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Groundwater in the Southern Member States of the European Union: an assessment of current knowledge and future prospects

Country report for Greece

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Greece Groundwater Report

1. Introduction

Greece is a country in South-Eastern Europe, situated on the southern end of the Balkan Peninsula. It is bordered by Bulgaria, the Former Yugoslav Republic of Macedonia and Albania to the north and by Turkey to the east. The Aegean Sea lies to the east of mainland Greece, while the Ionian Sea lies to the west. Both are parts of the eastern Mediterranean basin.

The surface area of Greece is 130.100 km^2 of which 20% is distributed to its 3.000 islands, whereas, two thirds of the Greek territory is mountainous, making the country one of the most mountainous in Europe. Greece has the longest coastline in Europe with a total length exceeding 15.000 km of which 5% belongs to areas of unique ecological value. The national population reaches 11 million with a density of 84 inhabitants/ km^2 (one of the lowest densities in Europe). About one third of Greek population concentrates along the coastline (Lazarou, 2006).

Greece is dependent on groundwater resources for its water supply. The main aquifers are within carbonate rocks (karstic aquifers) and coarse grained Neogene and Quaternary deposits (porous aquifers). The use of groundwater resources has become particularly intensive in coastal areas during the last decades with the intense urbanization, touristic development and irrigated land expansion. Sources of groundwater pollution are

- the seawater intrusion due to overexploitation of coastal aquifers
- the fertilizers from agricultural activities and
- the disposal of wastewater.

Greece is characterized by long coastline that favors hydraulic communication between coastal aquifers and seawater, also a non homogeneous distribution of rainfalls and water resources. Water resources are characterized by high water requirements for agricultural and tourism during the dry period (April-late October) when water availability is low. Greece is 31st in top 50 countries with severe water stress. The major water use is in irrigation for agriculture; 86% of the total consumption. The irrigated land increased greatly in last decades, as indicated by the number of boreholes.

Water needs are mainly covered by groundwater abstracted from the aquifers via numerous wells and boreholes (approximately 300,000 for the whole of Greece). As a result, a negative water balance is established in the coastal aquifer systems triggering sea water intrusion which has negative consequences in the socioeconomic development of these areas. Many aquifer systems are reported to be affected by quality deterioration (salinisation and nitrate pollution) due to irrational management (Daskalaki, 2006).

2. Scope

The aim of this report is to give an overview of the current groundwater quality and quantity networks and monitoring procedures of Greece. The information for this overview was obtained through literature review. The following information and topics are included in this report:

- Groundwater resources
- Groundwater uses
- Pressures and measurements of groundwater
- Institutions for groundwater governance and potential measures to counteract pressures
- Conclusions and recommendations

3. Groundwater resources

Greece's climate consists of three types that influence well defined regions of its territory. Those are the Mediterranean, the Alpine and the Temperate types. The first one features mild, wet winters and hot, dry summers. The Aegean Islands and the south-eastern part of mainland Greece are mostly affected by this particular type. The Alpine type is dominant mainly in Western Greece. Finally the Temperate type affects central and north-eastern part of the country. Athens is located in a transitional area featuring both the Mediterranean and the Alpine types.

Carbonate rocks cover more than 35% of Greece and many of them are cropping out at the coast. The karstic aquifers in Greece can be divided in the following groups: i) Central Greece (i.e. South Parnassos and Ghiona aquifers) with brackish water because of seawater intrusion influence, ii) Parnitha-Pateras and Hymittos aquifers with karstic conduits 150 m below sea level, iii) Eastern Peloponnese (Tripolis and Argolis aquifers) with a high discharge of water to the sea from submarine springs and iv) Crete island with the famous Almyros springs that can discharge over 50 m^3/s (Lazarou, 2006).

In Greece, the mean annual surface run-off of mainland rivers is 35 billion cubic meters. More than 80% of the surface flows originates in eight major river basins: the Acheloos (Central Greece), Axios, Strimonas and Aliakmonas (Macedonia), Evros and Nestos (Thrace) and Arachtos and Kalamas (Epirus). Nine rivers flow over 100 kilometers within Greece. Four major rivers originate in neighboring countries: Evros (Turkey), Nestos and Strymonas (Bulgaria) and Axios (FYROM). Total inflow from upstream neighboring countries amounts to 12 billion cubic meters. Some 41 natural lakes (19 with an area over5 km^2) occupy more than 600.000 hectares or 0.5% of the country's total area. The largest are lakes Trichonida, Volvi and Vegoritida. Lake Prespa is on the borders with Albania and FYROM. The number of Greek wetlands according to the inventory of Greek Biotope/Wetland Centre (or EKBY by its Greek initials), rises to about 400 with 10 of them designated as Ramsar wetlands of international importance. The 14 artificial lakes (ten with an area over 5 km^2) occupy 26.000 hectares.

Some 80-85% of freshwater resources are in the form of surface water and the rest are groundwater. Per capita consumption of water is around 830 m^3 with peaks recorded during heat wave days and days of intensive snow fall.

The rainfall in Greece is variable in space, increasing from the south to the north, due to the change of climatic conditions varying from dryer and warmer to humid and cooler conditions because of the increase in latitude, and also increasing from the east to west due to the separation of the country to two different climatic unities, brought by the Pindos range and its extension to Peloponessos and Crete.

Western Greece accepts the majority of rainfalls, more than 1500mm/year, while Eastern Greece, along with the islands of Aegean and Crete, have considerably smaller rainfalls e.g. Attica's mean interannual precipitation is approximately 400 mm/year.

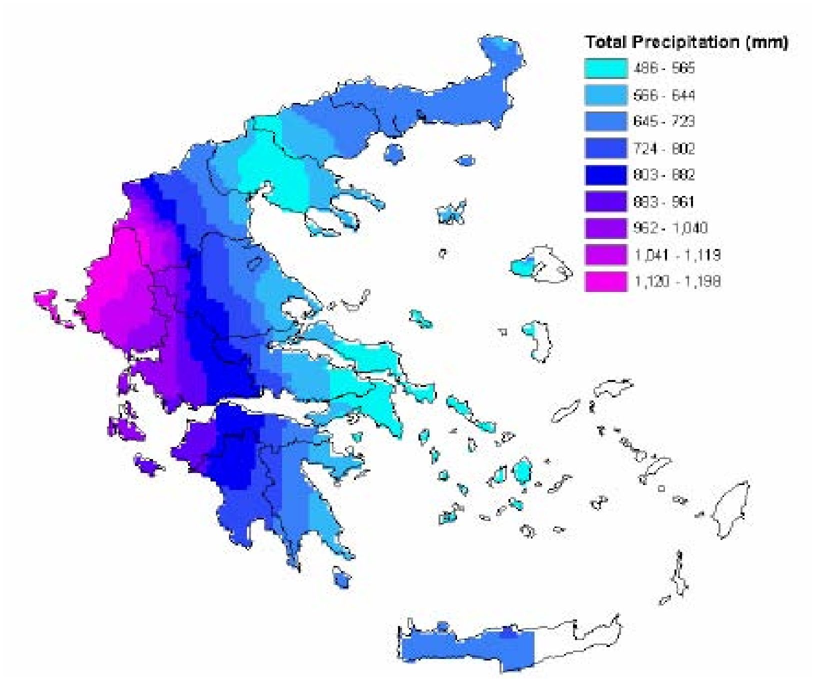


Figure 1. Distribution of total precipitation in Greece

The shortage of water (drought) in a region is not only related to the availability of the water resources, but also to the water utilization. Unfortunately, as previously mentioned, the major users of water in Greece are mainly located in the Eastern and Southern regions of the country, which is rather disadvantageous as compared to the natural enrichment.

As it results from Figure 2, Greece does not present a balanced scheme of water uses, as the rural usage takes the lion's share of 86% (Lazarou, 2006).

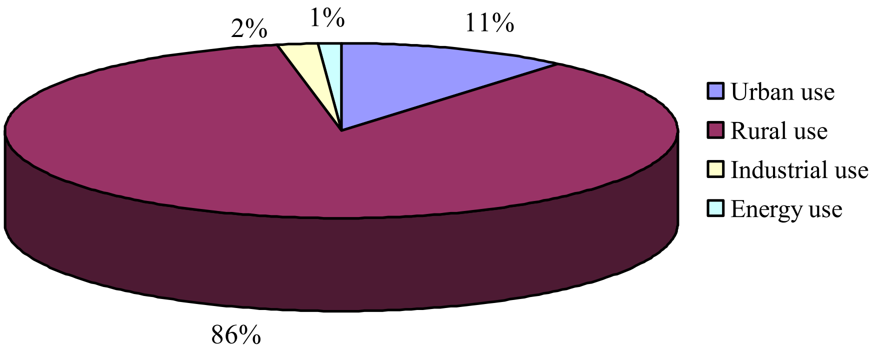


Figure 2. Water use in Greece

<u>Water regions of Greece</u>

According to water resources legislation (1739/87 for the management of water resources), Greece has been divided in 14 water regions as follows: West Peloponnese, North Peloponnese, East Peloponnese, West Central Greece, Epirus, Attiki, Central Greece and Evia, Thessaly, West Macedonia, Central Macedonia, East Macedonia, Thrace, Crete and Aegean Islands (Ministry of Development, 1987). The fourteen water regions of Greece are illustrated geographically in Figure 3.

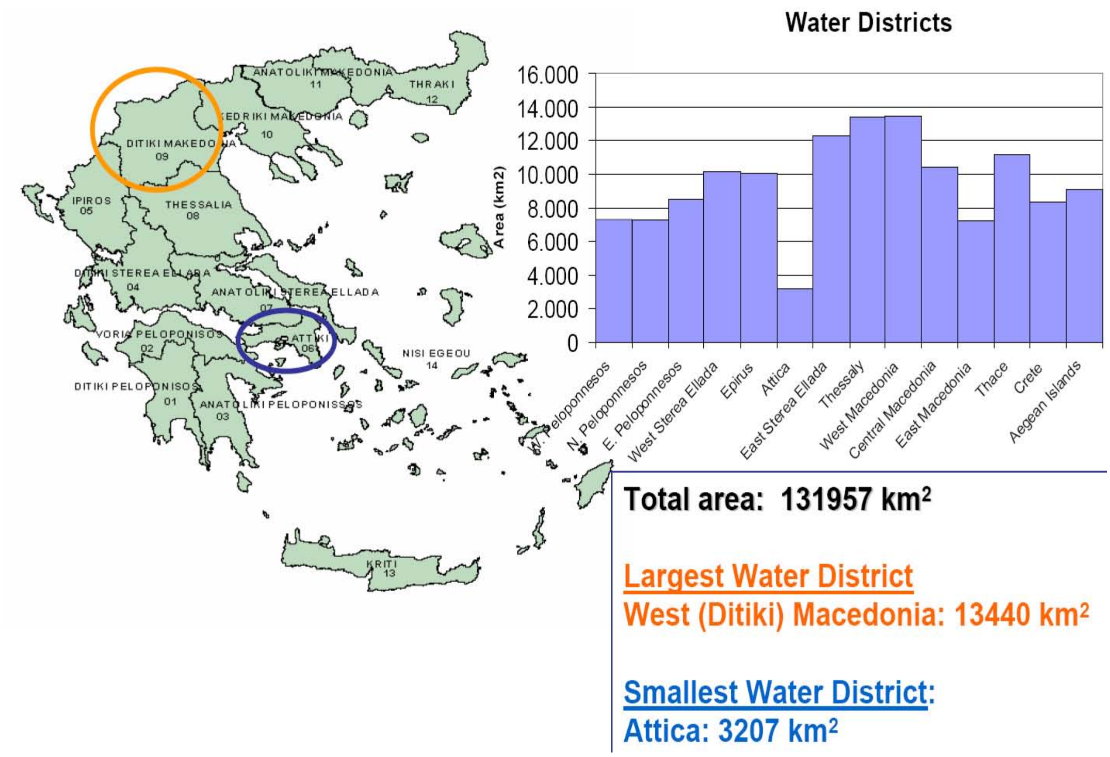


Figure 3. Greece 14 water regions

Groundwater renewable resources represent 13.9% of total renewable resources in Greece (table 1).

Groundwater abstractions in Greece can be seen in table 2. Groundwater withdrawals on renewable resources represent the 40.9% of total demand.

Table 1: Groundwater resources in Greece (EUWI/MED, 2006)

Country & Entities	Country & Entities	Date of estimation	Total renewable resources km^3/yr	Groundwater renewable resources km^3/yr	Groundwater renewable resources %	Exploitable groundwater renewable resources km^3/yr	Exploitable groundwater renewable resources %
ES	Spain	1997	111,5	29,9	26,8	4,5	4,0
FR	France	1994	189,5	100	52,8	30	15,8
IT	Italy	1990	191,3	43	22,5	13	6,8
MT	Malta	1995	0,06	0,027	45,0	0,015	25,0
SI	Slovenia	2002	31,87	13,5	42,4		
HR	Croatia	2002	71,4	11	15,4		
BA	Bosnia-Herzeg.	2002	37,5	6	16		
YU	Serbia-Monten.	2002	208,5	3	1,4		
MK	FYR Macedonia	2002	6,4	1	15,6		
AL	Albania	1995	41,7	6,2	14,9	2,45	5,9
GR	Greece	1990	74,25	10,3	13,9		
TR	Turkey	1998	231,7	69	29,8	12	5,2
CY	Cyprus	1998	0,78	0,41	52,6	0,2	25,6
SY	Syria	1993	26,26	5,4	20,6	3,8	14,5
LB	Lebanon	1998	4,8	3,2	66,7	0,685	14,3
IL	Israel	1994	1,67	1,075	64,4	1	59,9
GZ	Gaza Strip	1999	0,056	0,056	100,0	0,05	89,3
WB	West Bank	1999	0,75	0,68	90,7	0,54	72,0
EG	Egypt	2000	58,3	2,3	3,9		
LY	Libya	1998	0,82	0,5	61,0	0,5	61,0
TN	Tunisia	2000	4,57	1,55	33,9	1,15	25,2
DZ	Algeria	1994	14,32	1,73	12,1	1,7	11,9
MA	Morocco	1997	29	10	34,5	4	13,8
Total			1196	317	27	75,59	8

Table 2: Groundwater abstractions in Greece (EUWI/MED, 2006)

Country & Entities	Country & Entities	Total demand	Total groundwater withdrawals	Withdrawals partition to satisfy demands — Groundwater withdrawals on			
				Renewable resources	Non renewable resources	Renewable resources	Non renewable resources
		km^3/yr	km^3/yr	km^3/yr	km^3/yr	% Total	% Total
ES	Spain	35,32	5,017	4,822	0,71	13,7	2,0
FR	France	32,3	6,323	6,1		18,9	
IT	Italy	42	13,9	10,4		24,8	
MT	Malta	0,059	0,021	0,015	0,012	25,4	20,3
SI	Slovenia	1,28	0,1337	0,28		21,9	
HR	Croatia	0,718	0,42	0,42		58,5	
BA	Bosnia-Herzeg.	1	0,3	0,3		30,0	
YU	Serbia-Monten.	13	1	1		7,7	
MK	FYR Macedonia	1,845	0,014	0,2		10,8	
AL	Albania	1,4	0,6	0,63		45,0	
GR	Greece	8,7	3,563	3,56		40,9	
TR	Turkey	35,5	6,3	6		16,9	
CY	Cyprus	0,34	0,087	0,11	0,04	32,4	11,8
SY	Syria	14,71	2,3	1,8		12,2	
LB	Lebanon	1,3	0,4	0,4	0	30,8	0,0
IL	Israel	2,16	1	0,9	0,32	41,7	14,8
GZ	Gaza Strip	0,131	0,104	0,13		99,2	
WB	West Bank	0,17	0,284	0,17	0,03	100,0	17,6
EG	Egypt	73,7	5,14	5,4		7,3	
LY	Libya	4,5	4,5	0,65	3,63	14,4	80,7
TN	Tunisia	2,849	1,626	1,4	0,27	49,1	9,5
DZ	Algeria	4,8	2,85	2,2	0,41	45,8	8,5
MA	Morocco	11,48	2,7	2,63		22,9	
Total		289,26	58,58	49,52	5,42	17,1	1,9

Table 3: Groundwater pressure in Greece (EUWI/MED, 2006)

Country & Entities	Country & Entities	Natural groundwater renewable resources (1) km^3/yr	Groundwater renewable resources abstractions (2) km^3/yr	Groundwater pressure (2/1) %
ES	Spain	29,9	4,822	16
FR	France	100	6,1	6
IT	Italy	43	10,4	24
MT	Malta	0,027	0,015	56
SI	Slovenia	13,5	0,28	2
HR	Croatia	11	0,42	4
BA	Bosnia-Herzeg.	6	0,3	5
YU	Serbia-Monten.	3	1	33
MK	FYR Macedonia	1	0,2	20
AL	Albania	6,2	0,63	10
GR	Greece	10,3	3,56	35
TR	Turkey	69	6	9
CY	Cyprus	0,41	0,11	27
SY	Syria	5,4	1,8	33
LB	Lebanon	3,2	0,4	13
IL	Israel	1,075	0,9	84
GZ	Gaza Strip	0,056	0,13	232
WB	West Bank	0,68	0,17	25
EG	Egypt	2,3	5,4	235
LY	Libya	0,5	0,65	130
TN	Tunisia	1,55	1,4	90
DZ	Algeria	1,73	2,2	127
MA	Morocco	10	2,63	26
Total		317	49,52	16

According to recent studies and the "National Programme for the Development and Protection of Water Resources" that was prepared in 2007, by the Technical University of Athens for the Central Water Agency (http://www.itia.ntua.gr/g/docinfo/782/) the following results are derived:

- Precipitation: 116.330 hm^3/year
- Evapotransporation: 59.236 hm^3/year
- Total renewable water resources: 57.100 hm^3/year [including the water resources originated from neighboring countries: 12.953 hm^3]
- Total water withdrawal: 8.243 hm^3
- Water withdrawal for irrigation: 6.859,5 hm^3 [as percentage of total renewable water resources: 84%]
- Water withdrawal for stock farming: 106,8 hm^3 [as percentage of total renewable water resources: 1%]
- Water withdrawal for households: 956,6 hm^3 [as percentage of total renewable water resources: 12%]
- Water withdrawal for industry and energy: 161,4 hm^3 [as percentage of total renewable water resources: 3%]

A report "Initial Characterization of Groundwater Bodies" has been prepared by the Institute of Geology and Mineral Exploration for the Central Water Agency, in accordance with the Art.5 of the WFD requirements. This report has submitted to the European Commission. The main conclusion of the research undertaken are summarised in the following results:

- Number of Water Bodies: 236
- At risk : 110
- At no risk: 126

4. Groundwater uses

Although precise estimate of the available water resources in Greece have not been made, most authorities agree that water consumption and use constitute only a small percentage, less than ten and fifteen per cent of the annual precipitation and water potential, respectively (Table 5). The total annual precipitation is estimated to be 115,375x10^6 m³/yr and the total water potential is estimated to be 69,000x10^6 m³/yr (including water transported to Greece from northern countries). By the beginning of ninety's, the total water consumption was estimated at 5,500x10^6 m³/yr, while by the end of the last decade it increased of about 30%. It is estimated that water consumption in Greece increases by more than 3% per year.

The major water use in Greece is irrigation (17- 95%) while domestic use ranges among regions from 3 to 66% and industrial use from 0.2 to 16.0% of the total consumption. The increased demand of water, either for urban or agricultural use, cannot be always met despite adequate precipitation. Water imbalance is often experienced, especially in the coastal and southeastern regions, due to temporal and spatial variations of the precipitation, the increased water demand during the summer months, and the difficulty of transporting water due to the mountainous terrain. However, on an average, there is a relatively high per capita water availability, i.e. around 5,800 m³/inh.yr, although this is lower than most European countries, but much higher than that of other Mediterranean regions.

Greece's agriculture has been improved substantially since 1980 and additional agricultural development mainly depends on water availability. On the other hand, there are major losses (seepage, evaporation, leakage, etc.) from water delivered to the agricultural sites for irrigation and the municipal sites for domestic use. In some cases, these losses are estimated to be as much as 45%.

An alternative plan for water resources management should include the reclaimed wastewater originating from the wastewater treatment plant effluents. This plan may provide sufficient water for irrigation, while at the same time the pollution loads entering the sea or inland waters will be reduced (Tsagarakis, 2002).

The intensive use of groundwater is shown in table 4. Groundwater use represents the 42% of the total water demand. Furthermore, the major groundwater use is agriculture (36%), public supply (5%) and self-supplied industries (1%).

Table 4: Part of total Water Demand supplied with groundwater in Mediterranean countries (EUWI/MED, 2006)

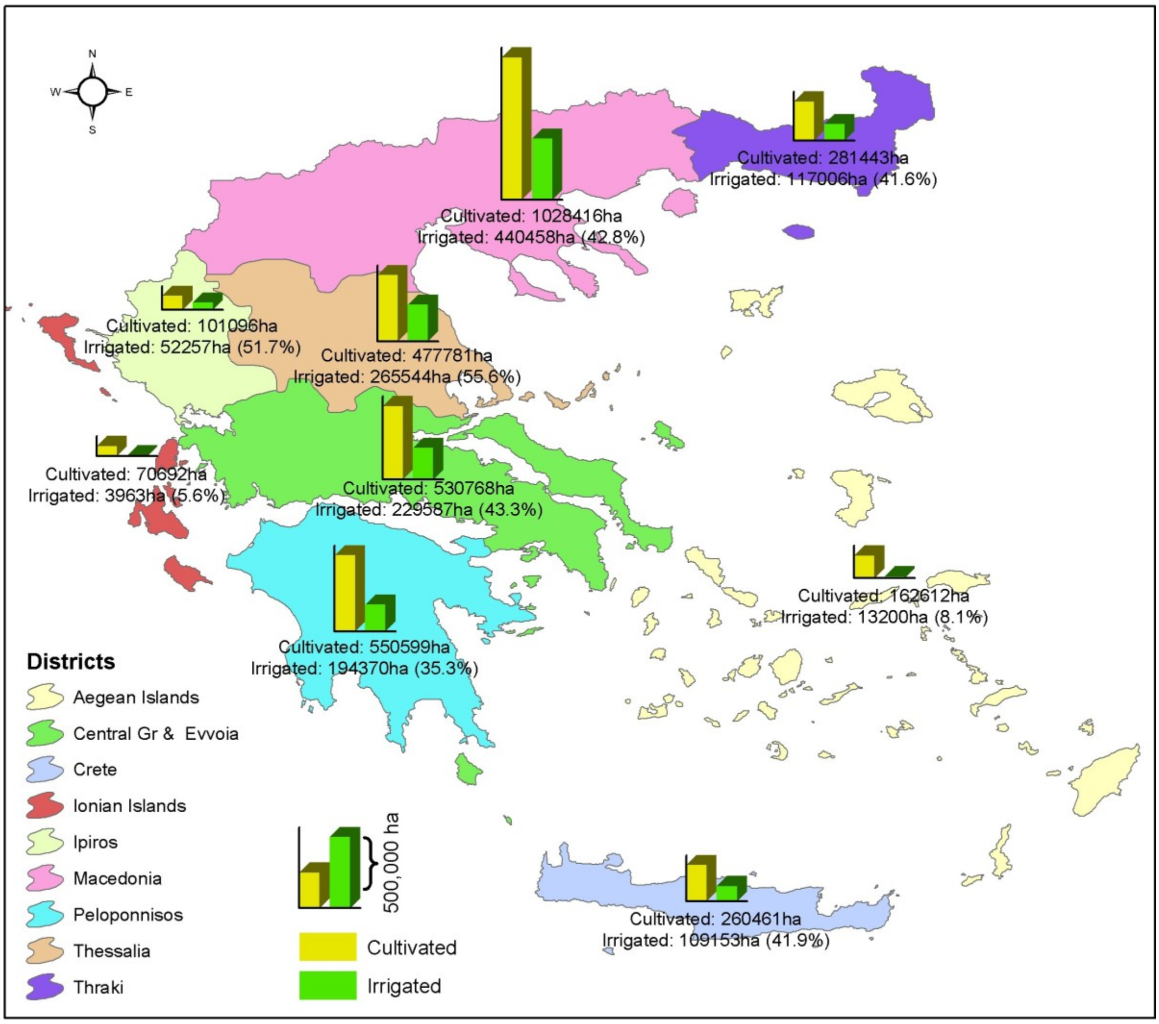
Country & Entities	Country & Entities	Population (million of inhab)	Total Water Demand (km³/yr)	Groundwater Sectorial Water Demand Supply				Groundwater Sectorial Water Demand Supply % Total demand			
				Total (km^3/yr)	Public Supply (km^3/yr)	Agriculture (km^3/yr)	Self-supplied industries (km^3/yr)	Public Supply %	Agriculture %	Self-supplied industries %	Total %
ES	Spain	39,11	35,32	5,017	1,2987	3,544	0,174	4	10	0	14
FR	France	56,45	32,3	6,323	3,713	1,11	1,48	11	3	5	20
IT	Italy	57,54	42	13,9	5,4	8	0,5	13	19	1	33
MT	Malta	0,366	0,059	0,021	0,018	0,003	0,00011	31	5	0	36
SI	Slovenia	2	1,28	0,1337	0,1098	0,0003	0,0239	9	0	2	10
HR	Croatia	4,8	0,718	0,42							
BA	Bosnia-Herzeg.		1	0,3							
YU	Serbia-Monten.		13	1							
MK	FYR Macedonia		1,845	0,014							
AL	Albania	3,39	1,4	0,6	0,29	0,31	0	21	22	0	43
GR	Greece	10,05	8,7	3,563	0,445	3,1	0,1	5	36	1	42
TR	Turkey	53,7	35,5	6,3	1,95	3,8	0,55	5	11	2	18
CY	Cyprus	0,726	0,34	0,087	0,003	0,083	0,001	1	24	0	26
SY	Syria	12,53	14,71	2,3	0,3	1,9	0,1	2	13	1	16
LB	Lebanon	3,2	1,3	0,4	0,052	0,31	0,036	4	24	3	31
IL	Israel	5,8	2,16	1	0,18	0,8	0,02	8	37	1	46
GZ	Gaza Strip	1,475	0,131	0,104	0,03	0,072	0,002	23	55	2	79
WB	West Bank	0,932	0,17	0,284	0,095	0,182	0,007	56	107	4	167
EG	Egypt	54,8	73,7	5,14	1,3	3,1		2	4		6
LY	Libya	5,22	4,5	4,5	0,328	4,1	0,074	7	91	2	100
TN	Tunisia	8,785	2,849	1,626	0,163	1,4	0,063	6	49	2	57
DZ	Algeria	25,06	4,8	2,85	1,3	1,4	0,15	27	29	3	59
MA	Morocco	25,09	11,48	2,7	0,432	2,268	0	4	20	0	24
Total/Mean		371,024	289,26	58,58	17	35,4823	3,28101	6	12	1	19

Table 5. Available Water Resources and Water Uses per Water Region in Greece (Tsagarakis, 2002)

Water Region	Area	Precipitation (mil. m³/yr)	Water potential (mil. m³/yr)			Water use (mil. m³/yr)				Consumption index (%)
			Surface	Ground	Total	Agricultural	Domestic	Industrial	Total	
1. West Peloponnese	7,301	8,031	3,050	700	3,750	560.0	23	22.0	605.0	16.1
2. North Peloponnese	7,310	6,404	2,650	900	3,550	653.5	40	68.0	761.5	21.5
3. East Peloponnese	8 , 477	5,811	1,000	950	1,950	780.0	20	25.0	825.0	42.3
4. West Central Greece	10,199	13,592	9,750	850	10,600	260.0	21	0.5	281.5	2.7
5. Epirus	10,026	17,046	8,500	250	8,750	230.0	31	4.0	265.0	3.0
6. Attiki	3,207	1,642	200	200	400	70.0	270	65.0	405.0	101.3
7. Central Greece and Evia	12,341	9,516	1,900	1,050	2,950	380.0	36	5.5	421.5	14.3
8. Thessaly	13,377	10,426	3,250	1,350	4,600	1,060.0	65	46.0	1,171.0	25.5
9. West Macedonia	13,440	10,599	4,100	850	4,950	582.0	48	30.0	660.0	13.3
10. Central Macedonia	10,389	6,596	6,900	700	7,600	477.0	75	20.0	572.0	7.5
11. East Macedonia	7,280	4,422	4,200	550	4,750	439.0	23	9.5	471.5	9.9
12. Thrace	11,177	8,574	10,900	400	11,300	536.0	35	6.0	577.0	5.1
13. Crete	8,335	7,500	1,300	1,300	2,600	320.0	60	4.0	384.0	14.8
14. Aegean Islands	9,103	5,216	1,000	250	1,250	80.0	37	1.0	118.0	9.4
Total	131,962	115,375	58,700	10,300	69,000	6,427.5	784	306.5	7,518.0	10.9

5. Irrigation Systems Performance in Greece

In Greece the main user/consumer of water is agriculture. For irrigation purposes 80-85% of the total water consumption is used. The cultivated land covers 3,470,000 ha from which 1,430,000 ha are irrigated. The participatory irrigation projects cover approximately 40% of the irrigated land and the private projects 60% respectively. A significant variety of irrigation systems exist with characteristic advantages for certain soil/climatic conditions as well as for crop requirements.



5.1. Evolution of Irrigation Systems

The effort of the Governments was focused at performing broader schemes of land improvement projects, giving priority to flood protection works in large plains (especially in Macedonia, Thessaly and Epirus), draining of swamps and lakes, reclamation of low lands, watershed stabilization works in mountainous areas and, of course, irrigation. This effort started in 1925 and continued uninterruptedly since then, the only exception being the Second World War years (1940-1944) and the years of internal conflicts (1946-1949). As a result, both cultivated and irrigated lands were impressively increased from the beginning of 20th century (Fig. 4).

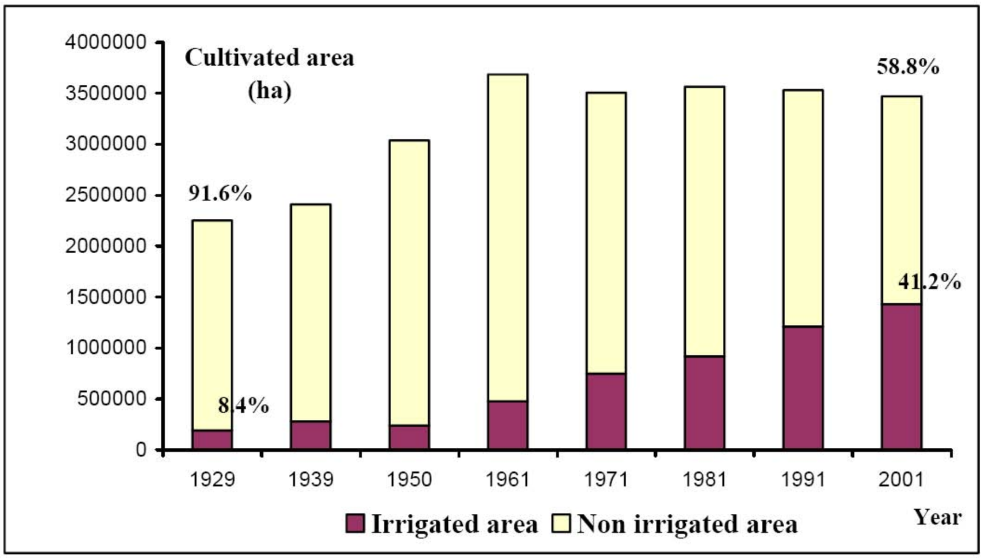


Fig. 4. Total cultivated area (irrigated and non irrigated) in Greece from 1929 to 2001.

The increase in irrigated lands was observed in all levels of altitude and especially in flat areas (Fig. 5), where the percentage is as high as 71% of the total irrigated area.

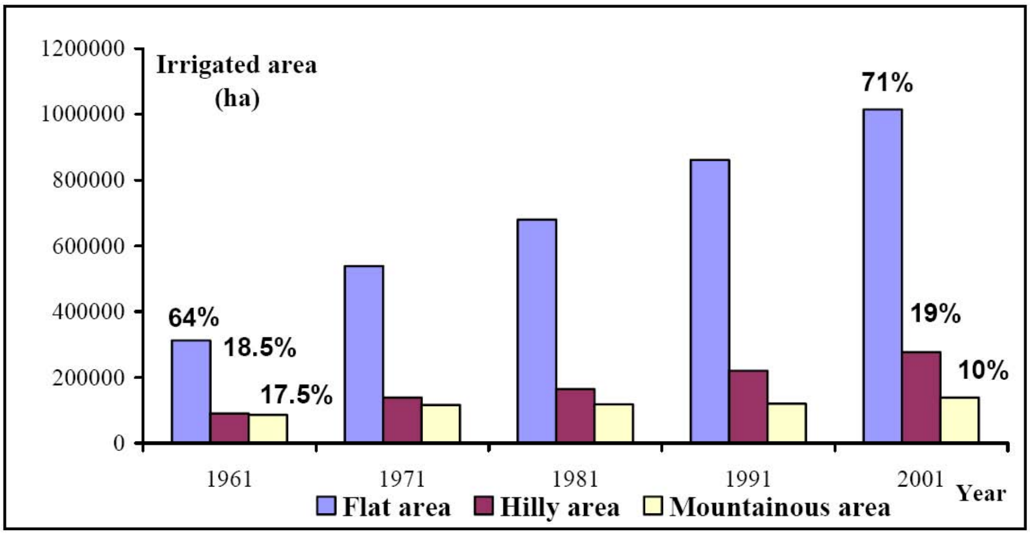


Fig. 5. Irrigated areas distribution into flat, hilly and mountainous ones.

Both private and public sectors contributed to the increase of irrigated lands. As regards the public sector, it has the tendency to cover 44% of the irrigated land instead of 26% thirty years ago (Fig. 6).

Arable crops exhibit the highest irrigated percentage, followed by fruit trees, vegetables and the vines in a decline order. As it is shown in Fig. 7 for the year 2001, the percentage of arable crops cover 65% (931,000 ha) of the irrigated land, fruit trees 24% (346,000 ha), vegetables 8% (113,500 ha) and vines 3% (40,000 ha).

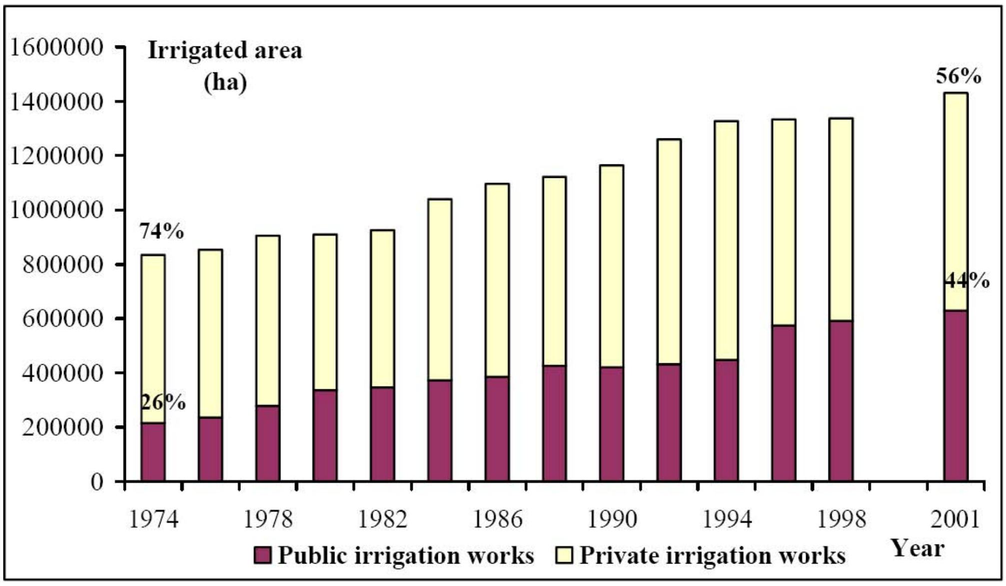


Fig. 6. Total irrigated area in Greece from 1974 to 2001.

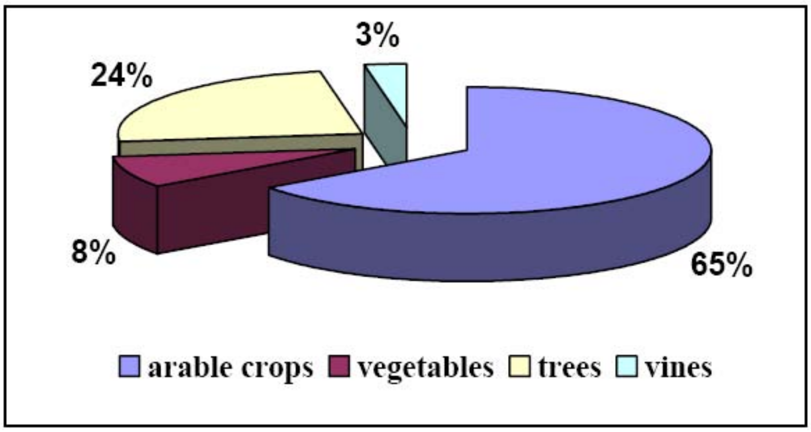


Fig. 7. Proportions of irrigated crops (data 2001).

5.2. Irrigation Systems Management

The authorities responsible for water management of the public irrigation projects are the Local Organization of Land Reclamation (LOLR) for projects of local importance and the General Organization of Land Reclamation (GOLR) for projects of general importance. The GOLR are actually second in the rank surveying the LOLR and both are under the supervision and scientific support of the Land Reclamation Directions in the Prefectural Services. There are 10 GOLRs and 382 LOLRs in total.

Planning and operation parameters of irrigation systems
A - Technical Parameters

After the seventies, sprinkler irrigation networks have become popular in both the public and private sectors. In Figs. 8 and 9, the trends of the irrigation techniques for both public and private networks are shown. Nowadays, the situation is formed as described below.

Field water in the case of public networks is applied by means of surface irrigation, sprinkler irrigation and drip irrigation in proportions of 37%, 53% and 10%

respectively, with a distinct falling tendency of surface irrigation. Water in the private networks is applied by means of surface irrigation, sprinkler irrigation and drip irrigation at rates of 7%, 49% and 44% respectively.

The way of irrigation water conveyance is given in figures 10 and 11. The conveyance proportion of pumping water is increased in public networks in relation to the water flow in open ditches. In the private networks the proportion of pumping water remains at a high level. In public networks the conveyance of water is done mainly by means of earthen or concrete channels with a tendency to be replaced by pipelines.

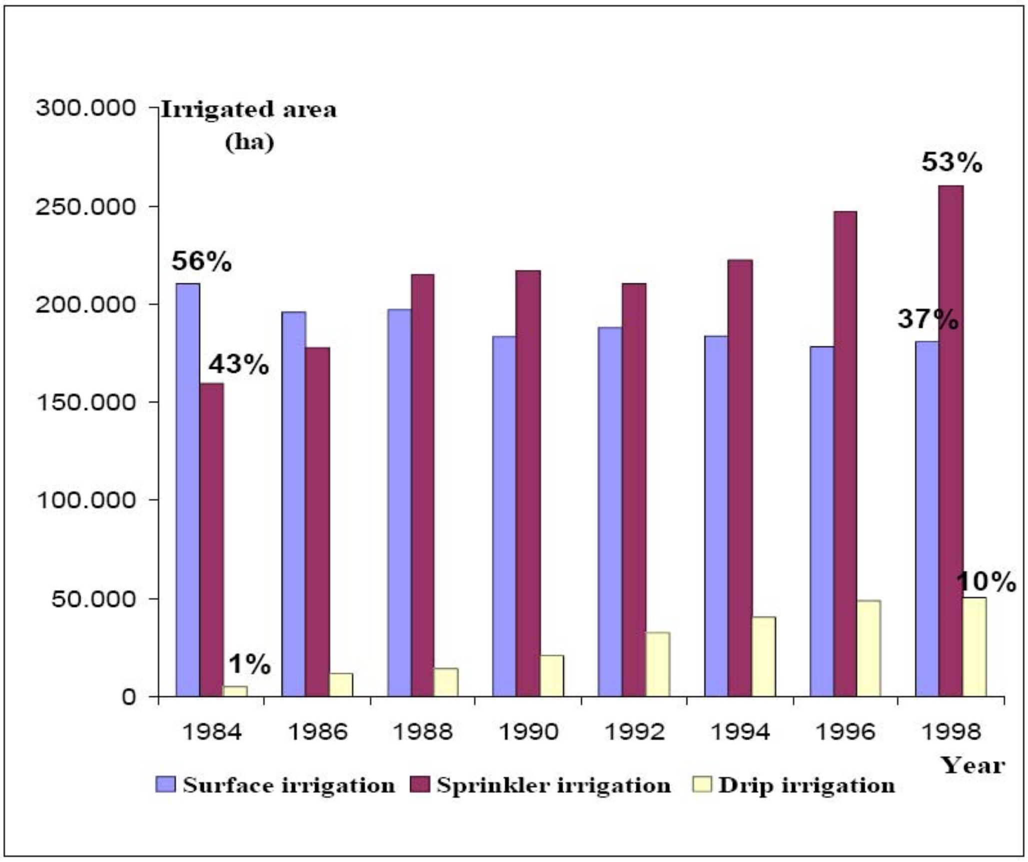


Fig. 8. The trends of irrigation techniques used in public networks.

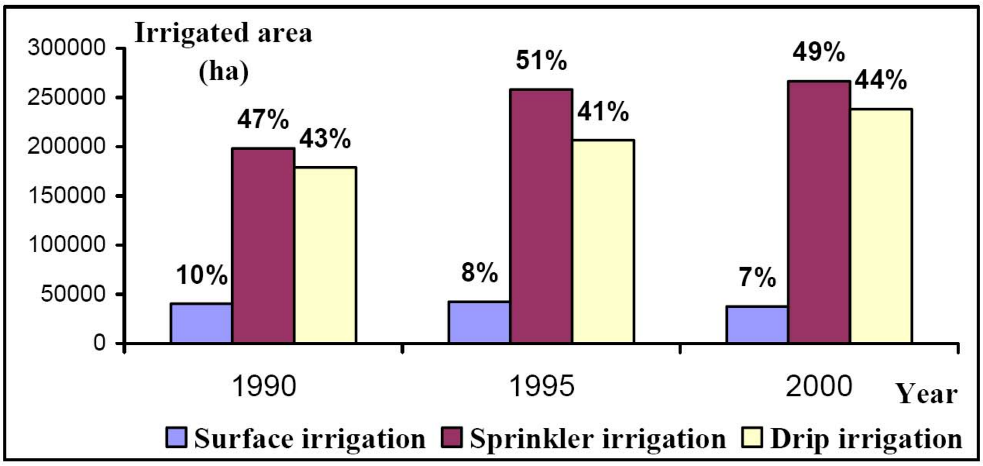


Fig. 9. The trends of irrigation methods used in private networks.

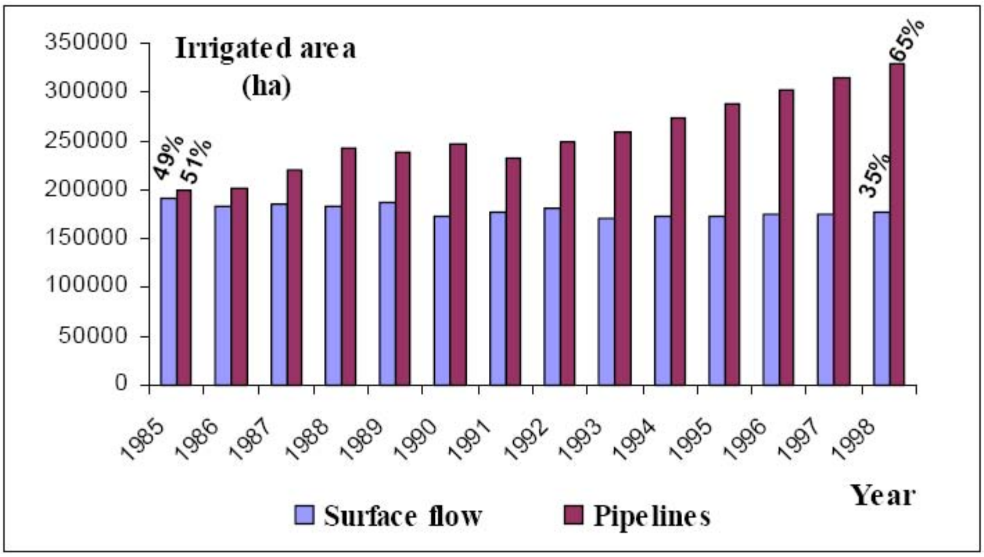


Fig. 10. Conveyance of irrigation water in public networks.

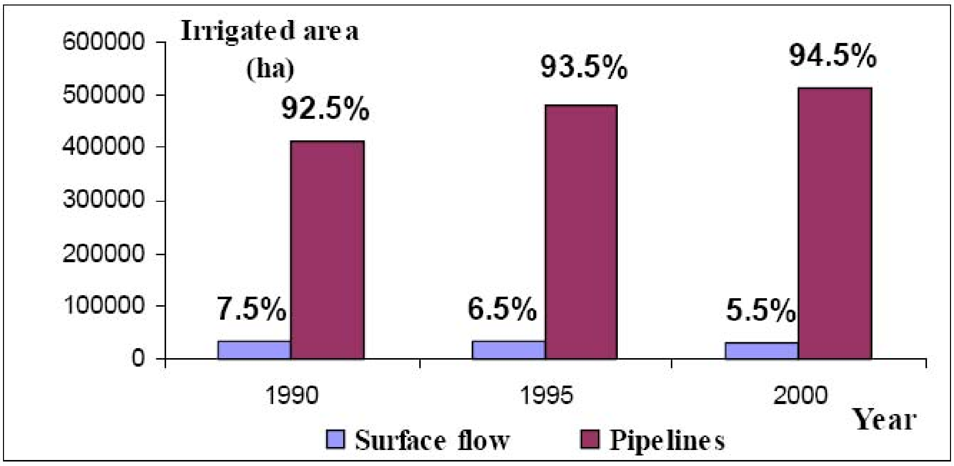


Fig. 11. Conveyance of irrigation water in private networks.

Finally, the water sources differ radically between public and private networks. The public networks, mainly use surface water, while the private ones use underground water (Figs 12, 13). The water used in public participatory irrigation networks originates from rivers and springs (42%), artificial lakes (25%), drilled wells and wells (24%), natural lakes (5%), drainage ditches (4%). There is a rising interest for artificial water reservoirs. The water used in private irrigation networks comes from drilled wells (82%), rivers and springs (13%), drainage ditches (3%) and artificial lakes (2%).

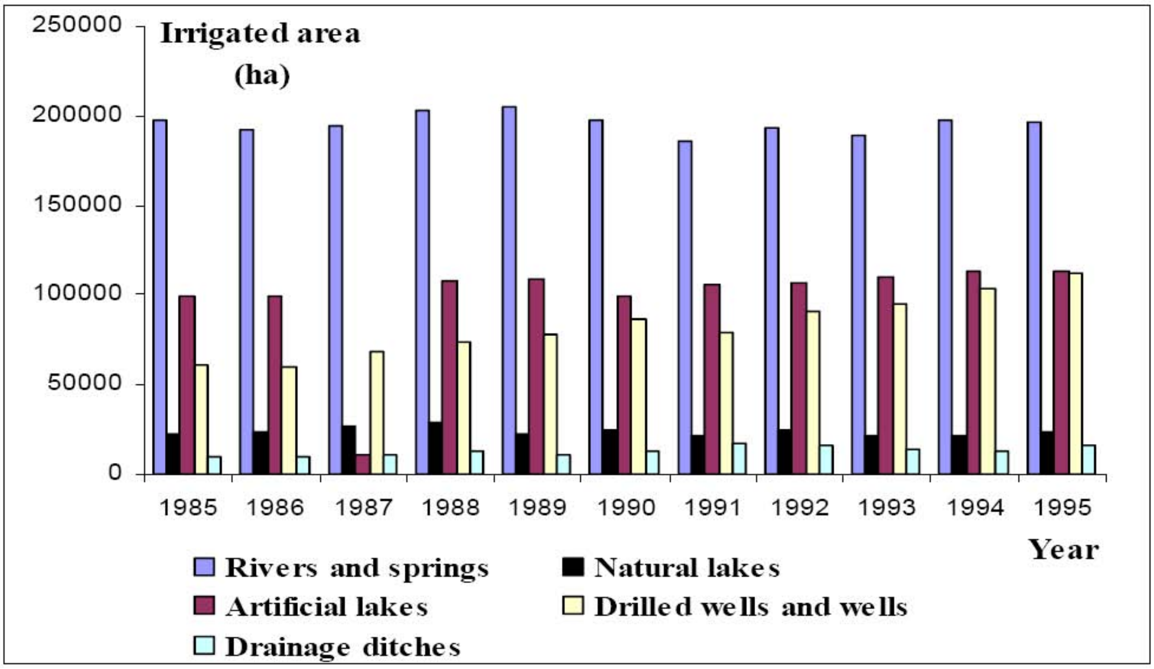


Fig. 12. Source of irrigation water in public networks.

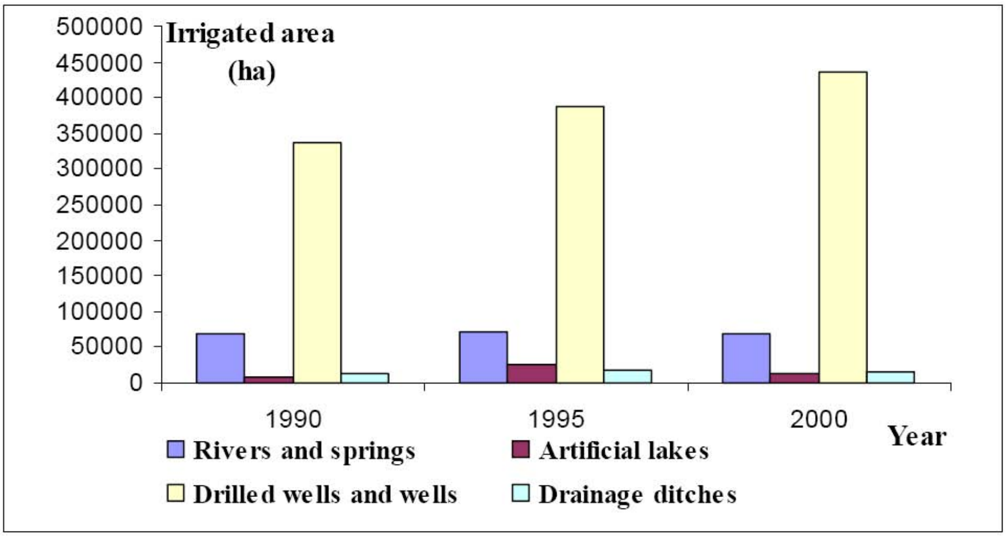


Fig. 13. Source of irrigation water in private networks.

It is worth pointing out that in Greece there are about 200,000 drilled wells and wells for irrigation purposes, 13 rivers with a summer discharge bigger than 3 m^3/sec, 21 large lakes covering an area bigger than 320 ha, 52 big carstik springs (and thousands minor ones) and more than 70 artificial lakes with a total effective volume bigger than 9.5 billion m^3. The total annual water potential is estimated about 70 billion m^3, including the rivers water flowing from neighboring countries.

6. Pressures and Measurements of Groundwater

The Hellenic Ministry for the Environment, Physical Planning and Public Works supervises the existing national monitoring networks for water quality. This network that measures water quality systematically since 1995, relies on existing sampling stations, such as those set up since the 70s by the Ministry of Agriculture for monthly monitoring of irrigation water quality (90 sampling points in rivers, 30 sampling points in lakes plus seasonal sampling in 100 irrigation projects and 250 drillings).

The network encompasses upgraded Laboratories of the General Chemical State Laboratory (GCSL), as well as Municipal and Research Laboratories. Monitoring is based on 200 sampling points in lakes and rivers and samples are being analyzed for around 69 parameters (physicochemical parameters, nutrients, heavy metals and microbiological) on a trimester basis.

This Monitoring Network includes sampling points where water is analyzed for toxic substances contained in Lists I and II of the EU Directive 76/464/EC. More specifically, samples are monitored for 156 substances of Lists I (7 substances) and II (116 substances) as well as 33 priority substances, at 50 sampling points through out the country. For the transboundary rivers, 5 sampling points have been established at the entry points from the upstream neighboring countries, where 5 automatic monitoring stations have been situated at Axios, Strymonas, Nestos and Evros (2 stations) rivers.

Groundwater monitoring is carried out at approximately 400 sampling points covering the whole country except for the Aegean islands. Sample analyses focus on nitrates of agricultural origin. The Institute of Geology and Mineral Exploration (IGME) has also established a national network for monitoring qualitative and quantitative properties of groundwater, collecting systematically hydrological, hydrochemical and other data (heavy metals, pollutants). Data are then incorporated in a GIS database for compiling adequate timeseries and determining evolutionary trends of groundwater according to the WFD. Pesticide residue monitoring is carried out in cooperation with the Benakion Phytopathological Institute.

A water quality monitoring programme of rivers, lakes and groundwater, including the determination of all heavy metals and pesticide residues has been executed and will be continued in cooperation with the Aristotle University of Thessaloniki in the Regions of Macedonia and Thrace, in Northern Greece.

In the frame of the obligations derived from Directive 91/676/EC, YPEHODE assigned to the University of Patras the elaboration of a study and the organization and operation of a Groundwater Quality Monitoring Network in the country (monitoring parameters: NO_3, NO_2, NH_4, Cl, SO_4, ions, conductivity and pH). From the conclusions of this study and according to the criteria of the Directive, vulnerable zones have been designated as regards nitrate pollution of agricultural origin and .Codes for a Good Agricultural Practice. along with Action Programs for the promotion and implementation of such Codes, have been developed in these zones.

The National Surface and Groundwater Quality Monitoring Networks are currently under revision and readjustment, according to the requirements of the WFD and LAW

3199/03. Through this activity, a coherent and comprehensive overview of the chemical and ecological status within each River Basin District will be provided. This overview will enable, after assessment of the reference conditions, the classification of the surface waters into five classes, on the basis of specific quality elements and the development of national classification.

Groundwater quality, even though generally good, is threatened by uncontrolled wastewater disposal and salinization caused from over-extraction and seawater intrusion at coastal aquifers. High concentrations of nitrates, deriving from nitrogenous fertilizers and the use of livestock manure, as well as pesticide residues have been detected in northern and western parts of the country but do not always exceed maximum permissible values.

In Greece, the supply of clean and sanitarily appropriate water, from ground and surface waters, to every citizen in the country, consists one of the main responsibilities of Public Administration. The state is responsible for providing water and wastewater services to Athens and Thessaloniki and has effectively entrusted water services to two large companies: to EYDAP (Athens Water Supply and Sewerage Company) in Athens, which legally has private status but is supervised by the Ministry for the Environment, Physical Planning and Public Works and to DEYATH in Thessaloniki, a public sector company. In cities, over 10000 municipal companies manage water and wastewater services. In smaller towns and rural areas, communities are directly responsible (Country Profile: Greece, 2004; Lazarou, 2006).

Groundwater Quality in Greece

According to the results of chemical analyses (Daskalaki and Voudouris, 2006) the following general characteristics can be drawn: High values of electrical conductivity (E.C.) along the coastline are attributed to seawater intrusion, as a result of the intensive exploitation. The electrical conductivity shows a gradual increase from the mountainous recharge areas towards the lowlands discharge areas. The fluctuation of pH between 6.8 and 8.3 shows that groundwater is slightly acid to alkaline.

Groundwater contains $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ and $HCO_3^{-} > SO_4^{2-} > Cl^{-} > NO_3^{-}$. High sulphate ($SO_4^{2-}$) concentrations in western Greece can be associated with the dissolution of gypsum. High potassium concentration is related to mixed-type fertilizers and/or to the presence of K-feldspar. High concentrations of Fe and Mn are attributed to lithological conditions. High concentrations of heavy metals (Zn, Cu, Ni, Pb) are recorded in areas with mining activities (Lavrio, Chalkidiki).

The Ca-Mg-HCO_3 water type is the dominant type in Greece, representing freshwater of recent infiltration.

The overexploitation of coastal aquifers always produces a lowering to the water table levels. When the extracted volumes are greater than the recharge, even on local base, a salinisation process begins in the aquifer as the seawater flows towards inland. Seawater intrusion in most coastal areas has progressed a great distance inland with the consequence of a chloride concentration greater than 100 mg/L. The total area of aquifers affected by seawater intrusion due to overexploitation was estimated to be 1500 km^2 (Fig. 4).

Locally (Macedonia, Thrace), groundwater salinity is correlated with the trapped seawater in sediments or connate fossil water in recent deposits. The Cl^- concentration is higher at the end of the dry season (October). Seawater intrusion has been favored by some preferential paths, depending upon the geological conditions of each area. Because of its salt content, about 2% of seawater mixed with freshwater makes the resulting water unusable in terms of drinking water standards. Once contaminated with seawater, an aquifer can remain contaminated for long periods (50-600 years). Conventional methods of groundwater treatment do not eliminate chloride ions.

Seawater intrusion in coastal karstic aquifers is a very common phenomenon due to the connection of deep conduits of seawater with shallow inland conduits. The position of the seawater-freshwater interface depends on the elevation of the hydraulic head and defined as the point where the seawater pressure is equal to the respective of freshwater. In wet period when the discharges are high the equilibrium plane is low, while during the low discharges of the dry period seawater enters. For example, the Almiros-Heraklion karstic spring is discharged ($250x10^6$ m^3/yr) at a distance of 1.1 km from the sea. At low discharge (dry period), the spring water is brackish due to seawater intrusion and the concentration of chloride (Cl^-) can mount to 6,000 mg/L.

Nitrate is the most abundant nutrient in groundwater and can be attributed to different sources. In many porous aquifers, nitrate content exceed the maximum admissible concentration of 50 mg/L set by EU Council for drinking water, rendering most of groundwater improper for human consumption.

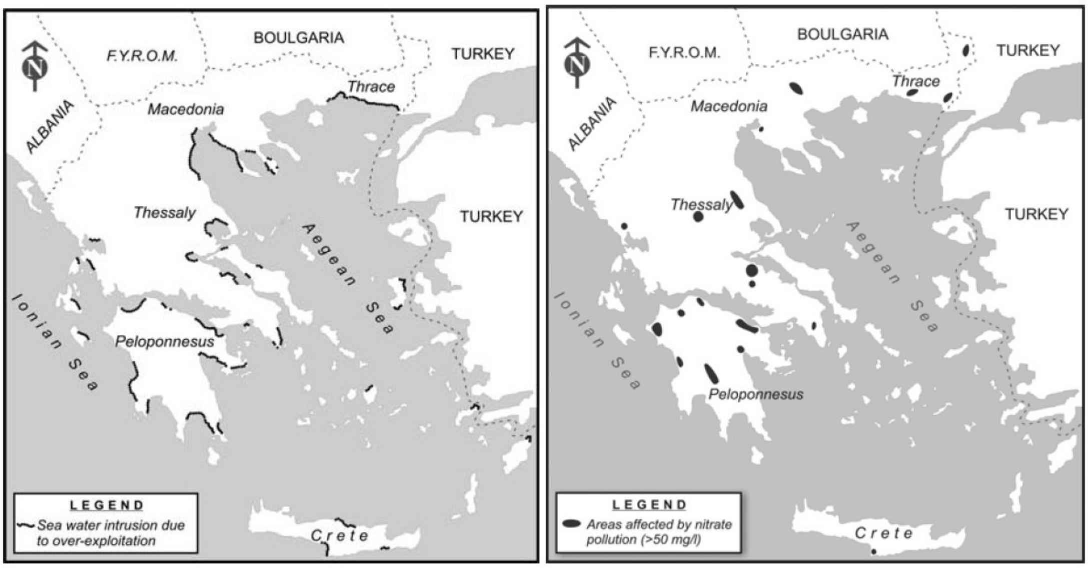


Figure 4. Groundwater over-exploitation and saltwater intrusion in Greece (left). Areas affected by nitrate pollution, due to agricultural activities (>50 mg/L) (right).

The applied fertilizers [NH_4NO_3, $(NH_4)_2SO_4$, mixed types Nitrogen Phosphate Potassium] in cultivated areas (vineyard, cotton, tobacco, citrous), the cattle units, the great number of industries of rustic products (cheese maker units, tanneries) in urban areas and the disposal of domestic and industrial wastewater through rivers are the most important sources of nitrates. In the urban areas the high nitrate concentration are attributed to the direct disposal of untreated domestic wastewater in former wells that are presently used as septic tanks.

The most vulnerable areas to nitrate pollution from agricultural activities are North Peloponnesus, Thessaly, Kopais basin and Strimonas basin (Fig. 4). Statistical processing of the chemical analyses results leads to the conclusion that there is a trend of increasing concentrations of nitrates in these areas. The highest concentrations are recorded in the dry season, due to the downward movement of shallow water, which is rich in nitrate.

Alluvial and shallow aquifers are particularly vulnerable to nitrate pollution, whilst deep or confined aquifers are generally better protected. However, surface or near-surface outcrops of confined aquifers can allow nitrate to migrate towards deeper strata. Based on the average hydraulic parameters of the alluvial aquifer of northeastern Peloponnesus it is calculated that a period of 16.5 years is required to restore groundwater quality to a background level of 15 mg/l nitrate, provided that complete cessation of fertilization is enforced.

Groundwater Quality in North Peloponnesus

Groundwater plays an important role for urban and agricultural water supply in northern part of Peloponnesus. Despite increasing environmental awareness in this area, groundwater is a resource that is being stressed (Voudouris et al., 2005)

The northern part of the Peloponnesus, in South Greece including the Achaia and Korinthia prefecture, has an extent of 6,000 km^2 and a population of about 477,400. Between the 1970's and 2000's the population grew quickly, increasing by 35%. The population density in the coastal areas is 200 persons per km^2 and it decreases to 15 persons per km^2 in the mountainous area.

The water supply is mainly covered by groundwater abstracted from the alluvial coastal aquifers via numerous wells and boreholes. The number of wells and boreholes has reached 8,000 in Korinthia prefecture. As a result a decline of ground water levels has been observed, since 1980's due to overexploitation of agricultural and municipal water intakes in coastal part of the study area combined with prolonged drought periods. Furthermore a negative water balance is established in the coastal aquifer systems. In these systems seawater intrusion is recorded due to over-pumping combined with prolonged dry periods. An increase in the dissolved components in the groundwater, especially chloride and sodium, has been observed in many boreholes drilled into aquifers, along the coastline of the study area.

Nitrate pollution is the second major source of groundwater degradation in the study area. Nitrate is a common contaminant identified in groundwater of the study area, due to the irrational application of fertilizers. The common fertilizer applied throughout the irrigation area is $(NH_4)_2SO_4$, phosphate and potash. Under a nitrification process in the presence of oxygen, ammonium is transformed into nitrate. The high levels of nitrate are probably the result of the lack of sewage systems in some urban areas. The main pollution source of surface water results from uncontrolled direct disposal of raw olive mill waste effluent into the torrents and rivers

Seawater intrusion occurs in some coastal aquifers, where negative water balance has been established. High percentage of the examined samples exceeded the maximum admissible nitrate concentration of 50 mgl^{-1}, set by EU for drinking water. Groundwater in urban areas has been contaminated to varying degrees. The water quality is classified into Ca-HCO_3 type (fresh water) and Na-HCO_3 or Na-Cl type (brackish waters) in the coastal part, due to seawater intrusion.

Degradation of groundwater quality is mainly caused by: seawater intrusion and nitrate pollution. The coastal part of this area is characterized by ongoing urbanization, tourism development and intensive agriculture. As a result, in some coastal aquifer systems of the study area a negative water balance is established, triggering seawater intrusion. Intensified fertilization has led to considerable groundwater quality deterioration, as evidenced by the increased nitrates concentration. Other sources of groundwater pollution are leaking septic tanks in urban areas. Groundwater alone cannot meet the water supply requirements in the study area and thus a need exists to supplement with surface water (Voudouris et al., 2005).

Groundwater Quality in Naxos Island, Cyclades

Naxos island is located in Cyclades Archipelago (Aegean sea, Greece), covering an area about of 428 km^2. Approximately 18,188 people inhabit the island; the summertime population increases, due to tourism. Average annual rainfall is 380 mm and the real evapotranspiration is estimated to be 74 % of the annual rainfall. The salinity of rainfall in Cyclades Archipelago is high, due to airborne sea spray and that has a strong effect on the chemical composition of the groundwater of the islands.

The island is characterized by increased demands of water, during the last decades, due to tourist development and intense irrigation. Groundwater is the main source for domestic and irrigation uses and is a resource that is being stressed. As a consequence, problems relevant to intensive exploitation combined with the lack of irrational management appeared: salinization, quality deterioration, and decline of groundwater level. Sources of groundwater pollution are the seawater intrusion due to overexploitation of coastal aquifers, the fertilizers from agricultural activities and the disposal of untreated waste in torrents or in old water pumping wells.

Forty one (41) groundwater samples collected from boreholes, during August-October 2004. The samples were analyzed in the laboratory of Engineering Geology & Hydrogeology of Aristotle University of Thessaloniki for major ions, Total Hardness (TH) and SiO_2. The water temperature (^oC) at the head of the boreholes, the Electrical Conductivity (EC) and the pH values of 87 samples (including the aforementioned 41 samples), were measured in situ. Based on the results of chemical analyses, pH values are greater than 7, indicating the slightly alkaline character of groundwater. Electrical conductivity values range between 270 and 14,100 $\mu S\ cm^{-1}$. High values of are recorded in the coastal part of the island, due to seawater intrusion. Chloride concentration ranges between 24 and 5460 mg L^{-1}. The highest Cl concentration is 29% of the chloride concentration found in seawater. Nitrate concentrations range between 3.5-141 mg L^{-1}, the mean nitrate value is 27.8 mg L^{-1}. Nitrate concentrations in most of the analyzed groundwater samples exceed the maximum admissible concentration of 50 mg L^{-1}, that was set by EU for drinking water, due to human activities.

Generally, a significant relationship is observed in the major ions having the different charge but a same valence: Na^{+}-Cl^{-}, Na^{+}-$HCO_3^{\ -}$, K^{+}-$HCO_3^{\ -}$ and in the ions having the same charge and the same valence Na+-K+, Cl--HCO3 -. Two main groundwater types may be identified: Ca(Mg)-HCO_3 (freshwater) and Na-Cl (water affected by seawater intrusion). Results of cluster analysis identified the existence of two aforementioned types of groundwater. It is not possible to establish a generalized trend for temperature distribution in the island. Groundwater temperatures range from 13.6-18.5 ^{o}C in the north central part of the island, 19- 22 ^{o}C in the coastal part of the island, 21-25.5 ^{o}C and 26.7-32.6 ^{o}C in the southwestern part of the island. High temperature values indicate a local geothermal anomaly (Vasalakis et al., 2005).

The Hydrological Regime of the East Basin of Thessaly

A typical example of an area with a serious water shortage due to poor water resources management and increased demand for water is the East Basin of Thessaly. This basin constitutes part of the Pinios River basin and covers approximately 3860 km^2. The current situation relative to water resources in the East basin is thoroughly analyzed and evaluated. The average annual rainfall is approximately 530 mm and ranges from 353- 734 mm per year. 87% of the rainfall is lost through evapotranspiration. 45×106 m^3 of surface water from the Pinios River serve irrigation purposes (Petalas et. al., 2005)

In the basin, nearly 100% (or 30×106 m^3) of the drinking water requirements and 76% of the irrigation water requirements (145×106 m^3) are met from groundwater. The irrigation of the 75,000 ha used for agriculture in the basin requires 335×106 m^3 of water. The aquifer systems are in many cases overexploited. A continuous decline of the water level (as much as 2m/year) has occurred in the last two decades as a result of human activities. Despite the fact that official data on groundwater contamination are scarce and sketchy, aquifer pollution by human activities may be serious in some areas. In parts of some aquifers there are areas in which NO_3^- exceeds the 50 mg/L limit for drinking water. Seawater intrusion occurs in the coastal areas. Valuable wetlands have been destroyed (e.g., Lake Karla) by incorrect water resources development and management. The human activities adversely affected the long term established interaction between groundwater and surface water in some reaches of the Pinios River.

The quality of groundwater is generally suitable for most uses. Groundwater quality is most commonly affected by nonpoint source pollution and waste disposal. Deterioration of groundwater quality in the alluvium is caused by three processes. First, where river water recharging the aquifer is of poor quality; second, point source pollution from dumping or sewage lagoons; and third nonpoint source pollution from agriculture. Groundwater exploitation started at the beginning of the 1970s. The amount of wells gradually increased as shown in Table 6, and so did the quantity pumped from the aquifers. A permit system was developed in the study area entitling the holders to drill wells and use groundwater. Permits may be for the withdrawal of a particular quantity of water for uses as urban or agricultural use. Generally, permits are not based on scientific criteria. About 12.000 permits for drilling wells were recorded in the study area from 1980 to 1995. About 11.400 wells were finally drilled. An unknown number of illegally drilled wells also exist in East basin of Thessaly, as well as a great number of abandoned wells.

Locally, groundwater has been affected by seawater intrusion. Improper management of fertilizers has lead to excess nitrate levels, sometimes to the point where the water becomes unsuitable to consumption as potable water. Nitrate concentration varies from 0.53 to 143.14 mg/L. The average concentration is 21.05 mg/L. Ammonia concentration varies from 0 to 0.76 mg/L with an average concentration of 0.55 mg/L. Table 7 presents chemical and physical parameters of groundwater for the period 1999-2000. Groundwater sampling included 24 wells.

Table 6:
Permits allocated annually from 1981 to 1995, that entitle the holders to drill wells and use groundwater in the study area.

1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
320	431	568	1012	1284	939	320	971	860	849	461	798	852	544	620

Table 7:
Chemical parameters of groundwater in the study area during the period 1999 -2000.

	pH	SEC (μS/cm)	Salinity type	Cl^- (mg/L)	CO_3^{--} (mg/L)	HCO_3^- (mg/L)	SO_4^{--} (mg/L)	Ca^{++} (mg/L)	Mg^{++} (mg/L)	Na^+ (mg/L)
Average	7.48	851	C2 -C4	49.04	26.50	326.50	52.07	66.28	43.04	75.98
Min	7.00	449		4.01	0.00	3.50	2.49	30.70	8.10	8.44
Max	7.90	2790		307.96	72.00	567.30	335.85	134.50	89.80	554.95

Distribution of arsenic in groundwater in the area of Chalkidiki, Northern Greece

An integrate study aiming at the occurrence and distribution of arsenic in groundwater in the area of Chalkidiki, Northern Greece has been carried out. Groundwater samples from public water supply wells and private wells were analysed for arsenic and other quality parameters (*T*, pH, EC, Ca, Mg, Na, K, Cl, HCO_3, NO_3, SO_4, B, Fe, Mn).

Arsenic showed high spatial variation; ranged from 0.001 to 1.840 mg/L. Almost 65% of the examined groundwaters exhibit arsenic concentrations higher than the maximum concentration limit of 0.010 mg/L, proposed for water intended for human consumption. Correlation analysis and principal component analysis were employed to find out possible relationships among the examined parameters and groundwater samples. Arsenic is highly correlated with potassium, boron, bicarbonate, sodium, manganese and iron suggesting common geogenic origin of these elements and conditions that enhance their mobility. Three groups of groundwater with different physicochemical characteristics were found in the study area: (a) groundwater with extremely high arsenic concentrations (1.6–1.9 mg/L) and high temperature (33–42 ◦C) from geothermal wells, (b) groundwater with relatively high arsenic concentrations (>0.050 mg/L), lower temperatures and relatively high concentrations of major ions, iron and manganese and, (c) groundwater with low arsenic concentrations that fulfil the proposed limits for dinking water (Kouras et al., 2007).

<u>The role and importance of shared aquifers</u>

Interstate borders may cross aquifers without recognising hydrological and hydrogeological processes that may take place in different ways from each side of the border.

In internationally shared rivers and lakes much progress was made on how to determine what type of water resources problems are or will likely be posed for bilateral or multilateral interstate solutions. A large number of international agreements for solving various types of interstate surface water resources problems are available for reference and act as precedents.

The situation is quite different in the case of transboundary groundwater resources. Difficulties arise in scientific and technical matters (groundwater monitoring, data interpretation, modelling), the lack of political willingness for cooperation and the weakness of the institutions involved. Major difficulties in designing groundwater development plans is that groundwater flow and groundwater quality are subject to several types of uncertainties much more important than in surface hydrology. These are related to the high variability in space and time of the hydrogeological, chemical and biological processes. The principal challenge is to set up a cooperative framework in which institutions involved from both sides could work together effectively.

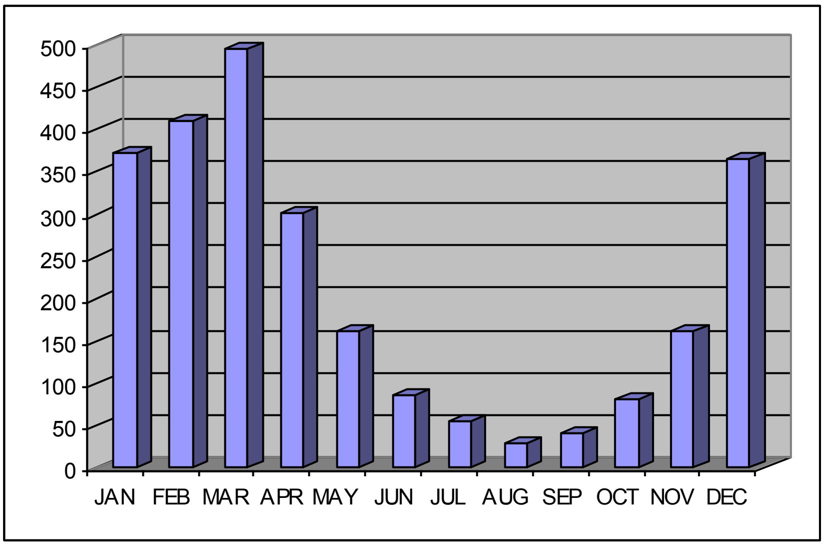
A very characteristic case of groundwater-surface water interdependencies can be found in the South Balkans, in the region of the Dojiran lake, internationally shared between Greece and the Former Yugoslav Republic of Macedonia (FYROM). In the last decade, during a multiple year's drought period, extensive pumping from the Greek side for irrigation may have contributed to lowering the lake's water level substantially (EUWI/MED, 2007).

<u>Pinios Pilot River Basin</u>

Pinios River (216 km) is located in the central section of mainland Greece, in Thessaly (Thessalia) Water Region. It is located in the ecoregion 6 for both rivers - lakes and transitional - coastal waters.The total surface area of Pinios River Basin is 10.550 km^2 (including the drainage basin of the Former Lake Karla - about 1.050 km^2). Pinios River is rising in the Pindos Mountains and outflows, after 216 km, in the Aegean Sea

The number of inhabitants in the river is about 700.000. The major cities are Larissa and Volos. Pinios River Basin lies in an area of intense agricultural activity. The area is not notably industrialised and food transformation and metal production industries are the most prominent. The coastal zone is a favourite destination for many tourists during the summer and as a consequence of this, the water supply requirements are increasing during the tourist season. Other economic activities in the region are breeding, fisheries and forestry.

<u>Water resources and uses</u>
The total water availability is about 3.209 hm^3 and consists of 2.596 hm^3 surface water and 613 hm^3 groundwater. The average surface natural flow is 45-60 m^3/sec with high fluctuations between winter and summer months.



The amount of the water used for irrigation purposes accounts for about the 96% and for water supply about the 3,3 % of the total water consumption in the catchment area. The Thessalic plain is heavily exploited for agriculture. Pollution loading from non-point sources is significant and can be attributed to the agricultural and breeding activities. The areas destined for cultivation are spread all over the plain areas and the land-application of all nitrogen-containing fertilizers feeds the watercourses causing significant pollution trends. Pollution trends in the watercourses are caused also by point sources (municipal waste water, industry). Although loading from urban waste water is a major source of pollution in the catchment, the total outlets have been reduced due to the urban waste water treatment plants, constructed in the major cities of Thessaly during the last decade.

The surface water quality in the river basin is generally in good condition and only in a few sampling sites the nitrites and the pesticides show elevated levels due to the cultivation carried out to serve agriculture. Concerning the groundwater, nitrate and ammonium exceed, in some cases, the critical value for drinking water and as a consequence of this, the Thessalic plain is designated as a vulnerable zone (according to the criteria of 91/676/EC Directive) and "Codes for a Good Agricultural Practice" along with Action Programs, have been developed. This involves measures to reduce overall inputs of nitrogen to agriculture in the form of fertiliser and organic manures.

Water abstraction for irrigation purposes and the intensive use of groundwater have produced problems of over-exploitation in some aquifers in the catchment area. Groundwater levels are strongly controlled by the seasonal exploitation of the resources over the summer irrigation period, mainly exercised by several shallow and often hand-dug wells. Saline water intrusion is also apparent in small parts of the aquifers nearby the coastline, where the water levels are lower than the mean sea level.

The aquatic environment is also affected by water level and flow regulations for flood protection, drainage channels and the tourist infrastructure in the coastal area. Extreme hydrologic events such as floods and droughts are quite common in the catchment (http://www.minenv.gr/pinios/page5.html).

DRIVING FORCE	PRESSURE
Agriculture	Nutrient loss from agriculture Pesticide application Modified water use by vegetation
Abstraction for irrigation	Reduction in groundwater volume
Urban activity	Effluent disposal to groundwater
Industry	Effluent disposal to groundwater

PRESSURE	POTENTIAL IMPACT
Nutrient loss from agriculture	Groundwater quality deterioration
Reduction in groundwater volume	Reduced dilution of chemical fluxes (increased concentrations) Aquifer compaction, subsidence at surface Modified flow Seawater intrusion Modified dependent terrestrial ecosystem
Modified water use by vegetation	Altered aquifer recharge
Pesticide application	Groundwater quality deterioration Potential health risks on recovered water
Effluent disposal to groundwater	Groundwater quality deterioration Potential health risks on recovered water

7. Institutions for groundwater governance and potential measures to counteract pressures

Institutional context

Since December 2003, a new legislative and institutional framework has been put into force in the country. It consists of Law 3199/9-12-2003 (Official Journal of the Government - OJG 280A/2003) on water protection and the sustainable management of the water resources, with which the EU Water Framework Directive (WFD) (2000/60/EC) is transposed into the national legislation. This new framework Law foresees a radical reorientation of the respective administrative capacities in Greece and introduces an innovative and holistic approach concerning water management that recognizes explicitly the ecological function of water. It also lays emphasis on the management of water on the basis of river basins as well as on the water pricing so that it reflects its full costs. In more detail, the main objectives of the new Law include: the long-term protection of water resources, the prevention of deterioration and the protection and restoration/remediation of degraded water resources and wetlands, the reduction and, in cases, the phase out of harmful and polluting discharges, the reduction of groundwater pollution and the prevention of its further deterioration as well as the mitigation of the effects of floods and droughts.

The Law 3199/03 also incorporates the polluter pays principle and the objective of maintaining or reaching a good ecological status for all water resources through the control of pollution by use of threshold levels and standards. It also introduces innovative approaches concerning the protection of water quantity and the transnational cooperation for the protection of transboundary water courses and lakes.

The new legislation for the protection and the sustainable management of the water resources in Greece provides a detailed identification of 13 Regional Water Directorates, which have the responsibility for organising and co-ordinating water policy activities and specific Water Programmes and Action Plans with specific measures for the River Basin Districts (RBDs) of the country. They are in charge for implementing the WFD in the RBDs and they are supervised by the Central Water Agency, a governmental authority with the overall responsibility for establishing the national water policy. In the new legislation there is also consideration about the most effective options for setting up legal coordination mechanisms relating to the designation and management of the River Basins that cross the borders of their competencies.

The 3199/03 Law also integrates the public participation requirements of the WFD. The active involvement of the interested parties is ensured by their representation at the National and Regional Water Councils that will be developed as a part of the new administrative framework. In order to complete the transposition of the WFD, besides this new law, further instruments, e.g. Presidential Decrees and Joint Ministerial Decisions, have been prepared, for the incorporation of the technical provisions of the Directive (Country Profile: Greece, 2004; Lazarou, 2006)

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Management of protected areas including wetlands, was defined in 1999 (Law 2742/99) through the establishment of administrative units (Management Bodies) and the competence of NATURA 2000 Committee, whereas in 2002, through Law 3044/02, 25 Management Bodies were established, additionally to the existing two ones. Management of the most important protected wetland sites in Greece, designated as Ramsar wetlands of international importance, is attained through the establishment of these Bodies (which are financially supported, for the time being, from the state), that will collaborate with the respective regional services to be established according to Law 3199/03, with the mandate to develop and implement regional water management plans.

The development of the National Strategy for the management of Water Resources is closely linked with the efforts of Greece to comply with the Water Framework Directive (2000/60/EC). In this context, the Hellenic Ministry for the Environment, Physical Planning and Public Works has already proceeded to the necessary actions for the implementation of the Directive.

The National Strategy for the management of Water Resources (NSWR) concerns the sustainable use of existing water reserves, the efficient protection of water ecosystems and the attainment of high quality standards for all surface and ground water bodies by the year 2015.

The basic sectors of action of the NSWR are:

- Integrated approach for water management: Development of Management Plans on river basin level including transboundary water courses, based on water quality and quantity considerations and the interaction between surface and ground waters.
- Upgrading and expansion of infrastructure: This includes the promotion of specific measures and actions for meeting the demand for water supply through the expansion of existing networks as well as through the decrease of losses, the construction of new and the upgrading of existing wastewater treatment plants with emphasis on recycling, the construction of new multi-purpose reservoirs and finally, the establishment of more effective mechanisms for monitoring water quality and quantity with focus on creating an updated Data Bank.
- Incorporation of socio-economic considerations in water management: This includes measures to reinforce public participation in water management efforts as well as adaptation of pricing policies to include the social cost in water services provision.
- Preventive and remedial Measures: Protection of the aquatic environment of the country and promotion of remedial measures, where required.

More specifically, the NSWR contains a wide series of activities according to the requirements of the WFD that will allow meeting set targets at national, EU and international levels, by fully implementing the WFD and law 3199/03, such as:

- Participation of national experts in the Common Implementation Strategy for the implementation of WFD
- Completion of WFD transposition into national legislation.
- Participation in the intercalibration exercise
- Update of the National Qualitative and Quantitative water data bases
- Encouragement of active involvement of all interested parties
- Participation in the PRB network, established by the EC, with the Pinios Pilot River Basin in Thessaly RBD.
- Development of a new monitoring network for inland surface, transitional, coastal and ground waters, including the development of monitoring programs for biological quality parameters and the assessment of their ecological quality.
- Categorization and determination of Reference Conditions of water bodies
- Designation of heavily modified and artificial water bodies.
- Development of water pricing policies that enhance the sustainability of water resources.
- Development and publication of River Basin Management Plans for each river basin district of the country.

Furthermore, according to the requirements of the EU Directive 91/676/EEC (transposed into national legislation with JMD 195652/ 1906/1999, OJG 1575B), four vulnerable zones towards nitrogen pollution from agricultural run-offs have been established and respective special Action Programmes have been planned and adopted, according to art.5 of the Directive, focusing on the minimization of the adverse impacts on the environment of Greece. The implementation of these programmes is obligatory for all farmers of these vulnerable zones. These Action Programmes include:

- Action programme for Thessaly plain (JMD 25638/2905/2001, OJG 1422B)

- Action programme for Kopaida plain (JMD 20417/2520, OJG 1195B)
- Action programme for Argolida plain (JMD 20416/2519, OJG 1196B)
- Action programme for Pinios basin, Prefecture of Ilia (JMD 20418/2521, OJG 1197B)

In 2001 three more areas were identified as sensitive areas (with JMD 20419/2522, OJG 1212B). For these areas Action Programmes have been established:

- Action programme for Thessaloniki plain ((JDM 16175/824 OJG 530B)
- Action programme for Strimonas Basin (under finalization)
- Action programme for Arta Preveza plain ((under finalization)

Finally, under the National Programme (OJG 1866/B/12.1.03) for the reduction of toxic substances of List II of Directive 76/464/EC, three special Action Programmes have been established: for the protection of Lake Vegoritida-Petron and Soulos stream MD (15782/1849/2001 OJG 797B), of Koroneia lake (JDM 35308/1838, OJG 1416B) and of Pagasitikos Gulf (JDM 15784/1864, OJG 819B).

8. Economics of Water use

An analysis on the water uses in Greece has been undrtaken by the Athens University of Economics and Business for the Central Water Agency, in accordance with the Art. 5 of the WFD requirements. This study was submitted to the European Commission, for the needs of the WFD Art. 5.

The study allows an assessment of the recovery level of water services in each sector of the economy and assists policy making in implementing efficient, equitable and sustainable water resources management policies in compliance with the EU Directive. The main conclusions of the research undertaken are summarised in the following tables:

Table A: Socioeconomic characteristics of each River Basin District

River Basin District (RBD)	Population of RBD (2001)	Area Of RBD (km^2)	Domestic demand for water (Million Cubic Meters per year)	Demand for irrigation water (Million Cubic Meters per year)	Industrial water demand (Million Cubic Meters per year)
1.West Peloponnesos	331,180	7,301	23	201	3
2.North Peloponnesos	615,288	7,310	36.7	395.3	3
3. East Peloponnesos	288,285	8,477	22.1	324.9	0.03
4.West Sterea Ellada	312,516	10,199	22.4	366.5	0.35
5. Epirus	464,093	10,026	33.9	127.4	1
6. Attica	3,737,959	3,207	400	99	1.5
7. East Sterea Ellada	577,955	12,341	41.6	773.7	12.6
8.Thessaly	750,445	13,377	69	1,550	0.054
9. West Macedonia	596,891	13,440	43.7	609.4	30
10. Central Macedonia	1,362,190	10,389	99.8	527.6	80
11. East Macedonia	412,732	7,280	32	627	0.321
12.Thrace	404,182	11,177	27.9	825.2	11
13.Crete	601,131	8,335	42.33	320	4.1
14. Aegean Islands	508,807	9,103	37.19	80.20	1.24

Table B: Cost Recovery of Water Services Level in each Water District

River Basin District (RBD)	Cost and Recovery	Domestic	Irrigation	Total
1.West Peloponnesos	Financial Cost (€)	106,825,222	4,689,283	111,514,505
	Resource Cost (€)	-	0	0
	Environmental Cost (€)		0	0
	Agricultural Subsidies (€)	-	27,196,649	27,196,649
	Recovery (€)	63,420,580	3,647,690	70,105,941
	Cost Recovery Level (%)	62.21	11.44	50.54
2.North Peloponnesos	Financial Cost (€)	183,128,952	3,028,191	165,264,301
	Resource Cost (€)	-	0	0
	Environmental Cost (€)	0	0	0
	Agricultural Subsidies (€)	-	15,783,835	15,783,835
	Recovery (€)	115,963,093	5,519,490	123,507,697
	Cost Recovery Level (%)	77.31	19.41	68.22
	Financial Cost (€)	152,607,460	12,656,841	186,157,143

3. East Peloponnesos	Resource Cost (€)	-	3,510,184	3,510,184
	Environmental Cost (€)	0	0	0
	Agricultural Subsidies (€)	-	28,941,94	28,941,994
	Recovery (€)	68,631,114	5,740,844	75,121,958
	Cost Recovery Level (%)	37.89	15.66	34.18
4.West Sterea Ellada	Financial Cost (€)	106,447,222	18,603,213	125,050,435
	Resource Cost (€)	-	0	0
	Environmental Cost (€)	0	0	0
	Agricultural Subsidies (€)	-	31,781,567	31,781,567
	Recovery (€)	64,998,931	7,197,206	72,434,138
	Cost Recovery Level (%)	61.29	14.28	46.19
5. Epirus	Financial Cost (€)	198,389,698	9,736,162	208,125,860
	Resource Cost (€)	-	0	0
	Environmental Cost (€)	0	0	0
	Agricultural Subsidies (€)	-	2,826,432	2,826,432
	Recovery (€)	136,499,203	2,818,647	143,671,846
	Cost Recovery Level (%)	71	22.44	68.11
6. Attica	Financial Cost (€)	334,735,000	906,238	334,735
	Resource Cost (€)	-	0	0
	Environmental Cost (€)	0	0	0
	Agricultural Subsidies (€)	-	7,036,644	7,036,644
	Recovery (€)	361,995,000	1,691,811	363,686,811
	Cost Recovery Level (%)	108.14	21.30	106.13
7. East Sterea Ellada	Financial Cost (€)	183,128,952	3,767,101	186,896,053
	Resource Cost (€)	-	20,515,680	20,515,680
	Environmental Cost (€)	3,117,546	3,919,685	7,037,232
	Agricultural Subsidies (€)	-	50,018,126	50,018,126
	Recovery (€)	64,998,931	12,499,562	152,371,950
	Cost Recovery Level (%)	75.1	15.98	57.61
8.Thessaly	Financial Cost (€)	473,083,126	15,090,667	488,173,793
	Resource Cost (€)	-	89,356,467	89,356,467
	Environmental Cost (€)	2,007,512	7,129,974	9,137,486
	Agricultural Subsidies (€)	-	84,194,914	84,194,914
	Recovery (€)	159,844,929	40,167,390	200,067,757
	Cost Recovery Level (%)	33.66	6.38	29.82
9. West Macedonia	Financial Cost (€)	289,954,174	12,874,290	302,828,464
	Resource Cost (€)	-	0	0
	Environmental Cost (€)	3,749,696	10,785,902	14,535,598
	Agricultural Subsidies (€)	-	27,166,953	27,166,953
	Recovery (€)	126,906,888	20,866,602	178,150,204
	Cost Recovery Level (%)	53.55	41.05	51.71
10. Central Macedonia	Financial Cost (€)	376,115,174	8,123,200	384,238,374
	Resource Cost (€)	-	0	0
	Environmental Cost (€)	9,597,394	15,281,830	16,586,149
	Agricultural Subsidies (€)	-	29,713,081	29,713,081
	Recovery (€)	283,986,818	5,780,887	336,967,706
	Cost Recovery Level (%)	86.58	12.04	78.27
	Financial Cost (€)	167,868,206	9,494,351	177,362,557

11. East Macedonia	Resource Cost (€)	-	0	0
	Environmental Cost (€)	1,549,368	3,476,094.48	5,025,462
	Agricultural Subsidies (€)	-	20,819,898	20,819,898
	Recovery (€)	134,337,440	9,252,186	143,750,126
	Cost Recovery Level (%)	79.39	27.38	70.74
12.Thrace	Financial Cost (€)	106,825,222	9,601,762	116,426,984
	Resource Cost (€)	-	0	0
	Environmental Cost (€)	2,934,534	6,908,179	9,842,713
	Agricultural Subsidies (€)	-	40,642,261	40,642,261
	Recovery (€)	113,209,011	113,209,011	130,659,923
	Cost Recovery Level (%)	103.29	11.05	78.28
13.Crete	Financial Cost (€)	244,171,936	8,690,616	252,862,552
	Resource Cost (€)	-	0	0
	Environmental Cost (€)	-	0	0
	Agricultural Subsidies (€)	-	48,196,855	48,196,855
	Recovery (€)	117,263,413	32,000,000	153,281,413
	Cost Recovery Level (%)	49.67	56.25	50.91
14. Aegean Islands	Financial Cost (€)	366,257,904	1,688,152	367,946,056
	Resource Cost (€)	-	26,784,000	26,784,000
	Environmental Cost (€)	-	0	0
	Agricultural Subsidies (€)	-	23,276,539	23,276,539
	Recovery (€)	157,258,153	919,609	158,177,763
	Cost Recovery Level (%)	42.94	1.78	37.84

The mean cost recovery level for each River Basin District in Greece was found 44.49%. Providers of water and sewerage services in general do not even recover their financial cost from revenues from customers within their water service area. It is worth noting that the recovery level in agriculture is relatively lower compared to domestic water use highlighting the need for policy measures to address sustainable and efficient water resources management in this sector.

9. Conclusions and recommendations

Degradation of groundwater quality is mainly caused by seawater intrusion and nitrate pollution. Many coastal aquifers in Greece are affected by seawater intrusion, due to overexploitation. Intensified fertilization has led to considerable groundwater quality deterioration, as evidenced by the increased nitrate concentration. Other sources of nitrate pollution are leaking septic tanks in urban areas.

An integrated management strategy should be applied to develop new ways of providing adequate water supply sources in Greece. This strategy could be based on the conjunctive use of groundwater, surface water, the discharge of freshwater springs, and the rich and high quality groundwater reserves of the mountainous region, which are practically not exploited.

The economic value of the various groundwater uses should be evaluated, and finally, a monitoring programme on groundwater quality should be established in order to avoid seawater intrusion phenomena and nitrate pollution on a large scale. The Directive 2000/60/EC and the harmonisation from Greek authorities provides new legislation and opportunities for the sustainable management of water resources.

References

Country Profile: Greece, National Reporting to the Twelfth Session of the Commission on Sustainable Development of the United Nations (UN CSD 12) Greece, Hellenic Republic, Ministry for the Environment, Physical Planning and Public Works, Athens, March 2004, Available at: http://www.minenv.gr/4/41/000/csd12_final%20edition.pdf

Daskalaki, P., Voudouris, K., 2006. The Impacts of the Irrational Water Resources Management on the Groundwater Quality of Greece, 2nd International Conference, Water Science and Technology - Integrated Management of Water Recourses, 23 – 26 November 2006, Athens, Hellas, AQUA 2006

EUWI/MED, Joint Mediterranean Process. 2007. Mediterranean Groundwater Report. Technical report on groundwater management in the Mediterranean and the Water Framework Directive. Available at: http://forum.europa.eu.int/Public/irc/env/wfd/library?l=/framework_directive/groundwater_library/mediterranean_groundwate/_EN_1.0_&a=d

Min.Env. 2003. Groundwater Characterisation in Pinios Pilot River Basin. Hellenic Ministry for the Environment, Physical Planning and Public Works, Institute of Geology and Mineral Exploration (IGME), National Agricultural Research Foundation (NAGREF), Available at: http://www.minenv.gr/pinios/page5.html

EEA. 1996. Groundwater Monitoring in Europe. European Environment Agency. Topic report No 14/1996, Available at: http://reports.eea.europa.eu/92-9167-032-4/en/page009.html

EEA. 1999. Groundwater quality and quantity in Europe. Copenhagen

Karamanos, A., Aggelides, S., Londra, P., 2004. Irrigation Systems Performance in Greece, Proceedings of 2nd WASAMED (WAter SAving in MEDiterranean agriculture), Irrigation Systems Performance, Workshop Hammamet (Tunisia), 24-28 June 2004

Koreimann, C., Grath, J., Winkler, G., Nagy, W., and Vogel, W.R. 1996. Groundwater Monitoring in Europe, European Topic Centre on Inland Waters, European Environment Agency.

Kouras, K., Katsoyiannis, I., Voutsa, D, 2007. Distribution of arsenic in groundwater in the area of Chalkidiki, Northern Greece, Journal of Hazardous Materials Article in Press

Latinopoulos, P., 2005. Valuation and Pricing of Irrigation Water: An Analysis in Greek Agricultural Areas, Global nest Journal, Vol 7, No3, pp 323-335

Lazarou Anastasia, 2006. Country Report: Greece, Conference of the Water Directors of the Euro- Mediterranean and Southeastern European Countries, 6 & 7 November 2006, Athens

Petalas, C., Pisinaras, V., Koltsida, K., and Tsihrintzis, V.A., 2005. The Hydrological Regime of the East Basin of Thessaly, Greece, Proceedings of the 9th International Conference on Environmental Science and Technology, Rhodes island.

Report on Greek Activities in relation to Systematic Climate Observations and Global Climate Observing Systems (GCOS). Ministry for the Environment, Physical Planning and Public Works October 2005, Available at: http://unfccc.int/resource/docs/gcos/grcgcos.pdf

Tsagarakis, K.P., Paranychianakis, N.V., Angelakis, A.N. 2002. GREECE, aqualibrium – Country Report Greece, Aqualibrium, European Water Management Between Regulation and Competition, Available at: http://www.oieau.fr/aqualibrium/Aqualibrium_08.pdf

The EU Water Framework Directive: Statistical aspects of the identification of groundwater pollution trends, and aggregation of monitoring results" Final Report December 2001, Available at: www.wfdgw.net

Vasalakis, A., Voudouris, K., Fytikas, M., and Dimopoulos, G., 2005. Groundwater Quality in Naxos Island, Cyclades Creece, Proceedings of the 9th International Conference on Environmental Science and Technology, Rhodes island, Greece.

Voudouris, K.S., Daskalaki, P., Antonakos, A., 2005. Water Resources and Groundwater Quality in North Peloponnesus (Greece), Global NEST Journal, Vol 7, No 3, pp 340-353.

Water Framework Directive, Integrated Testing of Guidance Documents in Pilot River Basins, Pinios Pilot River Basin – Greece, Available at: www.minenv.gr

Greek Biotope/Wetland Centre (or EKBY by its Greek initials), Goulandris Natural History Museum. *http://www.ekby.gr/*