



TRANSNATIONAL INTEGRATED MANAGEMENT OF WATER RESOURCES IN AGRICULTURE FOR EUROPEAN WATER EMERGENCY CONTROL (EU.WATER)

Priority Axis: Protection and Improvement of the Environment

Area of Intervention: A.O.L. 1.2 Improve integrated water management and flood risk prevention

Project Duration: 36 months

Regional report for the collected information: Sarigkiol basin, Western Macedonia, Greece

WP3: Knowledge capitalization and sensitive area maps

Act 3.2: Organization / rationalization of data concerning the available information, deliverables and guidelines about water management in agriculture (relevant normative frameworks & agronomic features included)

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Contents

1. Water Resources Management in National-regional level (Greece).....	2
1.1 Institutional framework for water resources management.....	2
1.2 Reference laws.....	7
1.3 Pilot area knowledge (undertaken studies, field surveys).....	7
2. Sarigkiol Basin, Kozani Prefecture, Western Macedonia Greece.....	9
2.1 Location and topography of the study area.....	9
2.2 Hydrometeorological data	11
2.3 Soil properties.....	18
2.4 Land uses and agricultural land.....	21
2.5 Surface waters.....	23
2.6 Hydrogeology and ground water quality.....	24
2.6.1 Hydrogeology and aquifer characteristics.....	24
2.6.2 Groundwater quality.....	29
2.7 Pollution Sources.....	31
References.....	32
3. Questionnaire for Srigkiol basin, Western Macedonia, Greece.....	35

1. Water Resources Management in National-regional level (Greece)

1.1 Institutional framework for water resources management

Greece is organised in 14 Water Districts, 9 regions are situated on mainland and 4 are constituted by groups of islands (1 region is autonomous-Athos). These regions are divided into 51 prefectures and include areas with homogeneous enough hydrological and hydrogeological features. National and Regional Management Plans exist in every sector (water supply, irrigation, cattle breeding, industry, tourism, pisciculture, energy production); moreover, prefectures and municipalities have developed specific plans in order to guarantee availability of water resources both for human and agricultural uses. The competent Regional Organization for each Water District accomplishes the following functions:

1. planning and supervising the functionality, maintenance and expansion of existing irrigation networks,
2. coordinating and monitoring the activities related to water resources uses,
3. rational management of agriculture water resources,
4. management cost optimization;
5. planning of water resources for irrigation use.

The transposition of the WFD (European Water Framework directive) into Greek legislation has led to a new institutional organisation with a new Central Water Agency, 13 Regional Water Directorates, a National water Committee (interministerial political body), national and regional water councils (consultative bodies). The protection and management of the river basins and the implementation of the WFD are a responsibility of the 13 Regional Water Directorates. In case of shared river basins, the National Water Committee must determine which regional authority is responsible. The National Water Agency is responsible for defining a national water policy and coordinating the activities of the regional directorates. Note that the regional directorates are under the General Secretary of each region. The current laws related to water resources have individuated institutions concerned with water resources, that form a specific administrative structure that concerns the water resources management in Greece (Fig.1). These institutions are the following:

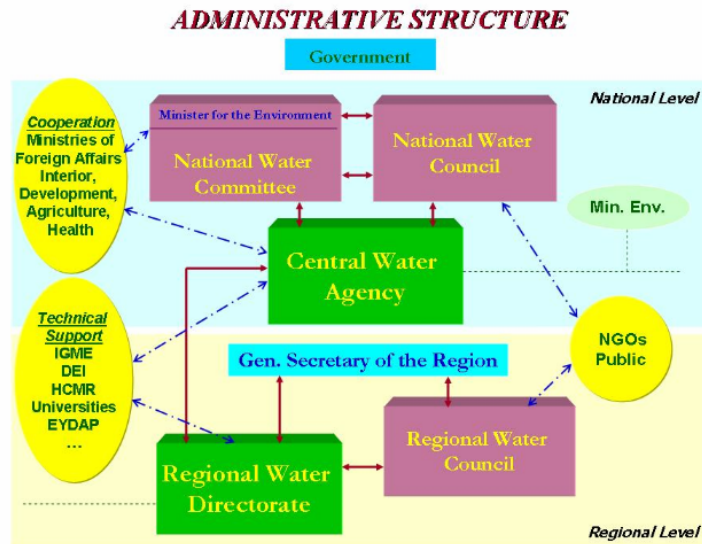


Fig. 1. The administrative structure in Greece for water resources management

(http://www.semide.net/countries/fo1135532/country204771/national_program/water-institutional-framework-greece)

National Water Committee, composed by ministers from:

1. Ministry for the Environment, Energy and Climate Change
2. Ministry of Economy and Finance
3. Ministry of Interior Decentralization and E-government
4. Ministry of Development
5. Ministry of Health and Social Solidarity
6. Ministry of Rural Development and food

National Water Committee, plans the policy for the protection and management of water resources, monitors and controls the application of policy, approves the national management and protection of water resources plans after proposals of the respective ministries after the approval of the National Water Council. The National Water Committee submits to the Parliament and to the National Water Council annual report regarding the status of national water resources, the application of legislation about the protection and management of water resources, as well as legislation compatibility with European status.

National Water Council, composed by 24 members, including representatives of political parties, Municipal Societies for aqueducts and sewage, etc. The Council

mainly has a consultant role regarding management and protection programs for water resources.

Central Water Agency, within the Ministry for the Environment, Regional Planning and Public Works. Its principal task is to coordinate all public services involved in water management, as well as to supervise all the administrative, economic and monitoring processes in progress. Specifically Central Water Agency has the following responsibilities:

- It draws up the national programs regarding the protection and management of water resources. It monitors and controls the application of these programs. The national programs separated into long – range (duration up to 6 years) and mid – range (duration from 2 to 6 years).
- It draws up the annual report regarding the status of national water resources, the application of legislation about the protection and management of water resources as well as legislation compatibility with European status.
- It recommends the general roles regarding the cost – accounting and pricing of water and monitors its application according the long – range and mid – range national programs.
- It recommends legislative and management measures regarding the protection and management of water resources.
- It monitors at national level the quality and quantity of water resources in cooperation with Regional Water Offices and looks after for the development and operation of water resources' monitoring national network.
- It manages at national level database of hydrological and meteorological data and looks after for database's continually update. Each authority that participates at the national monitoring network of water resources is obliged to provide water quality and quantity data for the update of the above database. The same obligation has any legal or independent person that has taken permission for water use or work construction for water utilization.
- It controls the operation of Regional Water Offices and gives directions for the implementation of their responsibilities.
- It is obliged until 22.12.2004 to apply the following for each river basin:
 - i. to draw up a fully and detailed report of its characteristics

- ii. to note the sequences of human activities at the surface and underground waters.
- iii. to proceed at the economical analysis of every water use in the river basin.
- It draws up until 22.12.2004 the National Record of Protected areas.
- It looks after, until 2015, for the protection, upgrade and restoration of surface water aiming at the achievement of good water quality.

Regional Water Councils, Consisted in each region and each one include 40-50 members and play a consultant role related to the Water District Management Plans, which are proposed by the Regional Water Office, before their approval. The Regional Water Council publishes the Water District Management Plans, before its approval, so as the public to be informed about the content of Management plans and to participate in a debate.

Regional Water Offices/Directorates, consisted in each region; their task is to implement in their own regions all the rules and measures indicated in law 3199/03. A Regional Water Office has been created in every region. Specifically every Regional Water Office has the following responsibilities:

- It takes the necessary measures for:
 1. the prevention of downgrading of surface and underground waters
 2. the upgrade and restoration of water systems
 3. the gradually reduction of pollution and the pause or gradually elimination of emissions
 4. the promotion of sustainable water use according to long – range protection of existing water resources
 5. the secureness of balance between the amount of pumping water from the aquifers and the amount of the water that enrich the aquifers
 6. the moderation of sequences causing by floods and droughts
 7. the application of targets and standard that provided for the protected areas
- It specializes and applies long – range and mid – range programmes for the protection and management of rivers basin
- It draws up the Regional Management Plans and Measures Programmes

- It applies the Regional Management Plans and Measures Programmes and draws up annual report about their application. The annual report is forwarded at the Central Water Agency.
- It draws up Record of Protected Areas that it is updated in regular periods. This Record is forwarded at the Central Water Agency so as the National Record of Protected Areas to be drawing up
- It looks after for the effective participation of public at the procedures regarding the protection and management of water
- It concentrates and elaborates water quality and quantity data which are sent for the update of hydrologic and meteorological database. It monitors and controls the quality and quantity of water, the ecosystem of surface waters as well as the condition of protected areas.
- It coordinates the authorities related with the use and protection of water.
- It takes all the required measures for the realization of :
 1. analysis of each river basin characteristics
 2. recording of sequences at the water recourses causing by human activities
 3. Economical analysis of water use
- It controls the emissions at the water recourses
- It takes measures for the water pollution control through the establishment of limit emission values.
- It applies Water protection programmes
- It planning and enforces all the required preventive measures for the confrontal of emergency
- It enforces measures for the protection of underground water and for the confrontal of the increase of matters' concentration in the water.
- It licences for the water use and construction of water utilization works
- It enforces protection measures at existing constructions and activities that probably downgrade the water recourses
- It enforces limits and measures at the water use and the construction of water utilization works so as the targets of Regional Management Plans to be achieved.

1.2 Reference laws

The current laws related to water resources have individuated the following institutions concerned with water resources:

Reference laws are:

- **Law 1650/1986** “For environmental protection”
- **Law 1739/87** “ For water resources management ”
- **Law 3199/2003** “*Water protection & management*” according to *EC Directive* 2000/60 (23/10/2000)
- **Ministerial Ordinance 43504/** Gov. Gazette 1784 B/20-12-2005 “*Categories of licenses for water utilization and for implementation of water exploitation works, procedure of issuing a license, content and validation time*”.
- **Ministerial Ordinance Y2/2600/2001** (Gov. Gazette 892B/ 11-7-2001) “*Water quality for human consumption*”, in compliance to the *Directive 98/83 E.C.* of the European Community Council on the “quality of water for human consumption”, and the “*Ministerial Ordinance G3a/761/6.3.68*” (Gov. Gazette 189/volume II/1968)
- **Ministerial Ordinance 26857/553/1988** (Gov Gazette196 A) “*Protection of underground waters from certain dangerous substances*”, in compliance with the EC Directive 80/68
- **Ministerial Ordinance 46399/1352/1988** (Gov. Gazette 438B/3-7-1988) “*Quality of surface waters intended for potable, quality of bathing bathing waters, quality of fresh water to support fish life, quality of shellfish waters, methods of measurement , sampling frequency and analysis of surface waters intended for potable*” according to EU Directives 75/440, 76/160, 78/659, 79/923, και 79/869
- **Ministerial Ordinance A5/288/1986** “*Quality of potable water*”, according to *EU Directive* 80/778
- **Health order YM 5673/4-12-1957** (Gov Gazette 5B/9-1-58) “*About potable water disinfection*”.

1.3 Pilot area knowledge (undertaken studies, field surveys)

The EUWATER project will be carried in the pilot area “Sarigkiol basin”.

Sarigkiol basin is part of the Region of Western Macedonia, which represents the 9th Greek Water District, englobing 65% of the national water resources. This Region contains entirely the Florina and Kozani prefectures territories and only partially those of the Grevena (85.5%), Imathia (74.3%), Kastoria (87.6%), Pieria (92.6%) and Pella (66.9%) prefectures; moreover, this region includes also a small portion of the Ioannina, Larisa and Trikala prefectures. Sarigkiol basin is located in the north-west part of the Kozani prefecture territory, with a surface of 469 km². Overexploitation and nitrogen pollution of agricultural origin are the main environmental pressures induced by humans; they have a significant negative effect on the area's groundwater.

The existing studies and maps regarding the Sarigkiol basin (achieved on scale between 1:25.000 and 1:100.000), are related to: *geology, hydrogeology, soil texture, piezometry, rainfall, land use, water resources uses and water resources quality*. The principal realized studies concerning water resources are:

- Hydrologic study for water resources quality and quantity in Western Macedonia, 2001.
- Water distribution for irrigation in the Aliakmonas River Basin, 2003.
- Hydrogeological study of the Vegoritis Lake basin, 2001.
- Water resources evaluation and management in the Sarigkiol basin, 2003.
- Control of water quality and hydrogeological studies of water resources of Western Macedonia' Water district (9th Greek Water District), 2001
- Planning of National Water Management Plan, 2003
- Systems and tools development for the management of Water resources of regions: Western Macedonia, Central Macedonia, Eastern Macedonia and Thrace, 2006
- Continuous Potable Water Analyses of all Municipalities of Kozani Prefecture and in some Municipalities of the rest Prefectures of West Macedonia Region realized by Environmental Centre 2002-Today.
- Soil map development for Dimitrios Ypsilantis and Ellispontos municipalities. Prefecture of Kozani, 2007.
- Pollution risk maps and groundwater vulnerability maps for Sarigkiol basin, 2008.

2. Sarigkiol Basin, Kozani Prefecture, Western Macedonia Greece

2.1 Location and topography of the study area

Sarigkiol basin (Fig. 2) is located in the north-eastern part of Kozani Prefecture (Municipalities of Ellispontos and Dimitrios Ipsilantis), Western Macedonia region, Greece, covering an area of 469.2 km².

At the west side there is Askio Mountain, at the east side there is Vermio Mountain, at the south side there is Skopos Mountain. The north border is nowadays the open pit of the south field lignite mines and partly the tectonic horst of Komanos. Important surface waters (e.g. lakes and rivers) are not existed in the study area except Soulou Torrent (non significant flow and small river bed, is used as a drainage pathway), which intersects the basin and was artificially opened up in 1954. The part of the torrent's bed which is adjacent to the lignite mines is not stable and is adjusted according to the needs of the Western Macedonia Lignite Center.

The land is mainly used for cultivation of cereals and cows and sheep graze the area. In a large part of the area irrigated agriculture is practised. Lignite deposits occurring in the basin and are one of the most rich energy resources in the Balkans. A large amount of 65% of country's total electric power is produced in this area.

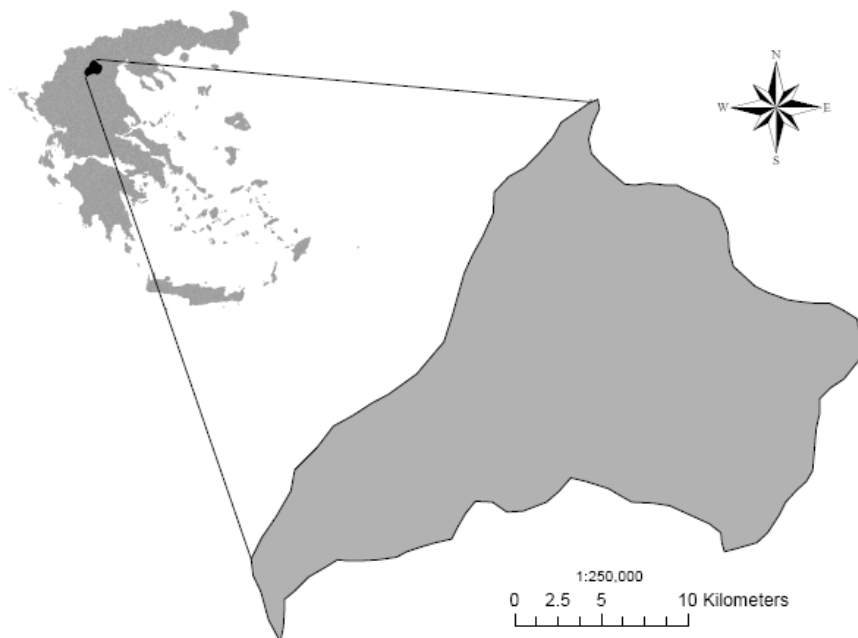


Fig. 2 Boundaries of the Sarigkiol basin, Western Macedonia, Greece.

Regarding the topography of the study area, analysis was conducted using the Digital Elevation Model (30x30 m) (Hellenic Military Geographical Service - HMGS). The lowlands (elevation <1000 m asl including lignite pite) and mountainous areas occupy 300.8 and 168.4 km², respectively, of the total area. The min, max and mean altitude of the basin is 640, 1796 and 952 m asl (Fig.3, 4) and the min, max and mean slope is 0, 116.5 and 18%, respectively (Fig. 5).

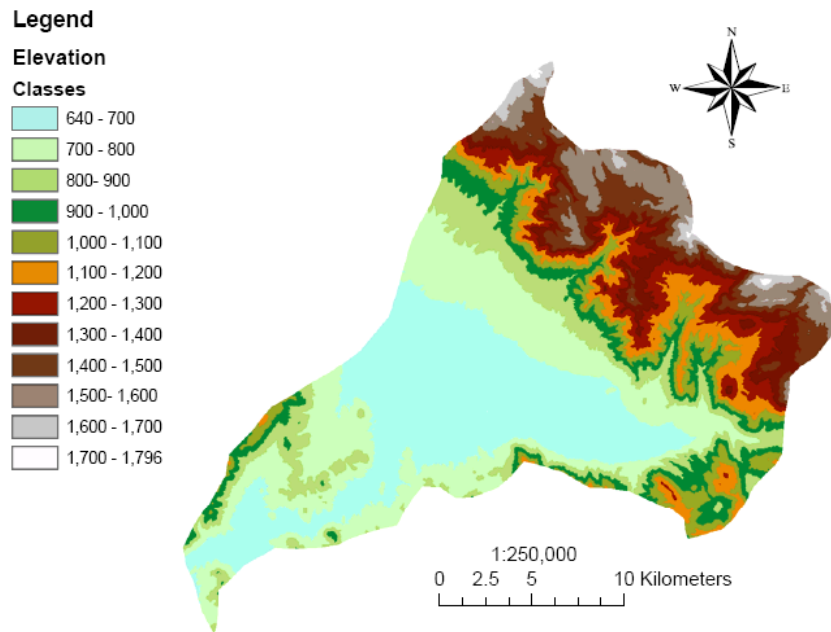


Fig. 3 Elevation classes of the study area.

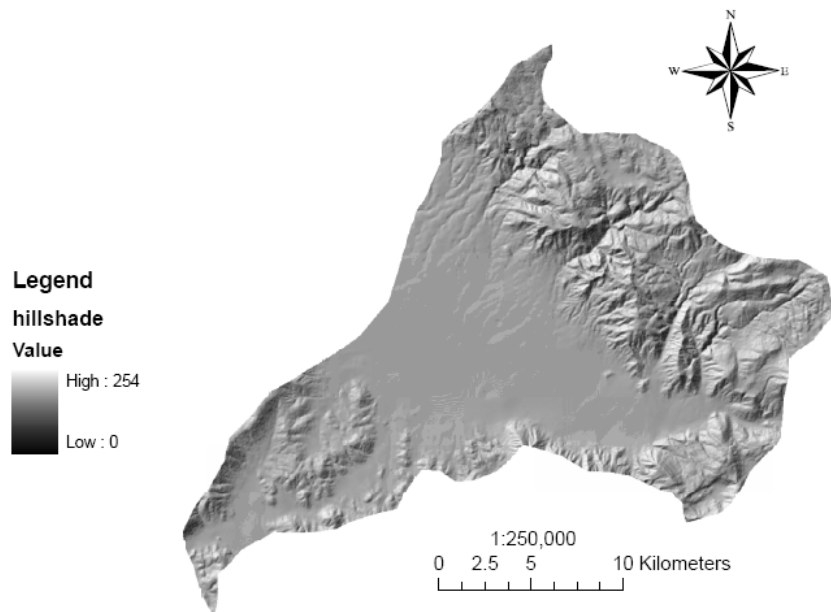


Fig. 4 Hillshade range of the study area.

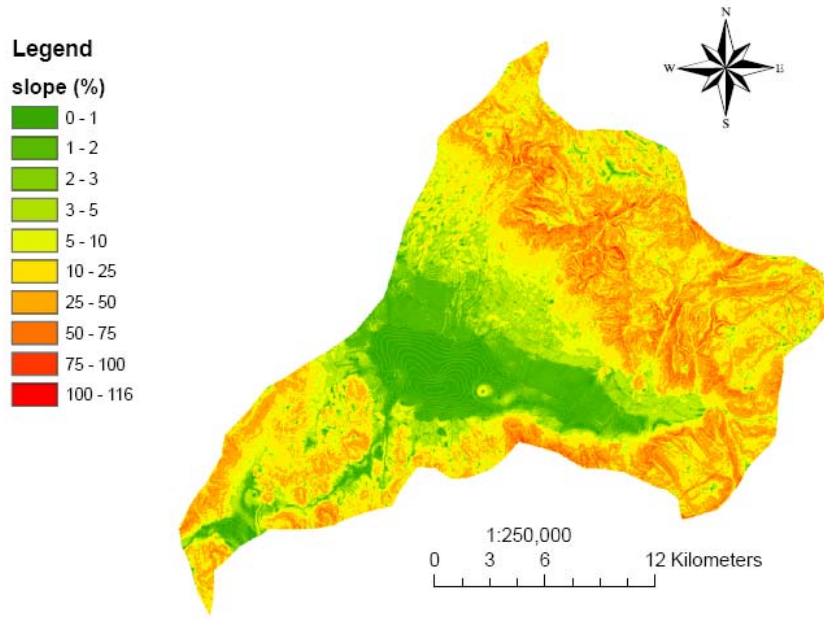


Fig. 5 Slope (%) classes of the study area.

2.2 Hydrometeorological data

The area is characterized by a semi-arid, Mediterranean climate, with an annual mean temperature 11.3 °C and an annual rainfall of 639.6 mm with the most raining periods Autumn and Spring, while summers are usually dry.

Regarding the rainfall surface integration, the rainfall height is strongly correlated with the altitude. Using the least square method (data from 10 rain gauges sited between 600 m < H < 1000 m of the wider hydrologic basin of Vegoritis Lake, where Sarigkiol basin is included) the relationship between the mean annual rainfall P (mm) and the elevation H (m) is described by the regression straight line (Voudouris et al., 2006):

$$P = 0.28 \cdot H + 373$$

Thus, the mean annual rainfall increases by 28 mm per 100 m of ground elevation.

Kozani station (Elevation 710 m and 40° 18' N, 21° 47' E) (Fig. 6) was used as a base to conduct surface integration of temperature, using the average temperature gradient for average latitudes (0.65 °C/100 m) (Baltas, 2004).

Potential evapotranspiration was determined by the Thornthwaite (1957) method. This method uses only the parameter of temperature and the location characteristics of the target area on the earth and is given by the following equation:

$$E_p = 16 \left(\frac{10t_i}{J} \right)^a \frac{\mu N}{360}$$

$$j_i = 0.09t_i^{3/2}, \quad J = \sum_{i=1}^{12} j_i, \quad \alpha = 0.016J + 0.5, \quad N = \frac{24}{\pi} \omega_s$$

where E_p : monthly average potential evapotranspiration (mm), t_i : monthly average temperature ($^{\circ}\text{C}$), μ : number of days of the month, N : daily average sunshine hours of clear sky (hr), J : yearly temperature parameter, j_i : yearly temperature parameter, α : empirical parameter and ω_s : sunset hour angle (rad). The sunset hour angle is given by the following equation:

$$\omega_s = \arccos(-\tan\phi \tan\delta)$$

$$\text{and } \delta = 0.4093 \sin(0.0172Z - 1.39)$$

where ϕ : latitude (rad), δ : solar declination (rad) and Z : average Julian day of the month. Thornthwaite equation was transformed in a simpler power equation in order to give annual potential evapotranspiration as a function of the annual average temperature and to conduct surface integration:

$$E_p = 116.02 \cdot T^{0.7344}$$

The results of surface integration of annual rainfall, temperature and potential evapotranspiration are given in figs. 7,8 and 9, respectively.

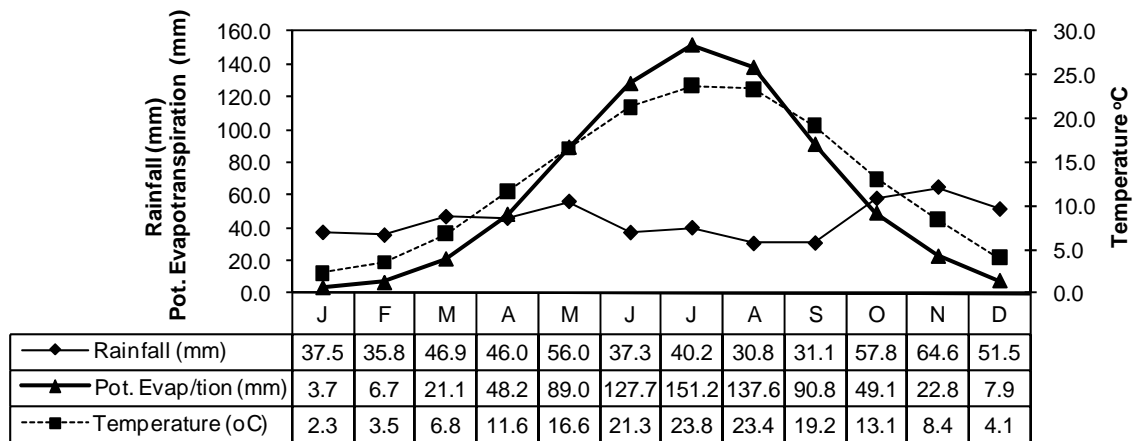


Fig . 6 Monthly rainfall, temperature and potential evapotranspiration variation of Kozani station.

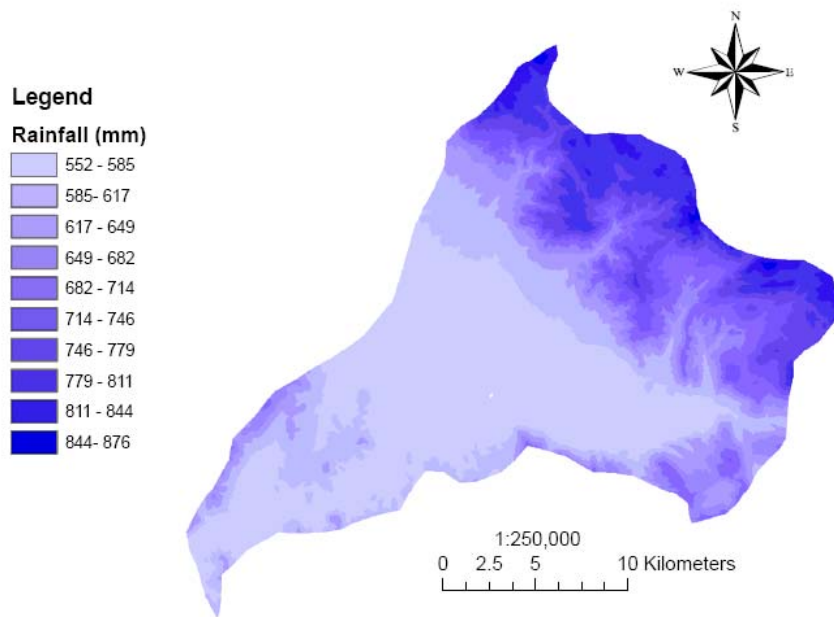


Fig. 7 Annual rainfall of the study area

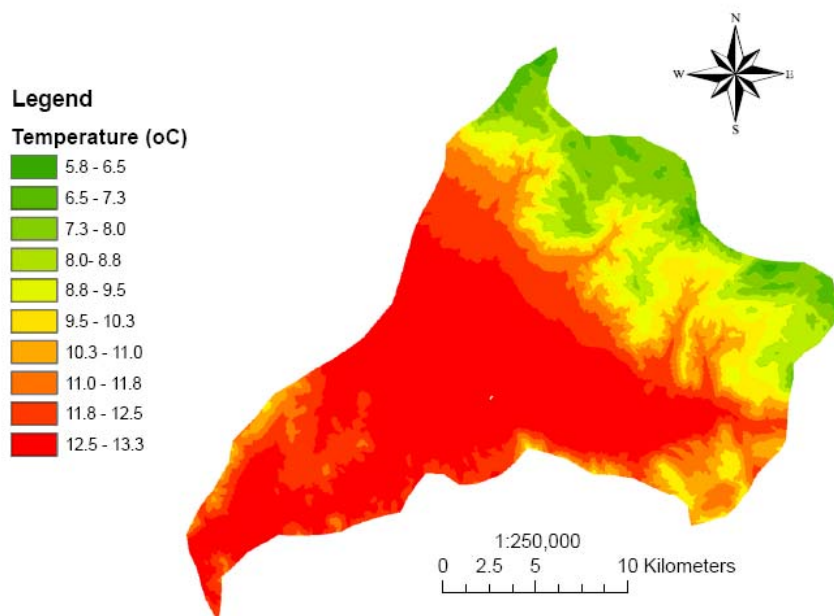


Fig. 8 Annual mean temperature of the study area

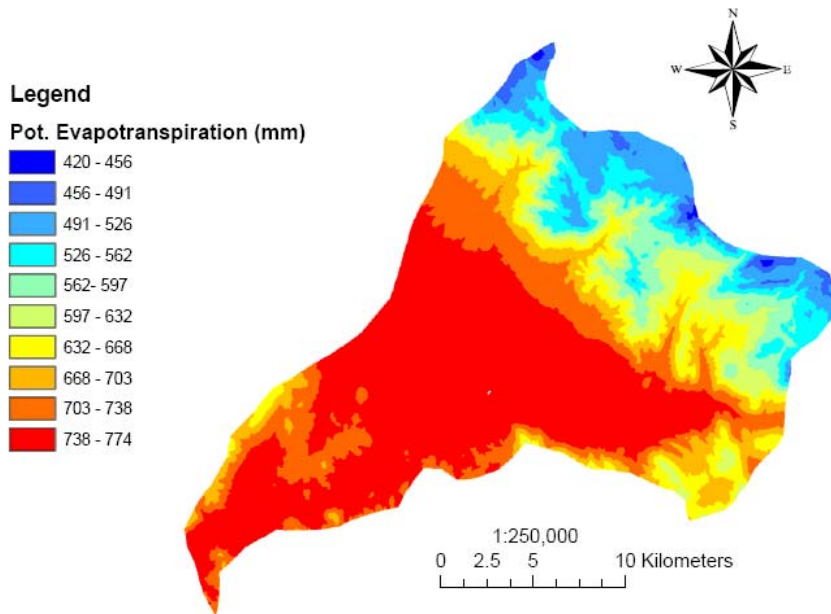


Fig. 9 Annual potential evapotranspiration of the study area

The annual rainfall percentage distribution and the monthly rainfall, temperature and potential evapotranspiration variation in the min, max and mean altitude of Sarigkiol basin are given in Figs. 10, 11, 12 and 13, respectively.

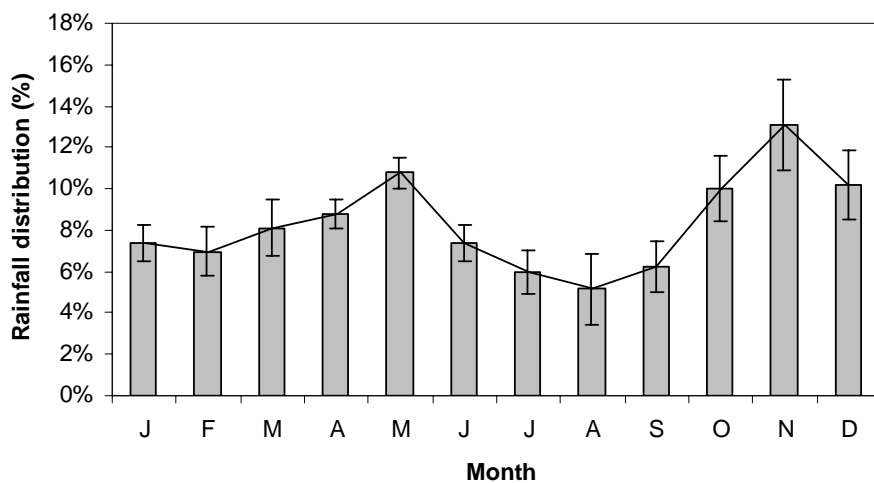


Fig. 10 Annual rainfall percentage distribution in Sarigkiol basin

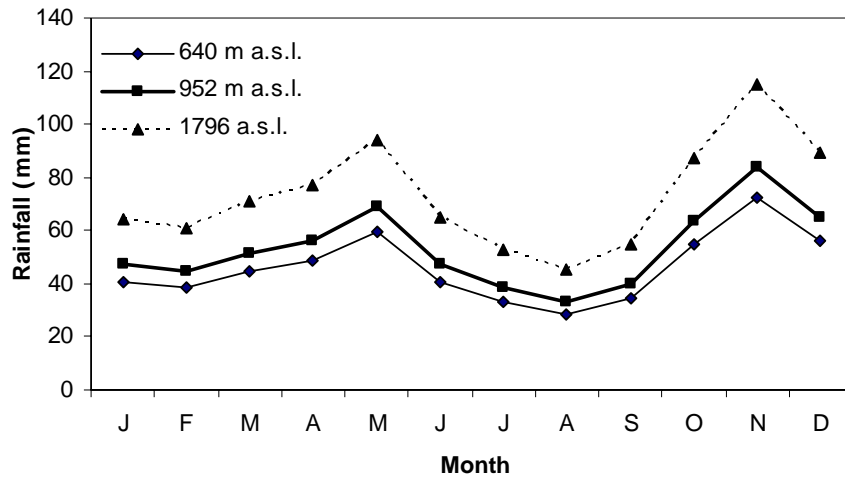


Fig. 11 Monthly rainfall variation in the min, max and mean altitude above sea level in Sarigkiol basin (a.s.l.).

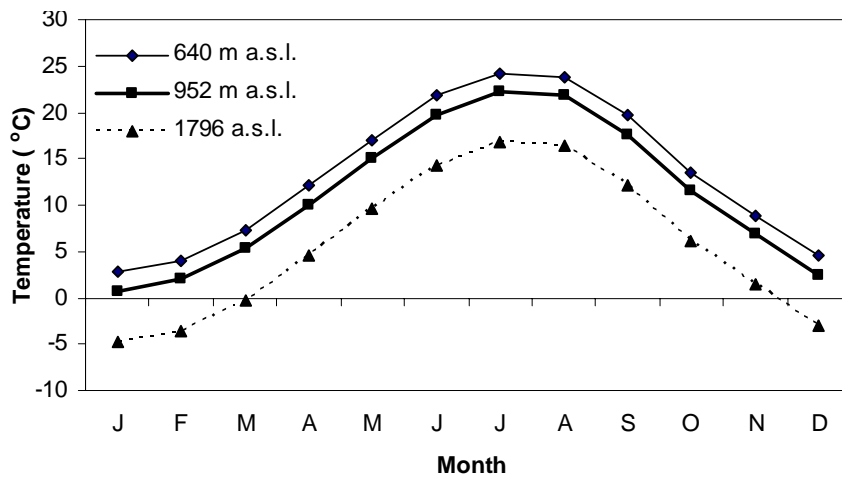


Fig. 12 Mean monthly temperature variation in the min, max and mean altitude above sea level in Sarigkiol basin (a.s.l.).

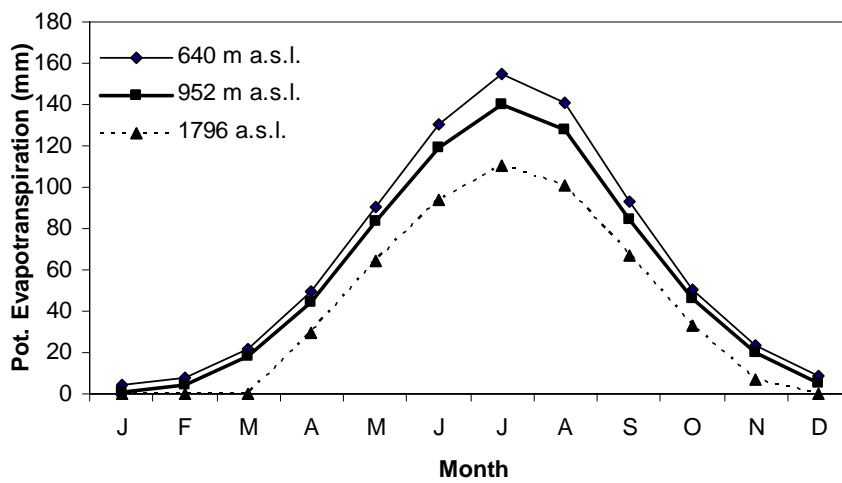


Fig. 13 Monthly pot. evapotranspiration variation in the min, max and mean altitude above sea level in Sarigkiol basin (a.s.l.).

Pontokomi station (Elevation 680 m and 40° 24' N, 21° 45' E), is the closest station to the LCWM¹ and is the more representative station to describe the climatic conditions of the lowland part of Sarigkiol basin where agricultural land is laid. The annual rainfall distribution and the temperature variation for the period 1951-2001 is given in fig. 14, where November and August are the most wet and dry months, respectively, and July and December the most warm and cold, respectively. The mean annual rainfall and temperature are 552.7 mm and 13.0 °C, respectively.

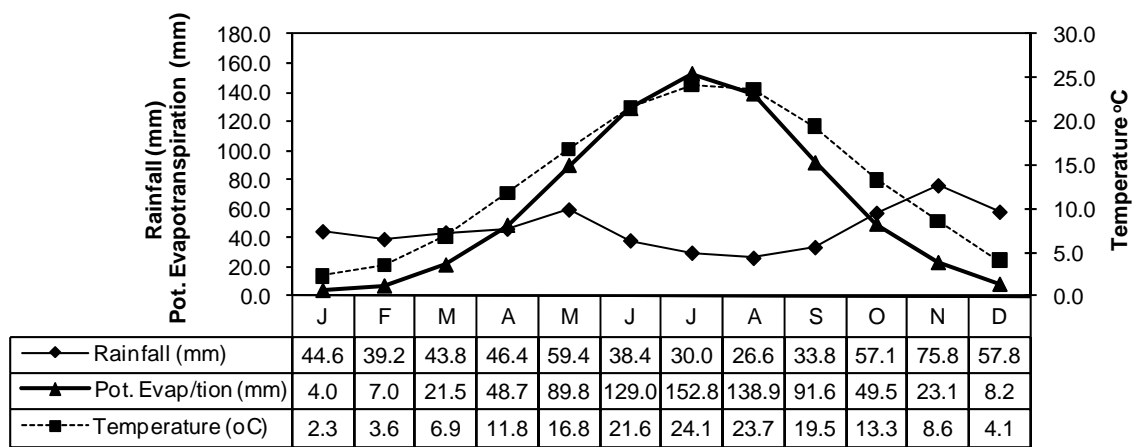


Fig . 14 Monthly rainfall, temperature and potential evapotranspiration variation of Pontokomi station.

Regarding the relationship between monthly rainfall and potential evapotranspiration for Pontokomi station, relative deficiency of water for evapotranspiration is observed during the period from April up to September (Fig. 14). Based on results of previous studies (Aschonitis et al. 2006), using SPI drought index (Mc Kee et al., 1993), a decrease of annual rainfall at the second half of the period 1951-2001 was observed, for stations near the LCWM, which was attributed to the intensification of LCWM operations (Figs. 15, 16 & 17).

¹ Lignite Center of Western Macedonia

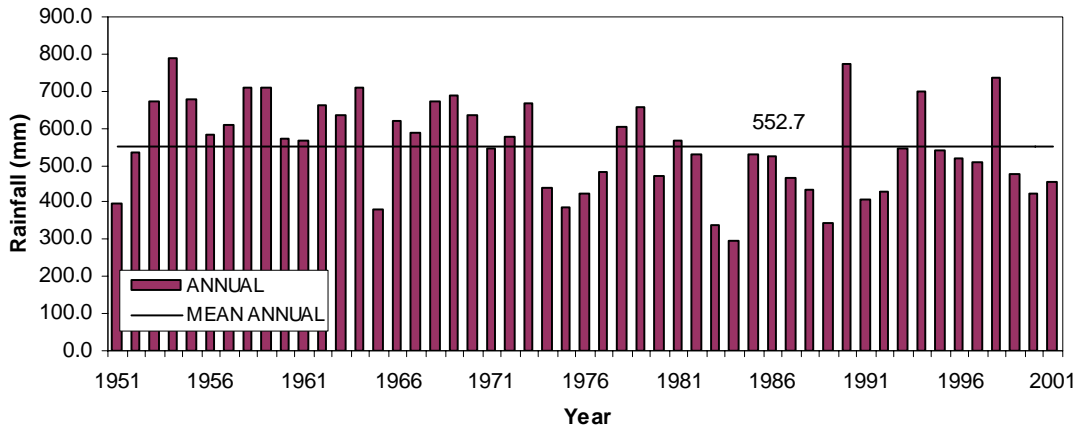


Fig. 15 Annual rainfall of Pontokomi Station.

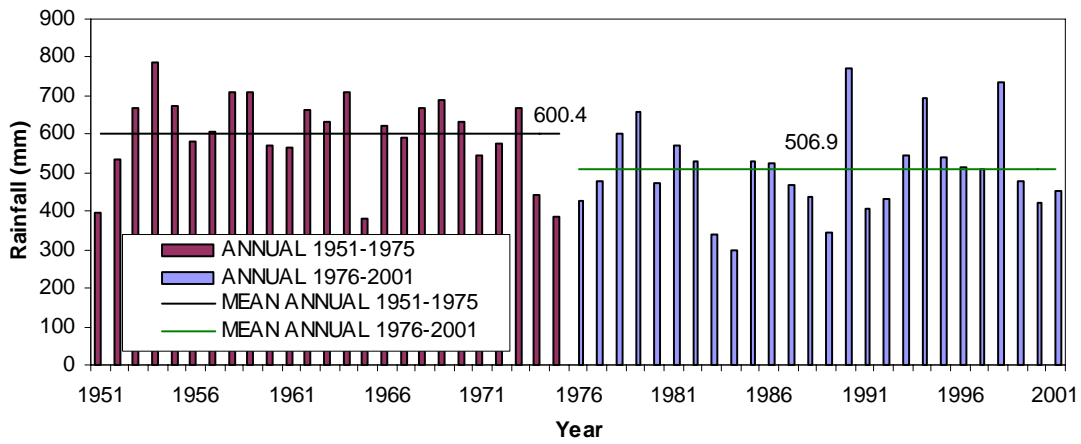


Fig. 16 Differences in annual rainfall of Pontokomi Station for the periods 1951-1975 and 1976-2001.

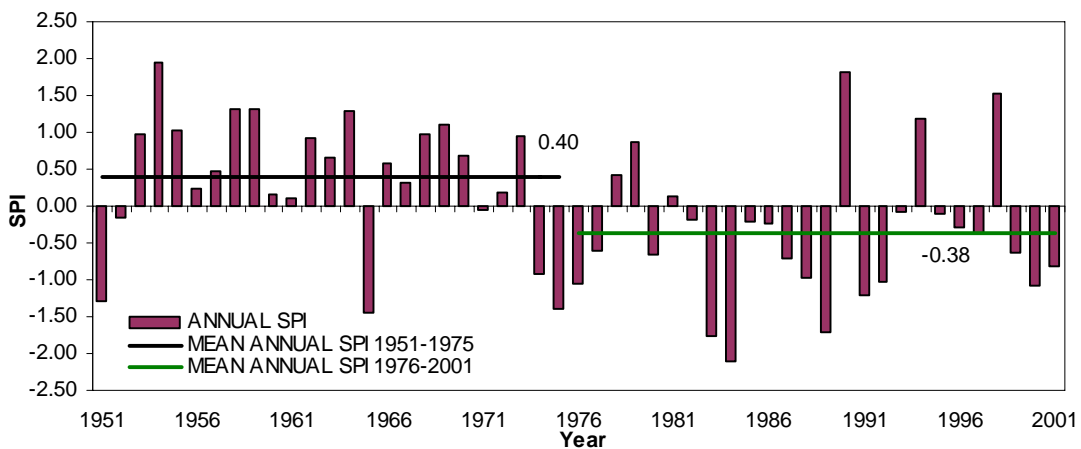


Fig. 17 SPI drought index of Pontokomi Station for the period 1951-2001.

Regarding the hydrologic balance of the Sarigkiol region, it was determined by Stamou (2001) using the general equation :

$$P = R + E + I + dw + dq$$

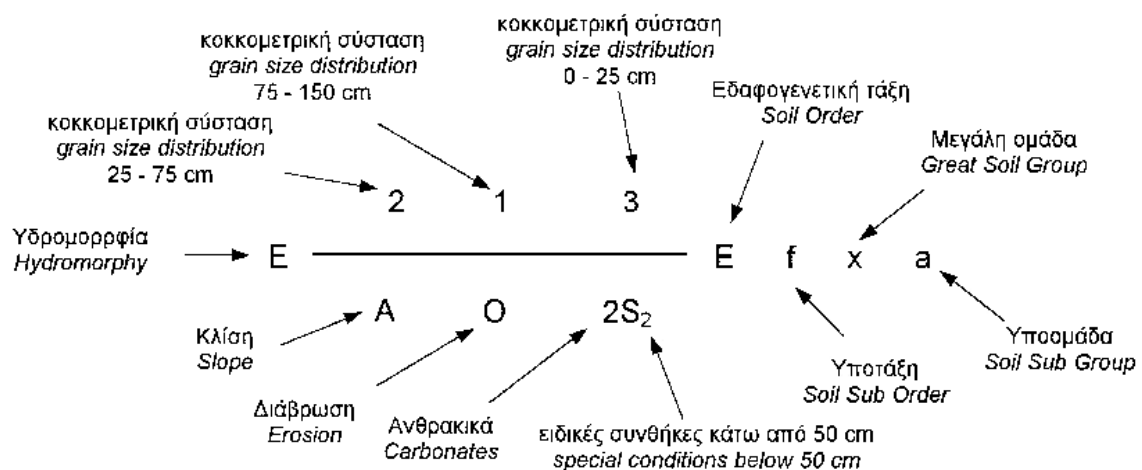
where: P: rainfall, R: the surface runoff, E: evapotranspiration, I: infiltration, dw: the change of the quantity of groundwater reserves and dq: the result of human intervention (the factors dw and dq considered as negligible). From the results of the study, actual evapotranspiration, infiltration and surface runoff were distributed as percentage of rainfall (Table 1.)

Table 1. Hydrological balance of Sarigkiol basin (Stamou, 2001).

Water balance factors	P	Er	I	R
Percentage (%)of P	100.0	72.4	20.6	7.0

2.3 Soil properties

Soil profile analyses and soil map development for Sarigkiol basin have been conducted by Soil Science Institute of Themi-Thessaloniki (N.A.G.R.E.F., 2007) according to the USDA classification (Soil Survey Staff, 1996) using the following soil mapping unit:



The hydromorphy classes (Table 2), grain size distribution (Table 3) and soil order-group of the Sarigkiol basin are given in Fig. 18.

Table 2. Hydromorphy classes (Soil Survey Staff, 1996)

CLASS	DEFINITION
A	Over-drained soils. Absence of mottles along the soil profile.
B	Well-drained soils. Fe and Mn mottles in 100 cm depth.
C	Moderately-drained soils. Mottles in 50 - 100 cm depth.
D	Poorly-drained soils. Mottles in 25 - 50 cm depth.
E	Very poorly-drained soils. Mottles in depth < 25 cm .
F	Soils with permanent ground water level in 50 - 150 cm depth.
G	Soils with permanent ground water level in depth < 50 cm.

Table 3. Grain size distribution classes – soil texture (Soil Survey Staff, 1996)

MAP SYMB.	SECTION A 0 - 25 cm	SECTION B 25 - 75 cm	SECTION C 75 - 150 cm
0	Gravels > 60 %	Gravels > 60 %	Gravels > 60 %
1	Sand (S) Loamy sand (LS)	Sand (S), Loamy sand (LS), Sandy loam (SL), or layers with coarse-grained material.	Sand (S) Loamy sand (LS) Sandy loam (SL)
2	Sandy loam (SL)	Silt (Si), Silty loam (SiL), Loam (L) or layers with Loam (L) predominated.	Loam (L), Silty loam (SiL), Silt (Si) or layers with fine material predominated.
3	Loam (L), very fine Sandy loam (vfSL), Silty loam (SiL), Silt (Si)	Clay loam (CL), Sandy clay loam (SCL), Silty loam (SiL) or layers with fine material predominated	finer than Silt (Si), or layers with fine material predominated.
4	Clay loam (CL), Sandy clay loam (SCL), Silty clay loam (SiCL)	Sandy clay (SC), Silty clay (SiC), Clay (C)	-
5	Sandy clay (SC), Silty clay (SiC), Clay (C)	-	-
M	MUSK	MUSK or MUSK layer	MUSK or MUSK layer
R	-	Parent rock	Parent rock
*	Superimposed on the grain size distribution symbol, if soil consists of gravels < 60 %		

Several hydrological applications require the characterization of the soil hydraulic properties at large spatial scales. Pedotransfer functions (PTFs) are being developed as simplified methods to estimate soil hydraulic properties as an alternative to direct measurements, which are unfeasible for most practical circumstances (Chirico et al., 2007). Specific soil parameters such as hydraulic conductivity and organic matter were correlated with the soil texture using pedotransfer functions (PTFs). Organic matter (OM) was determined using obtained PTF by Dexter, (2004)

and saturated hydraulic conductivity (K_s) combining two equations the one parametric sand depended PTF of Ferrer-Julia et al. (2004) and the other clay depended PTF of Dane and Puckett (1994). The PTFs are the following:

$$OM\% = 1.58 + 0.048 \cdot C \quad (\text{Dexter, 2004})$$

$$K_s = 0.920 \cdot \exp(0.0491 \cdot S) \quad (\text{Ferrer-Julia, 2004})$$

$$K_s = 303.84 \cdot \exp(-0.144 \cdot C) \quad (\text{Dane and Pucket, 1994})$$

where C: percent of clay content and S: percent of sand content.

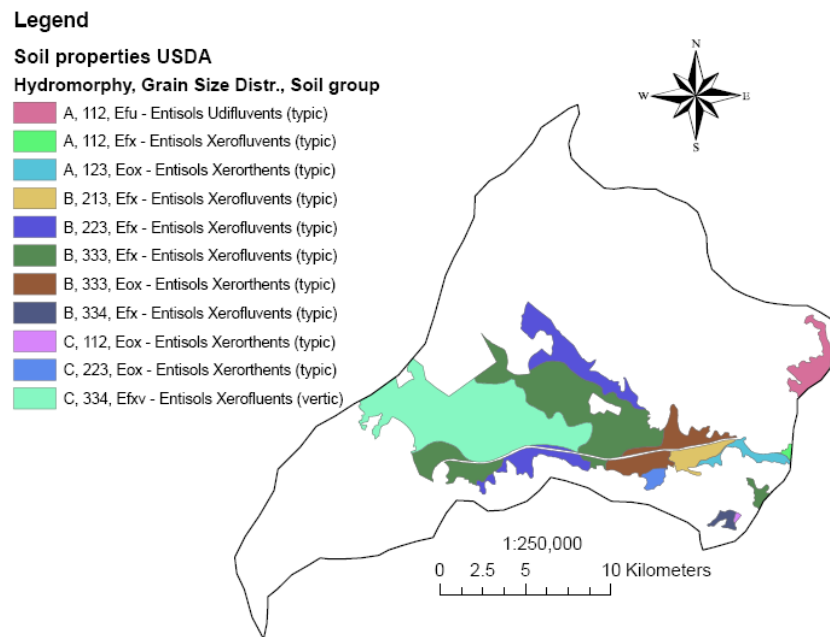


Fig. 18 Soil map – USDA classification (N.AG.RE.F., 2007)

2.4 Land uses and agricultural land

The most important activities in the Sarigkiol basin today, based on their economic and social impact on the wider region, are, in sequence, lignite mining by the mines of PPC, the agricultural exploitation of the lowland region and the livestock-farming on the fringes of the mountain ranges which surround the basin. The two first and foremost activities occupy land in the central area of the basin. The total extent of the basin amounts to 469.2 km², which are covered by agricultural land (32.7% - 153.3 km²), by forests and semi natural areas (56.9% - 266.8 km²) and by urban or artificial surfaces (10.4% - 49.1 km²) (Fig. 19), which includes coal mines and steam electric power plants that cover 31.7 km² (Corine Land Cover 2000).

Sarigkiol utilized agricultural area, is an area belonging to the municipalities of Ellispontos and Dimitrios Ypsilantis and exhibits three main sectors 1) non irrigated arable land (9318.7 ha), 2) permanently irrigated land (5207.0 ha) and 3) pastures (804.9 ha) (Fig. 20). Irrigation takes place mainly through private drillings, and in some cases by pumping from the Soulou stream and by the draining channels, in which the waters that drawn from the PPC mines are channelled. The crop distribution 61.45% hard wheat, 6.56% soft wheat, 6.28% barley, 9.89% sugar beet, 8.96% maize, 1.25% potatoes, 0.38% oat and 5.25% pastures (Table 4).

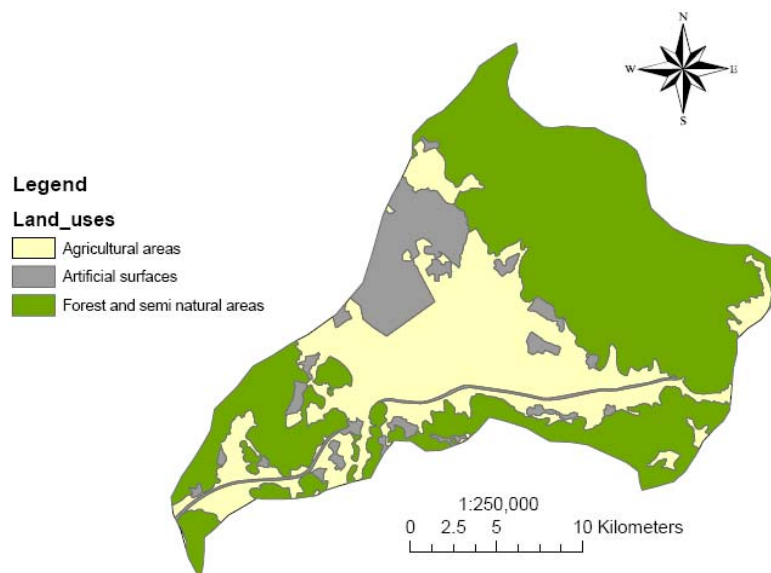


Fig. 19 Main land uses (modified Corine Land Cover 2000 including lignite mines expansion).

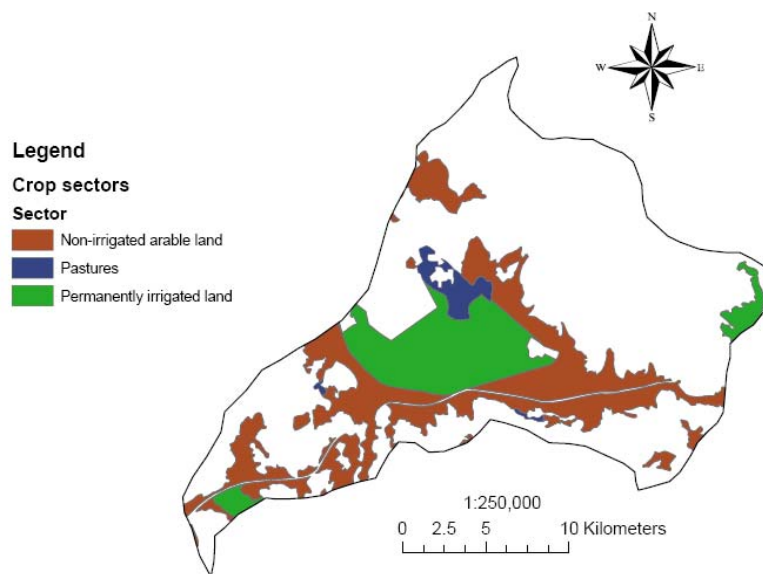


Fig. 20 Main crop sectors

The maize and sugar beet present important increase in the past years because of the increase of irrigated areas and the mechanisation of production, while other sectors present stability. The percentage of the total extent of Sarigkiol basin, which is occupied by xeric (dry) crops (wintry cereals) is a dependence of the generally applied rural policy (construction of irrigatory works, drilling permits), as well as the particular policy of PPC for reestablishment and output in the cultivation of grounds which are today occupied by the mines. It should be noted that the mines occupy a central section of the basin and should any section be subject to cultivation, at a first level, it will be irrigated either by private drilling or by draining waters of the PPC mines (even defectively) and consequently dynamic – instead of dry – crops will be preferred. Accordingly, the land that is cultivated with wintry cereals is expected to remain constant, with a percent proportion of wintry cereals decreasing or increasing, depending on the land which the PPC will provide or bind.

Table 4. Main crops cultivated in Sarigkiol basin.

No	Crops	(ha)	(%)
1	Soft Wheat	1004.9	6.56%
2	Hard Wheat	9419.6	61.45%
3	Barley	963.1	6.28%
4	Maize	1372.9	8.96%
5	Sugar beet	1515.7	9.89%
6	Oat	57.7	0.38%
7	Potatoes	191.3	1.25%
8	Set Aside/pastures	804.9	5.25%
Total		15330.1	100.00%

Source: National Statistics Service of Greece

2.5 Surface waters

Important surface waters (e.g. lakes and rivers) do not exist in the study area except Soulou Torrent (or Eordaios) (Fig. 21), which was artificially opened up in 1954. Soulou intersects the Vegoritis hydrologic basin (including Sarigkiol) and ends up to Vegoritis Lake. Its total length is approximately 55 km (14 km in the Sarigkiol basin) and a large part of the torrent's bed near LCWM is not stable and is adjusted according to the needs of the lignite mines expansion (Fig. 22). Soulou is mainly used as a drainage pathway for agricultural drainage water, natural surface runoff, processed or unprocessed industrial and municipal wastes. The south part of Soulou (Sarigkiol basin) is also used for irrigation.

According to hydrologic studies (Aschonitis et al., 2006) for the period 1951-2001, the mean annual flow of Soulou torrent before the final outflow to Vegoritis Lake is $1.3 \text{ m}^3/\text{sec}$, with minimum and maximum flow rates at August and January, respectively. According to the last water quality measurements in several sampling sites that conducted by E.C.K. (2009) in March of 2009, the range and average values of the main quality parameters in the Soulou torrent are given in Table 5 (E.C.K., 2009).



Fig. 21 Part of Soulou torrent in Sarigkiol basin



Fig. 22 Bed adjustments of Soulou torrent near LCWM

Table 5. Main water quality parameters of Soulou torrent (E.C.K., 2009)

Parameter	Unit	Range (average)
pH	0-15	6.9 - 8.6 (7.9)
Turbidity	NTU	1.1 - 11.7 (5.01)
EC	$\mu\text{S}/\text{cm}$	840 - 1009 (890)
NO_3	mg/L	2.8 - 10.6 (4.3)
NO_2	$\mu\text{g}/\text{L}$	78.3 - 303.7 (156.5)
NH_4	mg/L	0.039 - 1.82 (0.5)

2.6 Hydrogeology and ground water quality

2.6.1 Hydrogeology and aquifer characteristics

From a geological point of view (Fig. 23), carbonate rocks are mostly distributed on the highlands and Neogene and Quaternary deposits cover the lowlands. Lignite deposits occurring in the Plio-Pleistocene sediments (Fig. 24 & 25) (Voudouris, 2006; adapted from IGME).

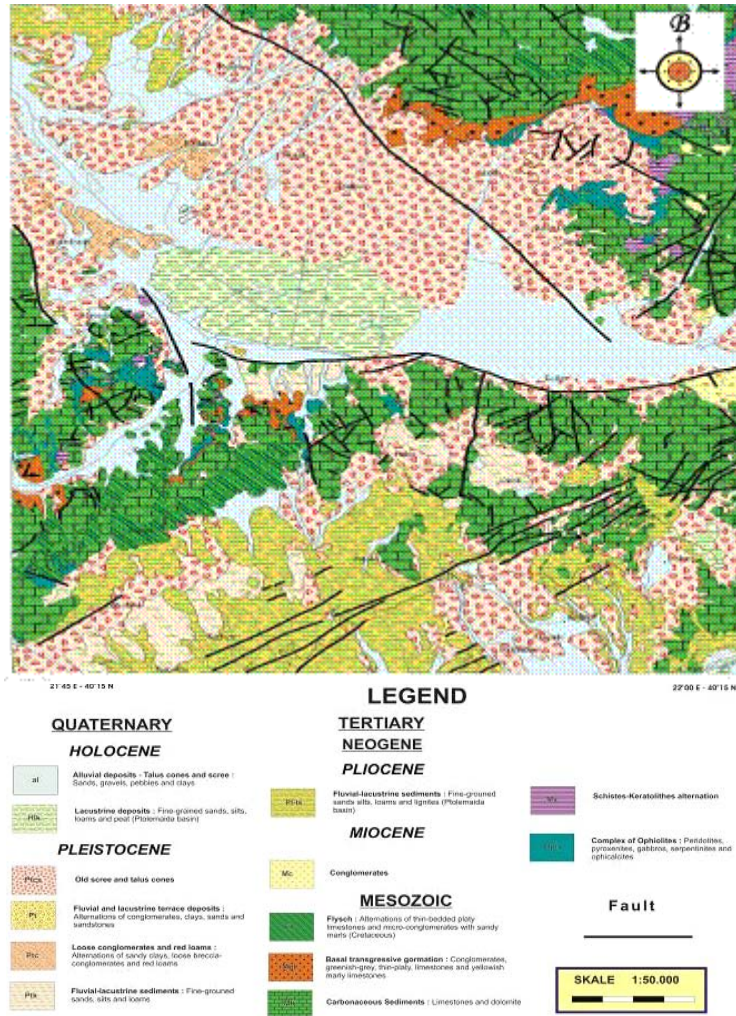


Fig. 23 Geological map of the study area.

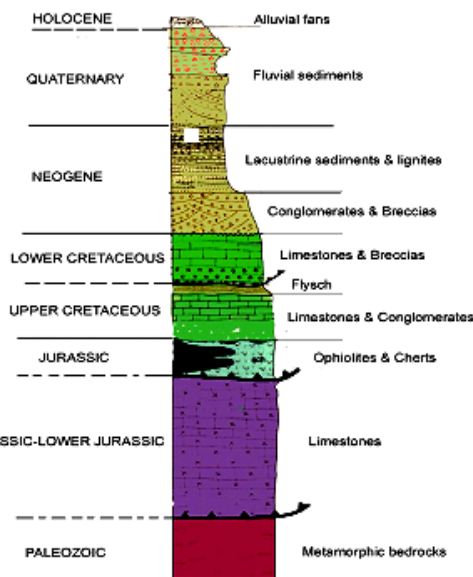


Fig. 24 Stratigraphic sequence in Sarigkhiol basin (adapted from IGME).

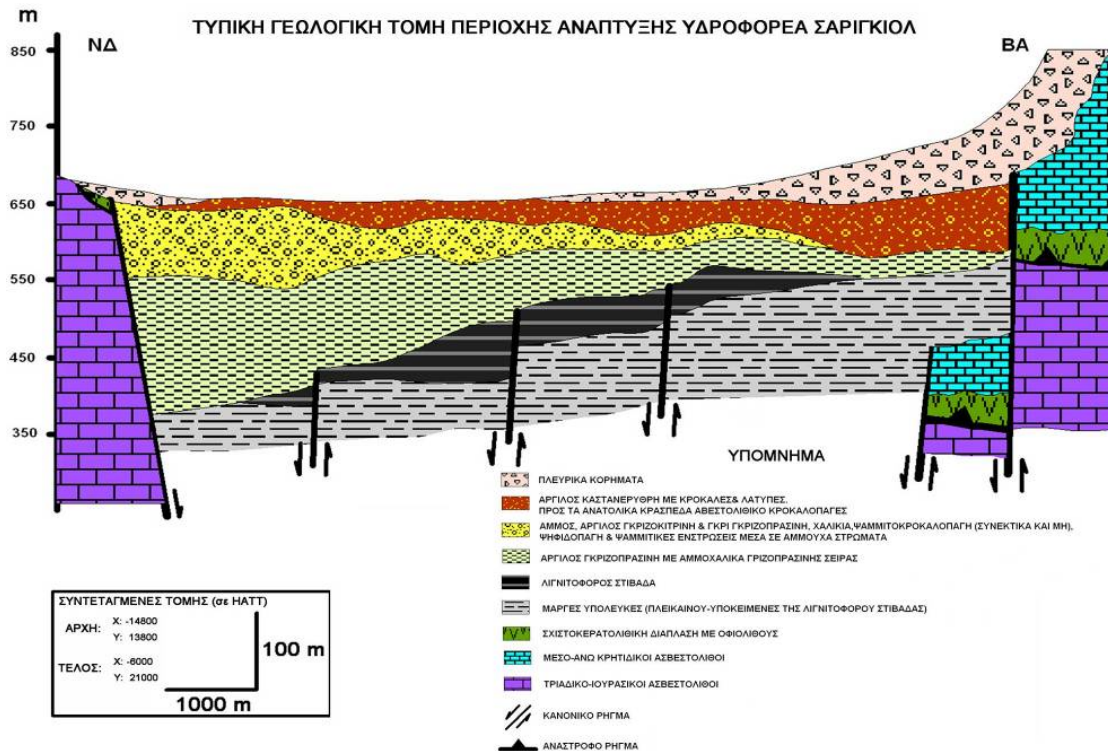


Fig. 25 Geological section in Sarigkiol basin (adapted from IGME).

The main aquifer systems are developed:

1. in Quaternary deposits (alluvial aquifer) above lignite deposits.
2. in Neogene sediments developed below lignite deposits,
3. in carbonate rocks (karst aquifer).

The water needs of the basin, are predominantly being covered by the exploitation of both alluvial and karstic aquifers, through a large number of boreholes (greater than 500). Water supply for the municipality of Kozani relies mostly on karstic waters from limestones and partly on alluvial aquifer of Sarigkiol basin. Additionally, Sarigkiol alluvial aquifer is partly being excavated (Fig. 26), in order to withdraw the lignite deposits, which lie down the overlying alluvial aquifer.



Fig. 26 Lignite mines in Sarigkiol basin

The irrigated land increased greatly in last decades, as indicated the number of wells and boreholes. The most important limiting factor in Sarigkiol basin is the seasonal variation in water availability and demand. Furthermore, agriculture requires increased supplies in late spring, summer, and early autumn, when the water availability is low.

The alluvial aquifer of the Sarigkiol basin covers an area of 60 km² (Fig. 27) and its maximum depth reach at 110 m below ground surface (b.g.s.) (Table 3). The depth to water table in the alluvial aquifer ranges from 7 to 75 m below ground surface or from +585 to +730 m above sea level. The alluvial deposits host a phreatic aquifer superimposed on successive confined or semi-confined aquifers. There is hydraulic connection between them due to its “lens” form, as well as with the phreatic aquifer. Despite the documented heterogeneities however, it is suggested that on a regional scale a uniform aquifer may be considered (Voudouris, 2006). The range of hydraulic properties of the alluvial aquifer system is large, as determined from extensive pumping test analyses (IGME, Stamou, 2001) (Table 6).

Table 6. Geometry and hydraulic parameters of the alluvial aquifer of Sarigkiol Basin
(Stamou, 2001; Voudouris, 2006)

Area (km ²) (the main part)	60
Mean altitude (m)	665
Max Depth (m below ground surface)	110
Transmissivity (T) (m ² /day)	300-1700
Storage coefficient (S)	0.7x10 ⁻² – 1.0x10 ⁻²
Hydraulic conductivity (k) (m/s)	2x10 ⁻⁴ - 8x10 ⁻²

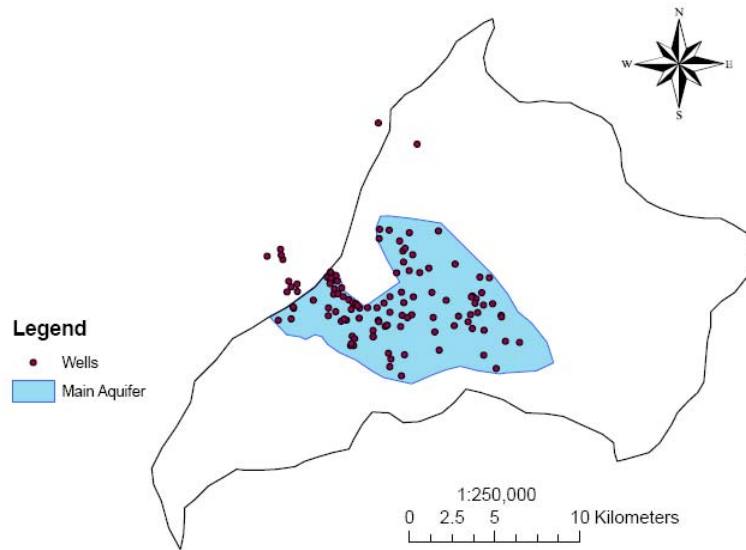


Fig. 27 Main part of the alluvial aquifer of the Sarigkiol basin and location of the drillings

The water balance of the alluvial aquifer has two components: the total input or inflows (Q_{in}) and the total output or outflows (Q_{out}). The equation for the groundwater balance can be written as:

$$Q_{in} = Q_{out} \pm \Delta S$$

where ΔS : is the change in groundwater storage.

The total groundwater input (Q_{in}) consists of: Rainfall recharge, Lateral subsurface inflows, Streambed infiltration and Recharge from irrigation returns. The aquifer recharge presents significant fluctuations, depending on the annual rainfall. The total groundwater output (Q_{out}) consists of Domestic water uses, Irrigation and industrial water uses and Subsurface outflows. The change in groundwater storage (ΔS) has been estimated by taking the difference between the average water level at the beginning and the end of the hydrological year.

According to Stamou (2001) the mean annual input to the alluvial aquifer system is $24.2 \times 10^6 \text{ m}^3$ and the mean annual output is $30.5 \times 10^6 \text{ m}^3$. The recharge from karstic aquifers is limited. The total annual discharge for irrigation use was estimated to be $12.5 \times 10^6 \text{ m}^3$ or 41% of the total discharge. The total discharge for domestic use was estimated to be $6 \times 10^6 \text{ m}^3/\text{yr}$ or 19.6% of the total discharge. A volume of water

$12 \times 10^6 \text{ m}^3/\text{yr}$ is abstracted from Public Electricity Company in order to withdraw the lignite deposits (Table 7).

Table 7. Groundwater balance of the alluvial aquifer of Sarigkiol basin (Stamou, 2001).

Water Input	($\times 10^6 \text{ m}^3 \text{ yr}^{-1}$)	Water Output	($\times 10^6 \text{ m}^3 \text{ yr}^{-1}$)
Recharge due to rainfall	6.9	Domestic use	6.0
Lateral groundwater fluxes	2.0	Agricultural use	12.5
Streambed infiltration	13.8	Mine drainage	12.0
Irrigation return	1.5		
Total water input	24.2	Total water output	30.5
Balance	-6.3		

Estimated water balance shows that the groundwater discharges from the alluvial aquifer system exceeds the recharge, indicating that the aquifer is over-exploited through a numerous boreholes (approximately 320). The yield of boreholes ranges between $70\text{-}150 \text{ m}^3/\text{h}$. The mean annual discharge from alluvial aquifer exceeds renewable water resources; thus the water balance in the alluvial aquifer of Sarigkiol basin is in disequilibrium with a deficit of $6.3 \times 10^6 \text{ m}^3/\text{y}$ (Stamou, 2001). Koumantakis (1999) also estimates a mean decline of $0.9\text{-}1.5 \text{ m}/\text{yr}$ in the NW part and $0.6\text{-}1.5 \text{ m}/\text{yr}$ in the eastern part of the basin. The above results are confirmed by the reduction of the groundwater level in the central part of the basin from $+650 \text{ m}$ above sea level (asl) at the beginning of 1980s to $+585 \text{ m}$ asl at the beginning of 2000 (Voudouris, 2006).

2.6.2 Groundwater quality

Based on hydrochemical data, it is concluded that, the Ca-Mg- HCO_3 water type is the dominant type. High nitrate (NO_3^-) concentrations are locally recorded in basin. Total Hardness varies between $300\text{-}400 \text{ mg}/\text{L}$ CaCO_3 indicating that the waters are hard (IGME, 2001).

In the following table are summarized the measurements of the groundwater quality parameters according to the initial measurements of IGME (2001) and the continuous potable water analyses realized in Sarigkiol basin by Environmental Centre from 2002 until today (Table 8).

Table 8. Groundwater quality parameters of Sarigkiol's basin

Parameter	Unit	Range (average)
pH	0-15	7.1 - 8.43 (7.66)
EC	($\mu\text{S}/\text{cm}$)	315.0 - 1100.0 (550.76)
Total Hardness		192.0 - 450.0 (292.5)
Ca ²⁺	(mg/L)	37.67 - 103.4 (67.73)
Mg ²⁺	(mg/L)	10.21 - 50.08 (30.18)
Na ⁺	(mg/L)	1.83 - 48.04 (10.57)
K ⁺	(mg/L)	0.39 - 4.69 (1.20)
NH ₄ ⁺	(mg/L)	0.0 - 1.57 (0.30)
HCO ₃ ⁻	(mg/L)	93.96 - 320.92 (240.69)
Cl ⁻	(mg/L)	7.09 - 33.67 (19.07)
SO ₄ ²⁻	(mg/L)	0.0 - 290.1 (82.08)
NO ₃ ⁻	(mg/L)	0.11 - 175.6 (35.17)
NO ₂ ⁻	(mg/L)	0.0 - 0.03 (0.01)
PO ₄ ³⁻	(mg/L)	0.06 - 0.57 (0.21)
Fe	($\mu\text{g}/\text{L}$)	0.0 - 173.0 (47.14)
Zn ²⁺	($\mu\text{g}/\text{L}$)	10.0 - 1000.0 (132.5)
Cu	($\mu\text{g}/\text{L}$)	3.0 - 50.0 (15.18)
Mn ²⁺	($\mu\text{g}/\text{L}$)	7.0 - 200.0 (84.90)
Pb	($\mu\text{g}/\text{L}$)	0.0 - 30.0 (16.23)
Cd	($\mu\text{g}/\text{L}$)	0.0 - 10.0 (1.55)
F ⁻	($\mu\text{g}/\text{L}$)	0.0 - 510.0 (110.0)
Ni	($\mu\text{g}/\text{L}$)	0.0 - 190.0 (43.46)
Cr	($\mu\text{g}/\text{L}$)	0.0 - 120.0 (18.08)
Total count bacteria 22°C/ml		0.0 - 101.0 (39.38)
Total count bacteria 37°C/ml		0.0 - 101.0 (20.54)

Also according to the evaluation of hydrochemical analyses that were conducted in the framework of the ELIMEIA project and these concern samples originated from the aquiferous system that overlies the lignitic line, the following had been concluded (Voudouris, 2006):

1. It is realised that the water of 31 drillings of the 44 examined, exceed the maximum acceptable limits of potability, in concentrations of one or more ions or trace elements. Consequently, they are firstly characterized as not potable, without previous treatment or mixture with other waters of a better quality.
2. The quality of underground waters for irrigatory purposes is generally good to medium. The spatial-temporal study of Soulou water quality, used for irrigations, is imperative.
3. Taking into consideration the fact that, as reported, the water of 31 drillings of the total 44 in which samplings and analyses were conducted have a certain problem so

that they are rendered as not potable, the issue of a qualitative degradation of the regional underground waters becomes of fundamental importance.

4. Because most problems are caused by the high concentrations of nitrous, nitric and ammoniac ions measures must be taken so as to drastically reduce nitrogen. Since nitrogen in underground waters is derived from nitrogen "sources" that are found on the surface of the ground, in the territorial area or in shallow subsoil areas, interventions should be made for its reduction in these places. The nitrogen "sources" are direct, such as e.g. fertilizers and waste, and indirect through processes during which they are nitrally produced by nitrogen of an organic origin or by NH_4^+ . The main interventions, consequently, that should immediately take place are the reduction of the use of fertilizers, the non-free disposal of liquid and solid waste and the rational use of water quantities disposed for irrigations in order to reduce the "returns" from irrigation water, which, as we know, considerably aggravates the quality of underground waters.

5. The problem that is presented by the realised high indices of concentrations of other ions and trace elements (Mg^{+2} , Fe^{+3} , Mn^{+2} , Al^{+3} , Cd^+ , Cr and Ba) is found in a small number of drillings, the water of which, indeed, simultaneously carry the problem of the increasing NO_2^- , NO_3^- και NH_4^+ .

2.7 Pollution Sources

In Sarigkiol basin the most important pollution sources, which are related to human activities, are originated by agriculture activities, urban, industrial, mineral extraction mines, abandoned waste fields, animal breeding wastes and LCWM operations (surface lignite mines, solid deposits and solid wastes from lignite mines, steam-electric power plants). The inventory of pollution sources has been performed in the field by observations as well as by data collected by the Municipal departments located in the Sarigkiol basin. Water resources quality deterioration is exhibited as a result of anthropogenic activities. Untreated waste effluent from industrial and livestock units and waste water treatment plant shortage form major pollution sources of surface water bodies; these circumstances are responsible in conjunction with the agricultural activities for the groundwater quality degradation. Groundwater quality deterioration is also caused by the discharge of liquid and solid waste directly into abandoned shallow wells in urban areas or abandoned quarries in rural areas. Central

municipal sewage-treatment systems do not exist in small villages. Fertilizers and agricultural chemical compounds are being used intensively to maintain the productivity of the soil. Agricultural impact on groundwater quality has been mostly associated with nitrate pollution.

In Sarigkiol basin point pollution sources are mostly concentrated at the perimeter of the agricultural land and within or near the urban areas (Fig. 28). At the centre of the basin where agricultural land is laid the main pollutant factor comes from the intensive agriculture activities and in some cases the irrational use of fertilizers and pesticides.

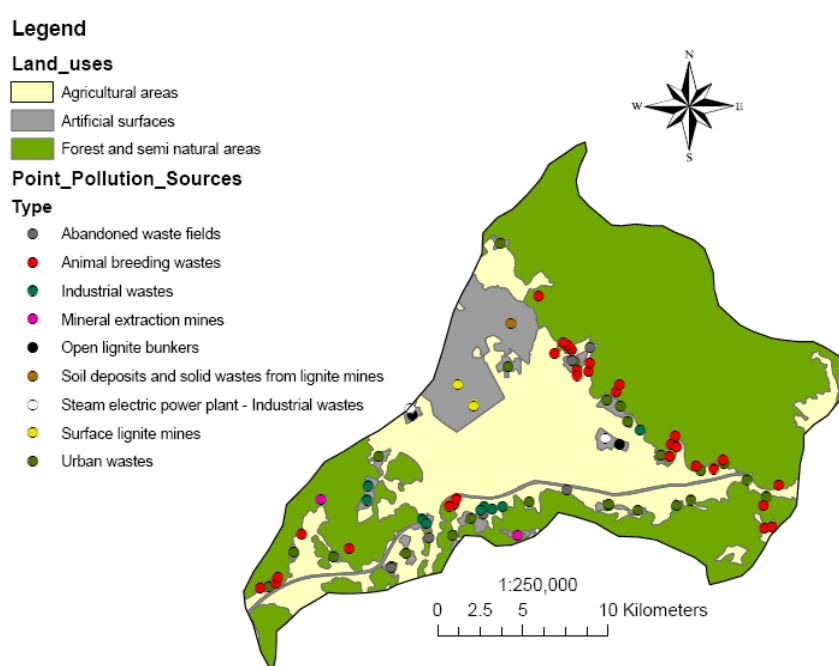


Fig. 28 Point pollution sources in Sarigkiol basin

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3. Questionnaire for Srighiol basin, Western Macedonia, Greece



Questionnaire (Qs) for data collection on water and nitrogen management in agriculture

Project Title: Transnational integrated management of water resources in agriculture for the EUropean WATER emergency control

Date: 4 November 2009

In the framework of: WP3 "Knowledge capitalization and sensitive areas maps"

Responsible Partner: Aristotle University of Thessaloniki, Greece

Introduction

This Qs has been prepared by the Aristotle University of Thessaloniki in the framework of the European-funded project EU-WATER in order to facilitate the collection of available data regarding water and nitrogen management in the designated target areas of the project. The aim of this task is to standardize the mapping process for the development of the GIS platform.

All partners are requested to fill in the Qs for their target areas. Each question is appropriately explained with added clarifications (red font) wherever necessary. Most questions are straightforward and require a short answer (yes, no, %, quantity etc.); if however, you need to elaborate any of your answers, please expand the size of the cells, as needed.

General

1	Date	3/1/2010
2	Partner name	Region of Western Macedonia
3	Country	Greece
4	Name of the target area	Sarigiol Basin
5	Target area coverage (km ²)	469.2
6	Agricultural area coverage (km ²)	153.3
7	Total population (No)	11224
8	Active population (%) (age>15)	83.7
9	Number of cities/towns/villages	19
10	Population density (no. / km ²)	23.9

Production sectors and economic data of the target area

1 Main production sectors (in terms of employment).

Please give approximate percentage of employment in the most important production sectors of the area (especially in agriculture and Public Services)

	(%)
Agriculture	29.02
Mining	4.19
Manufacture	9.2
Forestry	-
Energy	10.49
Tourism and entertainment	9.72
Public Services	1.61
other (health, education, communications,trade, other services)	35.77
TOTAL	100.00

2 Main production sectors (in terms of income).

Please give the income distribution to the most important sectors

	(%)
Agriculture	9.00
Mining	20.76
Manufacture	7.08
Forestry	-
Energy	27.16
Tourism	9.25
Public Services	4.00
other (health, education, communications,trade, other services)	22.75
TOTAL	100.00

3 Main agricultural products

Please mark the right answer below; if possible, provide type and quantities (tones)

	mark	type and quantity (ton)
Cereals	X	Soft Wheat (3517), Hard Wheat (27317), Barley (3853), Maize (16476), Oat (173)
Fruits		
Oil		
Wine		
Dairy products		
Vegetables	X	Potatoes (6707)
other	X	Sugarbeet (83361)

4 Livestock heads

Please give numbers of livestock heads

	System	Heads	
Cattle	in pasture		
	stabulated	2509	
Pigs	in pasture		
	stabulated	52	
Birds	stabulated		
Other	in pasture	17254	sheeps(10669), goats(6585)
	stabulated		

5 Percentage (%) contribution of the target area in the total Gross National Product (GNP) of the country

Comment (if necessary)

1.65%	GNP of Kozani Prefecture
-------	--------------------------

6 Unemployment rate

Please mark the right answer

0-5%	<input type="checkbox"/>
5-10%	<input type="checkbox"/>
10-15%	<input checked="" type="checkbox"/>
>15%	<input type="checkbox"/>

7 Is there a development plan for the area?

Please mark the right answer

Yes	No	Comment (if necessary)
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Rural Development Plan 2007-2013

8 Total percentage of enterprises that receive EU grants for agricultural production (i.e. CMO, CAP, Rural Development Program)

%	Comment (if necessary)
100%	95% Single Farm Payments + 5% RDP

Legislation

1 Are there any protected sites within the target area? (Places of natural interest, Natura 2000 sites, National Parks, natural heritage areas etc.)

Yes	No	Comment (if necessary)
	x	

2 Is the WFD in operation?

-

Yes	No
x	

-

3 Have management zones (based on river basins) been developed in the framework on WFD?

Yes	No
x	

4 Is the NFD in operation?

-

Yes	No
x	

-

5 Are there any designated "nitrate-vulnerable zones" (NVZs) in the target area in the framework of NFD?

Yes	No
x	

Climate and meteorology

1 Meteorological stations

Do you have monthly data from at least two meteorological stations (number, coordinates, altitude, datasheets)(Minimum parameters monthly rainfall and temperature)? If no, please answer Qs 2-7 below.

Yes	No
x	

If yes, this data will be entered in appropriate form in the database

upload pdf file

- 2** Average Temperature of summer growing season (May to October)
- 3** Average Temperature of winter growing season (November to April)
- 4** Average Precipitation of summer growing season (May to October)
- 5** Average Precipitation of winter growing season (November to April)
- 6** Average Reference Crop Evapotranspiration of summer period (May to October)
- 7** Average Reference Crop Evapotranspiration of winter period (November to April)

Value	Unit
19.9	°C
6.2	°C
245.2	mm
307.5	mm
651.6	mm
112.4	mm

Crops Data

- 1 Crops / Irrigation / Fertilization.
Please fill in the table for the main crops

Crop	Soft Wheat	Hard Wheat	Barley	Maize	Sugarbeet	Oat	Potatoes	Set aside/ Pastures
Area (ha)	1004.88	9419.58	963.13	1372.98	1515.66	57.68	191.26	804.9
Winter or summer crop	Winter	Winter	Winter	Summer	Summer	Winter	Summer	perrenial
Irrigation method (e.g. drip irrigation)	No	No	No	surface, sprinkler, drip irrigation	surface, sprinkler, drip irrigation	No	surface, sprinkler, drip irrigation	no
Water needs (mm)	300-350	300-350	300-350	600-700	600-700	300-350	600-700	-
Average crop factor of the growing season for the calculation of evapotraspiration	0.75	0.75	0.75	0.87	0.82	0.75	0.9	-
Nitrogen fertilization rates and type (kg N/ha) and methods (basal, surface and number of applications)	b100/s50	b80/s50	b80/s40	b120/s120	b100/s60	b80/s50	b100/s60	-
Average yield (kg/ha)	3500	2900	4000	12000	55000	3000	45000	-
Cost of seeds, fertilizers, pesticides, labor, machinery (€/ha)	355	368	320	660	830	245	2190	-

- 2 Origin of irrigation water (groundwater or surface water)

Groundwater	No	No	No	Yes	Yes	No	Yes	No
Surface water	No	No	No	No	No	No	No	No

3 Irrigation water pricing method

Please mark the right answer

Method A: Cost per ha for every crop (e.g. consumption is not considered)

Method B: Consumption-based pricing (e.g. type of crop is not considered)*

Method C: Both consumption and type of crop are considered

Other method (please describe)

x	100% of the target area

*In this method private wells (p.w.) are included (cost based on electric power or oil consumption)

4 Cost of irrigation water

Please give cost of irrigation water for each of the above methods

Crop				
Method A (€/ha for every crop; multiple values)				
Method B (€/m ³ ; single value)	7euro/cultivation + 0,035euro/m ³			
Crop				
Method C (€/m ³ /crop)				
Other method				

Pollution sources

1 Point sources

Please mark the point sources identified in the target area

Urban wastes (hospital, hotel, garage, car repair etc.)	x
Pit active or filled up with various waste types or abandoned used as inert wastes dump	x
Abandoned waste fields	x
Industrial wastes	x
Cattle breeding wastes	x
Fuel storage tanks (Petrol or gas station)	x
other (please add)	Air pollution from steam-electric power stations, surface coal mines, open coal bunkers

2 Non-point sources

Please mark the non-point sources identified in the target area

Agricultural practices (spreading of fertilizers and pesticides)	x
Surge of sea water	
Storage and disposal of manure	x
Stockpiling of materials	x
Road salting	x
other (please add)	

Nitrogen management

1 Are there any practices in order to limit nitrogen leaching?
Please mark the right answer

crop rotations	<input checked="" type="checkbox"/>
soil winter cover	<input checked="" type="checkbox"/>
catch crops	<input checked="" type="checkbox"/>
application of dissolved fertilization in irrigation water (e.g. during drip irrigation)	<input checked="" type="checkbox"/>
surface application of fertilizers in doses	<input checked="" type="checkbox"/>
other (please describe)	<input type="text"/>

2 Are there any Fertilization Plans in place?

Yes	No	Comment (if necessary)
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="text"/>

3 Is fertilization applied in regions close to water bodies (lakes and rivers)? **Please note that minimum restricted distance from water bodies is 2m, while in case of slopy areas the distance is proportionate to the % of slope (e.g. the maximum distance of fertilization for areas with 5% slope is 5m from water bodies)**

Yes	No	Comment (if necessary)
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="text"/>

4 Are there any rivers and lakes that show eutrophication symptoms or bring high nitrogen fluxes to coastal water and sea?

Yes	No	Comment (if necessary)
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="text"/>

5 Do soil analysis take place in the target area? If yes, how often?

Yes	No	If yes, how often?
<input checked="" type="checkbox"/>	<input type="checkbox"/>	approximately every 3-4 years

6 Do manure analysis take place in the target area? If yes, how often?

Yes	No	If yes, how often?
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="text"/>

7 Which approximately is the average dose of nitrogen in the manure applied in the region?

<input type="text" value=">120"/>	kg N/ha
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8 Have specific limits been set for the application of livestock manure?

Yes	No	Comment (if necessary)
x		

9 Time sampling to collect info and existing water quality data for nitrogen species?

	Existing data for nitrogen species	Type of measurements - Sampling frequency
Lakes	-	Lakes do no exist
Rivers	x	NO ₃ , NH ₄ , NO ₂ .Every year. Available water quality data of Soulou torrent (Environmental Center of Kozani)
Water wells (groundwater)	x	NO ₃ , NH ₄ , NO ₂ .Every year. Available water quality data of ELIMEIA drills (Environmental Center of Kozani)

GIS data (existing data will be entered in appropriate fields in the GIS platform)

1 Digital Data. Do you have digital data of the following elements?

	Yes	No
Digital boundaries of the study area (polygon)	x	
Digital data for land use (polygons)	x	
Digital Elevation Model - DEM (raster)	x	
Digital soil type classes (polygons)	x	
Digital data of agricultural fields-sectors (polygons)	x	
Digital data for surface waters i.e. lakes, rivers (polygons)	x	
Digital data for ground waters i.e. waterwells and aquifers (points and polygons)	x	
Digital data of point pollution sources (points)	x	
Digital data for protected areas (polygons)	x*	

*Protected areas in Sarigkiol basin do not exist