interannual variation of the groundwater level for a selected borehole can be seen in figure 92. The pattern of the water level change is the same at each site; a period of declining water levels took place from 1971 to 1977, which is followed by a recovery until 1985 when water levels once again began to decline, a trend, which has persisted until the present day.

Most subsurface geological information is drawn from the logs of 26 exploration boreholes drilled in the area by FAO between 1968 and 1970 (An integrated Monitoring and Modelling Study of Desertification and Climatic Change Impacts in the Messara Valley of Crete, final scientific report, 1996). Most of the higher values of permeability are concentrated in the Mires basin, where permeabilities between 10 and 120m/d reflect the presence of a large number of gravel and sand horizons in the alluvial sequence.

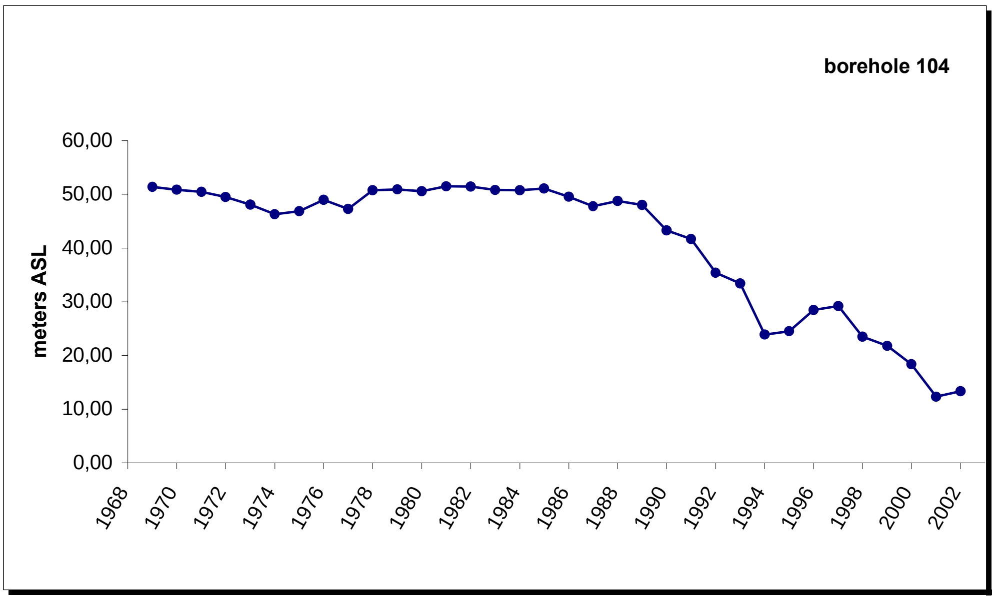


Figure 92: *Interannual variation of the groundwater level for borehole 104 for the years 1969 to 2002.*

The least permeable areas are in the Vayionia block, where the paucity of gravel and sand means that values are reduced to an average of only 1m/d. Lower values also occur on the northern side of the Mires basin, where lower Pleistocene rocks, similar to those of the Vayionia block crop out. Two regions of higher permeability occur in the eastern part of the area. The first is at the eastern boundary, where values increase locally to 40m/d. A second area of high permeability is located in the southern part of the Vayionia block at the foot of the Asterousia mountains. In this area permeabilities of up to 200m/d are probably related to the presence of a small fluvial fan carrying a high percentage of coarse gravel (final scientific report, 1996).

Aquifer storage coefficients have also been obtained from FAO pumping tests. Results from these tests and the nature of the water table show that although heterogeneous and locally confined, the aquifer at a regional scale behaves as an unconfined unit.

2.1.4 Agricultural situation

The Messara valley constitutes the most important agricultural region of Crete. About 250km^2 of the total valley area of 398km^2 are cultivated. Of the total area cultivated 56% are tree crops (mostly olives cv Koroneiki), 10% are vines, 11% are row crops and 7% are vegetables (mostly in open fields and some greenhouses) (HNSS, 1999). Olives mostly occupy areas of flat land and show a steady increase in density of cover as one moves east along the Geropotamos river. Density also diminishes as slopes become steeper on the northern edge of the Timbaki and Mires plains. Vines are less widespread with two main concentrations to the south east of Mires and in the extreme northeast of the catchment. The distribution of arable farming is predominant in the area to the south and east of Mires and on flat ground in the vicinity of Gortyna. Glasshouses and market gardening dominate the Timbaki plain. The forest classes exist only in relatively inaccessible parts of steep gorges, which are not suitable for olives or farming and where water is accessible from river channels. The quite large areas of forest to the south and east of Psiloritis are protected by legislation. Vegetation on the upper slopes of Psiloritis is extremely sparse in a very rocky landscape (An integrated Monitoring and Modelling Study of Desertification and Climatic Change Impacts in the Messara Valley of Crete, final scientific report, 1996).

Drip irrigation is used for olive orchards and tree crops, micro-sprinklers for potatoes and drip irrigation for the rest of the vegetables. The amount of the water applied is empirically defined with various forms of N-fertilisers being applied during the winter after the harvest. Weed control is performed with tillage (80%), while herbicides are rarely used.

2.1.4.1 Cultivated crops and cultivated land

Of the total crops cultivated more than 50% are olives (cv Koroneiki), 10% vines, 2% citrus and 7% vegetables (mostly open field and some greenhouses) (figure 93).

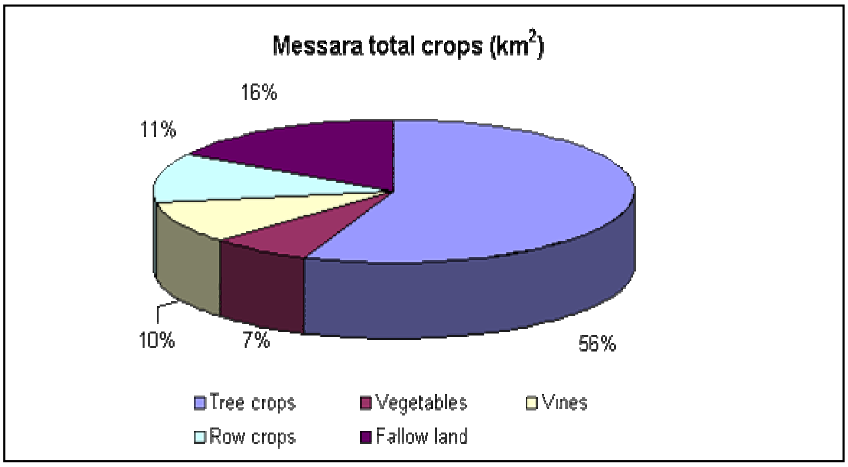


Figure 93: *Crops cultivated in the Messara catchment (HNSS, 1999).*

Olives occupy most areas of flat land and exhibit a steady increase in density of cover as one moves east along the Geropotamos river. Density also diminishes as slopes become steeper on the northern edge of the Timbaki and Mires plains. Vines are less widespread with two main concentrations to the south east of Mires and in the extreme northeast of the catchment. The distribution of arable farming is predominant in the area to the south and east of Mires and on flat ground in the vicinity of Gortyna. Glasshouses and market gardening dominate the Timbaki plain. The forest classes exist only in relatively inaccessible parts of steep gorges not suitable for olives or farming and where water is accessible from river channels. The quite large areas of forest to the south and east of Psiloritis are protected by legislation. Vegetation on the upper slopes of Psiloritis is extremely sparse in a very rocky landscape (An integrated Monitoring and Modelling Study of Desertification and Climatic Change Impacts in the Messara Valley of Crete, final scientific report, 1996).

2.1.4.2 Irrigation systems and scheduling

Drip irrigation is widely used for olive orchards and tree crops, micro-sprinklers for potatoes and drip irrigation for the rest of the vegetables. Modern type irrigation systems have been used since last decade increasing the water use efficiency. The amount of the water applied is empirically defined and comes from drills. The Messara valley is separated into 4 irrigation zones with the water price varying between 0,10 and 0,13€/m^3. The biggest TOEB (Local Board of Water Management) in Messara that irrigates 3,500km^2 has set limitations in water use for each crop i.e. if a farmer exceeded this limit, he would be fined.

2.1.4.3 Crop water requirements

Reference evapotranspiration was estimated in three stations in the Messara catchment for the period 1975-2001 (Pombia in the southern part of the catchment, Zaros in the north and Protoria at the eastern part). The average reference evapotranspiration of the three stations was used for crop evapotranspiration to be estimated for the Messara catchment using the Penman – Monteith (FAO 56) method. Missing data were provided by Gergeri and Timbaki stations. Crop water requirements for the main crops in the catchment are presented in table 38. In estimating crop water requirements for greenhouses, the water required for salt dilution and percolation, is not taken into account.

Regarding estimated crop water requirements citrus is the most highly water demanding crop in the Messara catchment, followed by watermelon and vegetables (open field tomatoes). Table vines seem to need a significant amount of water, but since they are not extensively cultivated, they do not account for much.

Table 38: *Crop water requirements in the Messara catchment.*

Crop	**Crop water requirements [$10^4 m^3/km^2$]**												
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**SUM**
Olives	-	-	-	-	3.5	6.0	7.5	7.0	4.0	(1.0)*	-	-	**28.0 (29.0)***
Citrus	-	-	-	-	7.5	11.0	14.0	12.5	8.0	4.0	-	-	**57.0**
Table vines	-	-	-	-	-	9.0	11.5	10.0	(6.5)*	-	-	-	**30.5 (37.0)***
Vines for wine	-	-	-	-	-	9.0	11.5	-	-	-	-	-	**20.5**
Greenhouse tomato (Oct – May)	2.0	2.0	3.5	5.5	11.0	-	-	-	-	3.5	2.5	2.0	**32.0**
Greenhouse cucumber (Aug – Nov)	-	-	-	-	-	-	-	4.5	10.0	9.0	6.0	-	**29.5**
Greenhouse cucumber (Mar – Jun)	-	-	3.5	7.0	9.5	10.0	-	-	-	-	-	-	**30.0**
Watermelon (Mar – Jun)	-	-	1.5	5.0	10.0	14.0	(18.0)*	-	-	-	-	-	**30.5 (48.5)***
Watermelon (May – Aug)	-	-	-	-	7.0	12.0	18.0	15.0	-	-	-	-	**52.0**
Melon	-	-	1.5	5.0	9.5	13.0	-	-	-	-	-	-	**29.0**
Potatoes (spring)	-	-	2.0	5.5	9.0	13.0	-	-	-	-	-	-	**29.5**
Tomatoes open (Jun – Oct)	-	-	-	-	-	8.0	12.5	14.5	10.0	5.0	-	-	**50.0**
Tomatoes open (Aug – Nov)	-	-	-	-	-	-	-	9.0	7.5	5.0	1.5	-	**23.0**

**Additional irrigation due to low rainfall and/or high temperatures and/or extended crop.*

2.1.4.5 Fertilisers

Various forms of N-fertilisers applied empirically during winter after the harvest, are used. Of the four catchments in Crete, fertigation (application of fertilisers through the irrigation system) is more frequent in Messara and is usually applied to vegetables crops.

2.1.4.6 Weed control

Weed control is mostly done by tillage with milling machinery, while herbicides are used in some areas usually in addition to tillage when needed and rarely as a sole weed control technique.

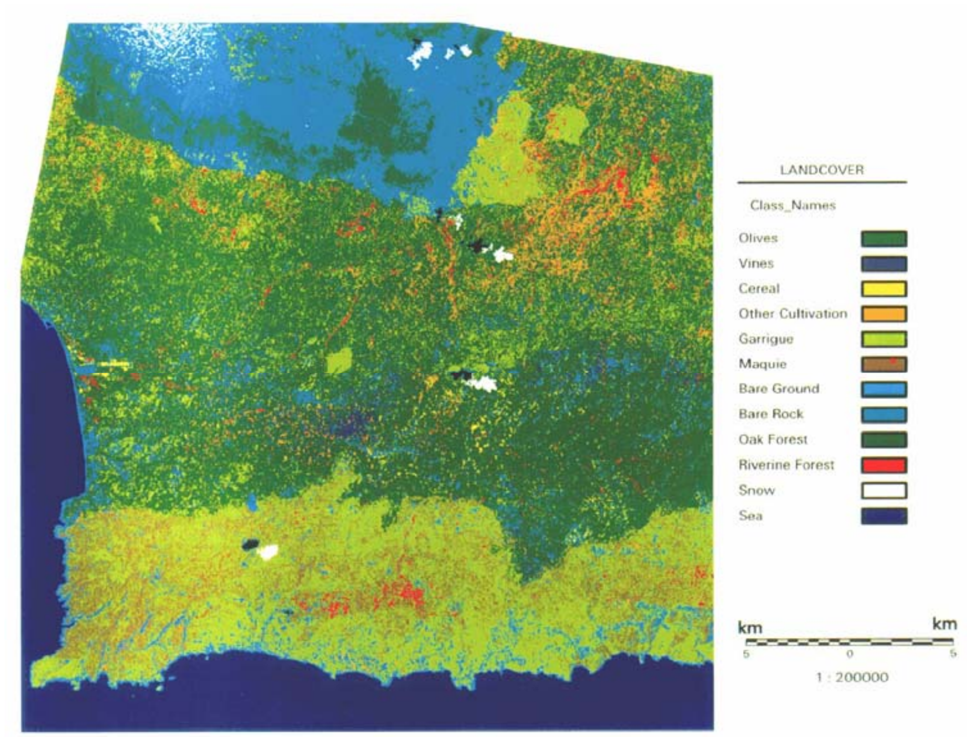


Figure 94: *Landcover classification in the Messara valley.*

2.2 Patelis Catchment – Physical characteristics

The Patelis catchment lies in the north-eastern part of Crete in the prefecture of Lasithi. The catchment covers an area of 123km² comprising a north-south plain with steeply rising mountains on the east and west sides. The catchment receives a mean yearly rainfall of 650mm. Around 90% of the total catchment area is cultivated. The main land use activities are grape vine cultivation (50%) and olive growing (20%). The remainder of the cultivated land (19%) is used for horticultural crops. The main source of irrigation water is groundwater. The pumping stations that have been installed allow drip-irrigated cultivation of olive trees and vines.

2.2.1 Relief and geology

The catchment comprises a north-south plain with steeply rising mountains on the east and west side. The mountains on the west side rise up to 900m, on the east side up to 800m. The valley extends at elevations between 200 and 50m. The main outlet of the catchment is the Patelis river in Siteia constriction in the north of the catchment. The mean elevation of the Patelis riverbed is 460m with a minimum elevation of 64m. The Patelis catchment has tectonic origin of trench type. Near the slopes two large fault systems extend almost from the north to the coast of the prefecture. The valley slopes consist of Neogene marly deposits and sandstone conglomeratic deposits. The west slope is mainly covered by clay, which is 1-1.5m deep. The east slope is mainly comprises rocky conglomerate formations with an average depth of 2.5m and layers of limestone and marly deposits. The west slope corresponds to a possible fault active during the Middle Pleistocene. The valley consists of stream deposits of the Patelis river which have a rather large thickness (>5m) and consist of sandstone and conglomerates. Generally, the valley consists 50% of marly deposits, clays and conglomerates and 50% of Quaternary alluvial and silty deposits. Alluvial deposits are made up of silty clay with conglomerates. The geophysical map of the catchment with the rainfall gauges is depicted in figure 95. The geological map of the area is shown in figure 96.

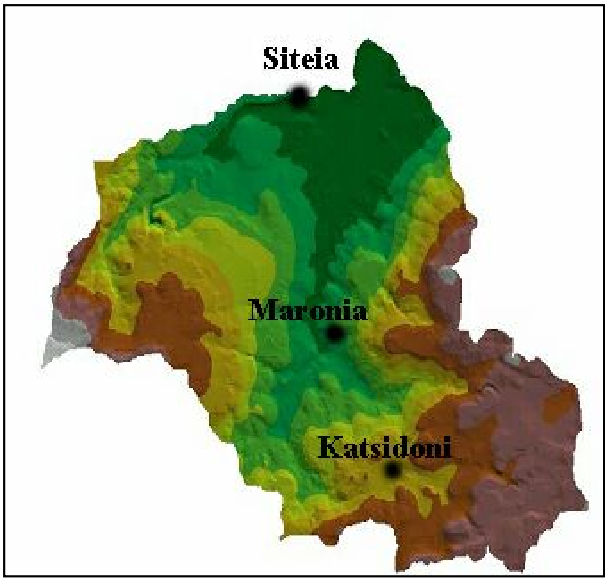


Figure 95: *Geophysical map of the Patelis catchment.*

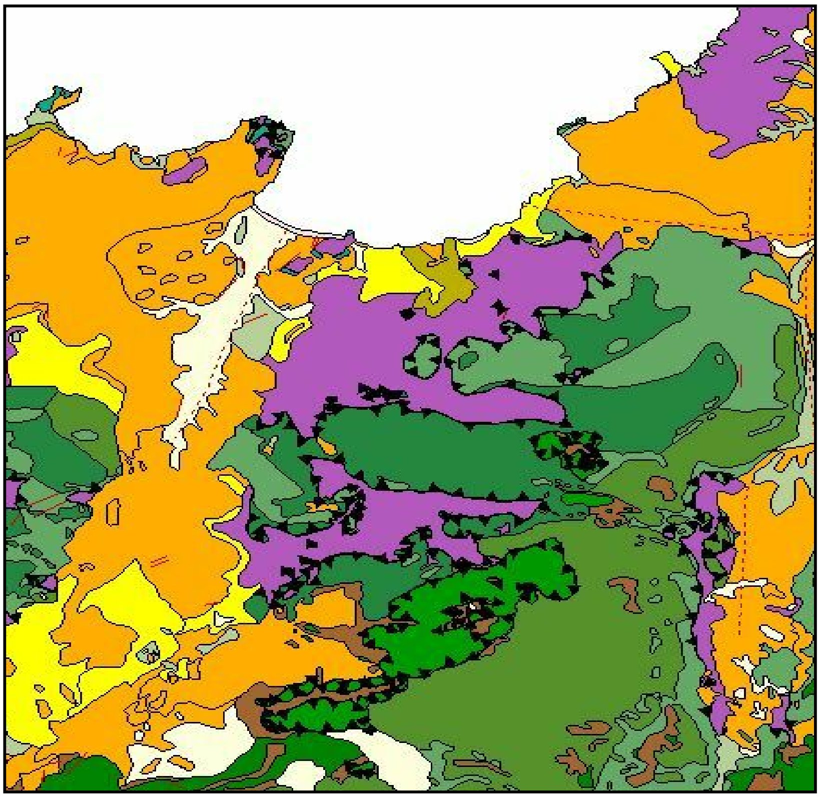


Figure 96: *Geological map of the Patelis catchment.*

2.2.2 Climate and hydrology

The climate is sub-humid Mediterranean with mild moist winters and hot and dry summers. The catchment receives a mean annual precipitation of 650mm. The hydrological year may be divided into a wet and dry season. About 40% of precipitation occurs in the months of December and January while from June to August there is negligible rainfall. The average winter temperature is 13°C, while for the summer it is 25°C. The Department of Agriculture in Crete has monitored the valley's water resources for more than thirty years. There are daily measurements of rainfall from 3 stations. The mean annual rainfall for the different stations in the Patelis catchment is shown in figure 97. There is a dependence of rainfall and elevation. For the Patelis catchment the rainfall shows a linear trend with elevation with the fit being.

$P_i = 437.48 + 0.8827z_i$

P_i and z_i = rainfall (mm) and elevation (m) of a particular location in the catchment

The correlation coefficient R is 0.85 as shown in figure 98.

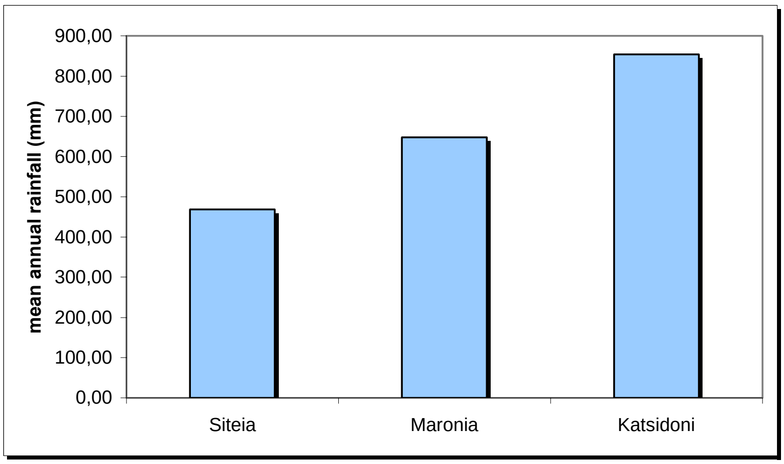


Figure 97: *Mean annual rainfall for different stations in the Patelis catchment.*

Rainfall ranges from 850mm for Katsidoni station at an elevation of 480m to 647m, for Maronia station at an elevation of 150m and 470m and for Siteia station at an elevation of 115m. Siteia station shows very low annual precipitation data compared to other stations in Crete, and Katsidoni station exhibits the high annual precipitation.

The mean annual and mean monthly rainfall for the Patelis catchment are shown in figures 99 and 100 respectively.

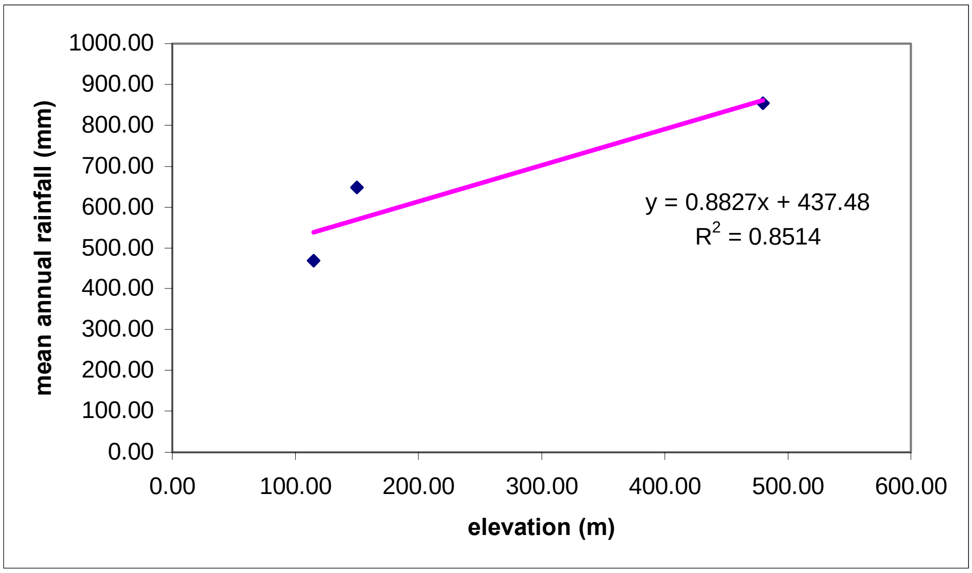


Figure 98: *Rainfall for each of the three stations plotted against elevation and linear regression for the catchment.*

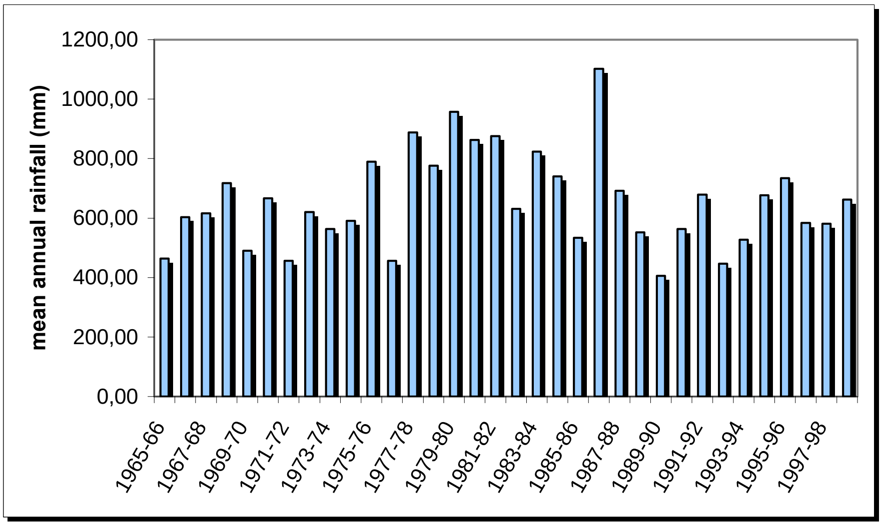


Figure 99: *Mean annual rainfall for the Patelis catchment.*

The hydrological year 1989-1990 was the driest year for the catchment, while the wettest was the hydrological year 1986-1987.

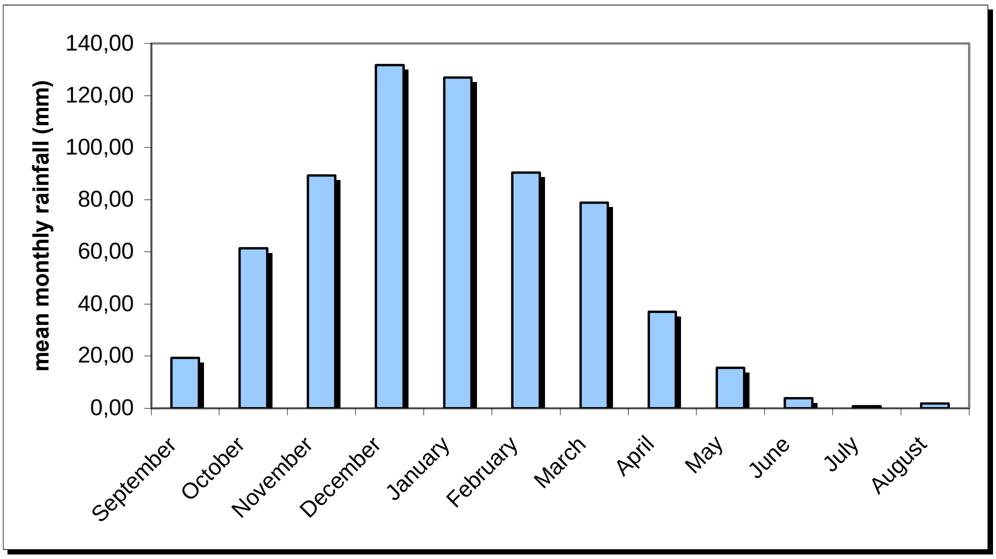


Figure 100: *Mean monthly rainfall for the Patelis catchment.*

Almost 40% of annual rainfall occur in December and January. The wet season lasts from November to March or April, while the dry season extends from June to September. There is one station measuring temperature in the catchment of Patelis, namely Siteia station. The mean annual temperature for Siteia station is 18.67°C. The highest temperatures occur in July and August (25.7°C) while the lowest temperatures are in January and February (12.2 to 12.3°C). Siteia station exhibits a high mean annual temperature compared to other stations in Crete. The monthly pattern of temperature for Siteia station is depicted in figure 24. The hot period extends from May to October and the cold period lasts from November to March or April. The average winter temperature is 13°C, while for the summer it is 25°C. The temperature range between the coldest and the hottest month of the year is 12.8°C.

2.2.3 Surface water

There are no big rivers in the area of the catchment but there are seasonal streams originating from the relatively low mountains in the central part of the catchment and flowing into the coastal area of Siteia bay. The most important stream of the area is the Patelis, which is the main outlet of the catchment at Siteia constriction. Important affluents of the Patelis river are the streams Xiropotamos, Petrolakkos and Platani. The mean elevation of the riverbed is 469m with a minimum elevation of 64m. The length of the river path is around 14km. The mean annual runoff for the Patelis river for the years 1967 to 1994 is shown in figure 101. Data for the hydrological years 1981 to 1983 are missing due to misplacement of the gauge. No flow was observed from May to

September 1990, July to November 1991, July to November 1992, August to October 1993, July to September 1994 and July and August 1995.

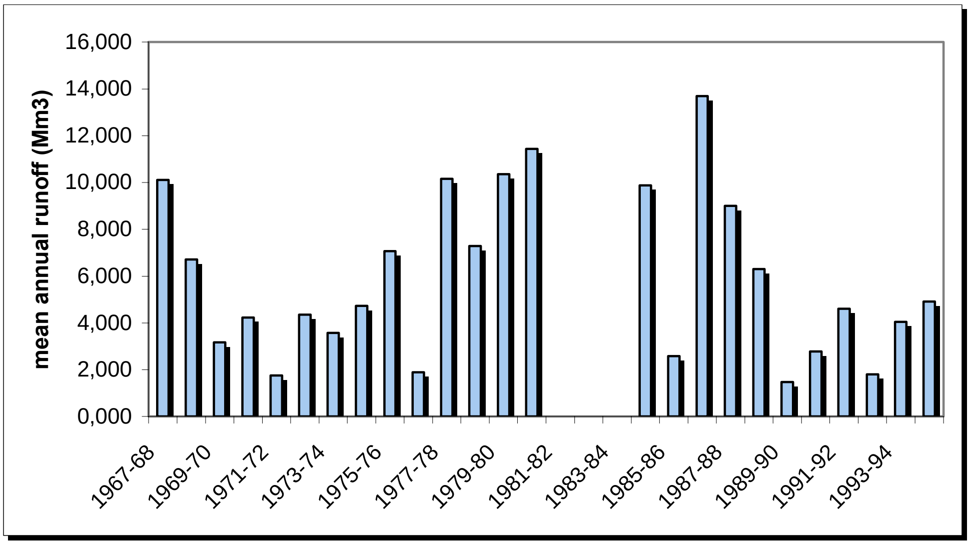


Figure 101: *Mean annual runoff of the Patelis catchment.*

The hydrological year 1989-1990 was the year with the lowest rainfall and runoff, while the hydrological year 1986-1987 was the hydrological year with the highest rainfall and runoff. The mean monthly runoff of the Patelis river is shown in figure 102. High flows are observed in January and February, while low flows are experienced in July and August. The mean annual runoff for the Patelis river is 6Mm^3. The annual runoff coefficient for Patelis is shown in figure 103.

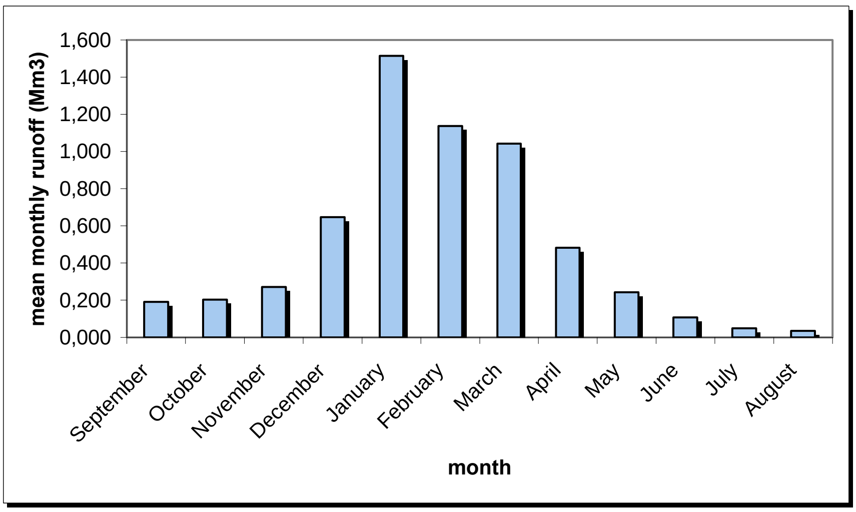


Figure 102: *Mean monthly runoff of the Patelis catchment.*

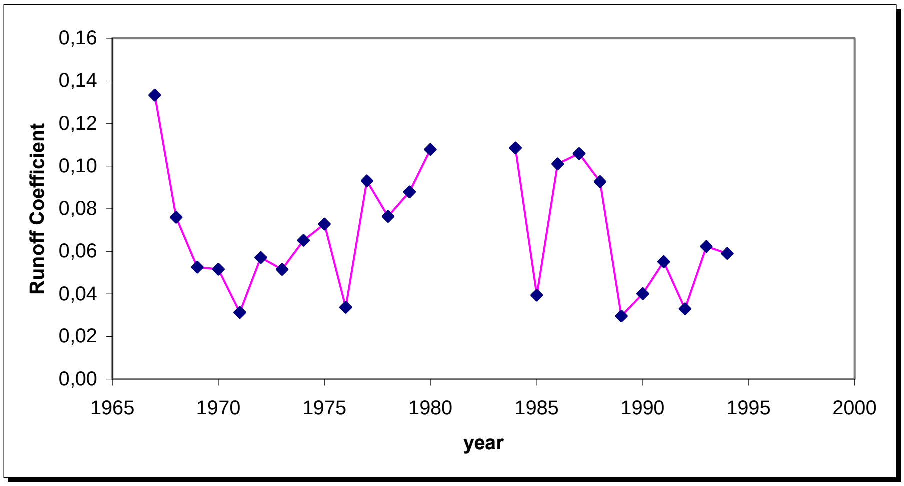


Figure 103: *Annual runoff coefficient of the Patelis catchment.*

The mean annual runoff coefficient is 0.06 and the standard deviations 0.03. This value of runoff coefficient implies that pumping takes place in the catchment. Figure 108 shows the mean annual runoff for the Patelis catchment compared with other streams in the Lasithi prefecture. Water is abstracted from the streams of the catchment for irrigation purposes.

2.2.4 Groundwater

The hydrogeological conditions of the catchment result from its geology. As mentioned above, 50% of the valleyconsist of marly deposits, clays and conglomerates and 50% of Quaternary alluvial and silty deposits. Alluvial deposits are made up of silty clay with conglomerates. Alluvial deposits exhibit a high specific yield and are considered permeable formations, which form an unconfined aquifer. The east slope is less permeable due to the existence of silty clays and Neogene marly deposits. The valley is the receptor of discharge from the mountains. Groundwater levels are estimated at 50m ASL. Surface and groundwater are used for irrigation purposes in the catchment area. Groundwater comes from pumping wells and springs. In the area of the catchment the spring of Zou is located. This spring has a mean annual discharge of 51l/s. The mean annual and monthly discharge of the spring is shown in figures 104 and 105 respectively.

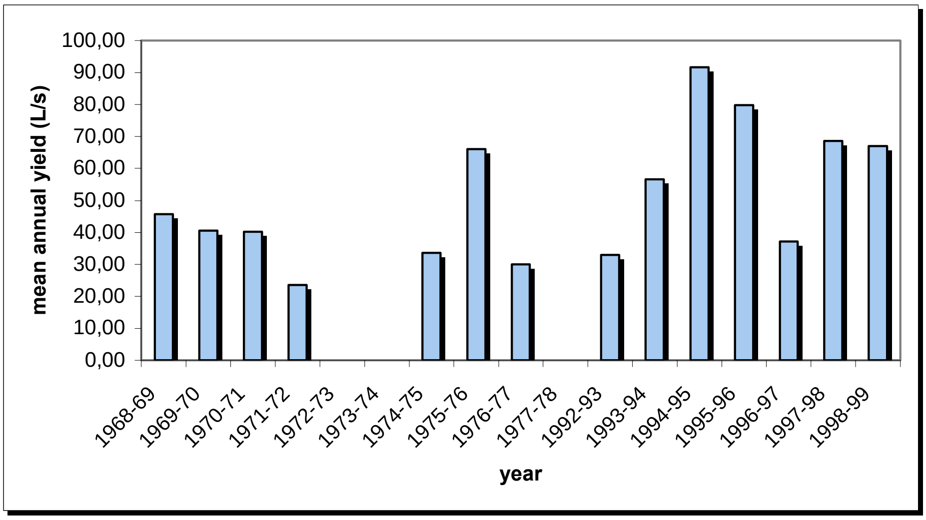


Figure 104: *Mean annual discharge of Zou spring.*

High yields are observed in February and March and low yields in August, September and November. A high percentage of the discharge of the spring ends up in the sea during winter time. From the spring of Zou 50m³/h are abstracted for water supply of Siteia and Pistokefalo and another 33m³/h for irrigation. There are about 35 registered pumping wells in the catchment, around 25 of which are used for irrigation purposes, 10 for irrigation and water supply while some have not been exploited or have not yielded any water.

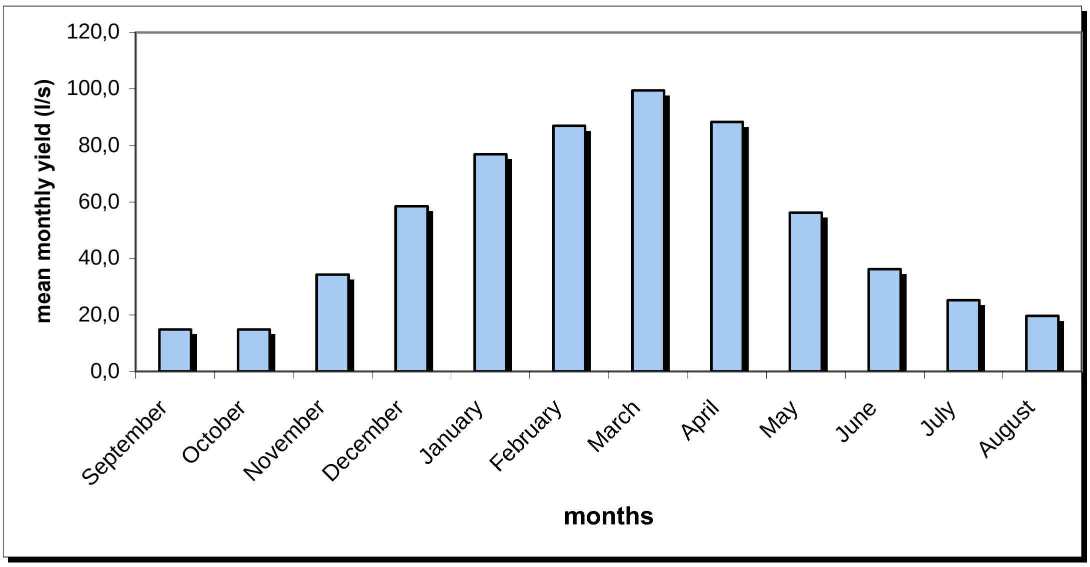


Figure 105: *Mean monthly discharge of Zou spring.*

2.2.5 Agricultural situation

Around 90% of the catchment area is cultivated, around 47% of the total tree crops are olives (cv Koroneiki), about 10% are vines (cv Sultanina), 6% are vegetables and 30% is fallow land and other crops.

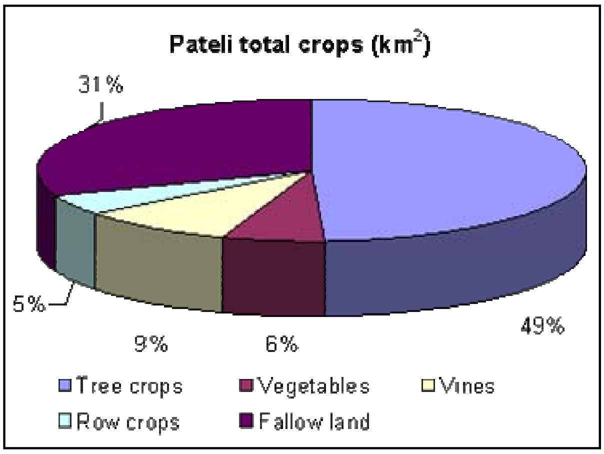


Figure 106: *Crops cultivated in the Platys catchment, (HNSS, 1999).*

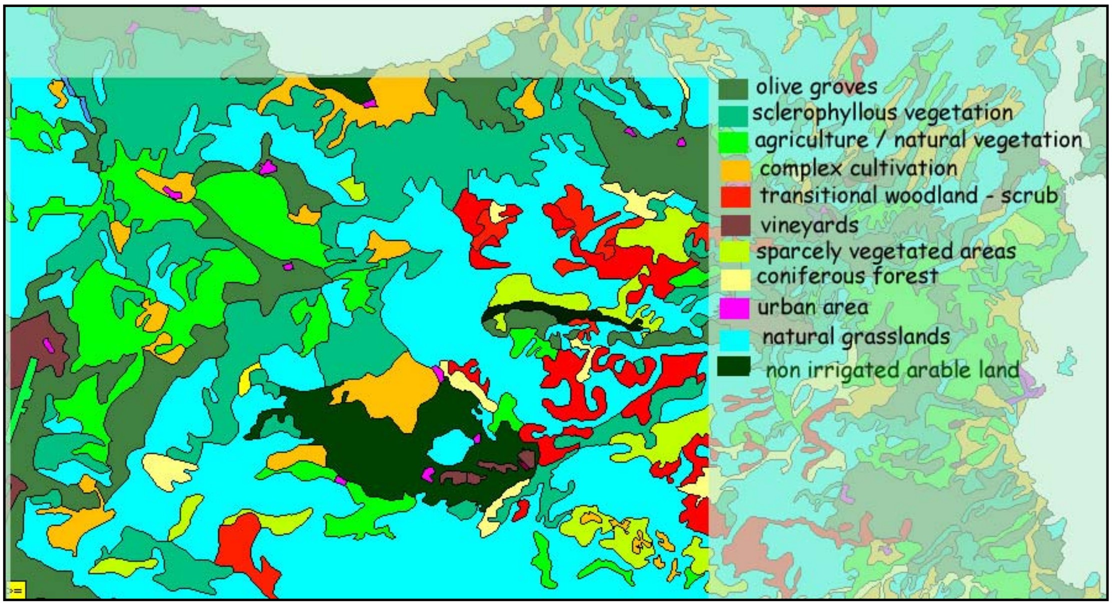


Figure 107: *Land – use map of the Patelis catchment, (CORINE).*

2.2.5.1 Irrigation systems and scheduling

Surface and groundwater are used for irrigation purposes from pumping wells, springs and stream runoff. Drip irrigation systems are applied in olive orchards; micro-sprinklers for potatoes and furrow are used for the other vegetables. The time and amount of the water applied is empirically defined. The average water price is about 0.21€/m^3. The price is increased compared to other catchments because the Local Board of Water Management (TOEB) has too many debts. When dept is paid, the water price will be reduced. The Local TOEB does not have water meters in all irrigated areas and thus it is not possible to know how much water the farmers in those areas use.

2.2.5.2 Crop water requirements

Reference evapotranspiration was estimated with Penman – Monteith method using data from Sitia weather station for the period 1971-1998.

Crop water requirements for the main crops in the catchment are presented in table 39.

Table 39: *Crop water requirements in the Patelis catchment.*

Crop	Crop water requirements (10^4 x m^3 /km^2)												
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**SUM**
Olives	-	-	-	-	4.0	5.5	6.5	6.0	3.0	(1.0)*	-	-	**25.0 (26.0)***
Citrus	-	-	-	-	8.0	10.0	11.5	10.5	6.5	1.5	-	-	**48.0**
Watermelons, Melons	-	-	-	-	9.0	12.0	14.0	12.5	8.0	-	-	-	**55.5**
Potatoes (spring)	-	-	3.0	5.5	10.0	12.0	14.0	-	-				**44.5**
Potatoes (autumn)	-	-	-	-	-	-	13.0	11.5	7.0	2.0			**33.5**
Tomatoes (open)	-	-		2.5	7.5	12.0	14.0	12.5	-	-	-	-	**48.5**

** Additional irrigation due to low rainfall and/or high temperatures and/or extended crop.*

2.2.5.3 Fertilisers

Various forms of N-fertilisers (40%) and composite fertilisers (60%) applied empirically during winter without any analyses reaching the nutrient needs of the crops (about 5kg per tree). Fertigation is rarely used in the catchment. Regarding the estimated crop water requirements, open field watermelons and melons are the most highly water demanding crops in the Patelis catchment, followed by citrus and vegetables (open field tomatoes, spring potatoes).

2.2.5.4 Weed control, irrigation systems and fertiliser application

Weed control in olive orchards is done equally with herbicides, tillage and no tillage. In vines tillage (50%) and herbicides (50%) are used. Generally, usage of chemicals is the most common used method in the Patelis catchment. In olive orchards weed control is done with herbicides (33%), tillage (33%) and no tillage (33%). In vines tillage (50%) and herbicides are used. Surface and groundwater are used for irrigation purposes from pumping wells, springs and stream runoff. Drip irrigation systems applied in olive orchards; micro-sprinklers for potatoes and furrow are used for the other vegetables. The time and amount of the water applied is empirically defined. Sultaninas are irrigated in winter and spring. Olives are irrigated after the irrigation period of Sultaninas. Various forms of N-fertilisers (40%) and composite fertilisers (60%) are applied empirically during the winter without any analyses regarding the nutrient needs of the crops (about 5kg per tree).

2.3. Platys catchment – Physical characteristics

The Platys catchment lies in the southern part of Crete, in the prefecture of Rethymnon. The catchment covers an area of 203km^2, comprising a north-south plain with mountains rising on the east and west sides. The catchment receives around 850mm of rainfall per year. Around 80% of the total valley area are cultivated with olive groves. The main source of irrigation water is groundwater. Pumping stations that have been installed allow drip-irrigated cultivation of olive trees.

2.3.1 Relief and geology

The Platys catchment comprises a north-south plain with mountains rising on the east and west side. Mountains on the west rise up to 1,500m while the plain stretches at an elevation of 250 to 50m. The Platys river is the main stream of the catchment and its outlet at the south coast is located at Agia Galini constriction. An important affluent of the Platys river is Ligiotis. Neogene and Preneogene formations make up the basic geological setting of the area. In more detail: Formations that are classified in the Pindos Zone (a geostratigraphical classification regarding the evolution of the Preneogene rocks in Greece) crop out mostly in this area. The basic formations of the Pindos Zone are upper Triassic limestones and radiolarites. They consist of pink finely bedded limestones underlying radiolarites and sandstones with sandstone limestones. Cretaceous thick bedded limestones consisting of pink limestones at the base, black-gray limestones in the middle of the stratigraphical sequence and a series of thin interchanging Palaeocene limestone and marl layers at the top of the sequence. Flysh of Eocene age comprises the most recent formation of the Pindos zone. It can be slightly metamorphic in places. Flysh is the most abundant formation in the area. Upper Miocene conglomerates, sandstones, sands with occasional lignites comprise the main Neogene outcrop in the Platys catchment. They crop out to the east and northeast of the Platys river. The geological map of the Platys catchment is depicted in figure 108.

2.3.2 Climate and water resources

The climate is sub-humid Mediterranean with mild moist winters and hot and dry summers. The catchment shows a mean annual rainfall of 850mm. Rainfall has been measured by the Department of the Ministry of Agriculture in Crete for around 30 years. There are four rainfall stations in the area. The location of these stations is shown in figure 109.

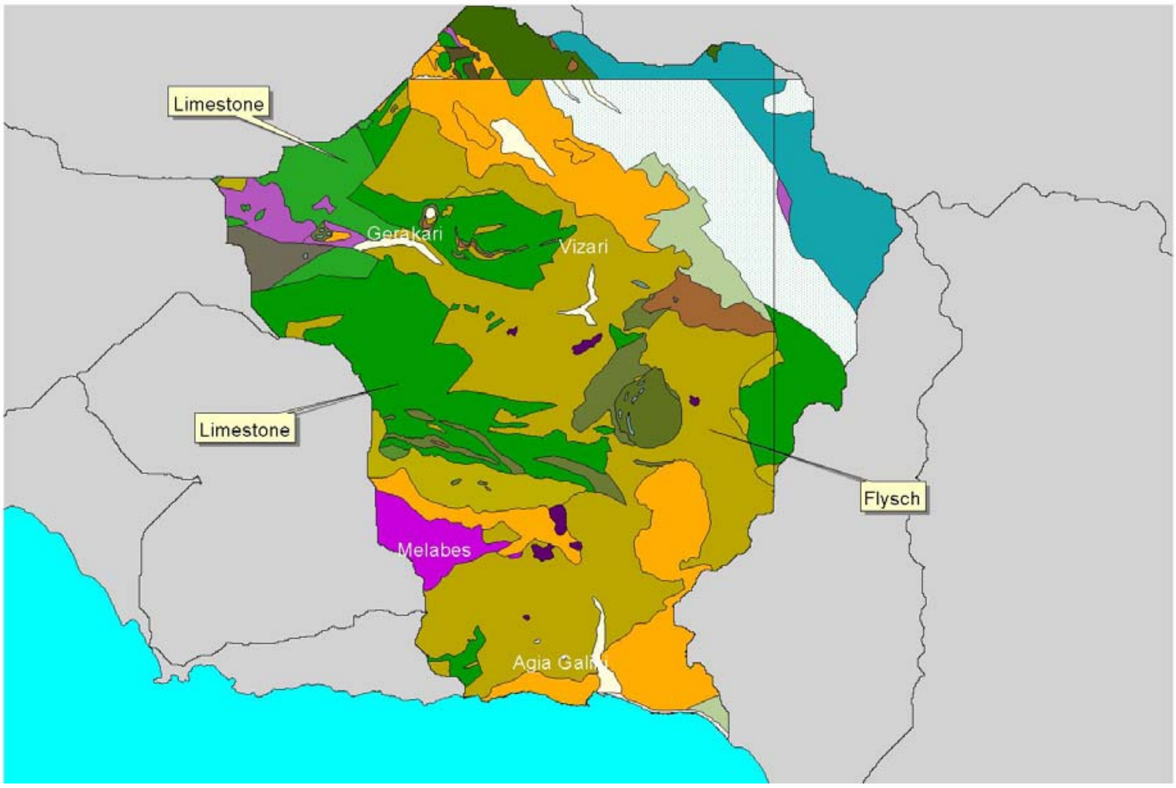


Figure 108: *Geological map of the Platys catchment.*

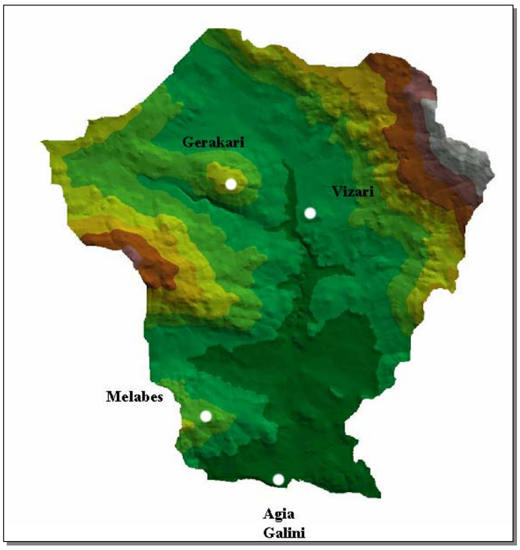


Figure 109: *Geophysical map of the Platys catchment with rainfall gauges.*

The mean annual rainfall for the four different stations in the catchment is depicted in figure 110. Gerakari station shows the highest mean annual rainfall, as it is located at high elevation. Rainfall ranges between 1,300mm at Gerakari station at an elevation of 580m, to 754mm at Vizari station at an elevation of 310m, and 574mm for Agia Galini station at an elevation of 20m. Agia Galini station shows very low annual precipitation compared to other stations in Crete and the lowest in the Rethymnon prefecture and Gerakari station is at the upper end of stations that exhibit high annual precipitation and the second highest in the Rethymnon prefecture. As shown in figure 111, rainfall increases with elevation. The Melabes station, which is located at an elevation of 560m ASL, shows lower precipitation than Vizari station located at an elevation of 310m. This is most probably due to the location of Melabes near the coast, while Vizari lies in the mainland close to the mountains. Agia Galini, Vizari and Gerakari stations show a linear dependence of rainfall with elevation, the fit being:

$P_i = 491.57 + 1.2991 z_i$ and

P_i and z_i = rainfall (mm) and elevation (m) of a particular location in the catchment.

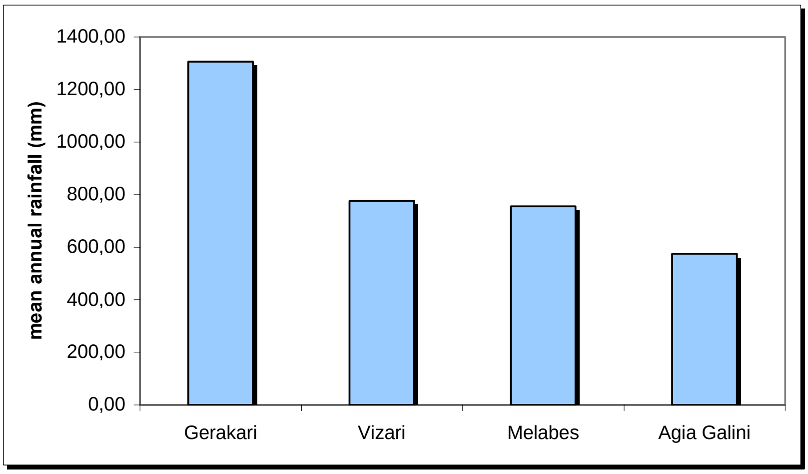


Figure 110: *Mean annual rainfall for the different stations in the Platys catchment.*

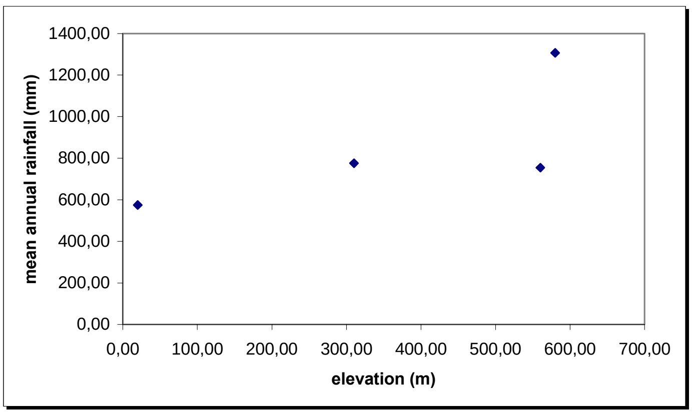


Figure 111: *Rainfall distribution with elevation.*

The correlation coefficient R is 0.927 as shown in figure 112. As shown in figure 113, the driest year was the hydrological year 1989-1990 and the wettest one was the hydrological year 1977-1978. Figure 115 depicts the seasonal pattern of rainfall for the catchment. Around 40% of its mean annual precipitation occurs in December and January. December seems to be the wettest month, while July and August are usually the driest. The wet season lasts from October or November to March and the dry season extends from May to September.

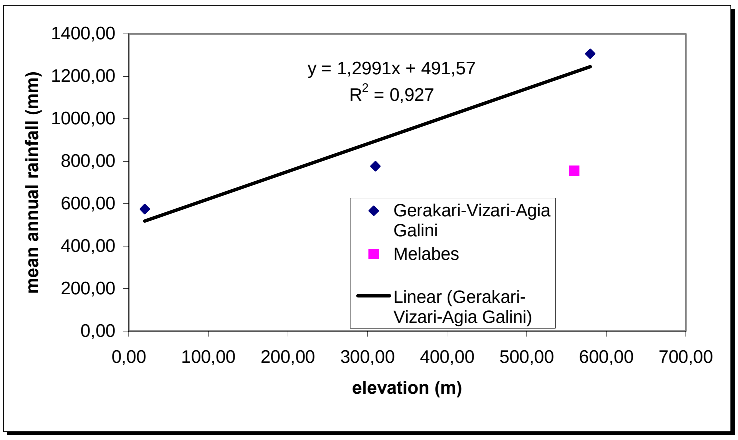


Figure 112: *Linear dependence of rainfall with elevation.*

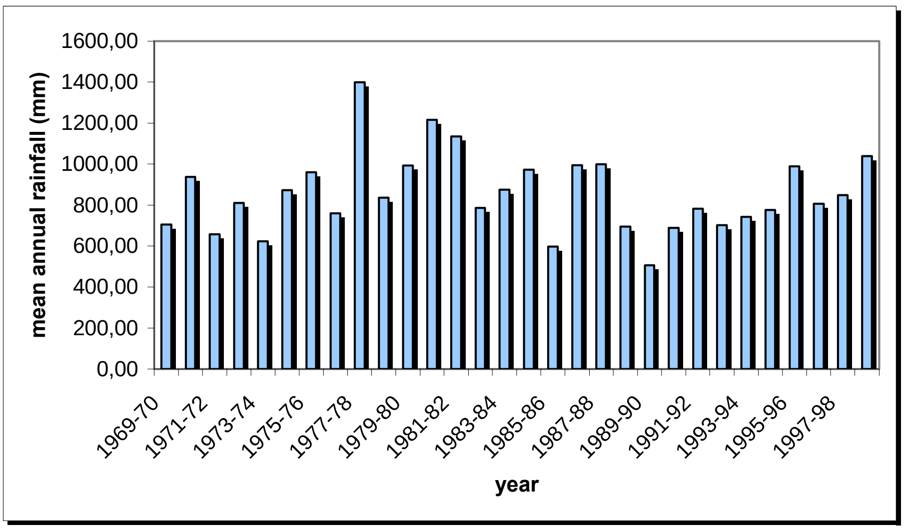


Figure 113: *Mean annual rainfall of the Platys catchment.*

2.3.3 Surface water

The Platys river is the main stream of the catchment and its outlet is at the south coast of Agia Galini constriction. An important affluent of the Platys river is Ligiotis. The mean annual runoff for the Platys river is depicted in figure 114. The river shows mean annual runoff of 50.7Mm³. The highest mean annual runoff is observed in the hydrological year 1977-1978 and the lowest in 1985-1986. As shown in figure 115 and 116, the highest flow is observed in January and February, while low flows or no flow are observed from June to October. The river was dry for all hydrological years in July, August and September and in October of 1969, 1971 and 1973 to 1998. For many hydrological years no flow was observed in June and even in November.

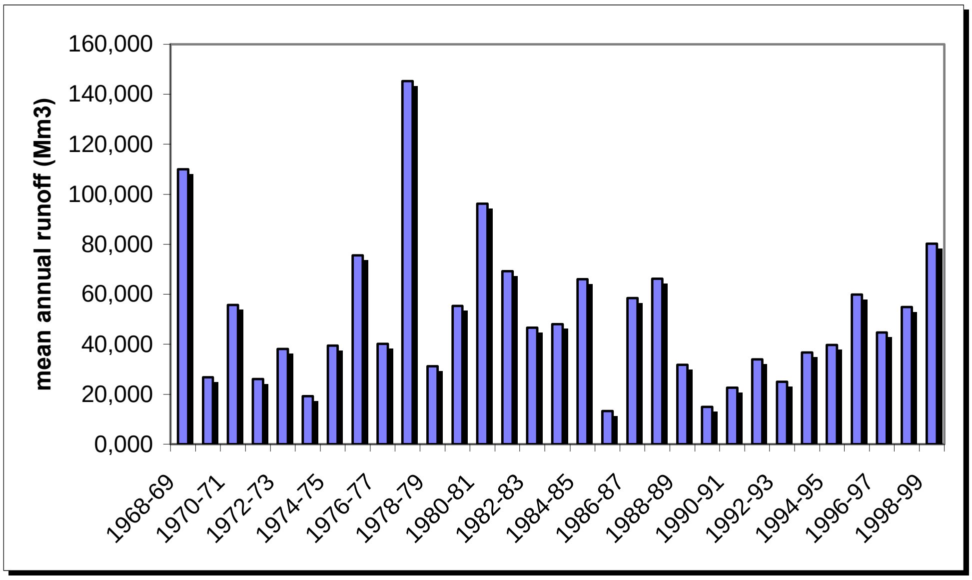


Figure 114: *Mean annual runoff of the Platys catchment.*

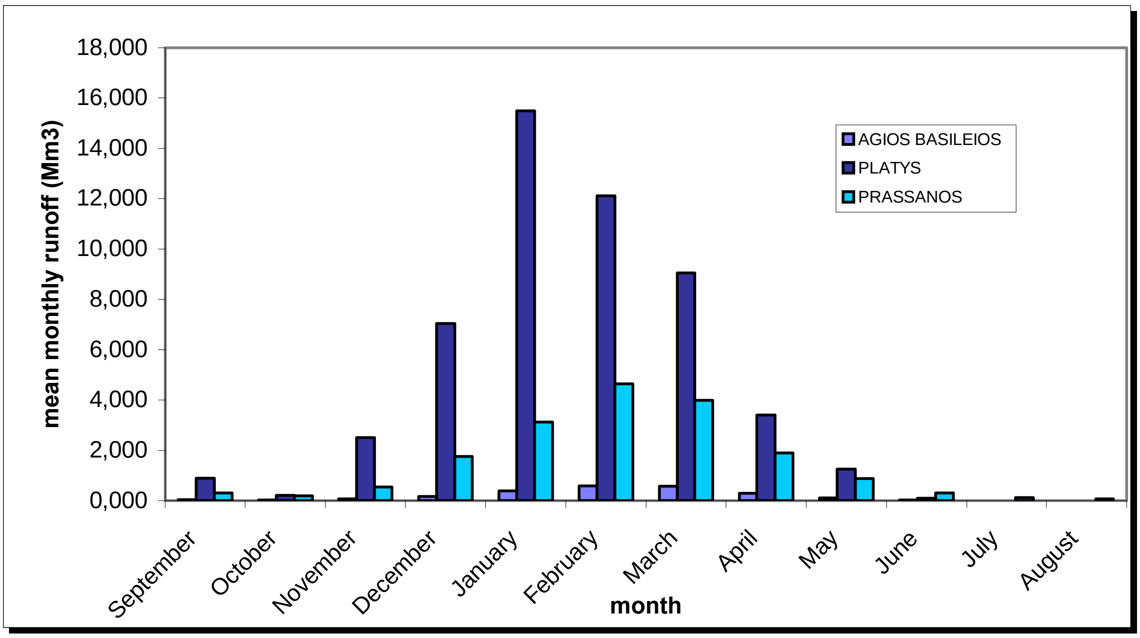


Figure 115: *Mean monthly runoff for different streams in the prefecture of Rethymnon.*

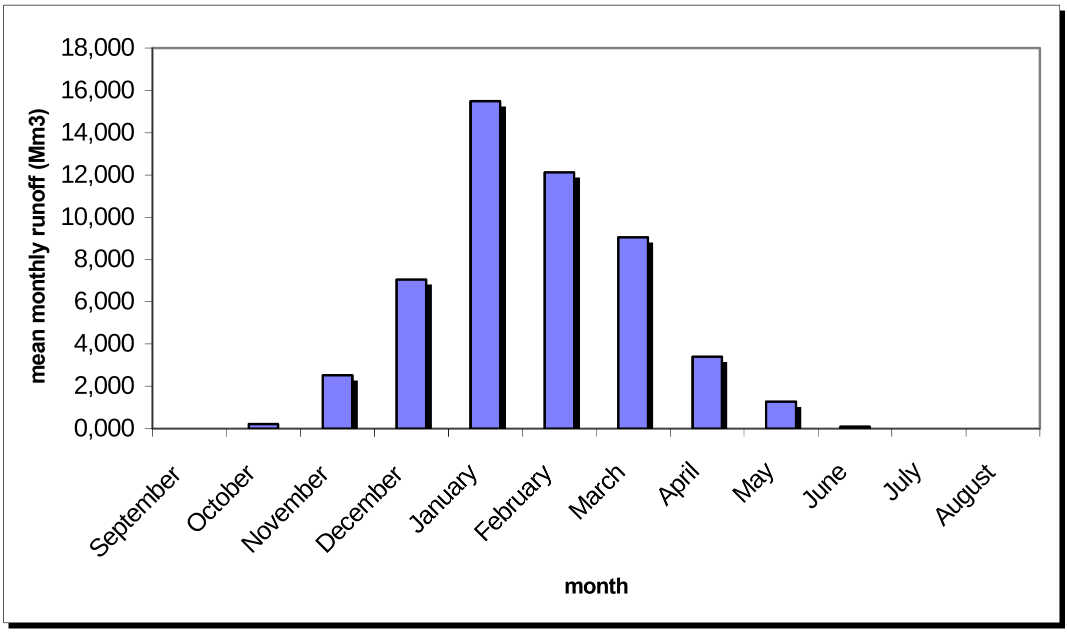


Figure 116: *Mean monthly runoff of the Platys catchment.*

The mean annual and mean monthly runoff coefficients are shown in figures 117. The mean runoff coefficient is 0.26 which is a relatively high value and shows that not much pumping takes place.

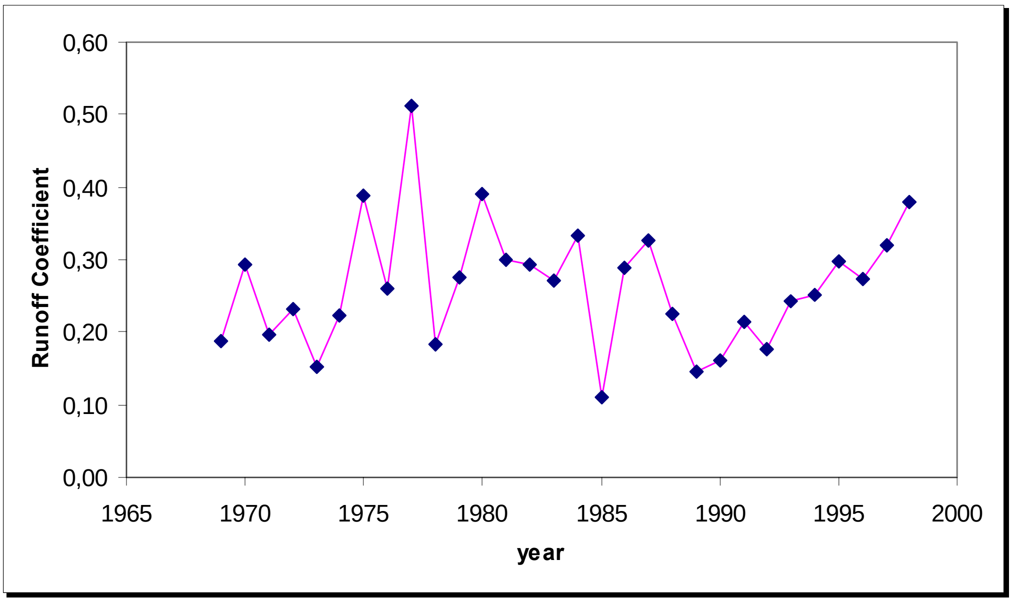


Figure 117: *Runoff coefficient for the Platys catchment.*

2.3.4 Water resources

The main source of irrigation water in the valley is groundwater. Around 20 pumping wells have been registered in the area. Most of them are used for water supply and irrigation purposes, while some are needed for research and some are either not in use any more or have failed. It is estimated that not much groundwater is pumped from the aquifer. There is also a small dam (0.5Mm^3) located at Vizary village.

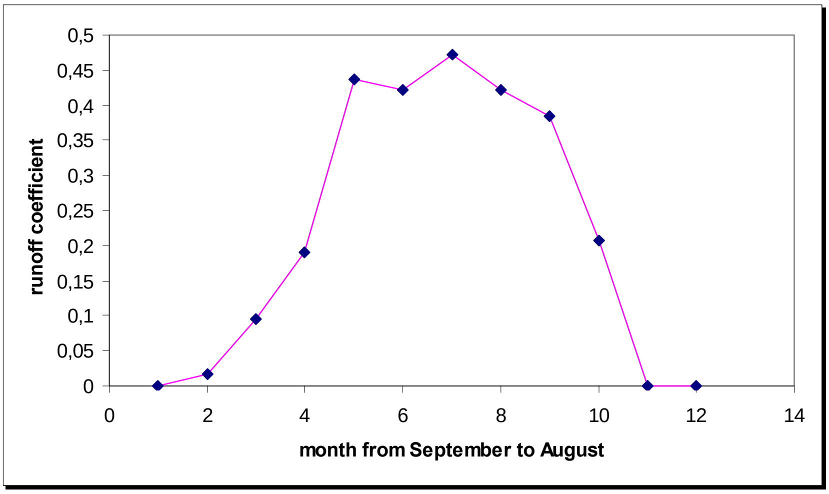


Figure 118: *Mean monthly runoff coefficient for the Platys catchment.*

2.3.5 Agricultural situation

Around 80% of the total catchment area is cultivated (fig. 119), but fallow land covers the biggest part of the cultivated area due to animal breeding and difficult (or even impossible) access to irrigation water. 95% of the total tree crops are olives (80% cv Throumbolia, 15% cv Koroneiki, 3-4% cv Mastoidis). Figure 120 shows the land use map for the Playts river basin.

2.3.5.1 Irrigation systems and scheduling

The main source of irrigation water is groundwater. Drip irrigation systems are used for olive orchards of cv Koroneiki. The cv Throumbolia is non-irrigated. Vines are also non-irrigated. The amount of water applied is empirically defined. The average water price is approximately 0.06€/m^3.

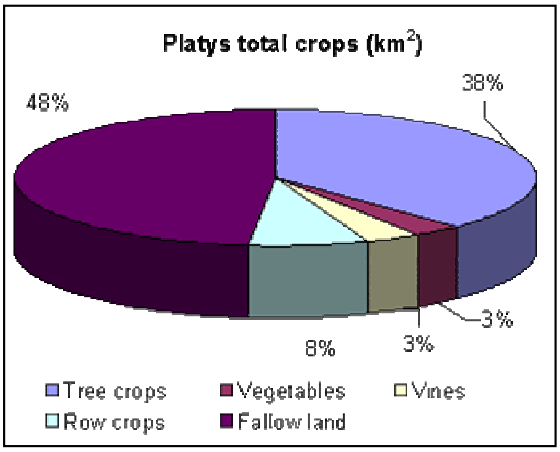


Figure 119: *Crops cultivated in the Platys catchment, (HNSS 1999).*

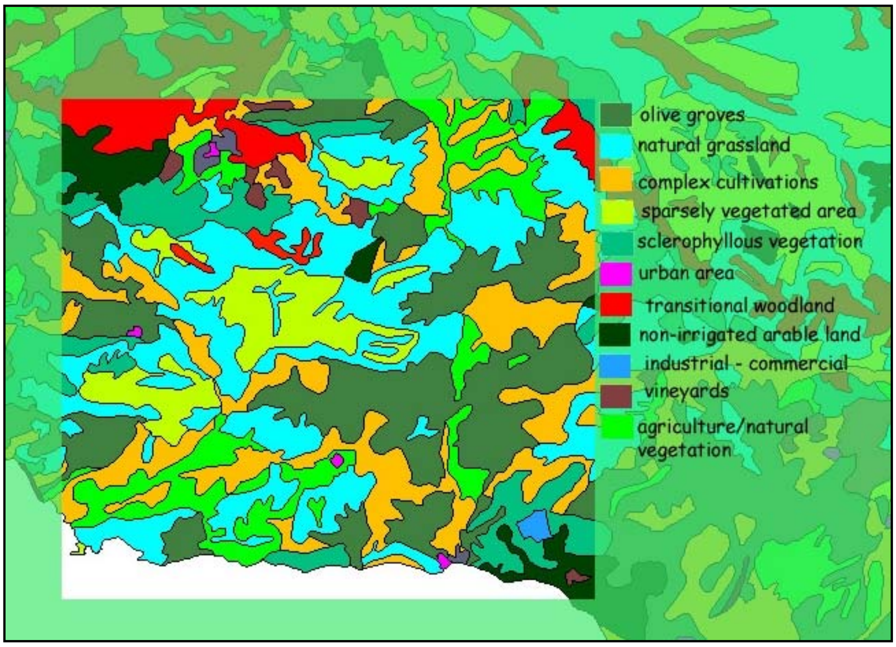


Figure 120: *Land use map of the Platys catchment, (CORINE).*

2.3.5.2 Crop water requirements

Data from Vizari station were used to estimate reference evapotranspiration with the Penman – Monteith method for the period 1971-2001. Missing data were filled from Gerakari and Leukogia stations. Crop water requirements for the main crops in the catchment are presented on Table 40.

Table 40: *Crop water requirements in the Platys catchment.*

Crop	Crop water requirements [$10^4 m^3/km^2$]											
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**SUM**
Olives	-	-	-	-	3.0	6.0	7.5	6.5	3.5	(1.0)*	-	-	**26.5 (27.5)***
Vines for wine	-	-	-	-	-	8.5	11.0	-	-	-	-	-	**19.5**
Cherries	-	-	-	4.5	8.5	13.0	16.0	-	-	-	-	-	**42.0**
Potatoes (summer)	-	-	-	-	-	13.0	16.0	14.5	9.0	2.0	-	-	**54.5**
Artichokes	-	-	-	-	-	-	-	3.0	3.5	1.5	-	-	**8.0**
Tomatoes (open)	-	-	-	1.5	6.5	13.0	16.0	14.5	-	-	-	-	**51.5**

**Additional irrigation due to low rainfall and/or high temperatures.*

Regarding the estimated crop water requirements, open field vegetables (summer potatoes and tomatoes) are the most highly water demanding crops in the Platys catchment, followed by cherry trees.

2.3.5.3 Fertilisers

Various forms of N-fertilisers are applied empirically without any analyses regarding the nutrient needs of the crops (about 4kg per tree for olive trees). Fertigation is rarely used in the catchment.

2.3.5.4 Weed control

Weed control is performed mostly with herbicides (40%) and tillage is used only in olives cv Koroneiki or supplementary to chemicals. 15% of the farmers use weed cutting.

2.4 Kissamos catchment – Agricultural situation

The Kissamos (fig. 121) catchment lies in the NW part of Crete in the Chania prefecture. It constitutes one of the most important agricultural regions on the island. Of the total crops cultivated, 65% are olives (cv Koroneiki), 20% are vegetables, 5% are vines and 10% are other cultivars. Irrigation systems are mostly used for olive orchards. The amount of water applied is empirically defined. Various forms of N-fertilisers are applied empirically without any soil or leaf analyses as to the nutrient needs of the crops. Weed control is performed mostly by tillage (70%), while herbicides are used by 20% only.

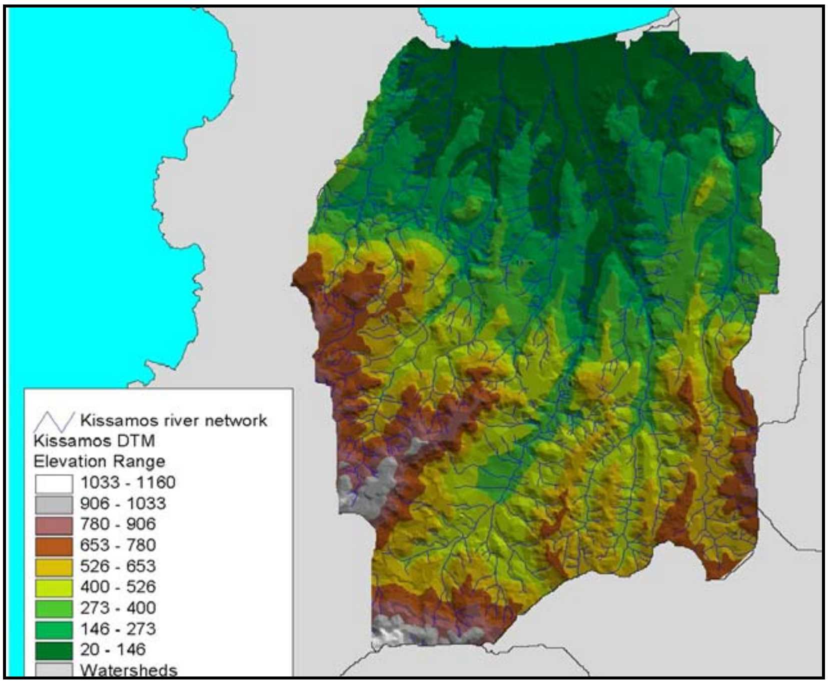


Figure 121: *Kissamos catchment.*

The basic geological setting of the area is formed by Neogene formations overlying Palaeozoic formations, mainly phyllites and quartzites**.** The Neogene formations of Miocene up to Pleistocene age consist of conglomerates, white-gray marls and marly limestones on the top of the stratigraphical sequence. The upper Palaeozoic phyllites and quartzites crop out to the south of the area where the terrain becomes more mountainous.

The total permanent population of the area amounts to about 5,000 inhabitants. The climate is sub-humid Mediterranean with mild winters and dry summers (aridity index=0.58). The mean annual temperature is estimated at 18+/-2^{0}C. The mean winter temperature is 13^{0}C and the mean summer temperature 24^{0}C. The mean annual precipitation is 745mm, while the average monthly precipitation from April to September is 12.7mm and from October to March 111.5mm. The lowest annual rainfall observed was 350mm and the maximum was 1,100mm in 30 years of record. Evapotranspiration varies from 1,190 to 1,420mm/yr.

2.4.1 Cultivated crops and cultivated land

Of the total crops cultivated, about 80% are olives, 8% are vegetables, 3% are vines and 10% fallow land and other cultivars (fig.122). Figure 123 shows the land use in the area.

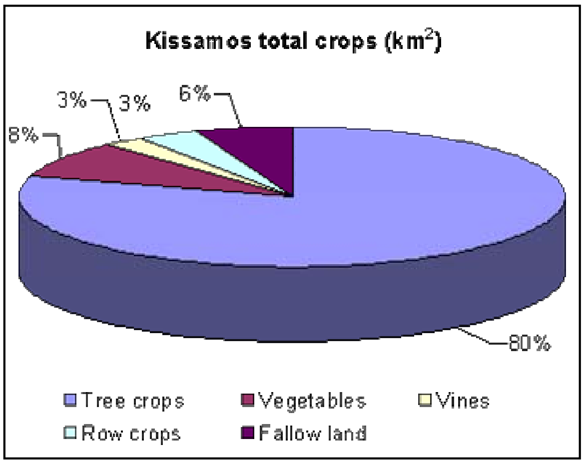


Figure 122: *Crops cultivated in the Kissamos catchment, (HNSS, 1999).*

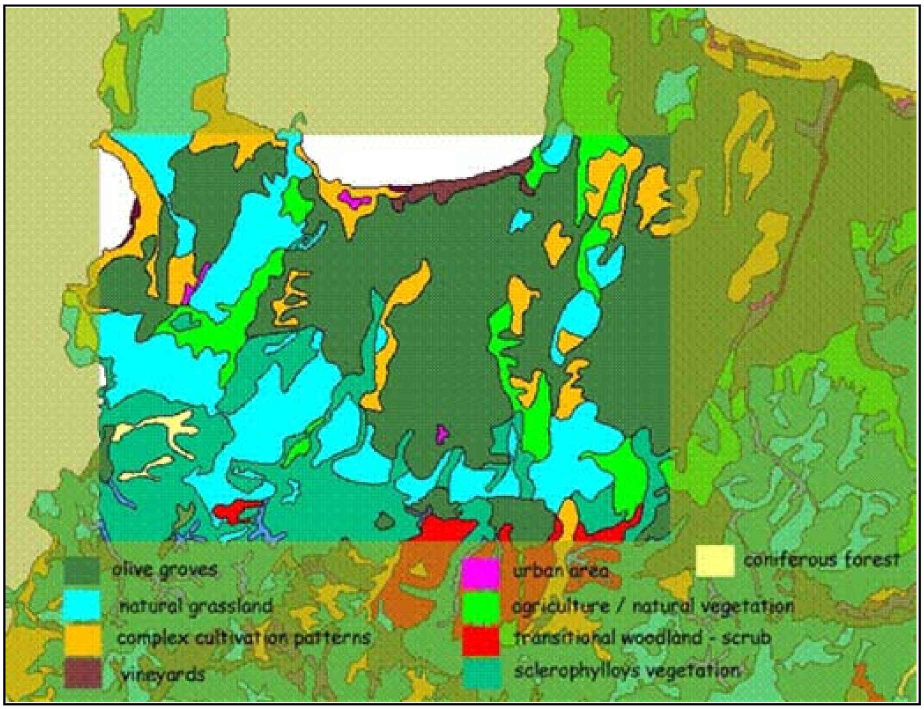


Figure 123: *Land use map of Kissamos catchment, (Corine).*

2.4.2 Irrigation systems and scheduling

The amount of water applied is empirically defined. Approximately 2Mm^3 of water is used for irrigation in the Kissamos area. The average water price is approximately 0.08€/m^3. The main irrigation system is drip irrigation.

2.4.3 Crop water requirements

Data from Drapanias station were used to estimate reference evapotranspiration for the period 1965-1992 with the Penman – Monteith method. Missing data were filled from a station nearby (Zimbragou). Crop water requirements for the main crops in the catchment are presented in table 41.

Table 41: *Crop water requirements in the Kissamos catchment.*

Crop	**Crop water requirements ($10^4m^3/km^2$)**												
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**SUM**
Olives	-	-	-	-	3.0	5.5	6.5	5.5	3.0	(1.0)*	-	-	**23.5 (24.5)***
Citrus	-	-	-	-	6.5	9.0	10.0	9.0	5.5	1.0	-	-	**41.0**
Table vines	-	-	-	-	-	7.5	8.0	7.5	4.5	-	-	-	**27.5**
Vines for wine	-	-	-	-	-	7.5	8.0	-	-	-	-	-	**15.5**
Greenhouse tomato (Oct – May)	2.0	2.0	3.0	5.0	9.0	-	-	-	-	2.5	2.5	2.0	**28.0**
Greenhouse cucumber (Aug – Dec)	-	-	-	-	-	-	-	3.5	7.5	7.5	5.5	4.5	**28.5**
Greenhouse cucumber (March – Jun)	-	-	3.0	6.0	8.0	8.5	-	-	-	-	-	-	**25.5**
Watermelons	-	-	-	-	8.0	10.5	12.0	10.5	-	-	-	-	**41.0**
Potatoes (spring)	-	-	2.5	3.5	8.0	5.0**		-	-	-	-	-	**19.0**
Onions	-	-	1.5	3.0	7.0	5.0**	-	-	-	-	-	-	**16.5**
Tomatoes (open field)	-	-	-	2.0	6.0	10.5	12.0	10.5	-	-	-	-	**41.0**

** Additional irrigation due to low rainfall and/or high temperatures*
*** Irrigation lasts until mid June*

As to the estimated crop water requirements, open field vegetables (tomatoes and watermelons) are the most highly water demanding crops in the Kissamos catchment along with citrus, followed by table vines which, however, do not account for a large area in the catchment.

2.4.4 Fertilisers

Various forms of N-fertilisers are applied empirically without any soil or leaf analyses as to the nutrient needs of the crops.

2.4.5 Weed control

Tillage and chemicals are equally used in weed control in the Kissamos catchment.

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Report on Cyprus

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Abstract

Cyprus is the largest island in the Eastern Mediterranean and covers an area of 9,251km² out of which 1,733km² are forested. The Troodos mountain range occupies one third of the island and its impressive topography of 1,951m above mean sea level affects its environment and every aspect of life on the island. The climate is Mediterranean with hot dry summers from mid-May to mid-September and rainy, rather changeable winters from mid-November to mid-March separated by short spring and autumn seasons. The mean annual precipitation is 467mm (1971-2000) with substantial variation from 300mm in the plains to over 1,000mm in the upper parts of Troodos. The precipitation records of the last 100 years indicate a 15% decrease of the mean annual precipitation but its inter-annual variation is considerable with common periods of three consecutive years with rainfall below average, affecting the annual water resources of the island significantly.

For the last fifty years the annual water demand in Cyprus was mostly satisfied by groundwater. The total storage of groundwater in 1969 was 3,174Mm³ and the annual extraction was 42Mm³ beyond the safe yield (UNDP & FAO, 1971). This resulted in saline intrusion and quality deterioration of all coastal aquifers and spoiling of valuable underground water storage space. Over-pumping caused depletion of inland aquifers and variable increase of their boron content. Intensive agriculture under irrigation and over-fertilisation increased the nitrate content, particularly in the coastal areas.

To increase the water resources of Cyprus, the Government embarked up on an ambitious program of tapping the surface water, which was lost to the sea. The storage capacity reached 307.5Mm³ in 2003, from 6Mm³ in 1960 (Water Development Dept., 2003) and conveyors over 100km long now transfer water from the water-rich areas in the west to water-poor areas in the east and thus supply domestic water for all major cities and tourist areas. The sum of the design yields of the dams is over 200Mm³ per year, but due to a decline in annual rainfall, particularly during the last 30 years, their average annual inflow over the 1971-2000 period has reduced to 127Mm³. Human intervention, such as the construction of off-stream ponds, overexploitation of the Troodos aquifers and extensive terracing for reforestation and agricultural land also contributed to the reduction of stream flow. Intensive agricultural activity in the catchment areas is responsible for a tendency of concentration of chlorinated pesticides in the reservoirs.

To increase the water resources further and especially to relieve the domestic water supply from the vagaries of the weather, the Cyprus Government signed contracts for the construction of two desalination plants on a BOOT basis and reverse osmosis type with an annual production of 33Mm³. An additional source of water is recycled/ reclaimed water. The first sewage treatment plant in operation produces 5Mm³ of tertiary treated water and the new plants under construction and planning will produce 13Mm³ of water by the year 2005 and 30Mm³ by the year 2012.

The total annual water demand and use for the year 2000 in the Government controlled area is estimated to be 266Mm^3. Agriculture is the main user (69%) followed by domestic use (20%), tourism (5%) and industry (1%); the environmental demand is 5% of the total. Improved irrigation methods are widely used with drip irrigation being the predominant method. The demand for domestic water supply for the year 2000 was estimated to be 67.5Mm^3 of which 53.4Mm^3 are for inhabitants and 14.1Mm^3 for tourism (Savvides et al., 2001).

In 2003, 359km^2 out of a total cultivated area of 1,564km^2 were under irrigation but they contribute 70% to the value of the annual crop production. The gross output of the agricultural sector in 2000 was C£318.4 million (~€ 554 million) with crop production contributing 51% and livestock production 46% (CyStat, 2004). Agriculture contributed 3.7% to GDP in 2003 and employees in agriculture represented 7.2% (2003) of the gainfully employed population of the island. Agriculture accounted for 21.2% of the total domestic exports in 2003 (CyStat website, 2004).

To bring about a balance between supply and demand it will be necessary to curtail the irrigation area, reduce losses in the conveyance systems and field applications, especially in the mountainous areas, change cropping patterns in favour of less water intensive crops grown preferably during winter months, increase water tariffs to cover a considerable part of the water cost. In the domestic supply it is essential to reduce the total losses by unaccounted water and to rehabilitate the distribution networks to minimize losses. A vigorous campaign on public awareness of the scarcity value of water and its importance on sustainable development is also essential.

For the implementation of any policy for better management of the water resources it is necessary to consolidate and update existing legislation and allocate all the responsibility of water management to one Ministry with the establishment of a WATER ENTITY and to harmonise Cyprus Legislation with the European Union Water Framework Directive 2000/60/EC.

Introduction

The island of Cyprus is located in the north-eastern Mediterranean between the Anatolian Plateau to the north and the foreland of the African Shield to the south. The birth of the island was the result of a series of unique and complicated geotectonic events which have made Cyprus an international geological showcase. The inhabitants of the island and the foreign visitors and tourists would never suspect that the pine-cladded top of the Troodos mountains range is actually a slice of a 90 million-year-old ocean crust, an ophiolite, which formed 8,000m below sea level and later thrust almost 2,000m into the sky through long and complex geological processes.

The resulting impressive topography has affected the environment and every aspect of the island's life directly or indirectly. The climate results from a variety of microclimates, favouring most kinds of vegetables and fruits from sub tropical bananas and avocados to colder weather apples, plums and cherries. Without the Troodos Mountains, Cyprus would have been an extension to the west of the Negev desert of Israel. Precipitation on the lowlands is 300mm while on Troodos it exceeds 1,000mm increasing its annual renewable water resources considerably. It affects forest growth, a variety of flora and fauna, agricultural production and natural beauty and it generally renders Cyprus as a very attractive place to live in.

The island has a 10,000 years long history of art and civilisation which was based on its natural resources (water, minerals, and forests) and its unique natural environment, its geographic position at the crossroads of three continents – Asia, Africa and Europe and at the centre of an area where the greatest ancient civilisations flourished. Troodos served as the basis for this civilisation because the thousands of springs at its various elevations supplied the necessary water for the settlements during the long dry parts of the year, but also supplied water to the rivers flowing to the lowlands, supplying domestic and irrigation water to the water-poor coastal cities and settlements.

Since prehistoric times, the inhabitants of the island have realised the importance of irrigation for the increase of agricultural production. Diversion and conveyance works had been constructed and operated in the major rivers throughout its history. Through these works water was transported beyond the riverbeds increasing the irrigated land for agricultural production even in the non-rainy periods. For centuries domestic and irrigation water supply was satisfied by natural springs from Troodos and the Karsts of the Kyrenia range. The demand however for water in the water-poor low lands and coastal areas had always been higher than the supply and for its satisfaction, water was transferred from springs to long distances. Good examples are the transport of water with a 20km aqueduct from the spring of Kissousa to the ancient Kourion (8th century B.C.) and from Kythrea spring to Salamis, 40km away during Roman times.

Cyprus has the oldest recorded water wells (8500 B.C.). Prehistoric cisterns helped to store water for the seven months or more that the island would be without rain.

Reverence for water and references to it have been part of Cyprus´ cultural heritage for longer than in most other places in the world. The importance of irrigation water is explicitly described in the extract by Euripides "VACHES" (408 B.C.) where the chorus sings …*"Oh! How I wish I were in Cyprus on your beautiful island Aphrodite, where Erotes, your sons, live in company with mortals and with magic hold our heart. Oh! How I wish I were in Paphos where runs the river with the hundred springs that flows and irrigates the land and produces without rain."* In the mosaics of Paphos, Daphne the nymph is represented as daughter of a river deity. After 2000 years the Venetian Giovani Francesco Camocio (1570 A.D.) reports … *"The winter river Pedieos passes through Levcosia-Nicosia from west to east. The plan was for the river to be diverted into the moat for defensive purposes. The river played its part in the development of the area. Early sites on the banks of the river indicate the existence of a developed civilisation through the Bronze age 2600-1500 B.C.".* After 2500 years in the Second Five Year Development Plan (1967-1971) of the Cyprus Government the economists of the Planning Bureau reconfirmed Euripides remarks. *"The role of irrigation water in agricultural development is emphasised by the fact that although in 1966 irrigated crops covered only 11% of the cultivated land they contributed 52% of the total plant production. On an average the yields from irrigated areas are eight and a half times greater than those from dry farmed areas. Irrigated land increased its share in total cropped land from 8.5% in 1960 to 11% in 1966. It is evident that water is of vital importance for the island's agricultural development."*

For the satisfaction of the imbalance between supply and demand, for centuries various techniques were used to extract groundwater such as: chains of wells; Persian wheels and towards the end of the 19th century, windmills imported from the United States. The capacity of these methods was small and limited to shallow depths. The extracted water was less than the annual replenishment and thus the exploitation of the aquifers sustainable. However, irrigated areas were very limited, the island suffered from droughts, in some cases lasting three consecutive years, making living conditions difficult, which is why thousands of Cypriots immigrated in search for a better life.

After the Second World War the systematic exploitation of the coastal aquifers of the island started with deep boreholes and pumps of big capacity. There was a rapid expansion of the irrigated land. The irrigated crops, such as citrus, potatoes and other vegetables were exported to Europe at very high prices and the income of farmers increased by about eight times compared to those made on dry farmed land. Agriculture and minerals were the main contributors to foreign currency earnings and employment on the island. Development and the standard of living rose rapidly.

In 1960, when the Republic of Cyprus was established, more than 10,000 boreholes were in operation and the annual extraction of groundwater exceeded the annual replenishment, the water levels dropped and the first signs of sea-intrusion appeared. The Government of Cyprus with financial and technical assistance of the United Nations Development Programme (1964-1969) carried out a survey of the water resources of the island. The total reserves of groundwater were estimated as well as the water storage capacity of the aquifers. But the most important finding of the survey was that the annual extraction of groundwater was $42Mm^3$ beyond the safe yield of the aquifers. After the 1970s prices for citrus and potatoes in Europe dropped, but their cultivation in Cyprus was still expanding, consequently increasing the irrigation water demand. Instead of managing the demand, the policy of the Cyprus Government in the 1980s was to increase the supply by an ambitious programme of constructing dams on most of the major rivers with the slogan "not a drop of surface water to the sea". The design of the dams was based on the 1917-1970 hydrological data. However after 1970 the mean precipitation decreased between 10 and 20% (Rossel, 2001) and the surface flow of the various rivers decreased between 20 and 60% (Rossel, 2002). The average yield of the dams is almost half of that calculated during their design.

At the same time the demand of domestic water increased considerably because of the population increase and its standard of living, with tourism increasing beyond expectations with a very important contribution to the economic activity of the island. The management of water resources was the allocation of the existing water resources to various sectors through rationing and imposing restrictions to the supply of both domestic and irrigation water. At the same time the efforts for increasing the supply continued by mining the aquifers, constructing more dams, desalination plants and sewage water treatment plants.

After 1969 a study of the water resources and water policy was carried out in 1998 by the Cyprus Geological Survey Department. One of the most important conclusions of the study was the urgent need for a detailed study for the reassessment of the water resources and demand of the island. This study was conducted between 2000-2002 by the Water Development Department in collaboration with the Food and Agriculture Organisation (FAO) of the United Nations (WDD & FAO, 2002). At the same time a Joint Project of the United States Geological Survey (USGS) and three Cyprus Government Departments, namely the Meteorological Service, the Water Development Dept. and the Geological Survey Dept. was launched. It aims at the design, construction and implementation of computerised water resources databases to serve the needs of water managers in both communities of the island and it is still in progress.

Chapter I: Overview of the Island

1.1 Physical characteristics

Geographical data

Cyprus is the third largest island in the Mediterranean Sea after Sicily and Sardinia and is situated 33° east of Greenwich and 35° north of the Equator. Maximum territorial dimensions are north – south 97km and east-west 241km. It covers an area of 9,251km^2 (of which 5,760km^2 are under Government control) of which 19% is forested, 47% is arable land and the remaining 34% is cultivated land. Its population in 2001 was 689,565 (120 inhabitants per km^2), 9.4% were foreign residents. The local time is GMT+2; Cyprus Currency is Cyprus pound (C£) divided into 100 cents (1C£=1.74 Euros in 2000).

Geomorphology

The topography of the island is dominated by the two mountain ranges, the Troodos range in its central part, rising to a height of 1,951m and covering about one third of its total area (figure 1) and the Kyrenia range at the north, rising to a height of 1,085m. Between the two ranges stretches the Mesaoria Plain which together with the coastal alluvial plains make up the bulk of the agricultural land of the island. All the rivers flow only in winter, have their source in the Troodos mountains and only one substantial river has its source in the Kyrenia range.

Climate

The climate in the lowland is semi-arid with an aridity index of 0.3-0.5 with hot dry summers from mid-May to mid-September and rainy rather variable winters from November to March separated by short autumn and spring seasons of rapid change; on the Troodos Mountains climate is sub-humid with aridity index of 0.5-0.55. Meteorological data available since 1900 indicate mean annual precipitation of 500mm with considerable inter-annual variations; spatial variation is from 300mm in the plains to over 1,000mm on the highest parts of Troodos (figure 2). There was a considerable decrease (15-25% at elevations >500m amsl) of the mean annual precipitation after 1970 compared to the 1917-1970 period with substantial decrease of the renewable water resources of the island.

Geology

The geology of the island is dominated by the geology of the Troodos ophiolite complex, the core of which is occupied by tectonized, serpentinised harzburgite surrounded in outward succession by dunites, peridotites, gabbros; sheeted diabase, basaltic pillow lavas and peripheral chalks. In the serpentines occurs the chysotile asbestos deposit (the biggest in Europe). The dunites are podiform chromite deposits and in the pillow lavas many cupriferous sulphide deposits exist. The higher parts of the Kyrenia range are occupied by allochthonous recrystallised limestones encased in the Kythrea flysch formation which is made up of alternating layers of clays sandstones and greywackes. The Mesaoria plain is occupied by the autochthonous sediments resting on pillow lavas. Their stratigraphy in upward succession includes umber, argillites, marls and chalks, gypsum, reef limestone and marls, upper Cretaceous to Pleistocene age. The southwestern part of the island is occupied by the allochthonous Mammonia melange, consisting of clays, volcanics, siltstones, serpentines, recrystallised limestones and schists.

Groundwater

The most important aquifers of the island are the deltaic sand and gravel deposits of Pliocene-Pleistocene age at the western and south-eastern ends of the Mesaoria plain. Smaller similar aquifers occur in the southern coast of the island. In all these aquifers most of the groundwater of the island was stored. Appreciable quantities of groundwater were stored in the limestone karsts of the Kyrenia range and in smaller karsts of younger limestone and gypsum deposits of the Mesaoria plain and southern and western Cyprus. The total reserves were estimated in 1969 to 3174Mm^3 and their total storage capacity to 4027Mm^3. Annual extraction through pumping and springs was estimated 297Mm^3 and flow to the sea 194Mm^3 giving an annual deficit of 42Mm^3 since annual replenishment was only 450Mm^3 (UNDP & FAO, 1971).

Surface water

The area under Government control of the island receives 2,670Mm^3 of rainfall every year, 86% of which is lost to the atmosphere through evapotranspiration. About 235Mm^3 is surface water and 135Mm^3 is groundwater (WDD, 2002). There are no perennial rivers or transboundary waters. About 54% of the surface flow is collected in dams; the rest is lost through streams to the sea. A considerable part of the precipitation evaporates during the flow or is used by farmers for spade irrigation in early spring through many diversion works operating on most of the rivers.

Water storage features

Many dams of various capacities have been constructed in all major rivers with an increase of storage capacity from 6Mm^3 in 1960 to 307.5Mm^3 in 2003. The annual inflow of all dams is 127Mm^3 (1971-2000 mean) much less than the sum of the design yields of about 215Mm^3 (Rossel, 2002). The water of the dams is used for irrigation and domestic supply. Many small off-stream ponds were constructed on the Troodos mountains to supply water to small local irrigation schemes.

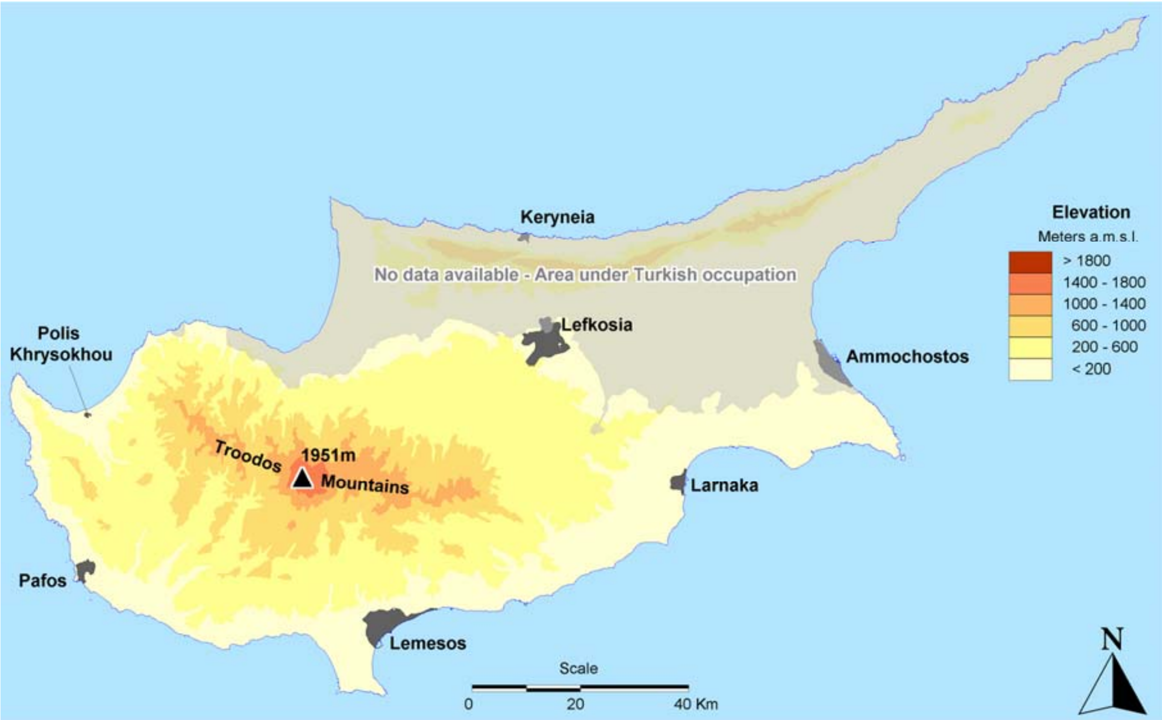

Figure 1: *Topographical map of Cyprus.*

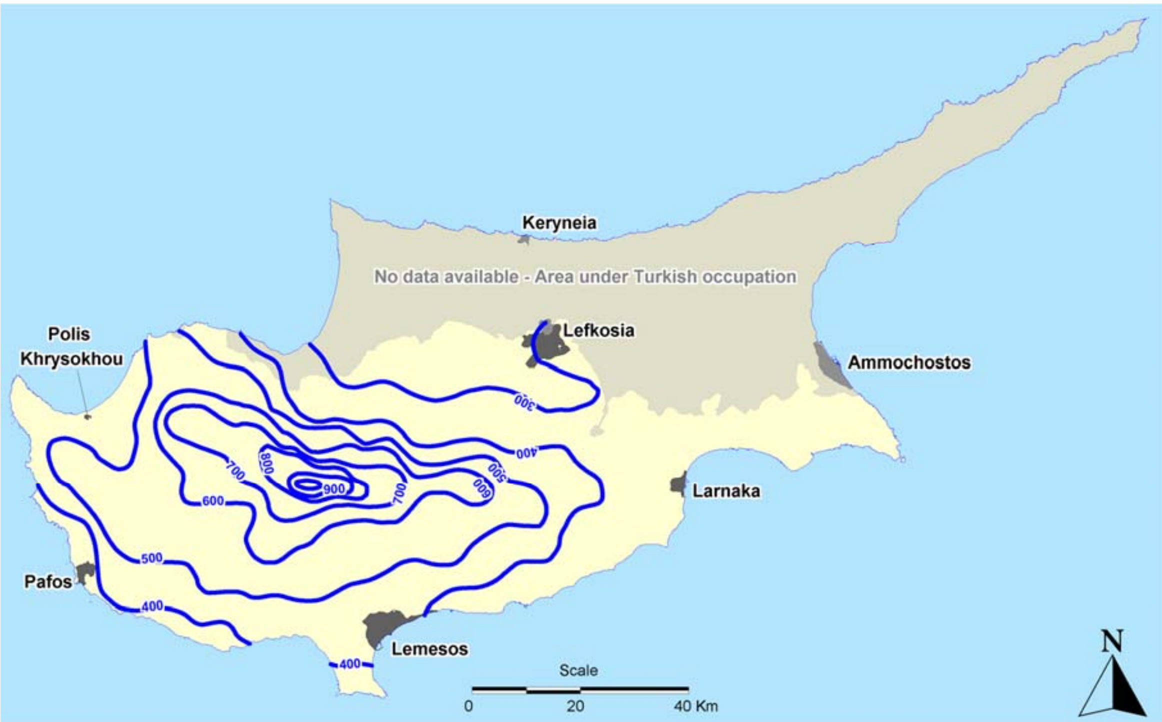

Figure 2: *Average annual precipitation 1970-2000 in Cyprus in mm. (Isohyets scanned and digitised from Meteorological Service-map).*

1.1.1 Water balance

1.1.1.1 Hydrological data

Meteorological data, including precipitation has been available since 1902, the study of which will help to improve water resources availability for current and future needs for informed water management in Cyprus. In the Geological Survey Study (1998) the following data were used: the island-wide mean annual precipitation (figure 3), the mean annual precipitation of a station on Troodos (Amiantos) and that of a station in the plains (Nicosia).

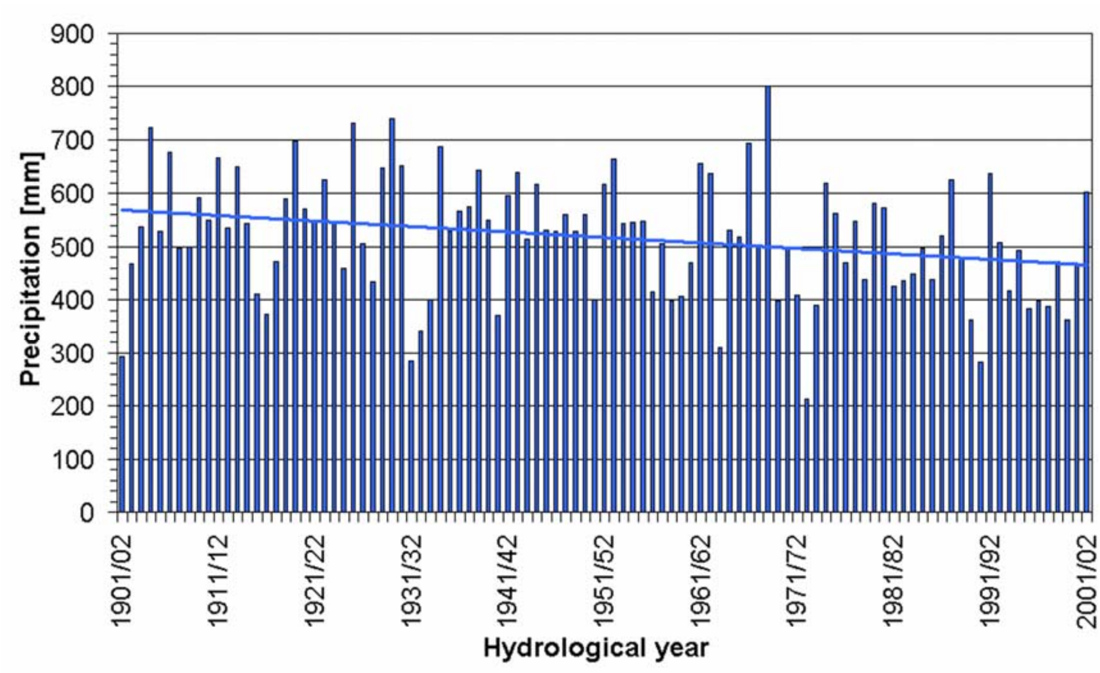

Figure 3: *Mean annual precipitation Cyprus wide: 1902-1997, (Geological Survey Dept., 1998).*

Based on this data, the moving averages for time series of 3, 10 and 30 years for all Cyprus and for the two selected stations were calculated. The moving averages give information about the general precipitation trend for each period. The moving averages of 30 years indicate the long term precipitation trend (figure 4), whereas the moving average of 3 years give information about the tendency of occurrence of three consecutive years with precipitation below average.

The conclusions of this study are:

1. the mean annual precipitation of the whole island in the last 100 years has decreased by 14% from 560 to 480mm,

2. there are great inter-annual variations,
3. in the last 100 years the island experienced five periods of three consecutive years of drought,
4. the decreasing trend of the mean precipitation occurred both in the mountains and the plains *and*
5. the mean precipitation in the plains (Nicosia) decreased 20% from 380mm to 300mm.

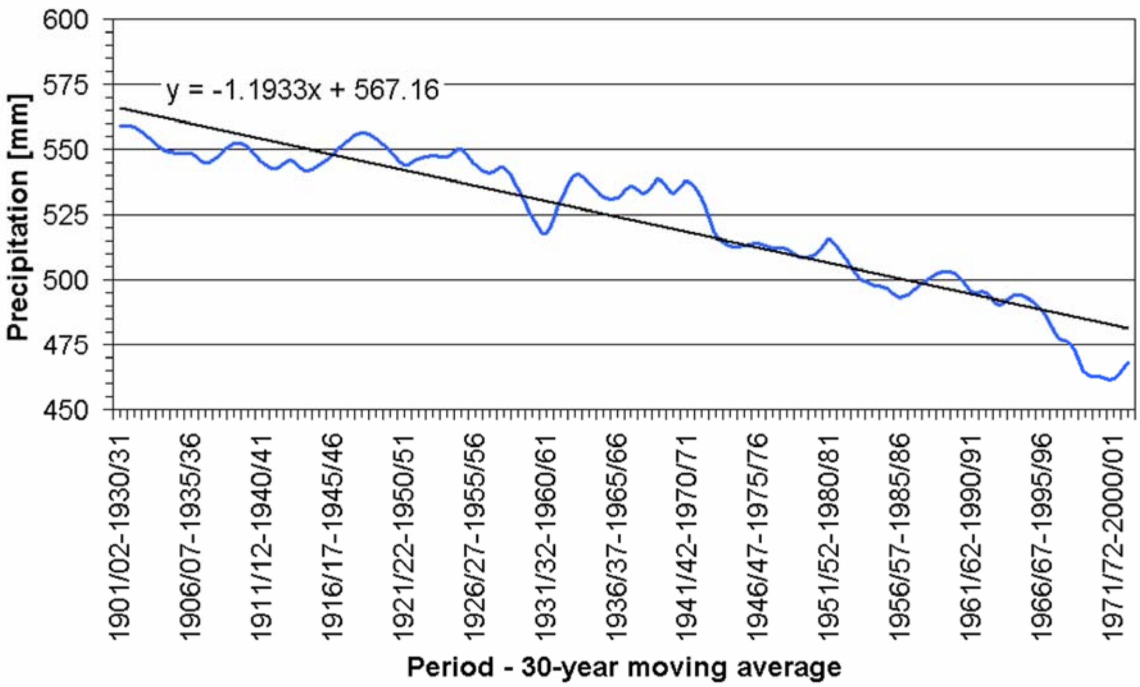

Figure 4: *Precipitation moving average for time series of 30 years, Cyprus wide: 1902-1997, (Geological Survey Dept., 1998, modified).*

A study of recorded rainfall (Rossel, 2001), which was carried out in the framework of the recent WDD-FAO "Assessment of Water Resources and Demand" project, investigated the rainfall records 1916/17-1999/00 of 44 rain gauging stations. According to this study precipitation displays a step change around 1970 and can be divided into two separate stationary periods (figure 5), with the precipitation during the 1970/71-1999/00 period being significantly lower compared to 1916/17-1969/70. It is also concluded that the precipitation in the recent period at elevations above 500m decreased by 100mm or more (i.e., 15-25%) and is more noticeable in December and January. It is difficult to predict a multi-annual increase in the future. For planning purposes the precipitation of 1970-2000 must be considered. A result of this decrease was a marked decline of the island's renewable water resources.

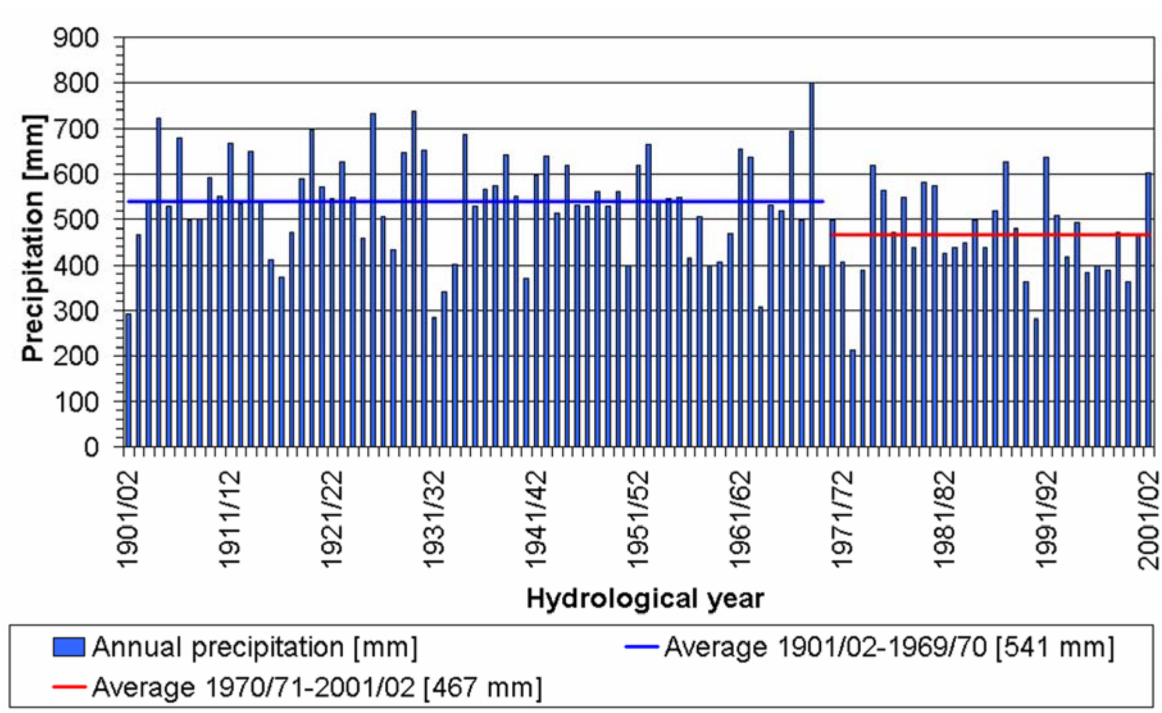

Figure 5: *Annual precipitation from 1901/02 to 2001/02 and average values for the years 1901/02 to 1969/70 and 1970/71 to 2001/02, (WDD, 2002).*

1.1.1.2 Hydrological balance

Cyprus is an island that has no transboundary water resources, thus, the sole source of the latter is its annual rainfall. The average amount of water from rainfall over the area under Government control is 2,670Mm^3, 86% of which evaporates (WDD, 2002). Evaporation is low in winter with the minimum in January and high in the summer with the maximums in July. The WDD-FAO study concluded that it is necessary to check the quality of existing Class A pan evaporation data before using these for water resources management (Rossel, 2002).

From the remaining 370Mm^3, 235 10^6m^3 are surface water and about 135Mm^3 replenish the aquifers (WDD, 2002). From the surface run off about 54% flows into the dams. This amount represents about 5% of the total annual rainfall. The rest of the surface runoff either evaporates during its flow or is lost to the sea through small streams and about 15Mm^3 are diverted from the rivers and streams and are used by the farmers for spade irrigation in late winter and spring, with the latter being practised for many centuries.

To satisfy the increasing demand and to minimize the losses of surface water to the sea the Government of Cyprus embarked on an ambitious programme of water development works with the construction of many dams and conveyors and irrigation networks. The storage capacity of the reservoirs increased from 6Mm^3 in 1960 to 307.5Mm^3 in 2003 (figure 7). Based on the standards of the International Commission of Large Dams (ICOLD) the island ranks as the first country in Europe including former USSR as regards to the number of large dams per square kilometre. The water of these dams is used for the supply of domestic water to all major cities and tourist areas and water for irrigation (figure 8). The total annual yield based on pre-1970 hydrological data at over 200Mm^{3}, but because of decreasing precipitation in the period after 1970, runoff decreased by 40% with respect to the 1916/17-1969/70 period and the annual yield of the dams to 127Mm^{3} (see table 1).

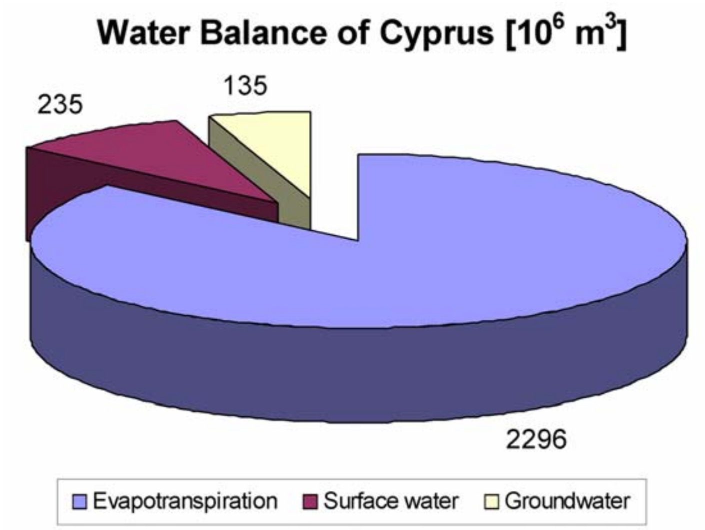

Figure 6: *Annual water balance of Cyprus (Area under Government control, (WDD, 2002).*

Further reduction of the stream flows was caused by human intervention, such as the construction of many off-stream ponds for small local irrigation schemes, extensive terracing for reforestation and agricultural land, widespread illegal pumping of base flow water from streams to irrigate agricultural land. The mountainous areas contribute to 80% of the surface runoff in Cyprus. In figure 9 it is clearly indicated that the inflow to the dams is directly related to the inter-annual variations of precipitation and therefore the reliability of the yield of the dams is very low for long term planning and management of the water resources. In spite of the extensive investments for the construction of all these dams, the island's problem of water shortage was not solved. On the contrary the construction of the dams and the transport of water from water–rich areas to water–poor areas have expanded the irrigated land and the demand for irrigation water with concurrent increase of the imbalance of water supply and demand on the island.

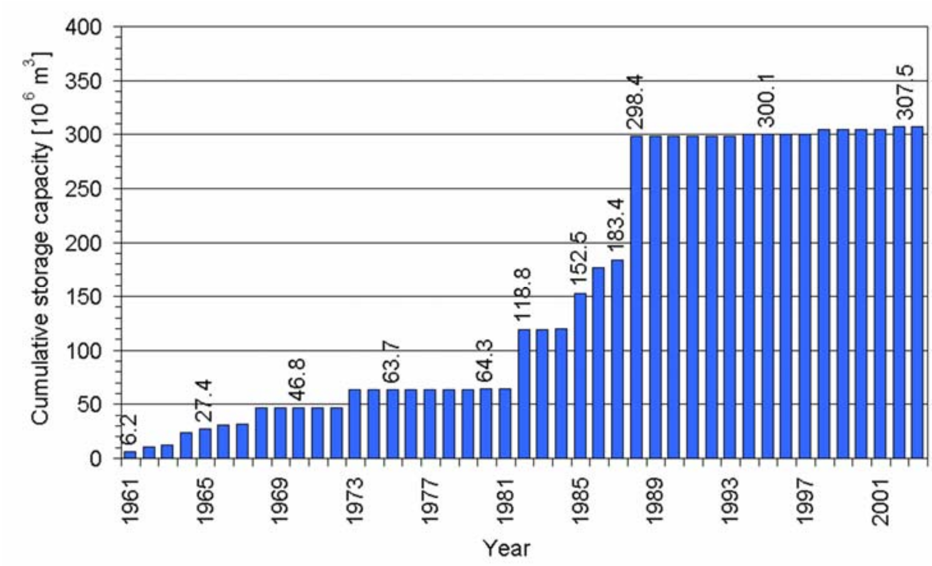

Figure 7: *Storage capacity of the constructed dams from 1961 to 2003 in Cyprus, (WDD, 2003).*

Table 1: *Mean annual inflow to a selection of dams (Mm³) (Rossel, 2002).*

Dam name	Design estimation	Observation 1971-2000	*Difference* (Obs-Est)/Est	Estimations with Rainfall			Rainfall decrease
				1917-1979	1971-2000	Decrease	
Pomos	5.0	3.4	-32%	5.1	3.1	-40%	-16%
Agia Marina	1.3	-	-	-	-	-	-
Argaka	8.5	2.6	-69%	4.1	2.3	-45%	-16%
Evretou	12.0	6.4	-47%	9.7	5.7	-42%	-17%
Kannaviou	9.1	8.0	-12%	11.9	7.0	-41%	-15%
Mavrokolymbos	3.9	-	-	-	-	-	-
Asprokremmos	31.9	14.9	-67%	23.0	13.5	-41%	-16%
Arminou	22.7	18.0	-21%	26.2	16.2	-38%	-15%
Kouris	46.3	30.0	-35%	41.7	27.7	-34%	-13%
Polemidhia	-	2.6	-	3.3	2.3	-30%	-10%
Yermasoyia*	14.0	9.8	-30%	16.6	12.5	-25%	-10%
Kalavasos	12.9	6.4	-51%	10.0	4.2	-58%	-15%
Dhypotamos	9.3	5.4	-43%	7.8	4.7	-40%	-14%
Lefkara	8.2	-	-	-	-	-	-
Kiti	-	1.3	-	1.6	0.9	-41%	-10%
Tamassos	-	5.2	-	8.1	4.7	-42%	-18%
Palekhori-	2.0	-	-	-	-	-	-
Xyliatos	3.0	2.5	-18%	3.2	2.3	-26%	-13%
Kalopanayiotis	11.5	5.1	-56%	6.3	4.8	-24%	-13%

***Figure 8**: Major water development works, (WDD, 1996, modified).*

Systematic exploitation of groundwater started after the Second World War with boreholes in the coastal and river aquifers. For many preceding centuries, the exploitation of groundwater had been through natural springs, chain of wells, Persian wheels and wind mills. This exploitation was limited to shallow depths and less than the annual replenishment and of the aquifers. With the drilling of deep boreholes and the use of high capacity pumps the exploitation of groundwater was intensified. For the first time the fertile land above the coastal aquifers was relieved from the vagaries of the eastern Mediterranean weather with big inter-annual variations of the precipitation and common drought of three consecutive years. The water supply for irrigation was reliable and the crop irrigation safe and cheap. The prevailing prices of irrigated crops such as citrus, potatoes, and other vegetables were high and the income of farmers eight times higher than those made from rainfed land. The result was the uncontrolled drilling of boreholes and in 1960, more than 10,000 boreholes were operated on the island, pumping water beyond the safe yield of the aquifers and causing sea intrusion.

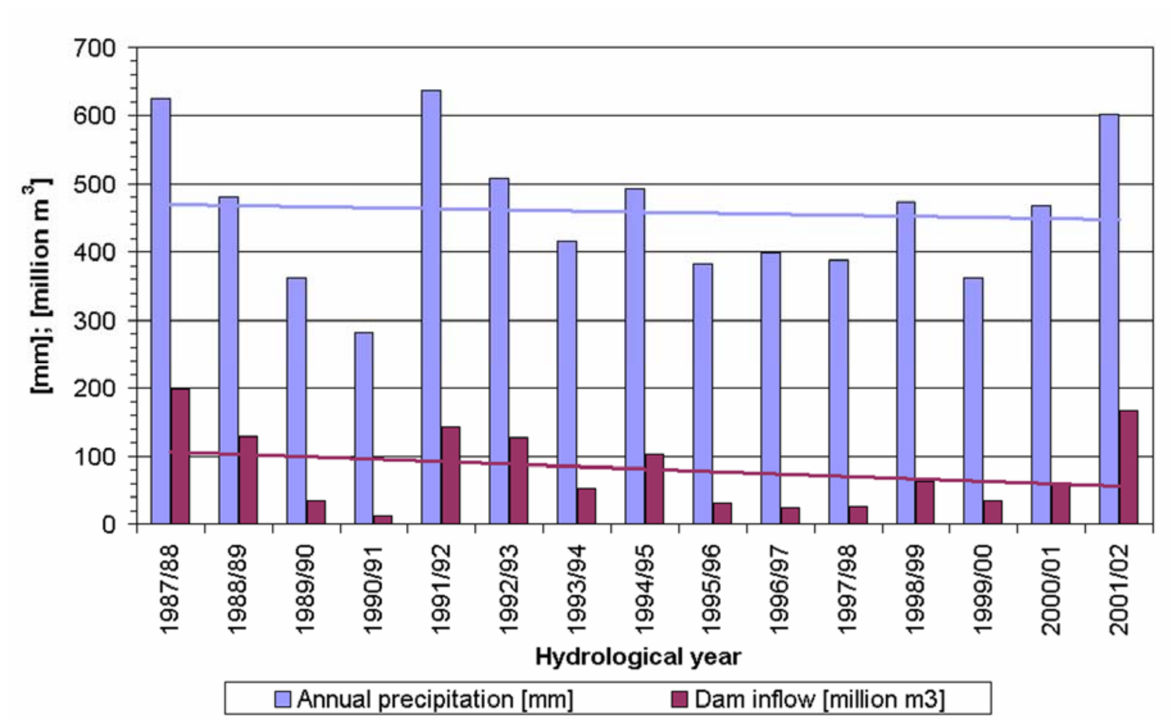

***Figure 9**: Inflow into the dams of Cyprus in relation to the mean annual precipitation (1987-2002), (WDD, 2002).*

A survey of the groundwater resources was carried out by the United Nations Development Programme (UNDP) from 1964-1969 including an appraisal of the total reserves of groundwater of all the aquifers, an assessment of the annual renewable groundwater resources and of the available extra storage capacity of the aquifers. The results are summarised in table 2 and indicate that the total water stored in the aquifers was 3170Mm³, the annual replenishment 450Mm³, and the extra storage capacity 850Mm³. However, the most important finding of this survey was a deficit in the groundwater balance, with total use of groundwater from springs and boreholes exceeding the annual replenishment by 42Mm³. Even if we consider that since 1970 there was no increase in the extraction and use of groundwater it is estimated that more than 50% of the water which was concentrated in the aquifers during geological times was used within 30 years by one generation alone. The table indicates a considerable sea outflow which is extensively reduced with most coastal aquifers suffering from flow from the sea to them.

Table 2: *Groundwater resources of Cyprus in 1969, (UNDP & FAO, 1971).*

Areas	Water in storage (1969)*	Optimum additional storage*	Average replenish-ment*	Extraction*	Flow to sea*	Water Balance
Western	900	600	62	86	2.5	-26.5
South-eastern	600	160	25	47	0	-22
Akrotiri-Kouris	215	6	48.5	29	20.5	-1
Central	320	60	14	15	0	-1
Maroni	90	1	8	1.5	6.5	0
Ay.Irini	35	6	6.4	2.6	3.8	0
Karpasia	70	4	20	8	12.5	-0.5
Larnaca area	230	0	28	8	20	0
Kyrenia Range	160	0	11.5	12	0	-0.5
Kyrenia Coast	160	0	11.5	12	0	-0.5
Pissouri-	300	0	53	7	46	0
Paphos Coast	32	16	13	7	6.2	-0.2
Paphos River	27	0	13	2	11	0
Polis Area	35	0	25	5	20	0
Troodos area	-	0	110	55	45	10
Total	3,174	853	448.9	297.1	194	-42.2

**Numbers are given in Mm³, Accuracy +/-25%.*

The situation of the groundwater resources has become critical because of the decrease of the annual precipitation during the last 30 years, particularly during the last 10 years. In the WDD–FAO study, the effect of the decreasing precipitation on the annual groundwater balance of the island was assessed (Georgiou, 2002). The result is summarised in table 3. The study by Georgiou (2002) concluded that the aquifers are at very low levels and partially are intruded by saline water. The groundwater resources of the island are overexploited by 40% of sustainable extraction and for their sustainable management and protection it is thus highly recommended that the total annual extraction of the aquifers should not exceed the 82Mm³ of water.

Table 3: *Annual groundwater balance of Cyprus for the period 1991-2000, (Georgiou, 2002).*

Replenishment of the aquifers [Mm^3]:	**[Mm^3]**	**[Mm^3]**
Natural recharge from:		
Rainfall	205.1	
River flows	44.8	
Return from irrigation/domestic	22.1	
Groundwater inflow	8.8	
Dam losses	1.7	
Sum of Natural recharge	282.5	282.5
Artificial recharge		9.8
Sea intrusion		12.9
Replenishment (Total recharge)		**305.1**
Outflow from the aquifers:		
Extraction		129.1
Groundwater outflow		166.7
Sea outflow		24.6
Total outflow		**320.4**

1.1.1.3 Hydrogeological Data

In Cyprus there are three categories of aquifers. The first category includes clastic aquifers that are developed in thick deposits of sand and gravel along the large river and their coastal areas. The second category includes karstic aquifers in limestones and gypsum deposits and the third one includes aquifers in the fracture systems of the Troodos ophiolite and the chalks surrounding it.

The most important clastic aquifer is that of Morphou area in the western part of the Mesaoria plain. It has a storage capacity of 1660Mm^3 and in 1969 it had only 900Mm^3 of water stored in it. Its annual replenishment was about 63Mm^3 and the annual extraction in 1969 was 26Mm^3 beyond its safe yield (UNDP & FAO, 1971). At present, a considerable part of the aquifer is suffering from saline water intrusion. At the same time, the water level from near surface in the 1950s went down 120m with a considerable reduction of the yields of the boreholes throughout the area. It is estimated that only 20% of the stored water in 1969 were left in the aquifers.

The second most important clastic aquifer is that of south-eastern Mesaoria. Its storage capacity is 760Mm^3. In 1969, the stored water was 160Mm^3, its annual replenishment 25Mm^3, and the annual extraction 50Mm^3. Unfortunately, today the whole aquifer is mined and considerable parts of it are filled with saline water. Most of the irrigation water in this potato and vegetable producing area is transferred from dams located in the Troodos Mountains via the Southern Conveyor; the domestic water particularly for its tourist's areas comes from desalination.

The third most important aquifer of this category is the Akrotiri west of Limassol. The total storage capacity is 90Mm^3 and the annual replenishment before the construction of the Kouris dam was about 18Mm^3. Although the aquifer is recharged artificially from dams and recently with recycled tertiary treated sewage water with the annual extraction being relatively controlled, a considerable part of it has suffered from saline water intrusion (figure 10). Smaller clastic aquifers occur in the river deposits of the Larnaca and Paphos districts. In all these aquifers extraction exceeds the annual replenishment and all of them suffer from saline water intrusion.

The most important karstic aquifer occurs in the Kyrenia range with 150Mm^3 of stored groundwater and an annual replenishment of 10Mm^3. Its intensive exploitation which started during the late 1960s, have reduced the yields of the large springs which exist at the contact of the recrystallised limestones and the Kythrea flysch considerably. Smaller karstic aquifers are scattered in limestone and gypsum deposits in various parts of the island. These aquifers are small and of local interest and most of them are exploited beyond their safe yield.

The aquifers in the Troodos ophiolite complex are developed in zones where the rocks are tectonised and fractured at great depths. The deep fracturing was the result of the differential uplift of the ophiolite in Pliocene-Pleistocene time. The natural replenishment of the Troodos aquifers is estimated to be 100Mm^3 and a great deal of this water flows out through springs which are found in various elevations throughout the mountain range. These springs supply water to settlements around them and through the rivers to the plains and coastal areas during the long dry part of the year.

The data available indicates that most of the Troodos aquifers are exploited by numerous boreholes beyond their safe yield. From the Pitsilia mountainous area dam about 15Mm^3 are extracted every year and the water levels of most boreholes descend by 3m every year. However, the Troodos aquifer is not uniform and in some areas the extraction is sustainable. Similar types of aquifers, which are less important though, have developed in tectonic zones and fractures of chalks at the periphery of Troodos ophiolite. They have been exploited extensively during the last 20 years for the supply of domestic water to Larnaca and Ammochostos tourist area, but also for local needs for irrigation water. By now the aquifers are nearly exhausted and some of the boreholes that started as artesian show a water table of 120m below the surface.

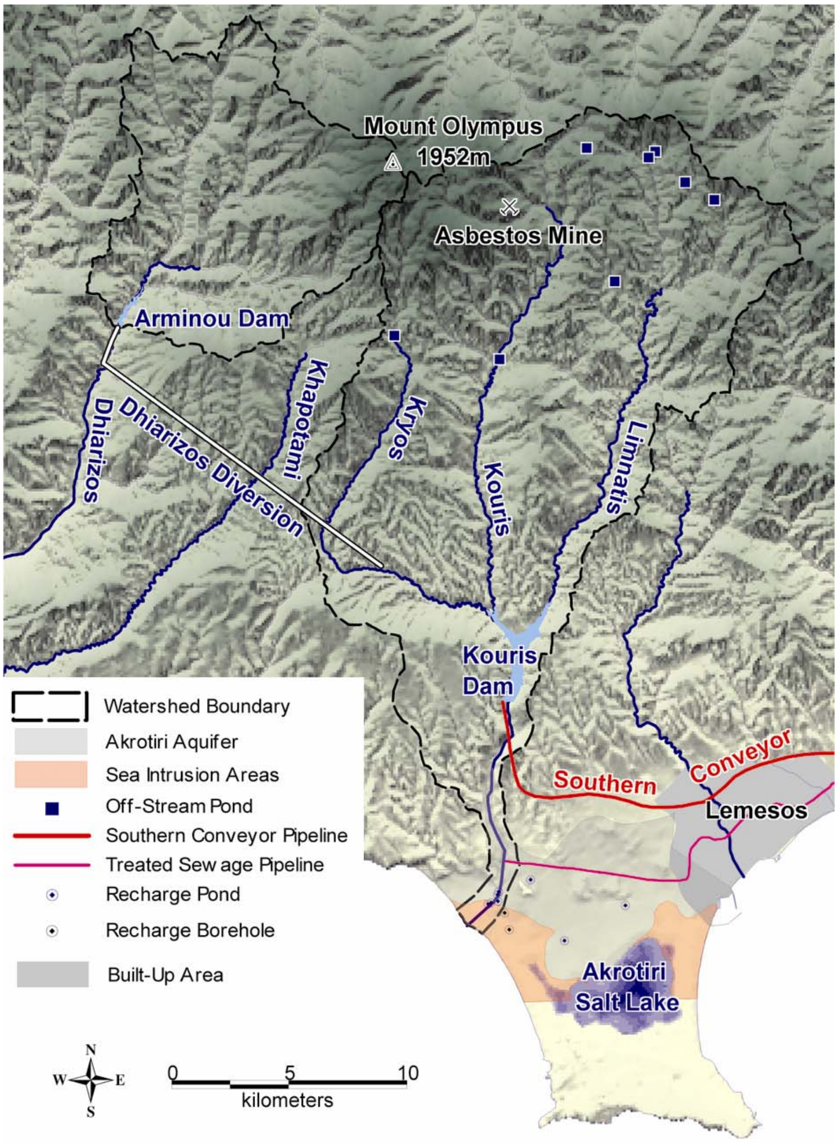

Figure 10: *Relief map of the Kouris and Arminou catchment areas.*

1.1.1.4 Non-conventional water sources

The considerable decline of the conventional water sources and the increase in water demand on the island have led to the use of non conventional water such as desalinated and recycled water, which have become additional sources to reduce the imbalance between supply and demand. Desalination of seawater was first conducted in Cyprus in April 1997 with the operation of a 20,000m^3/d plant at Dekelia, east of Larnaca (WDD, 1999). Owing to a continuing drought the plant soon expanded to 40,000m^3/d. The plant supplies domestic water to the cities of Larnaca and Nicosia and the coastal tourist areas of Ayia Napa and Paralimni. The plant operates on a Build Own Operate Transfer (BOOT) basis and the water produced is sold to the Cyprus Government at a basic price

C£ 0.54/m^3. (~€ 0.92/m^3) The recent increase of oil prices has raised the price for water from this plant to C£ 0.70/m^3.(~€ 1.20/m^3) A second plant with a capacity of 51,000m^3/d operates since April 2001 close to Larnaca Airport (WDD, 2003). The plant also operates on a BOOT basis and the price for water at this plant is C£ 0.40/m^3 (~€ 0.69/m^3). Yett again, the rise in oil prices have also increased the price of water from this plant. Future plans of the Government include the construction of two more plants in Limassol and Paralimni with a capacity of 20,000m^3/d for the first and 10,000m^3/d for the second plant. Furthermore, a proposal of the Electricity Authority of Cyprus to construct a plant with a capacity of 40,000m^3/d is being investigated. All these desalination plants are of a reverse osmosis type. It must be noted that Cyprus imports all its energy requirements and all power stations operate with oil. In addition to the costs of desalinated water we have to add the costs for construction, maintenance and operation of conveying systems and the losses in the distribution networks, which increase the costs for desalinated water considerably. However, their use is unavoidable to relieve the island's domestic water supply especially the economically important tourist sector, by providing a reliable source of good quality drinking water. Recycled water (treated waste water) is becoming an additional source of water. The first large sewage treatment plant started to operate in Limassol. In 1995 it produced 4Mm^3 of tertiary treated water used for irrigation in agriculture, the urban environment; in the future, it should be used for artificial recharge of the Akrotiri aquifer. Recycled water is a fast growing resource because new sewage treatment plants are under construction and design in all major cities and rural areas with provisions for tertiary treatment in order to use the treated effluent. It is estimated that by the year 2005 the available recycled water will have increased to 13Mm^3 and by the year 2020 to 30Mm^3.

1.1.2 Water demand

In the study of the Cyprus Geological Survey (1998) it was estimated that the total water demand in Cyprus was 300Mm^3 and its distribution to various sectors is as shown in figure 11a. In the more recent WDD-FAO study the total demand was estimated to be 266Mm^3 including 15% conveyance and distribution losses. Its distribution over various sectors is shown in figure 11b. It was shown in both studies that agriculture is by far the greatest user of water in Cyprus. The water demand by sector and the anticipated sources of supply for the year 2000 is shown in table 4. The projected annual water demand per sector for the years 2000, 2005, 2010 and 2020 is shown in table 5; its estimation was based on the assumption that the use of water by the agricultural sector will remain at the level of the year 2000 for all the years.

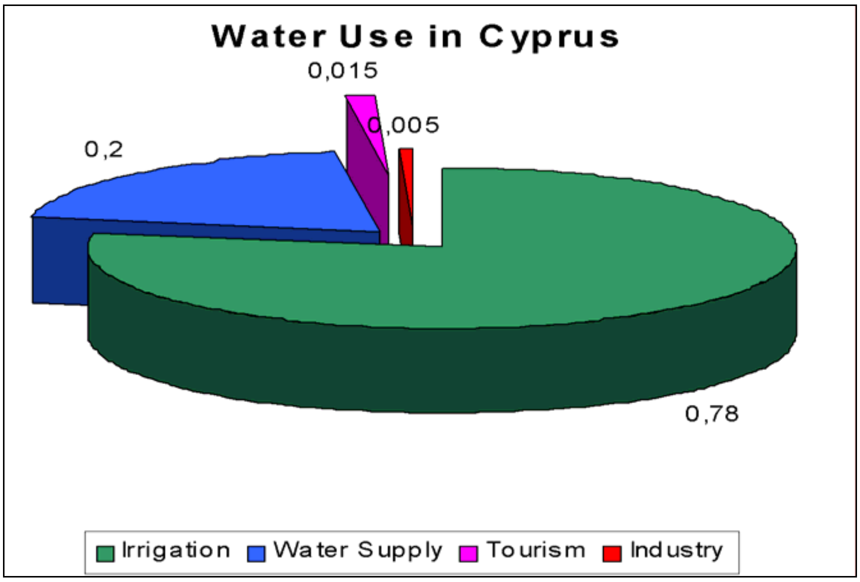

Figure 11a: *Water use in Cyprus, (Geological Survey Dept., 1998).*

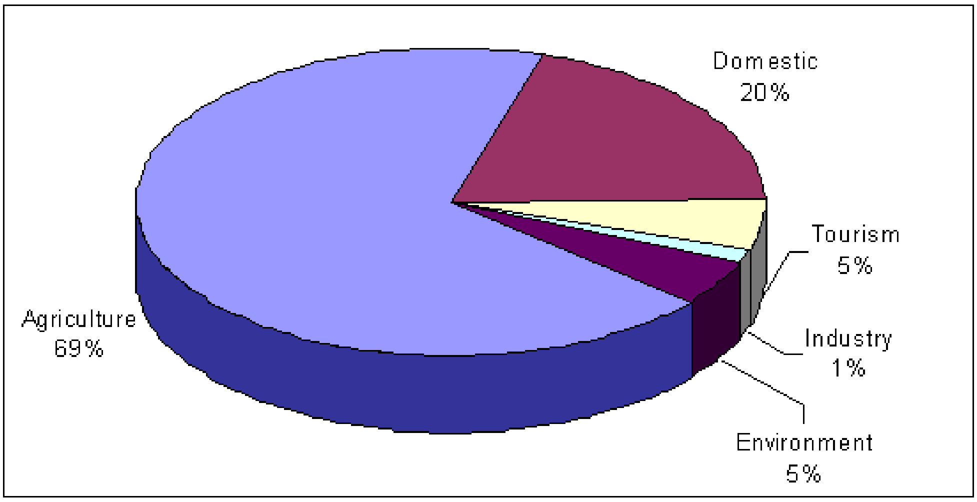

Figure 11b: *Distribution of water demand for various sectors for the year 2000, (Savvides et al., 2001).*

Table 4: *Annual water demand by sector for the year 2000, (Savvides et al., 2001).*

Sectors	Annual water demand [Mm^3]	% of domestic	% of total
Agriculture	182.4		69
Total Domestic *Inhabitants* *Tourism*	67.5 *53.4* *14.1*	100 *79* *21*	25 *20* *5*
Industry	3.5		1
Environment	12.5		5
Total water demand	**265.9**	**100%**	

Table 5: *Projected water demand per year for the main sectors (2000-2020), (Savvides et al., 2001).*

	2000	2005	2010	2020
Agriculture	182.4	182.4	182.4	182.4
Total Domestic *Inhabitants* *Tourism*	67.5 *53.4* *14.1*	76.4 *58.4* *18.0*	86.1 *63.2* *22.9*	104.3 *73.5* *30.8*
Industry	3.5	5.0	6.0	7.0
Environment	12.5	14.0	16.0	20.0
Total (Mm^3)	**265.9**	**277.8**	**290.5**	**313.7**

The total demand for agricultural water for the year 2000 was estimated to 182.4Mm^3 by Savvides et al. (2001), based on the irrigated area of each crop category on community level and the water demand of each irrigated crop. The water demand was determined for each community area and each crop based on climatic data from 41 meteorological stations distributed over the island. The sector of animal husbandry uses 8Mm^3 out of the 182.4Mm^3, and the rest is used for the irrigation of permanent and annual crops. Permanent crops, particularly citrus, were the biggest water consumers which becomes more obvious in drought periods with the preferential allocation of water for irrigation to ensure their survival.

Water demand for agriculture, particularly for citrus is high and after 1970 the profit of selling them has been negligible, in the last years the sales haven't even made up for the actual water costs from the Government Irrigation Projects (GIP). In 2000 the irrigation of citrus required 32% of the total irrigation water, i.e. about 51.9Mm^3. The contribution of this crop to the exports of the island was C£ 12.8 million (~€ 22.3 million) which is 37.2% of the exports of the total raw agricultural products and 5% of the total domestic exports (Statistical Service, 2002). The Government paid about C£ 20 million (~€ 35million) for the two desalination plants for replacing about 63% of the amount of water used for the citrus' production. It is commonly thought that citrus is the main cause of the imbalance of water supply and demand in Cyprus, it shows a very low value-in-use of water and negative to very low net benefits and thus calls for a closer scrutiny for the island's future agricultural water policy.

Yet the requirements of water for some annual crops grown in green houses are rather low. The modification of the irrigated crop pattern in favour of annual crops with less water requirements or annual winter grown crops which require considerably less irrigation water could assist the island to secure a balance between supply and demand which will be sustainable over time and at the lowest possible cost. This is an important strategy option for the elimination of the imbalance of supply and demand on the island. This need will become more obvious after a detailed analysis of costs for water, labour, finance etc. on the one hand and benefits per square kilometre of the various irrigated crops on the other hand. In 2000, vegetables consumed 26% of the irrigation water (i.e. 41.3Mm^3) and contributed C£ 3.5 million (~€ 6.1 million) to the exports of the island (Statistical Service, 2002).

In the context of increasing water scarcity and increasing water demand and the phasing out of subsidies for agriculture due to the harmonisation with the European Union Policies, a mix of policies would foster agronomical research and extension services covering a large diversity of suitable crops. Furthermore, small-scale farming and its irrigated agriculture need support to achieve collective marketing arrangements which can improve planning for high added value production for exports and for the increasing tourist sector, reduce the risks to the farmers which in turn will reduce urbanisation and enhance the role of rural inhabitants to protect their natural and environmental resources.

The total demand for domestic water for the year 2000 was estimated at about 67.5Mm^3 (Savvides *et al.*, 2001). The demand was calculated on the following per capita figures: For the main towns the demand is 215 l/per capita per day whereas for the villages and tourists it is 180 and 465 l/capita and day respectively. The figures for domestic demand are based on water supply figures from all major Water Boards (i.e., all major towns) and a survey of the water supply of 98 villages; the figures for tourism demand are based on a survey of the water use of 65 tourist establishments of various categories for 1996–1998. The results of the calculations are shown in table 6, whereas table 7 shows the actual daily water consumption for the year 2000. The town of Paphos has the highest per capita consumption followed by Limassol which is partly attributed to the higher losses in their distribution networks which in the town of Paphos are higher than 30%.

Cyprus has succeeded in applying conservation measures for domestic water such as subsidies for the use of inferior quality groundwater for irrigation of house gardens and for the flushing of toilets and also by means of a subsidisation plan for the purchase and installation of water saving equipment such as special toilets as well as apparatus for treating and recycling grey water in houses, military camps and football stadiums. Furthermore, every year the Government allocates a substantial budget to campaigns for raising public water awareness towards conservation and in order to achieve a caring public attitude towards precious and scarce water (WDD, 2002).

Table 6: *Domestic water demand for residents and tourists for the year 2000, (Savvides et al., 2001).*

Location	**Water demand [Mm³]**			**% of total**
	Resident	**Tourist**	**Total**	
Nicosia & Suburbs	16.6	0.7	17.3	26
Limassol & Suburbs	12.8	3.6	16.4	24
Larnaca & Suburbs	5.8	2.0	7.8	12
Paphos & Suburbs	3.0	3.5	6.5	10
Ammochostos	1.2	3.5	4.7	7
All villages	11.3	0.8	12.1	18
British Bases	1.8	-	1.8	3
Turkish Sector/Nicosia*	1.0	-	1.0	1
Total	**53.4**	**14.1**	**67.5**	**100**

**Note: The Water Board of Nicosia provides about 1Mm^3 of water annually to the Turkish sector of Nicosia (2001).*

Table 7: *Actual per capita daily water consumption during the year 2000, (Savvides et al., 2001).*

Town	**l/capita/d including losses**
Nicosia	150
Limassol	215
Larnaca	162
Paphos*	222
Villages	144

**Note: Paphos has the highest losses in the distribution network, which are over 30%.*

1.2 Environmental protection

Water quality problems faced in Cyprus are due to salt concentration and pollution from agrochemicals, as well as to domestic sewages, animal husbandry and industrial effluents. High salt concentrations are becoming increasingly important in the coastal aquifers due to over pumping and saline water intrusion into the aquifers. Concentration of salts in the soils of the irrigated areas on account of high evaporation and subsequent leaching into the aquifers contribute substantially to their pollution. In the inland, the continuous depletion of aquifers beyond replenishment results in the increase of salt concentration coming from the enclosing sedimentary rocks. The latter is also responsible for the considerable increase of boron in some aquifers (figure 12).

Recent studies indicate that reservoir water is becoming increasingly polluted with chlorinated pesticides and herbicides due to intensive fruit and vine agriculture in the mountainous areas and the watersheds of the rivers flowing into the dams. Recent studies also indicated an alarming increase of nitrate pollution in some aquifers due to over fertilisation of the irrigated areas as well as domestic and animal husbandry effluents (figure 13). In the potato producing areas the concentration of nitrogen in the soils is high resulting in concentrations of this element in the potatoes above the permissible levels thus making their export to the European Union problematic. Efforts by the Agricultural Research Institute through large scale field studies that proved that these soils contain enough nitrogen and need no fertilisers for a satisfactory production did not convince the potato growers. Statistical data indicate that in the year 2000 the costs of purchasing water from the Government Irrigation Projects was C£ 1.64 million (~€ 2.9 million), whereas the cost of chemical fertilisers most of which contain various forms of nitrogen were C£ 8.156 million (~€ 14.2 million) and the costs for animal manure, which is an appreciable source of nitrate pollution too, were C£ 1.6 million (~€ 2.8 million).

At present two detailed and island-wide studies are being undertaken by the Cyprus Geological Survey for the reassessment of the concentrations of boron and nitrates in the groundwater of the island in their final stages. The boron study is financed by the European Union, whereas the nitrate study is financed by the Cyprus Government. For the elimination of anthropogenic sources of boron pollution, the Government prohibited the import or manufacture and use of detergents containing boron setting up strict standards for the boron content in desalinated water (< 0.5ppm) to comply with the new standards of the European Union. The Government has established protection zones for boreholes and springs supplying domestic water.

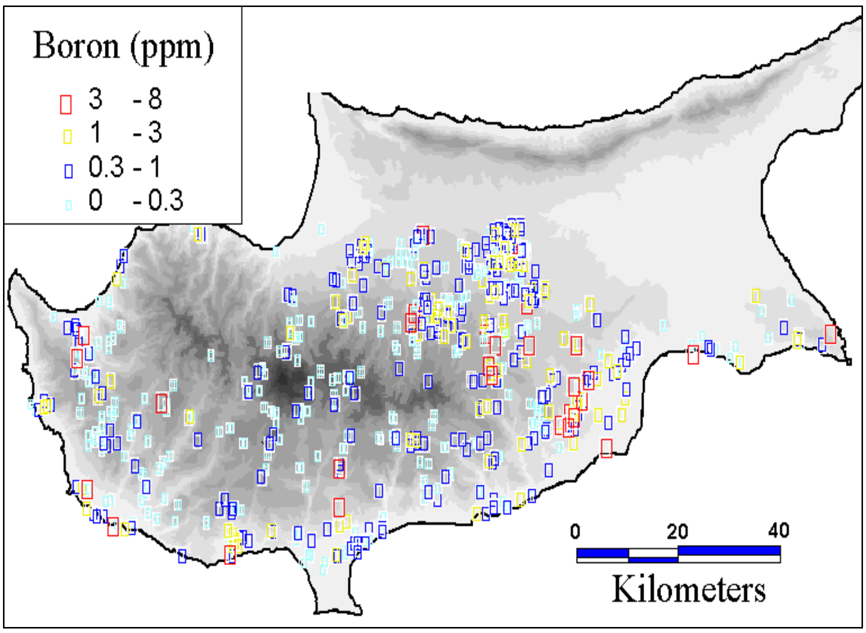

Figure 12: *Boron in Cyprus groundwater.*

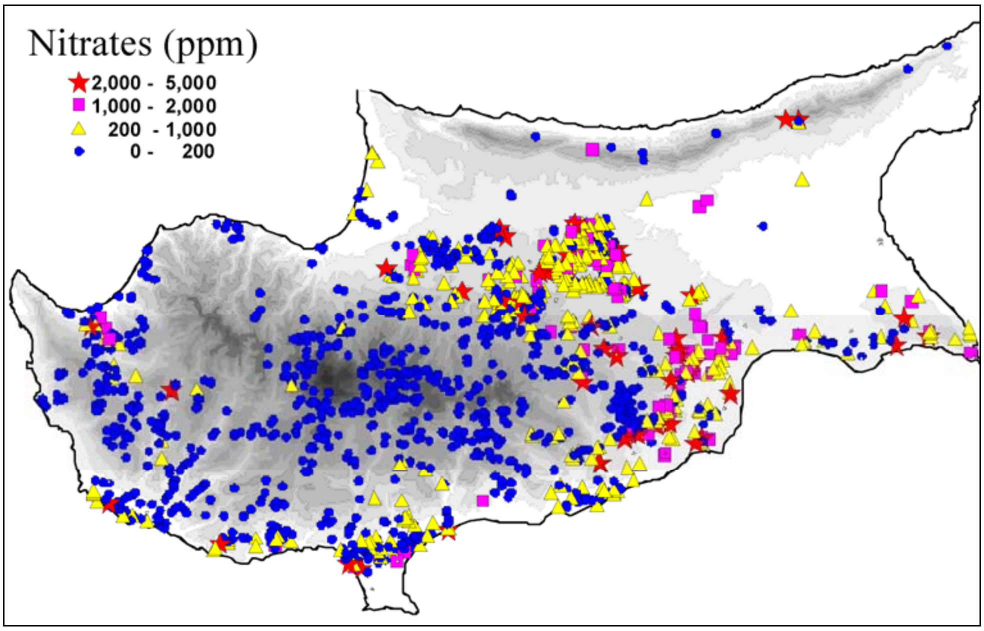

Figure 13: *Nitrate concentration in Cyprus groundwater.*

Recently, a treatment plant for industrial effluents was constructed and is now operating. The tertiary treated water is used for irrigation and the sludge containing heavy metals is disposed of in specially selected and constructed sites. Special care is taken for the selection of sites for the disposal of the rural domestic solid sewage, especially in the sensitive mountainous areas, to avoid pollution of the ground- and surface water.

For the urban and tourist areas central sewage treatment plants are in operation or are presently being designed and constructed. All the houses in the main cities and tourist areas will be connected to central sewage systems. The effluents will be invariably tertiary treated and the water should comply with the set of standards for irrigation and artificial recharge of aquifers. The treatment plants are geographically well distributed so that transportation costs of the treated effluent to agricultural areas are kept to a minimum. For this reason it is anticipated that as much as 60% of the recycled water will be used for amenity and environmental purposes, such as irrigation of hotel gardens, parks, road islands, football fields and golf courses.

Recently, the Cyprus Government decided to transfer at high costs recycled water generated by the Central Sewage Treatment Plant east of Limassol to the Akrotiri area west of Limassol. This recycled water will be used for artificial recharge of the Akrotiri aquifer through the use of specially constructed recharge ponds with the water being reclaimed through boreholes for irrigation purposes. 10.6Mm^3 are expected to be generated every year contributing considerably to the water sources of the area. The BODs and suspended solids content of the recycled water will be less than 10mg/l whereas the ammonia and total nitrogen content will be less than 2mg/l and 10mg/l respectively. An environmental impact assessment (EIA) study was carried out and it indicated that the quantity pumped can be equal to that of recharged recycled water without any noticeably negative effects to the local environment, and that the potable water boreholes located east of the recharge ponds will not be adversely affected from the recharge operations. Despite the EIA results and large efforts by the Dept. of Agriculture to convince local farmers, however, there is strong resistance by the local communities who reject the aquifer being recharged with treated sewage because they fear the pollution of their irrigation water source; so far, the aquifer is recharged with surface water from reservoirs.

Sewage treatment plants in 38 rural areas for the protection of sensitive areas of aquifers are also being studied and after their completion all houses will be connected with central sewage systems (WDD, 2003). The effluent will be tertiary treated water and will be used for irrigation. The charge for effluent collection and treatment for the households is based on the domestic water used (about 75% of the charge) and on the value of the property (about 25%). The latter is estimated by the Department of Lands and Surveys. For the capital investment of the sewage system, the property owner pays in annual instalments over a certain period, starting from the planning and design stage of the individual sewage system. The length of the period varies from community to community, but is in general about 20-25 years long. After the capital investment is paid off, the consumer is charged the operation and maintenance costs (Stylianou, 2005, personal communcation). Recycled water is expected to be an appreciable source of water for Cyprus and will contribute to the protection of the quality of its groundwater.

1.3 Water laws and regulations

The legal framework in Cyprus was enacted during the colonial era and still remains in force by virtue of the provisions of Article 188 of the Constitution. Additions and modifications have been suggested to the legislation since then to take account of changes, new developments and trends which, however, have been rather limited.

Water policy is formulated by the Water Development Department as the competent authority within the Ministry of Agriculture, Natural Resources and Environment, but other Ministries are also involved and the final responsibility lies with the Council of Ministers.

1.3.1 Formal legal regulations

1.3.1.1 Existing legislation

The existing legislation is rather complex and covered by numerous laws, some of which have been in existence since colonial administration. The legal power relating to water issues lies mainly with the District Officers, while at executive level these issues are largely in the hands of the Water Development Department. The latter also plays an important advisory role for the District Officers in water-related issues. The following is largely based on the extensive study by Marcoullis and Vassiliadou (2002).

All surface, ground- and wastewater is vested to the Government according to the *Government Waterworks Law (Cap 341 as amended)* and the written permission of the District Officer is required before any such water may be taken or used. This law also entitles the Government to construct works related to water supply, water resources management, flood protection etc.

The above definition of all water being property of the Government is subject to certain qualifications related to old existing water rights, which are determined, valuated and registered according to the *Immoveable Property Laws (Cap 223, 224)* by the Land Surveys Department.

For surface water, private individuals, who are often organised in Irrigation Associations, hold old *ab antiquo* water rights in the form of ownership of a certain amount of water for a specific period of time and taken from a specific spot. These rights may be acquired by gift, sale or inheritance. They have been widely discussed and it has always seemed unfair that certain persons, by accident of geography, happen to own land that includes an abundant source of water to which they are solely entitled. To extinguish such rights entirely is also unfair and considered to contravene the Constitution of Cyprus.

In case Government water works affect a water right, the owner of the right has to be compensated. Water rights can become an obstacle to efficient water management when water flows in excess of the water right's owner's needs are wasted, but could be compensated for with a moderate sum or, more likely, with the provision of alternative supply from a new irrigation scheme.

However, as stated by Marcoullis and Vassiliadou (2002), the problem of *ab antiquo* water rights is not too serious and was overestimated in the past. Many Irrigation Associations do not exploit their water rights any more because the yield of water has diminished drastically or the source, e.g. a chain of wells or riverbed scheme, is now dry as a result of falling water tables and the reluctance of the Government to make contributions in financing the rehabilitation and maintenance of the works.

In ideal cases, the Irrigation Associations are reformed into Divisions and provided with a new supply, wherever possible. The compensation for taking over a seasonal source and replacing it with a year-round source is naturally low and the cost of buying out most ancient rights is rather small. The difficulty is to determine whether they exist and how much water they used to yield.

On the few rivers of Cyprus that flow all the year long the ancient right situation is complicated and difficult. It has to be tackled, however, because the right to free water for irrigation does not encourage its economic use and much water that could be used for irrigating new areas is lost by inefficient irrigation procedures by the proprietors of the water (Marcoullis and Vassiliadou, 2002). In the Kouris catchment such a situation exists in the region of Trimiklini, where according to an officer of the Department of Agriculture (Rodosthenous, 2004, personal communication), twice the current area could be irrigated, or half the water saved, if the owners of the water rights were cooperative and willing to implement modern irrigation techniques.

Groundwater is also vested to the Government and in order to make use of underground water, permits have to be obtained from the District Officer. The exceptions to that rule are wells that were lawfully sunk before 19 May 1928, the day of enforcement of the law. The scope of these old rights, however, is believed to be small (Marcoullis and Vassiliadou, 2002) because many old wells were shallow and ceased to yield water when the water table became lower. Yet, these old rights have to be considered today when a permit for a new well or borehole is issued because of regulations in the Wells Law (see below, cap 351).

Sewage water, i.e. all liquid waste disposed off at governmental treatment plants as well as water coming from governmental desalination plants or governmental water processing plants, also vest in the Government.

Concluding, surface, ground- and wastewater is property of the Government except in cases where one of the above-mentioned old *ab antiquo* rights exists.

Before a well or borehole is sunk or constructed, a permit from the District Officer is needed according to the *Wells Law (Cap 351 as amended)*. When the well is sunk and water is found, an abstraction license is needed from the District Officer. In this license, conditions and restrictions regarding the abstraction quota or the use of the water from the well may be set.

The Wells Law also entitles owners to protect existing wells because their requirements are considered before a new well or borehole permit is issued in the same area. Even if a new well permit is issued, the owner of an existing well will be given the right of action against the owner of the new well, if the amount of water in the existing well is, or is likely to be, substantially diminished; for this right of action to go in force, some conditions regarding the distance between the two wells have to be met. Depending on the specific case, the court may order the new well to be filled in or the owner of the existing well may be compensated.

The *Water Supply (Special Measures) Law 1964* authorises the Council of Ministers to declare an area to be a “controlled area” if a serious shortage or deficiency of water exists or is likely to exist in a certain area and if special measures are necessary for the conservation of water resources and the maintenance of water supplies in the area. The important effect of this law is in relation with well permits according to which the District Officer must obtain the agreement of the Director of the WDD to issue the permit. During the 1990s droughts the policy of the Government was not to grant new well permits in the “controlled areas” at all. To some extent the farmers, however, sunk illegal boreholes, which are pumped without any control at all.

In the area of study of the MEDIS project the Akrotiri aquifer and the Garyllis (Limassol Town) aquifer fall under the Water Supply (Special Measures) Law.

From the above it is clear that according to the Law, no borehole may be sunk without a permit, and in most cases the WDD as technical authority is consulted by the District Officer to specify conditions for the use of water from each new well. However, the District Officer as the responsible authority neither has a mechanism to control and monitor the operation of the boreholes nor to check the conditions specified in the permit, e.g. extraction quotas, are adhered to.

The *Water (Development & Distribution) Law (Cap 348)* is interesting because it was passed in 1955 to facilitate the development of water resources by catchment areas, an idea that is nowadays an important principle of EU water regulation. The law enables the President to appoint a Committee that takes over all water rights and works in one area.

The *Irrigation Divisions (Villages) Law (Cap 342 as amended)* and the *Irrigation Association Law (Cap 115)* regulate the establishment and operation of Irrigation Divisions and Irrigation Associations. For both types of organisation, the District Officer is in charge from a legal point of view while the WDD provides technical support in design and construction of the works. The Irrigation Divisions Law empowers the divisions to set their own rates and charges for irrigation water.

The establishment of Water Boards is regulated by the *Water Supply (Municipal & Other Areas) Law (Cap 350)*. Apart from specifying the powers of the Boards the law also says that all supplies have to be metered. It authorises the Boards to impose their own rates and charges for the supply of water, which however need the approval of the Council of Ministers and the Parliament.

The water supply of communities by Community Boards is regulated under the *Communities Law (L.86(I)/99)*. This law requires Community Boards to provide suitable and sufficient domestic water supplies, maintain the drainage systems and build, operate and protect the irrigation system of the community, if there is one. It also requires the construction, operation and protection of a community sewage system, according to regulations in the Sewage and Drainage Law 1970.

The *Mines and Quarries Law (Cap 270)* provides that a mining licence does not give the operator of the mine the right to divert any water without a special permit. The law considers the pollution of any water an offence and demands that water used for mining operations must not leave the mining area if it contains substances detrimental to human, animal or vegetable life.

The *Public Rivers Protection Law (Cap 82)* deals with rivers declared "public rivers" and calls for instance the breaking down or damaging of the banks of a river. The law also allows the District Officer to prohibit certain acts e.g. removal of bed material or the dumping of rubbish or refuse in a river. Similarly, the District Officer may prohibit by means of the *Foreshore Protection Law (Cap 59)* the dumping of rubbish etc. on the foreshore, which is any land within a distance of 50 yards from the high water mark.

The *Sewage and Drainage Law 1970* empowers the Council of Ministers to determine, if certain conditions are fulfilled, areas for the purpose of this law with regard to the establishment, operation and maintenance of a proper sewage system, the treatment or disposal of sewage and the establishment of a Sewage Board to operate the sewage works. The Board is also responsible for the collection, conveyance, treatment and disposal of storm and surface waters through drainage systems. The law specifies the powers of the Board and regulates which rates and charges the Board may collect. According to this law, a property owner is obliged to meet the costs of all pipework from the property to the public sewer.

The *Control of Pollution of Waters Law (L.69/91)* seeks to prevent and convict the pollution of all waters of Cyprus except waters in private sewage or drainage or process of city sewage units as well as waters in private tanks etc. The law prohibits acts like:

- The deposition of anything that may pollute the water in any stream, beach water, lake or dam,
- The deposition of any sewage to the ground or underground in areas specified by the Minister of Agriculture, Natural Resources and Environment *and*
- Any action without permit in any area specified for the protection of sources or possible sources of water for domestic use by the Council of Ministers.

A polluter may be ordered by Court to clean up the pollution caused by him and if he refuses, the Minister of Agriculture may undertake the cleaning operation and charge the polluter with the costs.

The law provides that for any industrial unit to obtain a building permit, the obtaining of a waste disposal license is necessary, i.e. dropping any liquid or solid sewage from any industrial unit without such license would be an offence.

The *Quality of Water for Human Consumption (Inspection and Control) Law (L.87(I)/01)* harmonises Cyprus legislation with the EU Drinking Water Directives (Directives 80/778/EC, 98/83/EC). This law applies to the supply of water for human consumption and production of food, to the supply through its sale or distribution in tanks or bottles, but it does not apply to natural mineral water or water not intended for human consumption for which other legislation applies.

The law prohibits the provision of water for human consumption, which is not healthy and clean. With the permission of the Minister of Health given with or without conditions provision of such water is permitted in cases of force majeure, unusual meteorological conditions and where the water is to be used exclusively for the production of food and is not dangerous to health. A strict monitoring programme for water supply is in place to ensure the proper implementation of the act.

According to the *Evaluation of the Consequences to the Environment from Specific Projects Law (L.57(I)/01)*, the authority that examines an application for a public project, including projects that involve water e.g. commercial ports, sewage plants, dams, tanks etc., has to take into account the opinion of the environmental authority and must obtain a report from the Committee for the Evaluation of the Consequences to the Environment which has been established for the specific purposes of this Law. This law transposes the provisions of the EU Directives and Decisions on the lists of waste and hazardous waste.

The *Water Pollution Control Law (L.106(I)/02)* abolishes the Control of Pollution of Waters Law (L.69/91) while incorporating most of its provisions. It harmonizes Cyprus legislation with 16 EU Directives, e.g. the Directive on Integrated Pollution Prevention Control (IPPC, Directive 96/61/EC). Some Directives are incorporated in the basic law, while others come into force in the form of Orders by the Minister of Agriculture, Natural Resources and Environment. For example, in January 2001, an Order was issued harmonising the Directive of 1976 regarding the discharge of dangerous substances into the water (Directive 76/464/EC) and its six "daughter" directives. Two sets of Regulations, on the limitation of water pollution from asbestos and the management of sewage sludge, were approved in May 2002. In January 2004 the Minister by Order enforced an action plan for the protection of waters in areas sensitive to nitrate pollution, implementing the Nitrates Directive (Directive 91/676/EC).

A main part of the Water Pollution Control Law concerns the issuing of permits for the disposal of waste from all kinds of industries: conditions may be included in the permits, they may be issued for a certain period only and need to be renewed and they may also be withdrawn. A list with all granted permits has to be published every three years and a register has to be kept that must be made available to the public via a website.

According to the law, a Technical Committee for the Protection of the Environment is established; its members are representatives of several Ministries and other involved bodies like the Federation of Cyprus Environmental Organisations. The committee is responsible for the examination of certain Ministerial Orders before their publication, examination of applications for waste disposal permits or issues related to the withdrawal or amendment of permits; the committee then gives suggestions regarding the issues to the Minister.

The *Water Protection and Management Law (L.13(I)/04)* harmonises Cyprus legislation with the Directive 00/60/EC, i.e. is the EU Water Framework Directive (WFD). The authority responsible for the implementation of the law is the Ministry of Agriculture, Natural Resources and Environment. Apart from the many ecological and technical requirements, the WFD includes the obligation for the recovery of full costs for water services, the "polluter pays" principle and the explicit requirement of the active involvement of all stakeholders in the implementation of the Directive.

Several other laws, some rather obsolete but still in force, may involve water management issues under certain conditions. The *Factories Law (Cap 134)*, e.g., may require special measures for water supply and wastewater disposal in case of certain industries. The *Streets and Buildings Regulations Law (Cap 96)* deals with sub-divisions of properties for building purposes and the WDD is consulted by the District Officer on water supply issues but not on drainage. Issues dealt with under the *Soil Conservation Law (Cap 94)* might be related to irrigation projects or interfere with water resource. The *Fisheries Law (Inland) (Cap 135)* concerns fishing in rivers and reservoirs. The *Citrus Law (Cap 131)* and the *Land Consolidation Law (24/1969)* require the Director of the WDD to be member of committees set up under these laws.

Legal power is currently divided between several ministries: The Ministry for Agriculture, Natural Resources and Environment, the Ministry of the Interior, the Ministry of Health etc. Within the Ministry for Agriculture, Natural Resources and Environment, different Departments are responsible for specific water-related issues.

As a result of this situation the WDD and the District Officers, to name just two, execute overlapping jurisdictions, leading to decisions taken by one authority without seeking concurrence from the other authority, which is also responsible. Hence conflicting resolutions arise that do not always contribute to the efficient and integrated management of water.

The efforts of the Government to concentrate the responsibilities for water issues in the Ministry for Agriculture, Natural Resource and Environment are visible in the laws passed during the last few years, while most of the old laws still in force furnish legal power to the District Officers.

As regards the harmonisation with EU legislation there are some concerns that the EU Directives are just translated into Greek and become Cyprus law without a real harmonisation, i.e. a real adjustment to the already existing legal framework and local conditions would not take place. If so, there might again be problems regarding their implementation and enforcement due to overlapping jurisdictions etc. The extent of this problem will be revealed during the next few years.

1.3.1.2 Anticipated future changes to legislation

The *Unified Water Entity Bill* (or Water Entity Law) might solve many of the current problems once it will be passed by Parliament. The main aims of the proposed bill are:

- to establish a new Entity responsible for water *and*
- to abolish the Public Rivers (Protection) Law, the Government Water Works Law, the Water (Development and Distribution) Law, the Wells Law and the

Water Supply (Special Measures) Law, and embody them in a new, unified water code.

Initially, one of the mains aim of the Unified Water Entity Bill was to harmonise Cyprus legislation with the Water Framework Directive. However, due to the delays in passing the bill, the Government was forced to pass the Water Framework Directive as a separate law in order to meet EU deadlines which leaves unclear its content and when the Unified Water Entity Bill will finally be passed by Parliament. It is, however, anticipated that some of the main features will be:

1. the WDD becomes the Unified Water Entity with wide ranging rights and obligations,
2. most of the current water-related legal power vested in several Government authorities, and in particular in the District Officers, will be transferred to the Unified Water Entity,
3. water remains the property of the Government with the exception of existing water rights; permits to use, receive or develop water are issued by the Director of the Unified Water Entity,
4. water withdrawals from surface and groundwater systems will be controlled through a single permit *and*
5. charges and levies of supply for water will be unified and will be sufficient for cost recovery.

Concluding one shall hope that the Unified Water Entity Bill will provide the Unified Water Entity, i.e. the present WDD, with the legal power for the issuing what it is already involved in on the advisory or executive level. This will hopefully put an end to many of the current complicated procedures and also prevent several authorities from acting on overlapping issues leading to inefficient management of the island's water resource.

1.3.2 Pricing policy

Water pricing is an integral part of the Government policy on water. Water for municipal including industrial, commercial and tourist purposes is sold at full cost, while irrigation water is highly subsidised. There is a variety of water charges and no uniform policy of water rates. Water pricing in Cyprus follows an increasing block structure. This pricing system relates to the perception that sliding prices can be used as a tool to ensure social justice and conservation of a scarce natural resource.

The area of Cyprus under Government control is divided into 37 water authorities each having its own tariff structure and differences in the application of the block increasing tariff structure. This leads to a substantial water price heterogeneity ranging from an average price of 20 cents/m^3 (the greater urban area east of Limassol) to 74 cents/m^3 (Nicosia Town and its suburbs). Even more striking are differences in the price paid for the last cubic meter of water purchased from their local water authority area ranging from 33 cents in Greater Urban Area south-east of Paphos going up to over 105 cents in Nicosia Town and its suburbs. The domestic water tariff is C£ 0.335/m^3 (~€ 0.58/m^3) and thus much lower than the actual cost of desalinated water with C£ 0.70/m^3 (~€ 1.21/m^3) including distribution costs. Under the present water tariff system of Cyprus, domestic water consumption is heavily subsidised (Limassol and its suburbs in particular) despite some big water users.

In contrast, bigger consumers in other areas (especially in Nicosia and its suburbs) are heavily burdened by the current pricing system. The annual average cost for domestic water is about C£ 60 (~€ 104) per household. The European Union Water Framework Directive recommends that by 2010 the price for water should reflect the costs of providing it including capital cost operation and maintenance as well as environmental and scarcity costs. It is worth noting that with the integration of desalinated water in the domestic water resources, many inhabitants prefer bottled water which costs C£ 200/m^3 (~€ 348) or purchase water from automatic drinking water selling machines at C£ 25/m^3 (~€ 43.5), although the water is of good drinking quality

The price policy of Cyprus can be given in detail as follows:

1.3.2.1 Prices of water for domestic bulk supply

Domestic bulk supply is the water sold by the WDD in bulk quantities to Town Water Boards, Municipal Boards and Community Boards. To date, there are 138 such bodies that purchase water from the WDD in that manner.

Water prices are proposed by the WDD and set and approved by the Council of Ministers. Involved in the formation of the price proposal is e.g. the Ministry of Economics, which demands price adjustments analogous with the general increase of the cost of living. Revisions of the water tariffs are calculated by the WDD and approved by the Council of Ministers.

The price for domestic bulk supply has been 57.9€-cents/m^3 since 1993 and was increased to 77.85€-cents/m^3 on January 1st, 2004. This does not reflect the full cost of water, which increased significantly after costly desalination was introduced in 1997, and is currently estimated at 93.4€-cents/m^3.

One reason for not immediately raising the tariff to the full cost is that this would further increase the difference between the water prices the Water Boards are allowed to charge the consumer and the price at which they purchase the water from the WDD. Adjustments of water prices charged by Water Boards have to be approved by the

Parliament which has caused delays of up to five years in the past and has lead to huge debts of the Water Boards towards the Government.

It was announced recently that domestic water price would rise by as much as 100% in the near future due to EU harmonisation, i.e. the requirement of full cost recovery for all water services. The WDD expects opposition once these price rises have to be implemented and therefore tries to convince the political parties of the necessity of those adjustments.

1.3.2.2 Price for water in agriculture

Price for irrigation water or changes to them are proposed by the WDD. They are then discussed within the Ministry of Agriculture, Natural Resources and Environment by an Advisory Committee chaired by the Minister. Based on the suggestions of the Committee the Minister suggests changes to the WDD proposal and agrees on the final proposal with the WDD; the Council of Ministers is finally responsible for its approval.

The cost for irrigation water has been between 9.5 and 12.11€-cents/m^3, depending on the region, since 1992 (Akrotiri area: 9.5€-cents/m^3). Water for animal husbandry did cost 22.5€-cents/m^3 while treated sewage effluent (tertiary treatment) was sold between 9.5 and 12.00€-cents/m^3.

Since January 1st 2004 new prices have been in force. The irrigation water price is between 12.11 and 13.84€-cents/m^3, water for animal husbandry is 15.6€-cents/m^3; recycled water is sold between 5.2 and 6.9€-cents/m^3.

The prices for irrigation water were assessed by a recent study and it was concluded that the full cost was around 19€-cents/m^3. The Government policy is to gradually increase the water price to that level until 2007, simultaneously achieving a uniform price for all regions including those dominated by animal husbandry. This will put an end to the present situation of high subsidies leading to inefficient cropping patterns and wastage of water.

A farmer with plantations within a Government Water Scheme has to apply for irrigation water on an annual basis. He has to declare the crops and related planted areas he plans to plant, according to which the WDD allocates the appropriate water quantity to him, based on the water balance of the specific year. For the allocated water the farmer pays the subsidised price of currently 9.5-12.11€-cents/m^3; if he exceeds the allocated quota and consumes more, he has to pay the full price of 33€-cents/m^3 for the excess water.

There are continuous claims for abolishing this regulation regarding over-consumption, but the Government believes that it has to remain in force as an incentive to water efficiency and to prevent farmers from planting a larger area than they originally declared.

Water from private boreholes is not charged, and it is pointed out that the District Officers, who are the legal authority, do not control whether the conditions specified in the permit for each new borehole, e.g. extraction quotas, are adhered to or not. This situation has led to an uncontrolled exploitation of the aquifers and the current deteriorated condition of the majority of Cyprus' aquifers.

1.3.2.3 Price of water charged to the domestic consumer

The domestic supply by Town Water Boards is charged at theoretically full cost and at progressive rates, as can be seen for Limassol Water Board in table 8. The tourism industry pays the residential domestic water price.

The cost charged represents only the theoretically full cost because for price adjustments, for instance due to the introduction of expensive desalinated water the Water Boards need approval by Parliament. The Parliament was in the past reluctant to approve such adjustments thus preventing the Water Boards from charging their full costs.

Table 8: *Water rates of Limassol Water Board for residential customers, (Limassol Water Board website).*

Consumption [m^3/4 months]	Rate [€-cents/m^3]
1- 40	17.3 (10 £-cents)
41-80	31.14 (18 £-cents
81-120	60.55 (35 £-cents)
121-and over	346 (200 £-cents)
Fixed Amount	10.38 (£ 6)

It is worth mentioning that the domestic water rate is considerably higher, e.g. in Nicosia where for residential costumers, the first 20m^3 consumed in 4 months cost 60.55€-cents/m^3 and the consumption rate between e.g. 40 and 60m^3 is 86.5€-cents/m^3 (Nicosia Water Board website). This difference between Nicosia and Limassol is probably due to the fact that the Limassol Water Board covers more than half of its supply from its own boreholes, while Nicosia Water Board gets all supplies from the WDD at the bulk domestic rate. The water prices for the municipal water supply are set by the Municipality alone without approval of any other authority.

1.3.2.4 Water prices for industry

Industrial water supply provided through the domestic water supply network, is charged at full cost and with progressive rates, as can be seen from table 9. When industry withdraws water from private boreholes, this water is not charged.

Table 9: *Water rates of Limassol Water Board for commercial and industrial customers. (Limassol Water Board website).*

Consumption [m³/4 months]	Rate [€-cents/m³]
1- 400	32.87 (19 £-cents)
401-and over	50.17 (29 £-cents)
Fixed Amount	72.66 (£ 42)

1.4 Institutional framework and constraints

A bigger and more difficult constraint in Cyprus is the natural uneven distribution of the water resources. The impressive topography of 2000m in a small island of 9,250km² in a semi arid area in the Eastern Mediterranean produced an uneven spatial distribution of precipitation ranging from 280mm in the less favoured south-eastern coastal area to over 1000mm in the higher elevations of the Troodos mountain range. The area receiving more than 600mm of annual rainfall is limited to elevations above 500m in the south-western slopes, and above 800m in the north-eastern slopes of the range. The distribution of rainfall throughout the year is similar over the entire island with seven dry months and maximum precipitation in the three months of winter. The latter combined with the steep topography also implies the natural transport of water through many rivers to the less favoured central plains and coastal areas of the island. This natural redistribution of the annual water resources has been operated through geological times and resulted in the formation of large natural underground water reservoirs in the coastal areas of the island.

The majority of the mountainous areas is occupied by forest land. The steep topography and the rocky nature of these areas limited the agricultural land to the slopes of the river valleys where the inclination allowed the concentration of the products of weathering and the formation of a blanket of soil. The irrigated land was even more limited in the vicinity of natural springs throughout the Troodos range. Cultivation of land was more difficult than the flat land of the central plains and coastal areas and could sustain only a small population which was further reduced in the late 1950s and 1960s by the intensified urbanisation trend. This led to an intensification of the already existing uneven distribution of the island's population, resulting in a highly imbalanced regional development with the undeveloped water-rich mountainous areas being under relative poverty. At the same time, their valuable natural source (water) was increasingly transported to the water-poor lowlands and coastal plains, contributing to a higher development and standard of living in this area.

In an effort to reduce this imbalance in development the Cyprus Government carried out a Regional Development Project in the Pitsilia mountainous area with assistance from the FAO. This project included spreading of agricultural land through extensive terracing with heavy machinery, an increase of irrigated land through an extensive drilling program of boreholes and the construction of many small off-stream ponds, improvement of the road system and the encouragement, to establish small communal or family enterprises by offering financial incentives. It is still too early for a detailed assessment of the benefits of this ambitious project but it has definitely increased the standard of living for the inhabitants. At the same time the project has contributed to the reduction of export of water to water-poor coastal areas and has thus increased the imbalance of water supply and demand of the island.

The natural redistribution of water resources was only possible due to the administrative and institutional framework which is in place in Cyprus. As mentioned above, the ground and surface water resources of the island are vested to State and Government having the power to manage these resources. The responsibility is shared between the Ministries of the Interior and the Ministry of Agriculture, Natural Resources and Environment, in some cases with overlapping jurisdictions. The political decision has already been taken to initiate an effective management by allocating all the responsibility for the management and protection of the water resources to the new Water Entity under the Ministry of Agriculture, Natural Resources and Environment.

There are no serious financial constraints in the water development and management on the island as the water supply is the second most important problem after the political one. For this reason the Government is willing to provide all necessary funds for construction, proper operation, and regular maintenance of water development works. For some time the hydrogeological and hydrological issues relating to accurate monitoring of quantity and quality of ground and surface water were left behind. This situation has somehow improved a lot with the completion of various studies, e.g. the large WDD-FAO study, but the lack of staff is a serious constraint, especially at the Water Development Dept., which has to implement several EU Directives in addition to its responsibility of monitoring ground- and surface water.

1.5 Management, institutional and policy options

The water situation in Cyprus, as described above is without doubt not sustainable. The growing imbalance between supply and demand in the last decades has reached a critical stage with the recent droughts of 1989/1991 and 1995/2000 with concurrent dramatic decrease of the supply and considerable increase in demand. This predicament has demonstrated the urgent need for a redefined water policy for the island in order to ensure sustainability regarding the quality of life and continuous economic development, however not at the expense of the environment. Not one single policy option is currently available to resolve the problem of this growing imbalance of the water supply and demand in the island. There are a number of options and measures which complete each other and should be applied holistically. All options and measures available should be taken into consideration, following not only techno-economic but also socio-political criteria.

The first priority measure of the Ministry of Agriculture, Natural Resources and Environment was the reassessment of the water resources and demand of Cyprus. This urgent need was suggested in the study of the Cyprus Geological Survey (1998) on water resources and water policy of Cyprus. The reassessment was carried out in the multidisciplinary detailed WDD-FAO study over the period 2000-2002. Both studies warned the Government of an overexploitation (mining) of groundwater at a rate of about 40% above the sustainable extraction and also of the simultaneous reduction of the mean annual precipitation of the island by 15-25% and the subsequent decrease of the mean annual inflow to the dams by 40%. The WDD-FAO study indicated that the increase in demand is unavoidable because of the population growth and its standard of living, tourism, trade and other sectors of economic activity. With the present trend, the imbalance between supply and demand of water is estimated to reach 90Mm^3 by the year 2020.

The option to increase the supply from groundwater is out of question. On the contrary, for sustainable water management the extraction should be drastically reduced to allow aquifers to recover. One could also argue that the construction of the dams impounded water that was originally meant to recharge the aquifers and was subsequently pumped for irrigation and domestic use. The recent, prolonged periods of drought have demonstrated the urgent need of strategic reserves of groundwater for use in case of emergencies. Selected aquifers with minimum underground losses should be allowed to recover through strict monitoring of extraction. This process is technically easy and institutionally viable but needs political decision in view of the anticipated growing conflict among different users for limited supplies of water.

There is the option of increasing the supply by further development of the surface water with the construction of new dams with the purpose of increasing the storage capacity by about 100Mm^3. Most of the remaining surface water is difficult to be developed further for the moment, as it is related to the area under Turkish occupation and thus political implications are anticipated. Even for the surface water of Government controlled areas, its development is unlikely to lead to substantial incremental water systems. The new dams currently being planned will tap water flowing to dams already constructed downstream or recharge aquifers with a high storage capacity. Furthermore, the experience of the last twenty years has demonstrated that most of the dams have increased the water demand so that now it is higher than their annual inflow. The new dams will make water available to new areas to a large extent at the expense of currently irrigated areas.

Growing conflicts among users could become critical because of competition between different regions and users for limited supplies of water, and growing resistance from water-rich regions to allow transport of water to less favoured regions, particularly for agricultural use.

The option to increase the water supply with desalination of seawater in view of its high cost is currently only feasible for use in domestic supply. The system is highly effective because any quantity of water could theoretically be made available at a high cost. The fiscal impact is high because of the initial investment and the annual operation and maintenance required. All the electricity required is produced by imported oil with steadily increasing prices. In the last two years the costs of desalinated water in Cyprus have increased by 25-30% because of the increase of oil prices. The environmental impact of desalination plants has an adverse effect on sea life of the discharged brine residues. Its political and public acceptability is high for domestic supply in view of water scarcity and the current per capita GDP. Drinking water of good quality could be made available and the existing distribution networks could be used and therefore contribute considerably to maintain regional development and quality of life.

Recycled water is another option for increasing water supply in Cyprus. Up to 30Mm^3 of tertiary treated effluent is expected to be available by 2020. Its fiscal impact is high because of the very high investment for the construction of treatment plants and sewage systems as well as the recurring costs for their maintenance and operation. Its effectiveness is high for the protection of health of the population, to eliminate pollution of the ground and surface waters and protect the environment by efficient disposal of domestic and industrial effluents. However most of this water will be used locally for recreational purposes including parks, hotels, gardens, golf courses, maximising green areas, maintaining natural ecosystems, with the remaining part being used for agriculture and artificial recharge.

All these options to additionally supply conventional and non-conventional water will not be able to satisfy the estimated increase in demand or domestic and irrigation water if it is left to reach the 90Mm^3 mentioned above by 2020. The problem is further complicated by the natural uneven geographical distribution of precipitation throughout the year and water resources, uneven distribution of population and economic activity, and the uneven distribution of tourists. Also, the uneven distribution of irrigated land in areas showing low annual precipitation and higher evaporation, results in an uneven geographical distribution of supply and demand. Under these conditions the ultimate policy option is a good management of water demand and supply.

The first priority measure for water demand management is a new water pricing policy which envisages the pricing for irrigation water from 23% (6.5 C£-cent/m^3, ~11.12€-cent/m^3) to 38% (10.7 C£-cents/m^3, ~18.30 €-cent/m^3) of the average cost for the immediate future. The domestic water tariff will increase from 33.5 C£-cents/m^3, (~57.29€-cent/m^3) to 51 C£-cents/m^3, (~87.21 €-cent/m^3), which is about the actual cost without taking into account the recent increase of the cost for desalinated water. This will increase production costs in agriculture, which again will eliminate irrigation of low value crops, but which will encourage farmers to optimise water use and view water as an important economic good. All on-farm investment has been installed and the implementation of optimisation can start quickly with no appreciable incremental cost. Water use efficiency on the farm level will be further improved if advanced agronomic practices are applied to determine the exact timing and quantity of irrigation water per application. Cyprus is considered of high standard regarding conveyance and field water application. The equity of the pricing increase is high because all consumers have to pay the same price of what they actually consume, but the strong farmers lobby will fight against an increase. Long term policy dictates a gradual increase in the price for irrigation water to the actual cost since this is a requirement after the island's accession to the European Union.

At the same time Water Boards will be encouraged to introduce progressive tariffs and seasonal pricing to support water efficiency by reducing losses. On the level of domestic water supply, mainly in the municipal distribution systems, there is still room for improvement. Unaccounted water ranges from 18% (Nicosia) to over 30% (Paphos), the average being about 23% of the total quantity of domestic supply. Although these figures compare favourably with the average losses in developed countries (25%) and for developing countries (40%), they are still high for a water-scarce country like Cyprus. A 7% reduction of the overall losses would imply water savings of 5Mm^3 which is the production of a desalination plant with a capacity of 14,000m^3/d.

Modification of current cropping patterns could be an effective tool for water demand management. Irrigated agriculture consumes approximately 70% of the water used on the island and was based on the overexploitation of all "cheap" conventional water resources. This invites closer scrutiny of an agricultural water policy and it would be useful to research the option of emphasising winter grown crops, such as protected vegetables and flowers which need less water than summer grown alternatives thus conserving water and thus helping to offset supply and demand. Some of the irrigated crops are water intensive perennial crops, such as citrus and bananas or summer vegetables. Citrus in particular show a very low value-in-use of water. It consumed 32% (51.9Mm^3) and contributed 24% to the total agricultural production in 2000, whereas animal husbandry used only 4% (8Mm^3 in 2000) of the agricultural water and contributed 46% to the total agricultural production. By limiting the citrus cultivation to a minimum, agronomic zones will be highly effective to balance the water supply and demand combined with adequate campaigns raising public awareness and financial incentives, such as compensating farmers for their share of costs and loss of earnings during the process will increase the acceptability. More resistance from farmers of water-rich regions is expected because their water will be transported to water-poor regions, especially for agricultural use. Within the context of the Cyprus accession to the European Union and the definite increase of the water tariff it will be necessary to restructure agriculture to become more efficient and competitive with crops having high-in-value-use of water.

A strict control of the conversion rate of rainfed land to irrigated land is an efficient measure for solving the problem of an imbalance of water supply and demand in Cyprus, because no incremental water will be needed for new irrigated land. It is highly sustainable in saving scarce water resources but its political and public acceptability will be very low for residents of water-rich regions as their water will be transported to water-poor regions, although their standard of living will not improve. Socio-economic incentives will definitely be necessary to implement this measure.

The Government is already fully committed to the option of protecting and enhancing the quality of the water. It is important to equip authorities with well-trained staff, not only in the field of water conservation, but also in monitoring activities of water quality and quantity. If necessary, the Government has to take early action to protect the quality of water.

All water management options indicated above could be quickly implemented with the existing administrative, legal and institutional framework in Cyprus, once political decisions have been taken. It is expected that the accession of the island to the European Union will act as a catalyst for political decisions. Furthermore, the expected allocation of all responsibility to the Water Entity of the Ministry of Agriculture, Natural Resources and Environment with the possibility of consultations could lead to a balance of water resources and demand in the island. Well organised campaigns with appropriate information will increase public awareness as to the value of water in every aspect of life on the island. Multidisciplinary data to encourage these political decisions is expected to come from the MEDIS-Project.

In the long run, a development of public awareness for water conservation and the recognition of water as a valuable economic good for sustainable development and quality of life should create a water culture among the new generations by introducing water education in primary and secondary schools. Ironically, the water culture is so much more developed in the water-rich countries of Northern Europe than on the water scarce island of Cyprus.

Table 10: *Policy options in Cyprus.*

Activity	Municipal Authority Water Utility	Regional Authorities	Ministry of Health	Ministry of Interior	Ministry of Agriculture	Natural Resources & Environment	Ministry of Finance
Surface water							
Use					X		X
Storage					X		
Recharge					X		
Diversion					X		
Quality monitoring					X		
Assessment					X		
Groundwater							
Use					X		
Storage					X		
Recharge					X		
Quality monitoring			X		X		
Assessment					X		
Well/drill permits				X	X		
Irrigation network					X		
Rehabilitation					X		
Modernisation							
Reuse							
Drainage water					X		
Wastewater					X		
Desalination					X		
Introduction of technology					X		
Efficient water utilisation							
Domestic					X		
Industrial					X		
Irrigation					X		
Legislation							
Regulation & codes					X		
Standards			X		X		
Policy setting					X		
Water allocation					X		
Project financing							X
Project design					X		
Project implementation					X		
Operation & maintenance					X		
Pricing					X		
Enforcement				X	X		
Water data records					X		

1.6 Agricultural situation

1.6.1 Cultivated and irrigated area and crops

The total agricultural land of Cyprus covered 1,970km² in 2003, of which 1,560km² were cultivated and the other 410km² were uncultivated, scrub land or wooded areas (CyStat website, 2004). Thanks to the diversity of topography and climate, a wide range of microclimatic conditions exist permitting diversified crop production. The main crop categories in Cyprus by area in 2002 were cereals (45%), fruit and tree crops (29%), fodder crops (17%) and vegetables incl. melons and potatoes with 7% (figure 14). From the cultivated land, 360 km² were irrigated (once or more times) in 2003, while the rest is rainfed land. The main irrigated permanent crops are citrus, deciduous, olives, bananas, table grapes, avocados (table 11), while the main irrigated annual crops are open field vegetables, greenhouse vegetables and flowers, potatoes, and fodder. The deciduous crops include apples, peaches, cherries, pears, plums, figs, walnuts, pecan nuts, and pomegranates. The main crops of the rainfed cultivated land are cereals, with a small part (4.5%) being fallow and grazing land.

In the central plain the main crops are wheat and barley grown under winter rainfall. Potatoes, vegetables, legumes and fodders are widely distributed throughout the island, while citrus orchards are generally concentrated along coastal areas. In narrow valleys at higher elevations of the Troodos Mountains deciduous fruits, nuts, vines and a wide range of vegetables are grown. Viticulture is very important in the hilly areas of Paphos and Limassol districts, and the grapes are mainly used for wine making, while table grapes are grown in the south-west areas near the coast. Bananas are cultivated in Paphos district. Marketing of agricultural commodities is undertaken mainly through private merchants, cooperatives and the producers themselves, though potatoes, wine grapes, milk, carrots, beetroots, olives and cereals go through semi-government marketing organisations.

The second important agricultural sector of Cyprus is animal husbandry. Its livestock includes pigs, goats and kids, sheep, lambs, and cattle in decreasing order of numbers. Fresh pork, poultry meat and eggs fully satisfy local demand and, imports of these items are generally not needed. However the local production of beef, veal, mutton and lamb are supplemented by imports. In the year 2000 the gross output of agricultural sector at current prices was C£318.4 million (~€554 million) with crop production contributing 51% and the livestock production 46%; other agricultural activities contributed 3% (CyStat website, 2004).

In the recent WDD-FAO study the total agricultural water demand for the year 2000 was estimated at 182.4Mm^3 (Savvides *et al.*, 2001). The assessment was based on the irrigated areas per crop category in a normal year. The amount of water consumed was then calculated according to the water requirements of crops for the climatic conditions of Cyprus. Irrigated agriculture used 174.4Mm^3, i.e. 96% of agricultural water. Of this water, 57% was used within the Government Irrigation Schemes and 43% in outside areas. The animal husbandry sector used only 8Mm^3, i.e. 4% of agricultural water consumption.

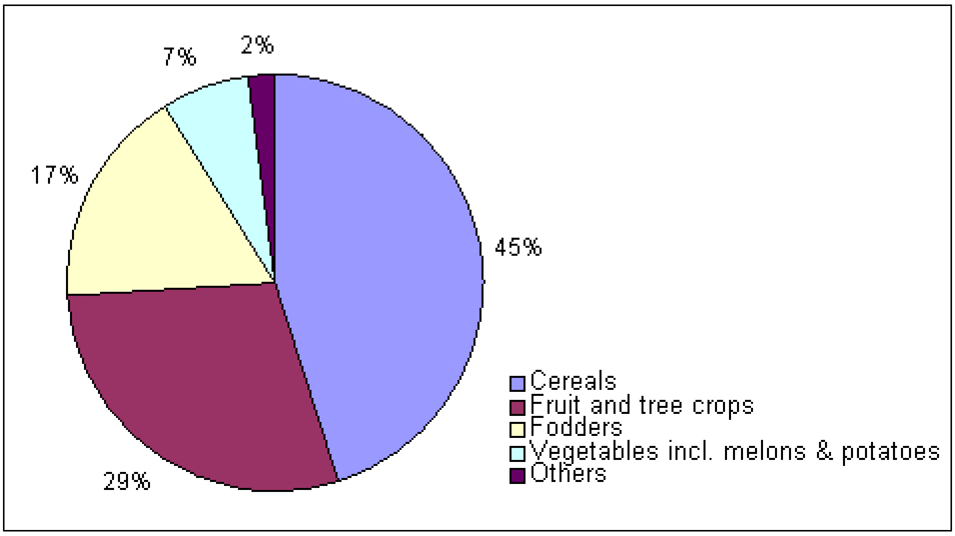

Figure 14: *Main crop categories by area in Cyprus in 2002, (Statistical Service, 2002).*

The water consumed by the various permanent and annual irrigated crops is shown in table 11. The data of this table indicates that the greater part of the irrigation water by permanent crops with citrus having the biggest share. This becomes more obvious in periods of drought with the preferential allocation of water for their irrigation for survival. It is worth noting that the biggest part of the irrigated land is located in the plains and coastal areas, with the highest water requirements of the irrigated crops, particularly the permanent crops. From the annual crops the open field vegetables and potatoes were the main consumers of irrigated water whereas vegetables and flowers grown in greenhouses consumed only 2.9Mm^3 which is 2% of the total irrigation water. This indicates the urgent need for the modification of the current cropping pattern in favour of crops with less water requirements particularly winter grown crops in greenhouses which require considerably less water for growth and production.

The water demand and the water required per kilogram of product for a selection of irrigated crops is shown in table 12. The data are the result of many years of studies by the Agricultural Research Institute of Cyprus. The water demand quoted in this table may look high for Mediterranean islands west of Cyprus. In the climatic conditions of Cyprus evaporation is higher and irrigation periods longer as effective precipitation in average hydrological years is restricted to the winter months only, whereas in periods of drought irrigation of citrus is necessary even in winter months. In the last decade there were periods of consecutive years of drought and the Government introduced conservation measures including rationing of water for irrigation. For citrus, 60-80% of their normal requirements were allocated and the consequence was the noticeable reduction of the quantity and quality of the products.

Table 11: *Distribution of irrigation water demand by crop in 2000, (Savvides et al., 2001).*

	Crop	**Water demand [Mm³]**	**Share of total irrigation water [%]**
Permanent crops	Citrus	55.81	32
	Deciduous	19.18	11
	Olives	8.72	5
	Table Grapes	5.23	3
	Bananas	3.49	2
	Others	10.46	6
	Total	**102.89**	**59**
Annual crops	Green houses	3.49	2
	Open field vegetables	39.24	22.5
	Potatoes	16.57	9.5
	Fodder	12.21	7
	Total	**71.51**	**41**

As mentioned above, the extensive expansion of citrus plantations in the 1950s and 1960s and the prevailing high prices of citrus fruits in Europe, contributed to an agricultural revolution and socio-economic development of the island but also to an overexploitation of its groundwater resources. The decline of the prices after 1970 and the considerable increase of production costs such as labour, fertilizes, plant protection chemicals, machinery, and fuel did not make the cultivation of citrus not profitable but still their plantation constitutes a considerable part of the irrigated land in Cyprus. This is obvious from the data shown in table 13 on the water required for the production of 1kg of lemon, orange, and grapefruit the cost of labour for harvesting, and the cost of water. The assessment of the latter was based on:

- The average price of groundwater,
- the tariff of water from Government Irrigation Projects (GIP),
- the real cost of the water from these projects *and*
- the cost of desalinated water at plant.

Table 12: *Yield of agricultural products in relation to irrigation water used, (Eliades et al., 1995).*

Produce	Amount of water [m³]	Production in [kg/km²]	Litres of water used per kg of produce
Tobacco	3,750	320,000	1,172
Groundnuts	4,800	450,000	1,067
Clover	10,800	1,810,000	597
Corn	6,100	1,240,000	492
Bananas	12,520	3,000,000	417
Olives	4,300	1,500,000	287
Apples	6,830	2,400,000	285
Peaches	6,830	2,400,000	285
Pears	6,830	2,600,000	263
Grapes	3,060	1,500,000	204
Lemons	8,000	4,000,000	200
Oranges	8,000	4,500,000	178
Grapefruits	8,000	6,500,000	123
Aubergines	5,700	10,630,000	54
Potatoes	2,230	444,000	50
Tomatoes	5,400	15,360,000	35
Cucumbers	4,750	17,640,000	27

Table 13: *Water cost in relation to the production of citrus.*

	Lemon	Orange	Grapefruit
Production [t/km²]	4,000	4,500	6,500
Water consumption [m³/km²]	800,000	800,000	800,000
Water consumption [l/kg of produce]	200	178	123
Price per tone of produce	C£ 120*	C£ 65*	C£ 35*
Produce collection cost	2.5 cent*	2.3 cent*	1.4 cent*
Selling price after collection	9.5 cent*	4.2 cent*	2.1 cent*
Water cost for a kg of produce for groundwater (5 cent*)	1 cent*	0.9 cent*	0.6 cent*
Water cost for a kg of produce for water from G.I.P. after subsidy (6,5 cent*)	1.3 cent*	1.2 cent*	0.8 cent*
Water cost for a kg of produce for water from G.I.P. without subsidy (33 cent*)	6.6 cent*	5.9 cent*	4.1 cent*
Water cost for a kg of produce for desalinated water (54 cent*)	10.8 cent*	9.9 cent*	6.6 cent*

**1 C£ ≈ 1.74 € (Year 2000).*

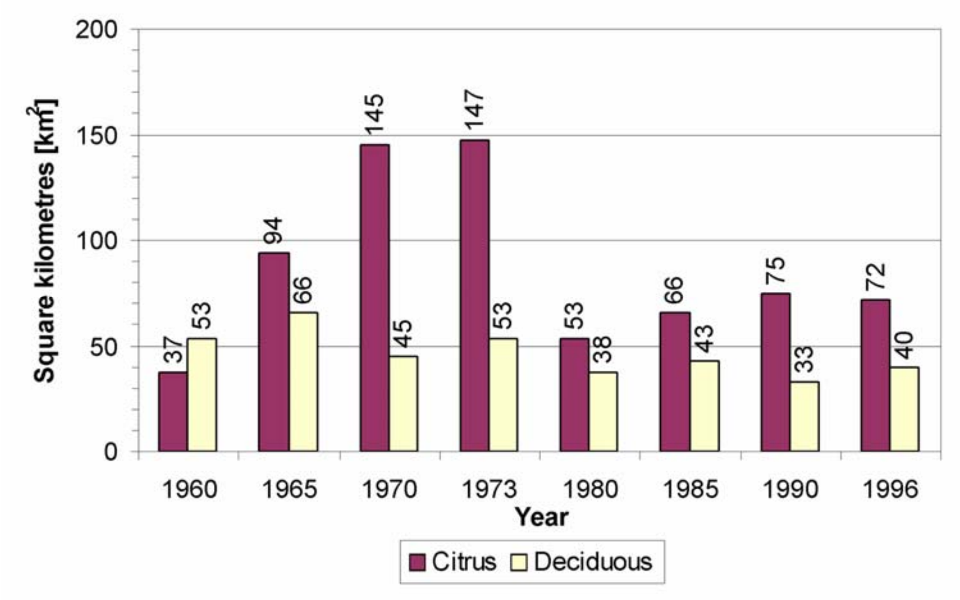

Figure 15a: *Irrigated land with citrus and deciduous.*

The data indicates clearly that the selling price of citrus products does not cover the actual costs for water from GIP. In 1996 the Cyprus Government took the political decision to use desalinated water to satisfy the increasing demand for domestic water. In the same year water used to irrigate the citrus trees could have satisfied the needs for drinking water of 1.7 million permanent residents (figures 15a, 15b, 15c). In 2000 the irrigation of citrus required 32% of the total agricultural water, which is about 51.9Mm^3 and the contribution of this crop to the exports of the island was C£ 12.8 million (~€22.3 million) which is 37.2% of the exports of the total raw agricultural products and 5% of the total domestic exports (Statistical Service, 2002). To replace about 63% of water used for the citrus' production, the Government paid about C£ 20 million (~€35 million) for the two desalination plants. Herewith it is very obvious that citrus is the main cause of the imbalance of water supply and demand in Cyprus, it shows a very low value-in-use of water and negative to very low net benefits and calls for a closer scrutiny of the island's future agricultural water policy.

On the other hand the water requirements for some annual crops grown in greenhouses are very low. In the case of cucumber in high greenhouses, where optimum irrigation techniques are used along with the actual plant requirements, the contribution of the cost of water is a minor percentage of the total cost and their irrigation is feasible even with desalinated water (table 14). The modification of the irrigated cropping pattern in favour of annual crops with less water requirements or annual winter grown crops which require considerably less irrigation water could assist the island in securing a balance between supply and demand which would be sustainable over time and at the lowest possible cost. In 2000, vegetables consumed 26% of the irrigation water (i.e. 41.3Mm^3) and contributed C£ 3.5 million (~€ 6.1 million) to the exports of the island (Statistical Service, 2002); greenhouse vegetables consumed 2.9Mm^3, i.e. 2% of the irrigation water used.

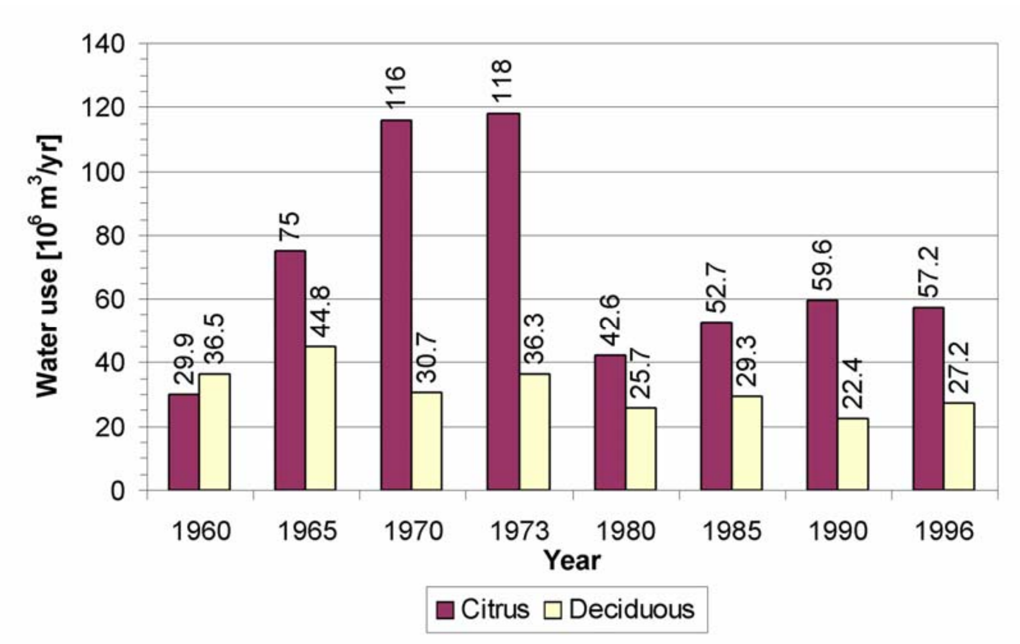

***Figure 15b**: Water consumption for citrus and deciduous.*

In 2000, agriculture contributed 3.3% to the GDP of the island and offered employment to 23,800 people which are 7.9% of the gainfully employed population (CyStat website, 2004). The contribution of this sector to the domestic exports of the island is given in table 15. Comparative statistics on the agricultural sectors between Cyprus and the EU countries are shown in table 16.

In the context of increasing water scarcity and increasing water demand and the phasing out of subsidies for agriculture with the harmonisation of the European Union Policies, a mix of policies should foster agronomical research and extension services covering a large diversity of suitable crops. Furthermore, the small-scale farming nature of irrigated agriculture in Cyprus needs support to collective marketing arrangements which can improve planning for high added value production for exports and the increasing tourist sector, reduce the risks to the farmers which in turn will reduce urbanisation and enhance the role of rural people in protecting natural and environmental resources of the island.

***Table 14:** Expenses and income in EURO per km² of cucumbers for the year 2000, (Markou and Mavrogenis, 2002).*

	Greenhouses	**Low tunnels**	**Open field**
Yield [t/km^2]	13,000	3,000	2,000
Price [EUR/t]	95,700	60,900	60,900
A. Gross revenue	12,441,000	1,827,000	1,218,000
Variable Cost			
Transplants	701,568	83,520	83,520
Fertilisers	86,652	42,108	42,108
Pesticides	238,902	62,466	74,124
Soil disinfection	281,880	-	-
Irrigation	**70,470**	**35,322**	**57,942**
Plastic cover	783,000	166,170	-
Supporting materials	52,200	-	-
Heating	1,348,500	-	-
Machinery	395,328	42,456	46,632
Hired Labour	1,567,566	258,390	172,260
Miscellaneous cost	552,624	69,078	47,676
Interest on operating capital	212,802	15,138	10,440
B. Total variable cost	6,291,492	774,648	534,702
Fixed cost			
Land lease	34,800	34,800	34,800
Family labour	4,524,696	697,914	391,500
Interest on fixed capital	388,890	30,798	27,144
Depreciation	827,718	105,270	83,172
C. Total fixed cost	5,776,104	868,782	536,616
D. Total cost (A+B)	12,067,596	1,643,430	1,071,318
E. Gross margin (A-B)	6,149,508	1,052,352	683,298
F. Net profit (A-D)	373,404	183,570	146,682
G. Production cost per ton	928	548	536

**1 C£ = 1.74 € (year 2000).*

Table 15: *Main indicators of the agricultural sector of Cyprus, (CyStat website, 2004).*

	1995	1996	1997	1998	1999	2000
Production index (1995=100)	**100**	**99.6**	**88.0**	**96.3**	**103.4**	**94.6**
Price index	100	98.8	106.8	105.7	99.2	105.9
Gross output at current prices (C£mn*)	**334.8**	**318.2**	**301.7**	**318.5**	**321.4**	**318.4**
Share of GDP (%)	**4.6**	**4.2**	**3.7**	**3.9**	**3.7**	**3.3**
Crop production	184.5	175.8	152	172.2	174.1	163
Livestock production	123.4	127	135.6	138	138.3	145.7
Other	26.9	15.4	14.1	8.3	9	9.7
Agricultural land (km^2)	**2005**	**1997**	**1994**	**1993**	**1993**	**1992**
Temporary crops	920	930	901	955	951	934
Permanent crops	424	434	429	427	421	418
Fallow land	71	60	80	46	60	80
Grazing land	15	12	11	11	11	11
Uncultivated and scrub	575	561	573	554	550	549
Livestock (thousand)	**200.5**	**199.7**	**199.4**	**199.3**	**199.3**	**199.2**
Cattle	68.1	70.1	62.4	55.8	54.0	54.2
Sheep and lambs	250.0	252.0	245.0	240.0	233.0	246.0
Goats and kids	220.0	240.0	302.0	322.0	346.0	378.6
Pigs	374.1	399.5	414.8	431.3	418.5	408.4
Employment (thousand)	**28.7**	**27.5**	**25**	**24.8**	**24.3**	**23.8**
% of gainfully employed population	10.1	9.6	8.7	8.5	8.2	7.9
Production of main crops (10^3 tons)						
Cereals	145.0	141.2	47.8	65.8	127.1	48.0
Potatoes	234.0	228.0	81.5	138.0	161.5	117.0
Grapes	118.0	114.0	101.0	124.0	105.3	108.0
Oranges	55.0	52.5	50.5	44.5	52.8	42.7
Grapefruit	73.5	52.0	47.0	35.0	44.2	28.1
Lemons	28.5	26.5	23.0	21.5	22.1	20.9
Olives	13.5	12.5	9.0	10.7	14.0	21.0
Domestic exports of raw agricultural products (C£*)	**67.7**	**53.3**	**35.9**	**40.5**	**36.5**	**34.4**
% of total domestic exports	12.2	10.5	7.6	8.6	8.2	6.4
Potatoes	43.1	27.7	8.4	19	14	12.3
Citrus fruit	16.8	18.1	17.3	12.7	13.8	12.8
Grapes	2.1	2.1	1.3	2.4	1.7	1.5
Vegetables	2.8	2.9	2.9	3.1	3.4	3.5

**1 C£ = 1.74 € (year 2000).*

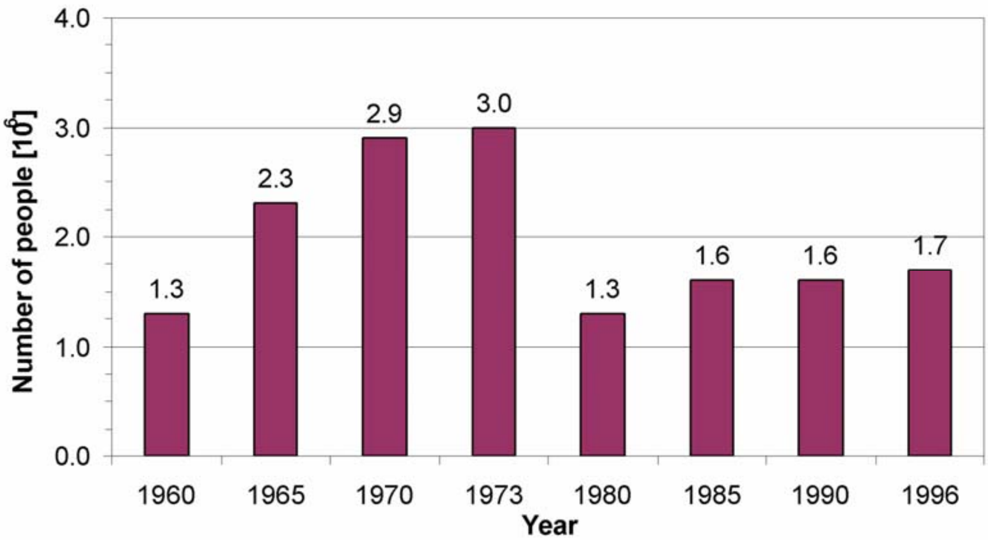

Figure 15c: *People who their water supply can be met by the water used to irrigate citrus and deciduous, (Q:140l per capita and day).*

1.6.2 Irrigation systems and scheduling

Advanced irrigation methods are extensively employed in Cyprus. For the irrigation of potatoes sprinklers, for permanent crops mini sprinklers and drip irrigation and for open field vegetables drip irrigation are predominately used. The most advanced irrigation techniques are applied in the greenhouses, where the plants get water and fertilisers along with their actual requirements and not on a regular basis.

The well qualified scientists of the water use section of the Department of Agriculture and its extension services, advise farmers on the requirements of water for the various irrigated crops, whereas the Agricultural Research Institute carried out extensive research and field trials to explore these requirements under the various climatic and soil conditions of the various irrigated areas.

It is worth noting that the statistical data shown in table 17 indicate that the cost of purchasing irrigation water from dams in 2000 which amounted to 100Mm^3, was less than the cost of fuel, of spare parts & repairs and less than half of the cost of electricity.

Table 16: *Comparative statistics on the agricultural sector between Cyprus and EU Countries, (OECD, 1999; EUROSTAT, 1997).*

Country	Agricultural Production (% of GDP)		Employment in Agriculture (% of total labour force)		Quality Index of Agricultural Production (1990=100)						Producer's Price Index (1990=100)					
					Crop production		Livestock production		Total production		Crop production		Livestock production		All products	
	1983	**1994***	**1983**	**1997**	**1991**	**1995**	**1991**	**1995**	**1991**	**1995**	**1991**	**1995**	**1991**	**1995**	**1991**	**1995**
Cyprus	8.3	5.3	15.3	8.9	87.3	116.7	96.1	117.5	90.6	117.0	109.4	104.4	103.5	111.3	107.1	107.0
EU Countries																
Belgium	3.0	1.7	3.4	2.3	100.9	118.5	105.3	109.0	103.7	112.6	108.8	84.6	96.9	85.1	101.2	84.9
Denmark	5.6	3.7	7.3	3.5	96.1	97.6	101.5	109.4	99.7	105.5	101.4	85.9	96.9	88.8	98.5	87.8
Germany	2.1	1.0	5.7	2.6	101.8	105.9	99.5	95.0	100.4	99.1	104.9	85.1	97.2	93.6	99.4	90.2
Greece	18.0	13.7	30.0	17.7	105.0	107.0	100.3	101.2	103.6	105.2	126.1	143.6	110.8	160.8	121.7	148.5
Spain	6.0	3.7	18.8	6.6	99.9	80.3	104.5	108.2	101.8	90.7	102.2	130.7	97.8	111.3	100.5	122.7
France	5.0	2.5	8.4	4.0	97.0	99.0	100.6	107.2	99.0	102.5	103.8	86.8	96.7	90.8	100.4	88.9
Ireland	12.0	7.7	17.5	9.2	105.7	99.0	104.1	110.1	104.3	108.7	103.7	105.7	95.3	100.2	96.3	100.8
Italy	6.0	2.9	12.0	6.5	104.8	101.6	100.1	103.4	103.0	102.3	113.6	112.4	102.6	112.7	109.2	112.7
Luxemburg	3.0	1.5	4.8	2.6	76.0	101.3	100.7	102.6	96.2	102.3	101.4	92.2	90.6	92.9	92.5	93.2
Netherlands	4.3	3.6	5.5	3.4	105.1	119.0	100.6	103.0	102.5	109.8	109.7	89.6	101.1	87.7	104.7	88.5
Austria	5.0	2.4	9.9	6.4	101.1	93.4	100.9	95.5	101.0	94.8	98.5	82.0	100.9	78.5	100.4	79.7
Portugal	8.4	5.1	26.7	14.1	105.4	83.3	101.0	106.7	103.4	94.5	97.6	126.4	95.9	114.1	96.8	120.4
Finland	9.0	5.2	13.1	5.9	96.5	74.9	96.3	93.9	96.4	87.5	94.1	71.8	97.9	66.6	96.8	68.2
Sweden	4.0	3.0	5.6	2.6	88.8	86.8	95.2	99.7	93.0	95.4	98.2	100.2	98.7	92.3	98.6	94.8
United Kingdom	2.0	1.6	2.5	1.7	100.6	97.0	100.6	102.5	100.6	100.2	101.1	114.3	97.9	115.6	99.2	115.1

** EUROSTAT (1997)*

1.6.3 Use of fertilisers and weed control

Agricultural practice in Cyprus is characterised by the abuse of fertilisers. In the year 2000 about 36,000 tons of various types of fertilisers (sulphate of ammonium, urea, calcium ammonium nitrate, ammonium nitrate, triple super phosphate, potassium sulphate, mixed fertilisers, other fertilisers like liquid, crystallic etc, animal manure) were used (Statistical Service, 2000), mostly in irrigated areas. The farmers very rarely carry out soil and leaf analyses to use the proper quantity and type of fertiliser, but follow more the data given in the promotion campaigns of fertiliser importers. This practice increases the cost of agricultural production considerably and is potentially critical for the deterioration of the groundwater quality and the environment. There is also an abuse of plant protection agrochemicals as it is indicated in table 17. Excessive use of herbicides endangers the quality of the water in dams, whereas excessive and uncontrolled use of pesticides and fungicides could adversely affect the environment and result to residues higher than the acceptable limits and increases unnecessarily the costs of production. Another constraint of agriculture in Cyprus is the extensive parcellation of the cultivated land, especially irrigated land. Big farms constitute only a minor proportion of this land. For this reason, crop rotation systems are rare, even in the rain fed land where the predominantly cultivated crop is barley. The farmers are convinced that crop rotation is dispensable by using more fertilisers. The parcellation of land increases the investment in machinery considerably. Every farmer has to buy the necessary machinery which in most cases is not justified by the size of his land resulting in under-use of the investment. Furthermore, it increases the cost of operation and maintenance (table 17) and in turn, the total cost of production.

Table 17: *Cost of production in C£000's* by type 1997-2000, (Statistical Service, 2002).*

	1997	1998	1999	2000
Irrigation	**7,940**	**7,600**	**9,730**	**9,040**
Fuels	2,190	2,006	1,800	1,958
Electricity	2,350	2,324	2,620	4,005
Spare parts and repairs	1,800	1,730	3,150	1,437
Purchase of water (from dams)	1,600	1,540	2,160	1,640
Fertilisers cost	**10,990**	**10,972**	**11,174**	**9,755**
Chemical	9,450	9,412	9,574	8,155
- Sulphate of Ammonium (21-0-0)	329	356	378	298
- Urea (46-0-0)	219	203	197	167
- Calcium Ammonium Nitrate (26-0-0)	198	192	169	165
- Ammonium Nitrate (33/34-0-0)	704	703	620	559
- Triple Superphosphate (0-46/48-0)	146	132	122	113
- Potassium Sulphate (0-0-48/52)	75	72	68	66
- Mixed fertilisers	6,204	6,159	6,489	5,356
- Other fertilisers (liquid, crystallic etc)	1,575	1,595	1,531	1,431
Animal manure	1,540	1,560	1,600	1,600

Table 17 continued.				
	1997	**1998**	**1999**	**2000**
Pesticides cost	**7,940**	**8,335**	**8,607**	**8,443**
Insecticides	3,250	3,150	3,276	3,093
Fungicides	1,720	2,410	2,216	2,468
Herbicides	1,535	1,590	1,764	1,548
Acaricides	545	455	854	615
Other	890	730	497	719
Machinery repairs & maintenance	**16,070**	**16,522**	**11,994**	**12,526**
Fuels, lubricants & electricity consumed	8,125	8,205	6,096	6,622
Tyres and tubes	589	622	556	565
Repairs of agricultural machinery and equipment	6,906	7,270	4,917	4,914
Hand tools & other implements	450	425	425	425

** 1 C£ = 1.74 € (year 2000).*

1.7 Socio-economic situation

1.7.1 Social profile

1.7.1.1 Population

According to the Census of 2001, the population of Cyprus in the area under Government control is 689,565, with 624,754 Cypriots (91%) and 64,811 foreigners (9%); the population density is 120 persons/km^2 in the area under Government control. The number of Turkish Cypriots is estimated to be 87,600. This does not include more than 115,000 Turkish settlers illegally residing in the Turkish-occupied part of Cyprus. The figure of the Greek Cypriot population includes about 5,300 Maronites, Armenians and Latins who, under the 1960 Constitution, were asked to choose between the two communities and chose to join the Greek Cypriot community. Table 18 depicts the development of the Cyprus population since 1992 and table 19 the distribution in the main cities.

As a result of the Turkish invasion in 1974, 36% of the territory of the Republic of Cyprus is still under the control of Turkish occupation troops. Moreover 162,000 Greek Cypriots (32% of the Greek Cypriot population) have become refugees. Since the Turkish invasion and occupation of more than a third of the island, the demographic balance has changed dramatically as a result of Turkey's colonisation policies. There are more than 115,000 illegal Turkish settlers in the occupied area while an estimated 55,000 Turkish Cypriots have emigrated.

Table 18: *Development of the population of Cyprus, (CyStat website, 2004).*

Year	Total population (including estimates of Turkish Cypriots)	Population in the Government controlled area
1992 (census)	697,025	602,025
1995	721,805	631,205
1996	730,132	640,932
1997	738,858	650,658
1998	748,585	660,385
1999	758,112	670,112
2000	767,638	679,838
2001 (census)	777,165	689,565
2002 (projection)	792,939	705,539

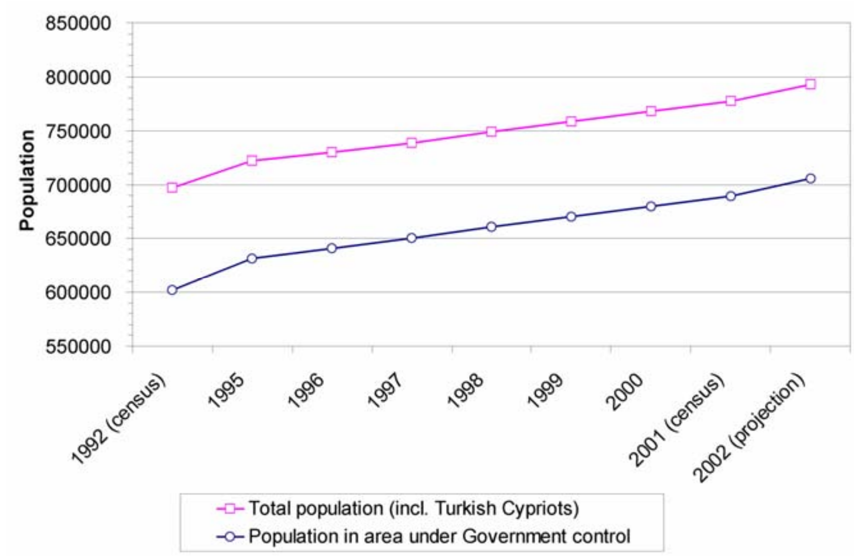

Figure 16: *Development of the population in Cyprus, (CyStat website, 2004, modified).*

Table 19: *Population of the main urban agglomerations of Cyprus on Oct. 1st, 2001, (CyStat website, 2004).*

Agglomeration	Population
Nicosia (Nicosia, Ag. Dometios, Egkomi, Strovolos, Aglangia, Lakatameia & Latsia Municipalities and Anthoupoli Refugee Estate)	194,243
Limassol (Limassol, Mesa Geitonia, Ag. Athanasios, Germasogeia & Kato Polemidia Municipalities)	94,250
Larnaca (Larnaca & Aradippou Municipalities)	58,114
Paphos (Paphos & Geroskipou Municipalities)	32,039

Table 20: *Development of the population distribution by age in the Government controlled area, (CyStat website, 2004).*

Population distribution by age (%)	1992 census	1995 end	1996 end	1997 end	1998 end	1999 end	2000 end	2001 census	2002 end
0-14 years	25.4	24.6	24.3	23.8	23.4	22.8	22.3	21.5	20.9
15-64 years	63.6	64.3	64.6	65.0	65.5	66.0	66.4	66.8	67.3
65 years and over	11.0	11.0	11.1	11.1	11.1	11.2	11.3	11.7	11.8

1.7.1.2 Family Structure

The following information is obtained from the CyStat website (2004).

Fertility

In 2002 the number of births in the Government controlled area of Cyprus was 7,883 compared to 8,167 in 2001 giving a crude birth rate of 11.1 per thousand population in 2002 compared to 11.6 in 2001. Similarly, the total fertility rate, which gives the mean number of children per woman, decreased to 1.49 in 2002 from 1.57 in 2001. Since 1996 the total fertility rate has decreased to a level below the replacement level of 2.10.

Mortality

The number of deaths reached 5,168 in 2002 compared to 4,27 in 2001 giving a crude death rate of 6.9 per thousand population in 2001. In 2002 the infant mortality rate was estimated at 4.7 infant deaths per thousand live births compared to 4.9 in 2001. Life tables for the period 2000-2001 put the expectation of life at birth at 76.1 years for males and 81.0 for females.

Marriages

In 2002 the number of marriages decreased to 10,284 from 10,574 in 2001. Ecclesiastical marriages decreased from 3,684 in 2001 to 3,620 in 2002, and civil marriages from 6,890 to 6,664. Only 102 cases of civil marriages concerned marriages between Cypriots.

Divorces

In 2002 the number of divorces increased to 1,320 from 1,197 in 2001. The total divorce rate which shows the proportion of marriages that are expected to end up in divorce was 208 per 1,000 marriages in 2002, whereas in 1980 it was only 42. This means that presently one marriage in five ends up in divorce.

Tables 25-27 depict the household-numbers by district, their development in time and the household size.

Table 21: *Households by district in Cyprus, (CyStat website, 2004).*

District		**Census**	
		1992	**2001**
Urban Areas	Nicosia	56,160	68,807
	Ammochostos		
	Larnaca	18,957	23,235
	Limassol	42,801	52,472
	Paphos	10,101	15,037
Total		**12,8019**	**159,551**
Rural Areas	Nicosia	20,588	22,571
	Ammochostos	9,151	11,814
	Larnaca	11,767	13,656
	Limassol	12,413	13,289
	Paphos	7,285	7,490
Total		**61,204**	**68,820**
Total urban and rural areas	Nicosia	76,748	91,378
	Ammochostos	9,151	11,814
	Larnaca	30,724	36,891
	Limassol	55,214	65,761
	Paphos	17,386	22,527
Total		**189,223**	**228,371**

Table 22: *Household development in Cyprus, (CyStat website, 2004).*

Year	**1992**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Households (thousands)	185.5	198.2	202.5	206.8	211.0	215.3	219.5	223.8
Average household size	3.23	3.23	3.21	3.19	3.16	3.13	3.09	3.06

Table 23*: Household size in Cyprus, (CyStat website, 2004).*

Household size	**1992**		**2001**	
	185,459	**100%**	**223,790**	**100%**
1 person	23,408	12.6%	35,841	16.0%
2 persons	46,010	24.8%	60,800	27.2%
3 persons	32,249	17.4%	38,356	17.1%
4 persons	47,361	25.5%	49,064	21.9%
5 persons	25,514	13.8%	26,337	11.8%
6 persons	8,027	4.3%	10,150	4.5%
7 persons	2,094	1.1%	2,421	1.1%
8 persons	547	0.3%	576	0.3%
9 persons	163	0.1%	149	0.1%
10+ persons	86	0.0%	96	0.0%

1.7.1.3 Education

Table 24 shows the educational development in Cyprus. During the educational year 2000-2001, there were 1,186 educational institutions at all levels of education, 166,130 pupils/students and 12,051 teachers, giving a pupil/teacher ratio of 13.8 (Statistical Service, 2003). Of the total number of pupils/students, 79.7% were enrolled in public schools and 20.3% in private schools. The enrolments of pupils/students by level of education were as follows: Pre-primary 2,6455, Primary 6,3387, Secondary 64,023, Tertiary in Cyprus 11,934 and Special education 331. The enrolments at the various institutions of non-formal education were 88,390. Cypriot students abroad totalled 13,650. Their distribution by level of education was as follows: Tertiary non-university 1,191 or 8.7%, Tertiary University Undergraduate 11,041 or 80.9%, Tertiary Postgraduate (Master's) 1,102 or 8.1% and Doctoral (Ph.D.) 316 or 2.3%. The most popular fields of study were: Business and Administration 13.2%, Humanities 12.1%, Social and behavioural sciences 11.3%, Health 9.6%, Engineering 8.0% and Teacher training and Education science 7.6%. The main countries of study were: Greece 55.4%, United Kingdom 21.5%, U.S.A. 12.5%, Hungary 2.1%, Russian Federation 1.3%, Bulgaria 1.9% and Germany 0.8%. Public expenditure in public and private education stood at C£ 309.4 million (€ 538.4 million), for all levels. The current cost per pupil/student in public schools by level of education was as follows: Pre-primary C£ 1,151 (€ 2,003), Primary C£ 1,574 (€ 2,739), Secondary C£ 2,310 (€ 4,019) and Tertiary C£ 6,217 (€ 10,818).

Table 24: *Statistical data on education in Cyprus, (Statistical Service, 2003).*

	1985/ 1986	**1990/ 1991**	**1995/ 1996**	**1996/ 1997**	**1997/ 1998**	**1998/ 1999**	**1999/ 2000**
Gross enrolment ratios (%)							
Primary level	96	105	100	100	99	97	97
Secondary level	87	83	97	97	96	96	97
Third level (total)	28	35	41	45	48	50	50
in Cyprus	6	15	20	23	24	24	23
Abroad	22	20	21	22	24	28	27
Pupil/teacher ratios							
Pre-primary level	25.0	23.3	19.8	18.2	18.1	17.4	16.7
Primary level	22.9	20.7	19.0	15.6	18.3	17.7	17.2
Secondary level	15.0	12.4	12.4	10.8	12.3	12.2	11.9
Third level	10.8	13.4	12.2	12.3	12.6	12.7	11.8
Third level students per 1000	25.0	27.0	28.0	30.0	32.0	35.0	34.0
	1985	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**
Public expenditure on education	56.7	95.0	186.1	210.1	249.0	272.2	268.8
(as % of GDP)	3.8	3.7	4.6	5.0	5.7	5.8	5.7

1.7.1.4 Health

The following table depicts some indicators related to health issues.

Table 25: *Health statistical data of Cyprus, (CyStat website, 2004).*

	1990	1995	1996	1997	1998	1999	2000	2001
Persons per								
doctor	483	405	402	398	394	390	385	381
dentist	1354	1198	1187	1170	1157	1136	1121	1106
nurse	234	231	232	231	231	233	237	237
hospital bed	170	197	202	215	221	223	220	229
Total Expenditure on Health Services (C£mn*)	114.3	201.2	235.3	266.2	273.4	289.4	324.6	360.1
as % of GDP	4.5	5.0	5.7	6.1	5.8	5.8	5.9	6.1

**1 C£ = 1.74 € (year 2000).*

1.7.2 Economic profile

1.7.2.1 Gross Domestic Product

The GDP of Cyprus increased from C£ 4,148 million (€ 7,218 million) in 1995 to C£ 5,679 million (€ 9,882 million) in 2000 in the area under Government control. The contribution of the primary sector to the GDP at constant prices decreased from 5.1% in 1995 to 3.8% in 2000 which makes a decrease of 25%, whereas that of agriculture fell from 4.6% to 3.3% which is 30%. The decrease of the secondary sector from 21.3% in 1995 to 18.6% in 2000 shows a drop of 13%. Only the tertiary sector experienced a growth increase from 67.9% to 74%; tourism shows an increase of 6%.

Table 26: *National accounts of Cyprus, (CyStat website, 2004).*

		1995	1996	1997	1998	1999	2000	2001
Gross Domestic Product at current market prices (C£mn)		**4148.2**	**4299.8**	**4522.1**	**4862.8**	**5214.2**	**5679.0**	**6103.6**
	% annual change at current prices	-	3.7	5.2	7.5	7.2	8.9	7.5
Gross Domestic Product at current market prices, by economic activity (C£mn)								
Primary	Agriculture hunting and forestry	191.0	178.5	167.1	188.2	191.4	187.8	211.9
	Fishing	8.5	10.5	11.0	10.7	12.4	11.4	11.4
	Mining and quarrying	11.2	11.4	11.0	14.1	14.9	16.9	17.4

Table 26 continued.								
		1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Secondary	Manufacturing	472.9	482.5	498.2	516.2	536.1	563.0	579.0
	Electricity gas and water supply	82.2	85.9	88.5	95.4	94.9	114.2	123.1
	Construction	327.3	345.4	349.7	363.7	371.1	378.2	412.3
Tertiary	Wholesale and retail trade	528.1	540.0	565.3	620.0	634.1	687.2	742.9
	Hotels and restaurants	361.6	353.2	384.5	418.1	469.9	526.5	574.2
	Transport storage and communi-cation	315.8	334.3	357.7	397.7	444.3	492.6	538.1
	Financial intermediation	203.6	218.6	245.3	269.2	354.2	399.7	386.4
	Real estate renting and business activities	608.1	657.2	708.0	770.7	821.3	884.5	991.8
	Public administration and defence	338.7	358.7	388.4	407.5	447.3	487.8	505.4
	Education	181.9	197.7	220.4	245.4	259.6	281.8	305.8
	Health and social work	128.6	141.4	153.1	166.0	178.5	191.6	206.1
	Other community social and personal services	135.4	148.9	169.0	186.7	199.8	220.6	232.5
	Private households with employed persons	14.3	17.9	19.7	21.8	24.0	27.5	33.2
Total gross value added		**3,909.2**	**4,082.1**	**4,336.9**	**4,691.4**	**5,053.8**	**5,471.3**	**5,871.5**

**1 C£ = 1.74 € (year 2000).*

1.7.2.2 Employment

The development of the employment divided into working sectors and unemployment according to sex, age and level of education between 1995 and 2000 can be seen in table 27.

Table 27: Labour development from 1995 to 2000 in Cyprus, (CyStat website, 2003).

	1995	1996	1997	1998	1999	2000
Economically active population (thousand)	**302.1**	**306.0**	**307.6**	**311.1**	**318.2**	**324.9**
as % of the total population	46.4	46.3	45.9	45.8	46.4	46.8
Gainfully employed population (thousand)	**283.8**	**285.9**	**286.1**	**288.8**	**294.7**	**301.8**
Males (%)	61.0	60.5	60.4	60.1	59.6	59.1
Females (%)	39.0	39.5	39.6	39.9	40.4	40.9
Economic activity (thousand)						
Agriculture. hunting and forestry	28.7	27.5	25.0	24.8	24.3	23.8
Fishing	1.1	1.1	1.2	1.3	1.3	1.4
Mining and quarrying	0.7	0.7	0.6	0.6	0.6	0.6
Manufacturing	44.0	42.2	40.8	39.6	38.0	36.7
Electricity, gas and water supply	1.4	1.4	1.4	1.5	1.5	1.5
Construction	27.7	27.3	26.9	26.1	26.2	26.5
Wholesale and retail trade; repairs	49.5	50.8	51.9	52.4	52.9	54.2
Hotels and restaurants	30.1	30.0	29.7	30.0	31.7	33.0
Transport, storage and communication	17.9	18.4	19.1	19.7	20.4	21.4
Financial intermediation	12.3	12.8	13.2	13.7	15.3	16.0
Real estate, renting and business activities	12.0	12.5	12.9	13.8	14.5	14.9
Public administration and defence; Compulsory social security	18.7	19.0	19.6	20.3	20.9	21.7
Education	13.3	14.2	14.9	15.2	15.7	16.1
Health and social work	10.3	10.7	11.0	11.2	11.5	12.0
Other community, social and personal services activities	12.1	12.3	12.4	12.5	13.2	14.2
Private households with employed persons	4.0	5.0	5.5	6.1	6.7	7.8
Extra territorial organ and bodies	3.1	3.1	3.0	2.9	2.8	2.8
Registered unemployed (thousand)	**7.9**	**9.4**	**10.4**	**10.4**	**11.4**	**10.9**
Unemployment rate (%)	**2.6**	**3.1**	**3.4**	**3.3**	**3.6**	**3.4**
Males	1.9	2.3	2.6	2.9	2.9	2.7
Females	3.7	4.3	4.6	4.1	4.6	4.4
Unemployed under 25 years as % of total unemployed	**14.8**	**14.4**	**14.4**	**14.0**	**12.2**	**11.0**
Unemployed by level of education (%)						
No schooling	1.0	0.9	0.9	0.8	0.7	0.6
Primary	27.0	26.6	27.2	27.4	29.5	28.1

Table 27 continued.						
	1995	**1996**	**1997**	**1998**	**1999**	**2000**
Unemployed by level of education (%)						
Secondary General	44.6	45.1	44.8	43.6	43.2	45.8
Secondary Technical	6.3	6.8	7.3	8.3	8.1	8.9
Third	21.1	20.7	19.8	19.9	18.5	16.6
Growth in rates of pay (%)						
in money terms	6.6	6.1	6.8	5.2	4.8	7.2
in real terms	3.9	3.1	3.1	3.0	3.0	3.0
Growth in earnings (%)						
in money terms	6.1	6.1	6.6	5.0	4.8	6.9
in real terms	3.4	3.1	2.9	2.7	3.0	2.7

1.7.2.3 Working sectors

1.7.2.3.1 Primary sector

Agriculture

Despite the reduction of its contribution to the GDP and to total employment, the broad agricultural sector continues to be a fundamental sector of the Cyprus economy, both with respect to the production of essential food items for the population and exports and with respect to the employment of thousands of rural residents and the containment of depopulation in the villages. During the period 1960-1974, the agricultural sector expanded rapidly, but in 1974 it was severely affected by the Turkish invasion and occupation of a part of Cyprus. The Turkish forces occupied and displaced the non-Turkish population from an area which accounted for 46% of crop production and much higher percentages of citrus (79%), cereals (6%), tobacco (100%), carobs (86%) and green fodders (65%), while 47% of livestock production also emanated from the area.

Despite the population concentration in the less productive part of the island, it was possible through concerted efforts and heavy investment in land improvement and irrigation to reactivate the agricultural sector and to approach pre-1974 production levels. Nevertheless, the occupation of a great part of Cyprus still causes problems in the agricultural sector, particularly with respect to the difficulties faced by displaced farmers, the shortages of fodders, the rational development of water resources, the spread of plant and animal diseases and many others. Cyprus agriculture may be divided into two major sub-sectors, namely crop and livestock production which, in 2000 contributed 49% and 43% respectively to the value, added of the broad agricultural sector. The contribution of the fishing sub-sectors was 5% and other agricultural activities contributed another 3% (CyStat website, 2004). According to results of the 2003 Census of Agriculture, the area of utilised agricultural land is about 1,560km^2 while about 410km^2 are unutilised agricultural land, wooded areas etc. In 1985, about 1,630km^2 were utilised agricultural land and 490km^2 were unutilised agricultural land (CyStat website, 2004).

Table 28: *Contribution of agriculture to Gross Domestic Product (GDP) and employment. (CyStat website, 2003).*

Year	Total	GDP from Agriculture		Total GEP	Employment in Agriculture	
	(£ million*)	(£ million*)	% of total	(000´s persons)	(000´s persons)	%of total
1960	91.6	14.7	16.0	218.2	94.8	40.3
1970	226.6	35.5	15.7	252.0	96.2	35.7
1980	732.1	72.9	10.0	188.0	36.9	16.8
1990	2,422.0	175.3	7.2	253.6	34.8	12.6
1991	2,576.1	165.6	6.4	255.2	32.1	11.5
1992	2,945.1	177.6	6.0	266.8	32.3	11.3
1993	3,063.3	183.8	6.0	267.1	31.5	11.0
1994	3,336.4	177.8	5.3	272.0	30.1	10.2
1995	3,627.3	199.5	5.5	301.0	30.4	10.1
1996	3,857.1	189.0	4.9	306.1	30.0	9.8
1997	4,369.3	178.5	4.6	267	26.2	9.1
1998	4,693.7	167.1	4.3	266	26.1	9.0
1999	5,015.7	188.2	4.4	261	25.6	8.2
2000	5,486.9	191.4	4.3	257	25.2	8.3
2001	5,869.2	184.1	3.8			
2002	6,229.3	207.8				

**1 C£ = 1.74 € (year 2000).*

Fisheries

Fish production is mainly derived from inshore and the trawl fishery as well as from aquaculture. Major activities include development of marine aquaculture which is pursued in Cyprus through open sea cage culture. By 1996, three private marine fish hatcheries and one shrimps hatchery - barm on land were in operation as well as eight private offshore cage farms. In 1996 the production of market size fish reached 675 tons valued at about C£ 3 million (€ 5.2 millions). In addition, 6.7 million marine fish fry were produced in 1996, out of which about 3 million, valued at about C£ 500,000 (€ 865,000) were exported. In 1996 the Trout production was 105 tons.

Mining

Irrigated agriculture and mining were the two most significant sectors in the economy of the island the first two decades after its independence in 1960. The mining industry declined because of the exhaustion of its mineral deposits of copper, chromite and the international pressure regarding the prohibition of use of asbestos.

1.7.2.3.2 Secondary sector

The secondary working sector includes the subsectors manufacturing, construction and energy.

Manufacturing

During 2002 the manufacturing sector remained at about the same level as in 2001 due mainly to domestic demand and the fact that there had not been an increase in exports of manufactured products. Value added of the sector increased by 0.5% in real terms compared to decrease of 0.2% in 2001. Food, beverages and tobacco, which are traditionally the largest group and contributed 38.8% to the manufacturing value added in 2002, registered a 1.0% increase in volume of production. This was mainly due to the increase of domestic demand. The contribution of other non-metallic mineral products to the manufacturing value added increased to C£ 66.5 million (€115 million) compared to C£ 62.2 million (€ 107.6 million) in 2001. This enabled the sub-sector to become the second largest group in the manufacturing sector. The price index of domestically produced manufactured goods rose by 1.9% over 2001, compared to a 2.0% rise in the previous year. This is attributed to an increase of 2.6% in local market prices and decrease 3.3% in export prices. Industrial exports rose from C£ 187.2 million (€323.9 million] in 2001 to C£ 191.6 million (€331.5 million) in 2002. Exports to European Union countries rose to 48.0% in 2002 from 39.3% in 1987 and 26.6% in 1982, while the share absorbed by Arab countries fell to 25.6% in 2002 from 45.1% in 1987 and 62.2% in 1982. Expenditure on fixed assets in the sector rose to C£ 75.4 million (€130.4 million) during 2002 compared to C £97.2 million (€168.2 million) in 2001. Machinery and equipment accounted for 64.6% of total investment, new buildings and works for 22.5% and transport equipment for the remaining 12.9%.

Energy

During 2002 there was an increase in the rate of economic growth in this sector, estimated at 10.2%, compared to 8.9% in 2001. Generation, transmission and distribution of electric energy, is by far the most important industry of the sector and in 2002 contributed 81.4% to the sectoral value added. Sales of electricity rose by 8.8% to 3,401.1 million kWh in 2002 from 3,124.8 million kWh in 2001. The highest increases were recorded in the consumption by electricity, gas and water wholesaling and retailing. In the manufacturing sector, the largest increases in the usage of electricity were recorded in the food and metal producing industries. Decreases were observed in the textile industry. Consumption of electricity by households rose by 11.0%, for public lighting by 2.7% and for water pumping purposes by 9.0%.

1.7.2.3.3 Tertiary Sector

The tertiary sector includes banking, tourism and trade.

Tourism

Table 29: *Revenue estimates from tourism, (CyStat website, 2003).*

Period	Arrivals of Tourists	Revenue [C£]	Arrivals of Tourists	Revenue
January-December 2001	2,696,732	1,271,630,043	% Change 2002/2001	
			-10.33	-10.96
January-December 2002	2,418,238	1,132,321,229	% Change 2003/2002	
			-4.76	-10.6
January-December 2003	2,303,245	1,015,028,241		

**1C£ = 1.74€ (year 2000).*

As a result of the strenuous efforts exerted by the Cyprus Tourism Organisation, the support given by the Government through various policy measures, and the entrepreneurial spirit of the Cypriot tourism professionals, tourist traffic to Cyprus began to increase once again after 1974. The number of long-stay visitors increased from 47,085 in 1975 to 827,987 in 1986 and by 1988 surpassed the 1 million mark reaching the record level of 1,111,818 tourists. Tourist arrivals continued to increase until 1991, the year of the Gulf crisis, as a result of which the number of long-stay visitors decreased compared to 1990 by 11.3%. In 1992 tourist arrivals reached the level of 1,991,000 reflecting the intense and timely efforts of the Government and the CTO in the form of additional advertising and PR and significant support to foreign tour operators. During 1993 arrivals dropped to 1,841,000 as a result of the economic recession in many European countries, foreign exchange fluctuations and the non-competitive pricing of Cyprus´ accommodation product. Tourist arrivals reached the level of 1,950,000 in 1996, 2,088,000 in 1997 and 2,222,000 in 1998. In 2000 the number of tourists reached 2.7 million, with a decline to 2.3 million up to 2003. The major share of tourist traffic to Cyprus originates from Central and Northern Europe. In 1998 the United Kingdom remained the major source of tourist traffic followed by Germany and Central Europe. Compared to 1997, there was an increase in tourist traffic from the UK, the Nordic Countries, Greece, Holland, Italy and a decrease from Germany, France, Russia and Switzerland in 1998. The contribution of tourism to the country's economy is of vital importance. In 1998 the total revenue reached C£ 879 million (€1,521 million) which represents 20% of the Gross Domestic Product (GDP). In addition 40,000 jobs are directly or indirectly related to tourism. Cyprus tourism is largely based on hotel capacity in the coastal areas. Following the reactivation of tourism, the hotel capacity of the coastal resorts, mainly that of the Ammochostos and Paphos area has experienced a great boom. On the other hand the hotel capacity of the Nicosia area and the hill resorts havechanged very little. Despite the great increase in hotel capacity, the total number of beds in the Government controlled areas first surpassed the bed capacity level of 1973 of the entire island in 1981.

Trade

Due to its small domestic market and the open nature of its economy, Cyprus considers access to international markets of utmost importance. As a result, trade has always been one of the main sectors of Cyprus´ economy, contributing considerably to the economic growth of the island. During 2002 exports accounted for about 8% of the country's GDP.

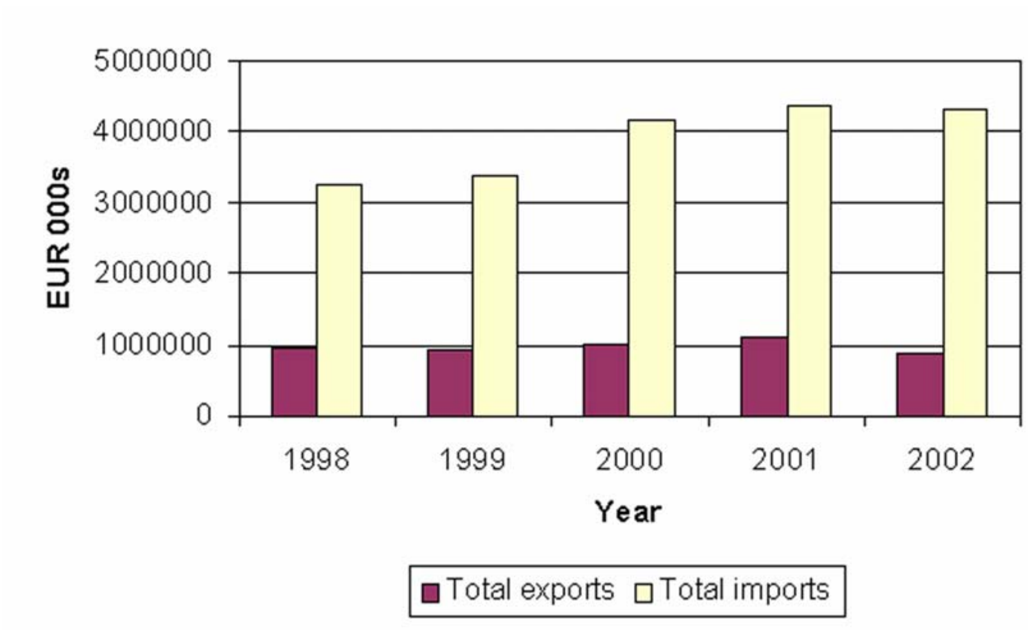

Figure 17: *Cyprus external trade 1998-2002, (CyStat website, 2004).*

The value of the foreign trade of Cyprus was C£ 2,998 million in 2002, experiencing a decrease of 5% from the previous year. This development was mainly due to the decrease in re-exports, which declined by 26.6% reaching in 2002 C£ 280 million, in comparison with C£ 381 million in 2001. Domestic exports also decreased, by 6.2%, falling to C£ 232 million in 2002 from C£ 247 million in 2001.

Table 30: *Cyprus external trade 1998-2002, (CyStat website, 2004).*

thousands C£*	1998	1999	2000	2001	2002	2001-2002 Change %
Domestic exports(1)	221,337	215,212	240,762	246,990	231,604	-6.2
Re-exports (2)	329,797	327,707	351,102	381,039	279,674	-26.6
Total exports	551,134	542,919	591,864	628,029	511,277	-18.6
Total imports	1, 904,710	1,970,905	2,401,926	2, 528,720	2, 486,612	-1.7
Total trade	**2,455,844**	**2,513,824**	**2,993,790**	**3, 156,749**	**2, 997,889**	**-5**

**1 C£ = 1.74 € (Year 2000)*
(1) Including ship stores of domestic produce.
(2)Including ship stores of foreign produce.
(3) Because of rounding there may be slight discrepancies between the totals shown and the sum of constituent items.

Total imports

Total imports in 2002 reached C£ 2,487 million (€4,302.5 million], compared to C£ 2,529 million (€4,375.2 million) in 2001, showing thus a decrease of 1.7%.

Imports by economic destination, (group of products)

Imports of intermediate inputs (raw materials) and consumer goods make up for most of the total imports, accounting for 29.2% and 28.7% of the total imports, respectively. They are followed by transport equipment (16.0%), fuels and lubricants (10.8%), and capital goods (9.9%). In 2002, imports of raw materials (intermediate inputs) reached C£ 725 million (€1,254.3 million) in comparison with C£ 737 million (€1,275 million) in the previous year. The overwhelming majority of the 2002 imports of intermediate inputs were raw materials for the manufacturing sector. Imports of consumer goods declined to C£ 713.6 million (€1,234.5 million), compared to C£ 793.2 million (€1,372.2 million) in the previous year. Imports of capital goods also decreased falling to C£ 246.8 million (€427 million) from C£ 269.6 million (€ 466.4 million) in 2001. Imports of transport equipment and parts increased and reached C£ 397.2 million in 2002 compared to C£ 329 million in 2001. Passenger motor vehicles accounted for nearly half of the total transport equipment imports, followed by motor vehicles for the transport of goods and parts for transport equipment. Finally, imports of fuels and lubricants declined to C£ 269.7 million from C£ 302.5 million in 2001.

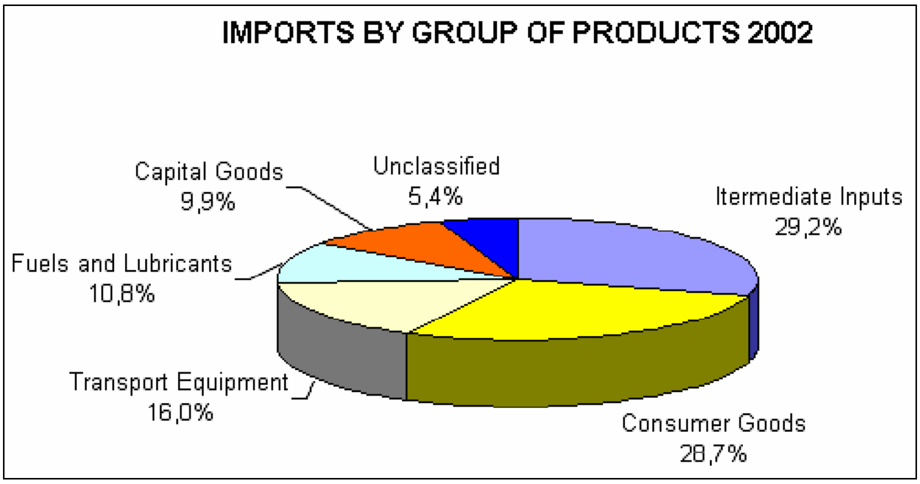

Figure 18: *Imports by group of products 2002, (Ministry of Commerce, Industry and Tourism/ Department of Trade).*

Domestic exports

During 2002 domestic exports reached C£ 231.6 million, representing a decrease of about 6.2% compared to the previous year.

Table 31: *Total imports by group of products 1998-2002, (Ministry of Commerce, Industry and Tourism and Department of Trade website, 2004).*

thousands C£	**1998**	**1999**	**2000**	**2001**	**2002**	**%**
Intermediate inputs	655,689	611,385	710,257	736,688	725,019	29.2
Consumer goods	650,679	689,089	793,111	793,223	713,567	28.7
Transport equipment	245,150	251,713	302,433	328,866	397,201	16
Fuels and lubricants	125,826	173,532	310,252	302,471	269,697	10.8
Capital goods	213,116	199,684	254,771	269,550	246,830	9.9
Unclassified	14,254	45,506	31,106	97,922	134,298	5.4
Total imports	**1,904,714**	**1,970,909**	**2,401,930**	**2,528,720**	**2,486,612**	**100**

**1 C£ = 1.74 € (Year 2000).*

Exports by broad economic sector (group of products)

Exports of manufactured products, which constitute the bulk of Cyprus' domestic exports with a 63.8% share in 2002, decreased to C£ 141.6 million from C£ 150.5 million in 2001. Domestic exports of raw agricultural products also decreased, reaching C£ 36.9 million compared to C£ 43.8 million in 2001, representing 16.6% of domestic exports. Exports of processed agricultural products increased reaching C£ 33 million representing 14.8% of the total.

Table 32: *Domestic exports (not including ship stores) by group of products 1998-2002, (CyStat website, 2004).*

thousands C£	1998	1999	2000	2001	2002	%
Manufactured products	137,676	133,000	148,815	150,452	141,574	63.8
Raw agricultural products	40,501	36,490	34,392	43,799	36,881	16.6
Processed agricultural products	24,449	25,347	28,229	28,030	32,932	14.8
Processed minerals	8,963	9,448	10,795	9,697	7,397	3.3
Minerals (raw materials)	1,473	2,018	1,562	1,882	3,076	1.4
Unclassified	99	225	165	84	58	0
Total domestic exports	**213,161**	**206,528**	**223,958**	**233,944**	**221,918**	**100**

**1 C£ = 1.74 € (Year 2000).*

Exports of Manufactured Products

Exports of manufactured products (i.e. industrial manufactured products) constitute the bulk of Cyprus' domestic exports representing 63.8% of the total exports in 2002. In 2002 they decreased to C£ 141.6 million, compared to C£ 150.5 million in 2001.

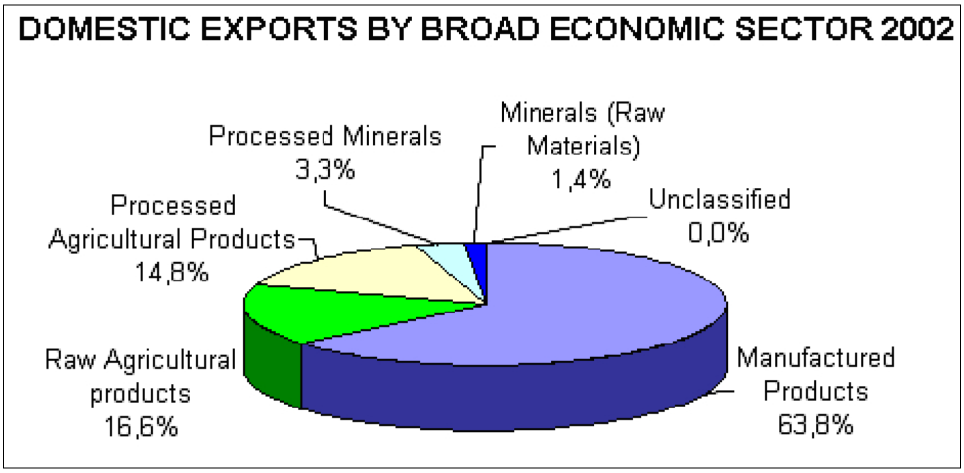

Figure 19: *Domestic exports by broad economic sector 2002, (Ministry of Commerce, Industry and Tourism and Department of Trade website, 2004).*

The most important products exported during 2002 were pharmaceuticals (C£ 43.1 million), clothing (C£ 16 million), cement (C£ 8.8 million), plastic products (C£ 6.3 million), furniture (C£ 5.9 million), paper products (C£ 5.5 million) and cigarettes (C£ 4.6 million).

Table 33: *Domestic exports (not including ship stores) of major manufactured products 1998-2002, (Ministry of Commerce, Industry and Tourism/Department of Trade website, 2004).*

Product	1998	1999	2000	2001	2002
Pharmaceutical products	20,281	25,166	30,859	39,411	43,107
Clothing	29,031	22,750	22,456	19,699	15,994
Cement	8,970	7,788	10,811	8,396	8,796
Plastic products	4,157	3,775	3,900	4,040	6,246
Furniture	7,388	6,693	7,862	6,828	5,922
Paper products	4,974	3,937	4,787	5,955	5,532
Cigarettes	12,179	14,051	16,192	10,767	4,545
Perfumery and cosmetics	2,859	2,214	2,445	3,370	3,586
Fats and oils	3,227	2,370	2,783	2,056	3,180
Footwear	8,357	7,089	6,126	3,849	3,174
Aluminium products	1,555	2,332	3,071	2,797	2,775
Water pumps	2,305	2,287	3,169	2,829	2,382
Refrigerators	1,712	1,762	1,987	2,774	1,946
Brooms brushes mops etc.	1,214	1,105	1,331	1,337	1,381
Filters for motor vehicles	1,139	957	1,035	1,163	1,243
Lighting fixtures and fittings	2,141	2,512	1,834	1,351	1,192
Electric accumulators	1,147	1,072	871	1,143	1,171
Other	25,040	25,140	27,296	32,687	29,402
Total	**137,676**	**133,000**	**148,815**	**150,452**	**141,574**

Values in thousands C£, 1 C£ = 1.74 € (Year 2000).

Exports of agricultural products

In 2002 exports of raw and processed agricultural products accounted for 16.6% and 14.8% of the total domestic exports, respectively. Exports of raw agricultural products decreased to C£ 36.9 million from C£ 43.8 million in 2001. Citrus fruit and potatoes were the most important products, with exports valued at C£ 18.3 million and C£ 11.1 million respectively. Yet exports of processed agricultural products increased during 2002 to

C£ 33 million from C£ 28 million in 2001. Halloumi cheese, wines, fruit and vegetable juices are the main products included in this group.

Table 34: *Domestic exports (excl. ship stores) of major agricultural products 1998-2002, (Ministry of Commerce, Industry and Tourism/Department of Trade website, 2004).*

thousands C£	**1998**	**1999**	**2000**	**2001**	**2002**
Raw agricultural products	40,501	36,490	34,392	43,799	36,881
Citrus fruit	12,731	13,838	12,785	14,718	18,304
Fresh grapes	2,458	1,732	1,565	1,506	561
Melons and watermelons	35	73	109	149	341
Potatoes	18,998	14,034	12,328	17,511	11,104
Okra	101	142	135	264	397
Beetroot	229	270	261	222	37
Other vegetables (fresh frozen or dried)	2,946	3,162	3,175	4,183	3,763
Live fish	845	1,460	1,682	1,978	2
Other	2,158	1,779	2,352	3,268	2,372
Industrial pr. of agricultural origin	24,449	25,347	28,229	28,030	32,932
Halloumi cheese	5,438	6,053	7,564	7,663	10,946
Cheese (not incl. halloumi cheese)	1,274	1,190	1,153	895	1,151
Wines	6,786	7,292	6,232	5,333	5,126
Fruit and vegetable juices	3,115	2,911	3,500	4,052	4,667
Meat (not incl. meat of quails)	2,675	2,513	3,240	2,880	4,523
Raw Hides and skins	839	778	1,281	2,040	1,281
Preserved fruit	1,548	1,539	1,531	944	937
Other	2,774	3,071	3,728	4,223	4,301
Total	**64,950**	**61,837**	**62,621**	**71,829**	**69,813**

**1 C£ = 1.74 € (Year 2000).*

Re-exports

A significant share in foreign exchange earnings comes from re-exports which in 2002 reached C£ 280 million. The bulk of these re-exports was directed mainly towards the countries of the European Union and the Arab countries. Re-exports to Central and Eastern European countries were also significant. The main products involved are tobacco and alcoholic beverages.

1.8 Summary

Table 35: Summary table.

Natural water conditions and infrastructure	***Regional context***	Area	9,251km^2 (5,760km^2 under Govmnt. control)
		Climate Type	Mediterranean (Csa): All mountainous areas, western & southwestern coast. Subtropical Steppe (BSh): Central plain, the Southeast.
		Aridity Index	0.3 – 0.5 (semi-arid) in lowlands 0.5 – 0.55 (sub-humid) in Troodos Mountains
		Permanent Population	689565 (Census 2001, area under Govmnt. control)
		Tourists (arrivals)	2.7 million (2001)
	Water availability	Precipitation (mean) Max. Min. 1971-2000 (mean)	 550mm 462mm 467mm
		Total Water Resources/Availability	370Mm^3
		Water resources •Surface water •Groundwater •Storage/dams/reservoirs •Desalination	235.0Mm^3 135.0Mm^3 127.0Mm^3 33.5Mm^3
		Water availability per capita and year	537m^3
		Resources to population index	
		Water availability per capita May-September October-April	} 537m^3
	Water quality	Quality of surface water	Very good
		Quality of groundwater	Very good
		Quality of coastal water	
	Water supply	Supply coming from: • Groundwater • Surface water • Desalination • Recycling	265.9Mm^3 100.0% 127.4Mm^3 47.0% 101.5Mm^3 38.2% 33.5Mm^3 12.6% 3.5Mm^3 1.3%
		Network coverage: • Domestic • Irrigation • Sewerage	 good good good

Table 35 continued.

Economic and social system agriculture and tourism	***Water use***	Water consumption by category: • Domestic • Tourism • Irrigation • Animal Husbandry • Industrial • Amenities & Environment	**$224.3Mm^3$ 100%** $42.7Mm^3$ 19% $11.3Mm^3$ 5% $148.2Mm^3$ 66% $6.8Mm^3$ 3% $2.8Mm^3$ 1% $12.5Mm^3$ 6%
		Water consumption For **domestic** coming from • Groundwater • Surface water • Desalination • Springs	**$42.7Mm^3$ 19.0%** $12.3Mm^3$ 28.8% $9.2Mm^3$ 21.5% $21.2Mm^3$ 49.7% Incl. in groundwater
		For **tourism** coming from • Groundwater • Surface water • Desalination	**$11.3Mm^3$ 5.0%** $3.3Mm^3$ 29.2% $2.4Mm^3$ 21.2% $5.6Mm^3$ 49.6%
		For **irrigation** coming from • Groundwater • Surface water • Desalination • Recycling	**$148.2Mm^3$ 66.0%** $76.8Mm^3$ 51.8% $69.7Mm^3$ 47.0% $0Mm^3$ 0.0% $1.7Mm^3$ 1.2%
		For **animal husbandry** coming from • Groundwater • Surface water • Desalination • Recycling	**$6.8Mm^3$ 3%** $6.8Mm^3$ 100% $0.0Mm^3$ 0% $0.0Mm^3$ 0%
		For **industry** coming from • Groundwater • Surface water • Desalination • Recycling • Importing	**$2.8Mm^3$ 1%** 2.8Mm 100% - - -
	Water demand	Water Demand trends	Increasing/decreasing
		Consumption index	Increasing
	Agricultural issues	Area used	1560km² (2003 census)
		Irrigated area	359km² (2003 census)

Table 35 continued.			
Economic and social system agriculture and tourism	***Agricultural issues***	Cultivated crop types (per area)	Permanent/annual
		Irrigation methods	Drip irrigation, mini sprinklers
		Water used for irrigation (per area)	-
		Water demand per crop and area	-
		Fertiliser used - average	Year 2000: C£9755 million*
		Pesticides used - average	Year 2000: C£8.43 million*
	Social and economic situation	Unemployment rate	3.4% (2000)
		Employees in agriculture tourist sector other sectors	22800 (2003), i.e. 7.3% of GEP 31900 (2003) 261300 (2003)
		Importance of water scarcity	Very important
	Pricing system	Average household budget for domestic water (pa)	C£60*
		Average household budget for agricultural water	Year 2000 purchase from Government schemes C£1.6 million*
		Average household income	
		Contribution of agriculture to island economy	3.7% (2003)
		Water prices	Irrigation C£ 0.06*/m^3 Domestic C£ 0.70*/m^3
		Energy prices for used water technology	Year 2000 fuel C£ 1.958 million* electricity C£ 4005 million*
		Cost recovery	low
		Price elasticity	Groundwater : low, cheaper than surface water
	Social capacity building	Public participation in decisions	medium
		Public education on water conservation issues	medium
		Acceptability in using treated waste water	high
Decision making process	***Water resources management***	Water ownership	State Government
		Decision making level (municipal, regional, national) regarding: Water supply for each sector Water resources allocation for each sector	national national national
	Water policy	Local economy basis	important
		Development priorities	Very important

**1 C£ = 1.74 € (Year 2000).*

1.9 Conclusions

The eastern Mediterranean and Cyprus have going through a period of climatological changes characterised by a slight increase of temperature and a considerable decrease of annual precipitation by 15-25%. The annual precipitation has principally decreased in the lowlands of the island and is now around 300mm. Even more significant are the inter-annual rainfall variations and the situation becomes critical in periods of drought lasting for three or more consecutive years. It is difficult to prove if these changes result from global climatic changes and if this period will end in the foreseeable future and if precipitations will increase again to the pre-1970 levels. The decrease in precipitation has reduced the renewable water resources of the island, the flow of rivers have decreased considerably, particularly in the summer and the average inflow to the dams has annually decreased by 40% to 127Mm^3.

Most of the aquifers are overpumped, seawater intrusion has occurred in all coastal aquifers resulting in a lowering of the water table throughout most of the island. With the depletion of its aquifers Cyprus has lost its immunity to the vagaries of weather because they cannot satisfy the increasing water demand in periods of drought any more. Uncontrolled extraction has lead to scarcity and uneconomic solutions. About 48% of the water used in Cyprus is still groundwater and most aquifers are mined. In some aquifers there has been an alarming increase of their nitrate and boron content. Extensive irrigation from surface reservoirs has brought about increase in soil salts which is expected to cause soil deterioration.

With the extensive construction of dams the demand for surface and groundwater has increased considerably and is much higher than the renewable water resources of the island are able to supply. The possibilities of increasing the supply of conventional water are rather limited and expensive. The supply of incremental non-conventional water by desalination is limited by the high costs and is thus applicable only to domestic water. The biggest consumer of water is the agricultural sector and the return from many irrigated crops does not cover the actual costs of the water used. The average selling price of groundwater is 5 times lower than the actual cost of water from dams and 10 times lower than the price for water from desalination plants.

Thanks to the Troodos mountains Cyprus has sufficient renewable water resources, provided every effort is made to perfect the management of demand of this essential natural resource. Sustainable development is based on a permanent supply of good quality water that has to be used prudently. Uncontrolled water demand leads to scarcity and uneconomic solutions usually detrimental to the environment.

The importance of the water scarcity problem, as compared to other national problems, rates second after the political problem, but in periods of drought, such as that of 1995-2000 it becomes a first range problem. During this period there was a rationing of water allocation for conservation purposes both, for domestic and irrigation water. In the capital and other major cities, domestic supply was reduced to 12 hours every 48 hours. At the same time water was allocated for irrigation of citrus and deciduous that could theoretically fully satisfy the domestic water needs for 1.7 million people. But the pressure for more water came from the owners of irrigated land.

In view of the problematic scarcity of water in Cyprus, which is expected to be further exacerbated by the continuing decrease of the annual precipitation in the area of the eastern Mediterranean, it is indispensable to reconsider the national water policy of the island in order to ensure the sustainability of its water resources, economic development, quality of life and natural environment. Cyprus is a unique case in the MEDIS-Project because it is the only independent country among all participating Mediterranean islands. The ground and surface waters, according to the country's constitution and legislation, are vested to the state. The Government of the island has the power to manage water resources and can determine any objectives, strategy options and measures in a redefined national water policy. For the success of the new water policy the objectives and strategy options must be analysed and justified technically, economically and socially with the maximum possible involvement of all consumers and non-governmental organisations in the processes of decision-making. The accession of Cyprus to the European Union and the imminent solution of its long lasting political problem will produce new socio-political developments that will call for more for political decisions regarding the water policy of Cyprus.

For the improvement of water management a redefined new water policy is essential with targets such as the balancing of the water supply and demand, investigating on the basis of technical, economic and well thought socio-political criteria all possible ways to increase the water supply, ensure efficient use of available water and modify the current water allocation matrix. It is also essential to gradually build up groundwater strategic reserves and to protect and enhance the quality of water. These targets can be accomplished through the establishment of a new water entity under one ministry only, which will introduce effective water management procedures. The objectives of the new water entity would be to secure a balance between supply and demand which will be sustainable over time and at the least possible cost, to increase water tariffs for all uses, to use recycled water for amenity purposes, irrigation and artificial recharge, to change current cropping patterns to less water demanding crops and high value in use of water and to reduce the horizontal expansion of irrigated land.

In Cyprus farmers, gardeners, inhabitants and tourists alike need to think carefully how they use, and often waste, this precious and limited resource and how they could easily help to conserve it. Like good health we ignore good quality water when we have it. But like health, when water is threatened in periods of drought and scarcity, it is the only thing that matters. Good quality water is the blood of our land, the nourishment of our forests and crops and the beauty of our environment and should remain a constant concern for all the residents of Cyprus to ensure sustainable development and quality of life.

Chapter II: Selection of a representative catchment

For the MEDIS-Project in Cyprus the catchment area of the Kouris River has been selected as it is considered to be the most representative catchment. Its geomorphology is typical for Cyprus, with elevations ranging from less than 200m in the coastal area to over 1800m in its upper parts (figure 20). It is characterised by an uneven distribution of precipitation from less than 300mm in the coastal area to more than 1,000mm in its highest parts (figure 21) resulting in quite an uneven distribution of water resources. Most water from the water-rich areas was naturally transported to the coastal areas, replenishing the Akrotiri aquifer with a considerable amount of losses to the sea.

The Kouris Dam was constructed to tapp this water. It has a storage capacity of 115Mm^3 (WDD, 2001), more than one third of the total storage capacity of all dams of Cyprus; its annual inflow was estimated at 46.3Mm^3 (Design inflow). The observed decrease by 13% of the precipitation in the catchment after 1970 reduced the average annual inflow to the dam to 30Mm^3 (Rossel, 2002). To increase the inflow, the Arminou Dam was constructed and through a 14km long diversion tunnel (figure 20) water is transported from the water-rich headwaters of the Dhiarizos River to the Kouris Dam. Farmers and inhabitants of the Dhiarizos valley opposed this decision strongly and the final decision was to transport water of floods only which would otherwise be lost to the sea.

With the Southern Conveyor that is more than 100km long, water from the Kouris Dam is transferred to water-poor areas of the southern and southeastern parts of the island (figure 8) for irrigation and domestic supply. For better water management the dams of Yermasoyia, Kalavasos, Dhypotamos and Lefkara were connected with the Southern Conveyor and now form an Integrated Scheme of the Southern Conveyor (ISSC) with a total water storage capacity of 170Mm^3. The ISSC supplies a number of irrigated areas with water (figure 8) which contribute considerably to the gross agricultural production of the island. It also supplies domestic water for the cities of Limassol, Larnaca, Nicosia and the tourist areas of Paralimni-Ayia Napa.

Most of the coastal aquifers in southern and southeastern Cyprus are depleted. The Akrotiri aquifer is overpumped and suffers from seawater intrusion (figure 20). Because of its importance, the extraction of water is now strictly monitored and the aquifer is artificially recharged with water from the Kouris and Yermasoyia Dams; it is planned to recharge with tertiary treated recycled water in the near future. The water is re-pumped from the aquifer for irrigation and domestic water supply. The annual water resources of the ISSC increased with the addition of 30Mm^3 of desalinated water and 5Mm^3 of tertiary treated recycled water.

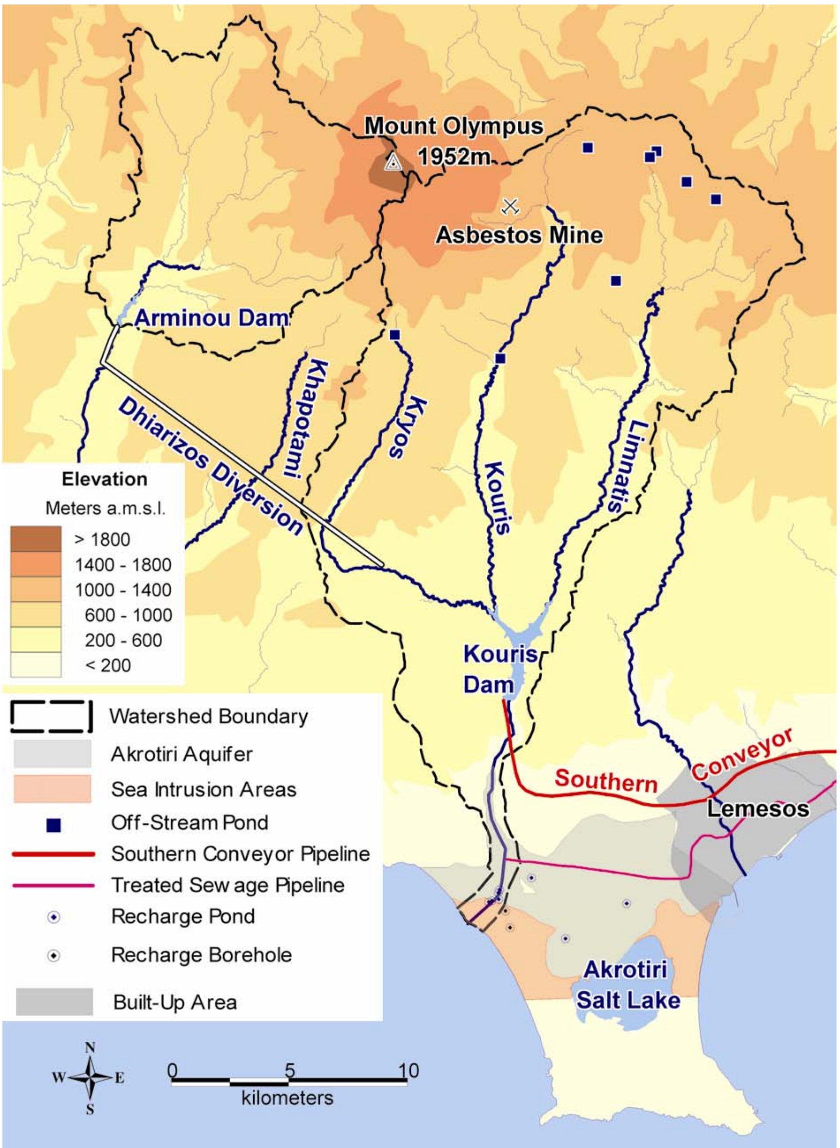

Figure 20: *Variation of elevation in the Kouris and Arminou catchments.*

In the Kouris catchment and the ISSC area, only a very small proportion of water used comes from non-governmental schemes. For the year 2002 the total resources of the ISSC were estimated at 173.9Mm^3. The main source of this water is reservoir water (126.2Mm^3) followed by desalinated water (30Mm^3) and groundwater (13.7Mm^3). The total demand for this year is 112.85Mm^3, the share of irrigation being 57.5Mm^3 and of domestic supply 55.35Mm^3. About 5Mm^3 from the Kouris Dam and 4Mm^3 of recycled water will be used for the artificial recharge of the Akrotiri aquifer. About 78.2Mm^3 will remain stored in the dams to guarantee safe supply for the year 2003. The Kouris catchment and the ISSC are typical examples of uneven distribution of water resources and water demand. The water-rich area is the mountainous area, in which the water demand is less than the available water. The excess is naturally transported with rivers to the coastal areas where water resources are limited and the demand is very high. The Kouris catchment is also characterised by uneven population distribution, tourism and other economic activities. This results in an uneven regional development and standard of living. The mountainous areas which are less developed and show lower standards of living than the rest of the island, have been suffering also from the continuing reduction of their population. At the same time the water precipitating in the mountainous areas is used for the development of the water-poor coastal areas.

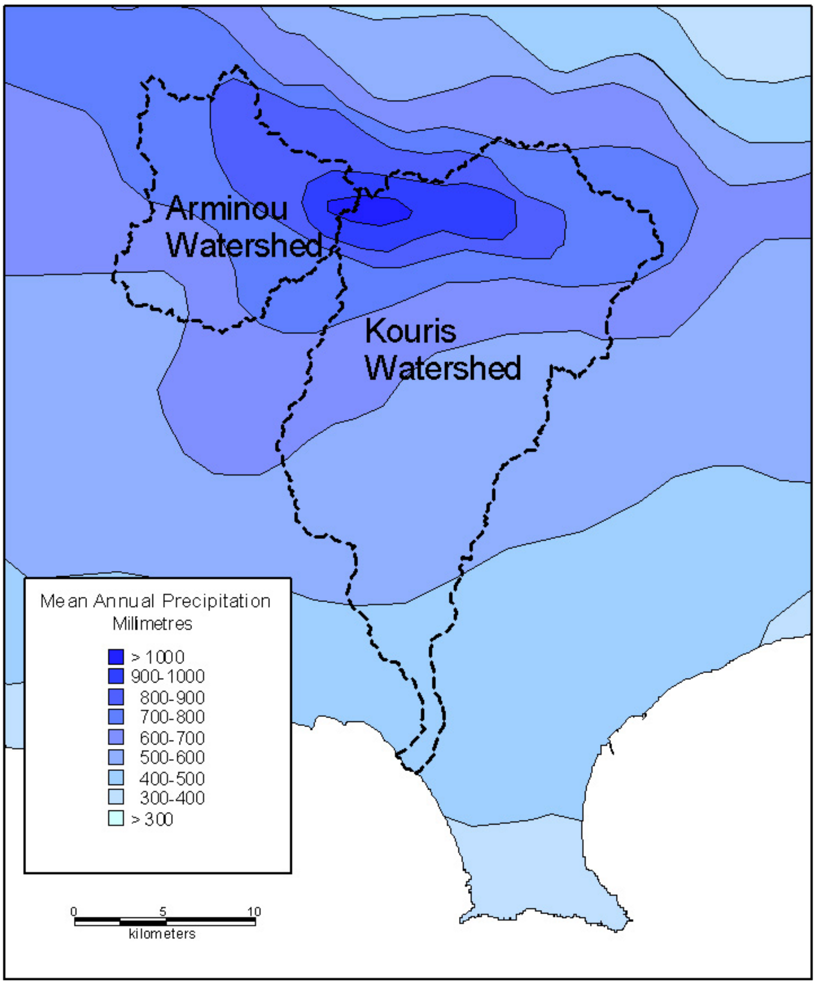

Figure.21: *Distribution of precipitation in the Kouris catchment. Timeseries: Oct. 1970 – Sept. 2000, (Georgiou, 2002).*

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