Application of the drought management guidelines in Greece [Part 2. Examples of application]

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Chapter 16. Application of the Drought Management Guidelines in Greece

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SUMMARY – Greece is often affected by recurrent drought. The study includes analysis of two watersheds, Nestos and Mornos, selected to represent drought episodes and management in Greece. The study focuses on the methodologies for the drought characterisation and the analysis of the hydrological and agricultural impacts of drought. Furthermore, it analyses the interrelations between the drought indices derived for certain return periods and the impacts on the socioeconomic system and the environment. The operational component reviews the procedures of previous drought events, in order to formulate proposals for successful mitigation actions. Although the Greek organisations have not developed concrete strategies concerning droughts, they have dealt with this phenomenon as a case to case basis, to a certain extent. However, from a review of the existing institutional structure, it can be concluded that the country needs a comprehensive effort to rationalise the entire drought analysis, monitoring and mitigation system. There is an obvious lack of scientific organisations, legal framework and operational capabilities to combat the effects of drought. It is also absolutely necessary to devise preparedness plans for achieving pro-active defence against drought. Needless to say that an operating mechanism should be instituted for an effective application of rational measures resulting from a scientific analysis. During drought, water restrictions are imposed mainly for domestic water consumption. However, the 84% of the water used in the country is consumed in the agricultural sector. It is logical therefore to re-direct water restrictions, giving emphasis to agricultural use, which is the principal consumer of water. Last but not least, it should be noted that there is a severe gap in the measures for combating drought, i.e. the lack of insurance of people and property in the event of a drought occurrence. However, it should be pointed out that following the Law 3199/2003 and the subsequent presidential decrees, scientific and technical commissions are established in order to analyse the occurrence and mitigation of droughts. The current framework in Greece is characterised by changes. The new law was approved by the Parliament in November 2003 to comply with the obligation of the member states to harmonise their legal system with the water Direct 2000/60.

Key words: Nestos Basin, Mornos Basin, legal framework, drought characterisation, risk analysis, drought plan.

The planning framework

Drought events in Greece

Due to its climatic conditions, Greece is a country often affected by droughts. Although the Greek organisations have not developed concrete strategies concerning droughts, they have dealt with this phenomenon as a case to case basis, to a certain extent. However, from a review of the existing institutional structure, it can be concluded that the country needs a comprehensive effort to rationalise the entire drought analysis, monitoring and mitigation system. There is an obvious lack of scientific organisations, legal framework and operational capabilities to combat drought. It is also absolutely necessary to devise preparedness plans for achieving pro-active defence against drought. Needless to say that an operating mechanism should be instituted for an effective application of rational measures resulting from a scientific analysis. It should be noted that during drought, water restrictions are imposed mainly in domestic water consumption. However, 84% of the water used in the country is consumed in the agricultural sector. It is logical, therefore, to re-direct water restrictions, giving emphasis to agricultural use, which is the principal consumer of water. Last but not least, it should be noted that there is a severe gap in the measures for combating drought, i.e. the lack of insurance of people and property in the event of a drought occurrence. However, it should be pointed out that following the Law 3199/2003 and the subsequent presidential decrees, scientific and technical commissions are established in order to analyse the occurrence and mitigation of droughts. The current framework in Greece is characterised by changes. The new law was approved by the Parliament in November 2003 to comply with the obligation of the EU member states to harmonise their legal system with the Water Framework Directive 2000/60.

The Nestos and Mornos Basins

Drought characterisation and operational management are analysed in the Nestos and Mornos Basins (Fig. 1). The Nestos watershed (Fig. 2) is located in northern Greece. The total catchment area, which is 5184 km^2, belongs partially to Bulgaria (2872 km^2) and partially to Greece (2312 km^2 or 45% of the catchment). The topography of the main part of the Nestos catchment is an alternating sequence of valleys and ridges, except of the Nestos Delta plain, which is flat. As far as the geology of the catchment area is concerned, the mountainous part of the Nestos watershed consists of metamorphic rocks (marbles, gneisses, schists), igneous rocks and deposits of quaternary to recent age. The study presented here in a concise form covers only the Greek part of the basin.

The hydrological drought was not examined for the purposes of this report because the three dams that exist in the site started to function in the year 1997. The meteorological time-series at our disposal finishes at 1998. Therefore, the two types of data could not be correlated, even if they existed. Besides, the data of the reservoir of the dams belong to the Public Power Corporation, whose policy is very strict in sharing its data.

Mornos watershed (Fig. 3) is located in the central Greece. The entire watershed occupies an area of 1025 km^2, while the study area covers 571 km^2. At the Mornos River, a dam has been constructed in the late 70's to supply potable water to Athens greater area. Most of the study area is very mountainous. The altitude of the Mornos dam is 320 m, while most of the peaks of the mountains are higher than 2000 m and the mean altitude of the basin is 1020 m. The parent rock is flysch and limestone, and the soils are clay-loam and loam. Analysis was performed on data collected all over the Mornos Basin. Monthly precipitation data were collected at 8 stations across the basin with a record length of 39 years.

Fig. 1. Nestos and Mornos Basins in Greece.

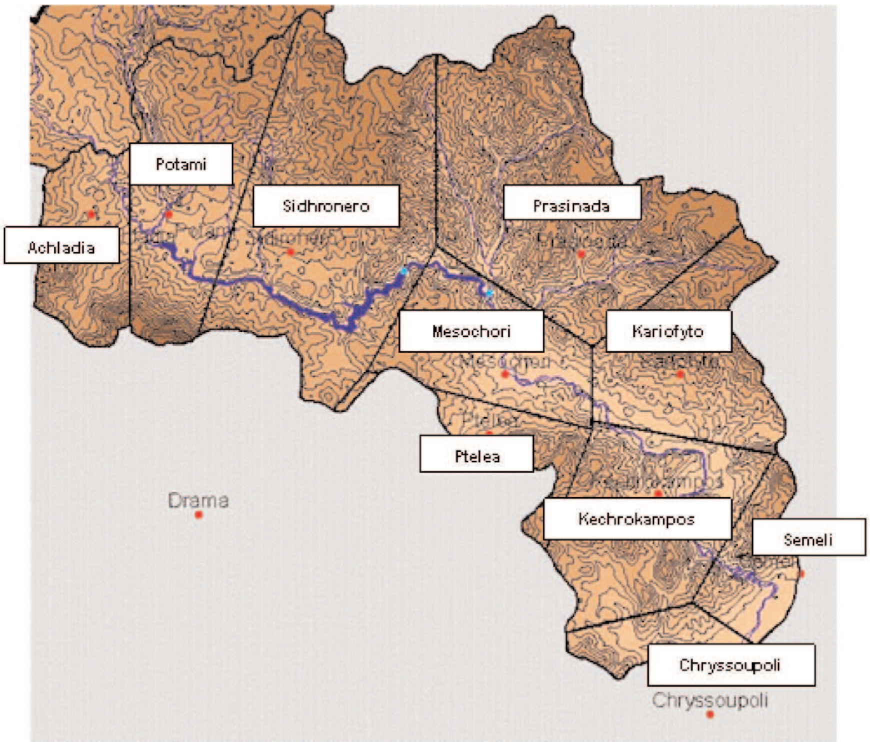


Fig. 2. The Greek Nestos Basin.

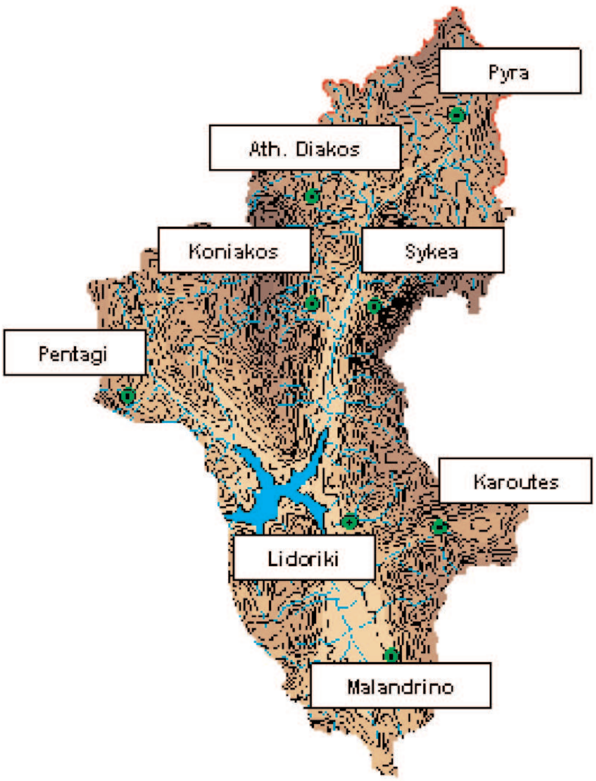


Fig. 3. The Mornos Basin.

Organisational component

Legal framework

The key legal actions in Greece related to water and drought management are:

(i) The Law 1739/1987 "for the Management of Water Resources".

(ii) The Law 1650/1986 "for the Protection of the Environment", regarding the quality of water

(iii) The European Framework Directive 2000/60/EU.

(iv) The Law 3199/2003 of "Protection and Management of Water".

(v) The legal implications of the UNCCD (94) convention.

The Law 1739/1987 "For the Management of Water Resources" covered all issues related to water policy (research, organisation, planning) by establishing procedures and structures that permitted water management on a national and a regional scale.

However, the lack of presidential decrees covering specific aspects of the application of this Law resulted in a fragmentary and incomplete application. Nevertheless, the Law 1739/1987 served as a framework for the management of the water resources in Greece for the last 15 years.

This statutory framework for Water Resources Management exists for 14 years. It includes the Law 1739/87 "management of water resources and related provisions", regarding water use and management of water quantity, and the Law 1650/1986 "for the protection of the environment", regarding water quality.

The Law 1739/87 defines, inter alia, the River Basin Districts, the responsible Authorities according to the type of water-use, the cardinal role of the Ministry of Development, an Intra-ministerial Water Committee, Regional Water Committees, Regional Water Resources Management Authorities, programs of water resources development, research on surface and ground-water, works of water resources development, water use-permits, the preservation and protection of water resources, the disposal of waste water, the disposal of industrial waste and the disposal of low-quality water to aquatic recipients according to the Law 1650/1986. According to the Law 1739/87, the regional administrative authorities will be responsible for the water supply system and the arrangement of conflicting uses.

The Law 1739/87 sets as primary goal the reservation of adequate water supply to satisfy the present and future demand for different water uses.

However, there are some points that led to the unsuccessful implementation of the Law 1739/87, such as: the multiple distributions of authorities to different Ministries, which have hampered integrated actions, the fact that water resources management was not incorporated in the environmental policy, and the allocation of water quality and quantity issues within the same area to different authorities.

The Law 1739/87 institutes the concept of planning for the development of water resources (preparation of water resources development programs). However, the planning focuses only on satisfaction of water demand, without dealing with the adaptation of the demand on the available water resources.

Integrated management of aquatic ecosystems was hampered by the distinction between management of water resources and environmental policy.

Several problems arose during the process of transfer of authorities from the Ministry to the districts, mainly because the overall infrastructure and specifically the operational infrastructure in the districts is inadequate to respond to the present demands.

Water management is assigned to the Ministry of Development which is deprived of the adequate infrastructure, human resources, knowledge and material, and especially of the political will needed in order to apply water policy.

Incapability to perform the appropriate water authorities satisfactorily has been created from the complete assignment of the water authorities to the state sector and the lack of autonomy and self-reliance.

According to the Law 1739/87, as far as the water permits are concerned, every person has the right to use water. In order to use this right, the person should be supplied with a permit, issued by the responsible ministry. Permits for multiple water use are issued only in special cases. The water permit defines the quantity and the conditions of water use. A water permit is not required for the satisfaction of personal or family needs; still this use should never be expanded in productive activities for product or service sharing and exploitation. The water supply is of first priority compared to any other water use. The permit of water supply for domestic use can neither be abolished nor limited.

The European Directive 2000/60/EC "Establishing a Framework for Community Action in the Field of Water Policy" imposed the need for adopting a new framework for water, fully compatible with its content.

On November 12th, 2003 the Law for the "Protection and Management of Waters" was adopted by the Parliament of Greece. The Law 3199/2003 is based upon the principles of the European Directive. This Law establishes a framework for the achievement of a sustainable water policy and, as a consequence, of a sustainable development of the Country and aims at:

(i) The creation of a contemporary and effective institutional/legislative framework.

(ii) The development of long-term planning.

(iii) The decentralisation of responsibilities and the strengthening of regional structures.

(iv) The creation of national laws with the UE Framework Directive 2000/60.

(v) The implementation of the objectives of the Directive taking into account local specificities of the Country.

The Law 3199/2003 contains the following chapters:

1. Chapter A: Application field and definitions (Articles 1 and 2).

2. Chapter B: Institutions and Authorities (Articles 3, 4, 5 and 6).

3. Chapter C: Management plans, programs of measures (Articles 7, 8, and 9).

4. Chapter D: Use of water, financial regulations (Articles 10, 11 and 12).

5. Chapter E: Penalties (Articles 13 and 14).

6. Chapter F: Repeals, transitional and final provisions, (Articles 15, 16 and 17).

Provisions of the Water-Directive 2000/60 and of its Annexes, not included in the Law 3199/2003, were embodied in Presidential Decrees.

According to the Law 3199/2003, apart from the central authorities, decentralisation is attempted by establishing water directions in all regions of the country. The Law also establishes regional water councils in which most of the stakeholders take part. The water councils are bodies of social discussion and of consultative type. The decisions on water resources for each basin are taken by the region in the territory in which they belong. In case that a river basin belongs to more than one regions, the ensemble of the regions co-operate for the water resources management of the river basin.

Regarding the water permits for water supply or the construction of a water project, they are issued, following a prescribed procedure by the general secretary of the corresponding region.

Finally, several penalties in case of violation of the Law are described in the last articles. Most of the articles of the Law 1739/87 are replaced by the Law 3199/2003.

Although there are no specific articles regarding drought mitigation, it is implied that the bodies responsible for the water resources management will be also responsible for drought issues.

Although the major framework of bodies responsible for the water resources management according to the Law 3199/2003 has been decided, further elaboration is needed in order to render this Law functional. For this purpose a series of ministerial decrees should be issued, in order to customise the various directions provided in this framework Law. At the same time, several actions have been taken for testing the proposed structure at a pilot scale.

Specific measures of drought mitigation have not been legislated in the past in Greece. However in 1994 Greece signed the Desertification Convention of the United Nations, which was ratified by the Greek Parliament in 1997. Desertification may be considered related to drought. The implementation of this Convention the National Committee to Combat Desertification (NCCD) has been established and in 2002 the Greek National Action Plan (NAP) for Combating Desertification was developed. The Greek Government accepted officially the National Action Plan in July 2001, through a Common Ministerial Decision (CMD) of six involved Ministers.

Structure and linkages among the relevant Institutions, organisations and stakeholders

The Law 3199/2003 establishes and defines the institutions and authorities responsible for the water protection and management. The NGOs can express opinion and, from time to time, they are invited to make proposals to the responsible Ministries. However, it is left totally to the Minister to decide whether the proposal will be accepted or not. The institutional structure is depicted in Fig. 4.

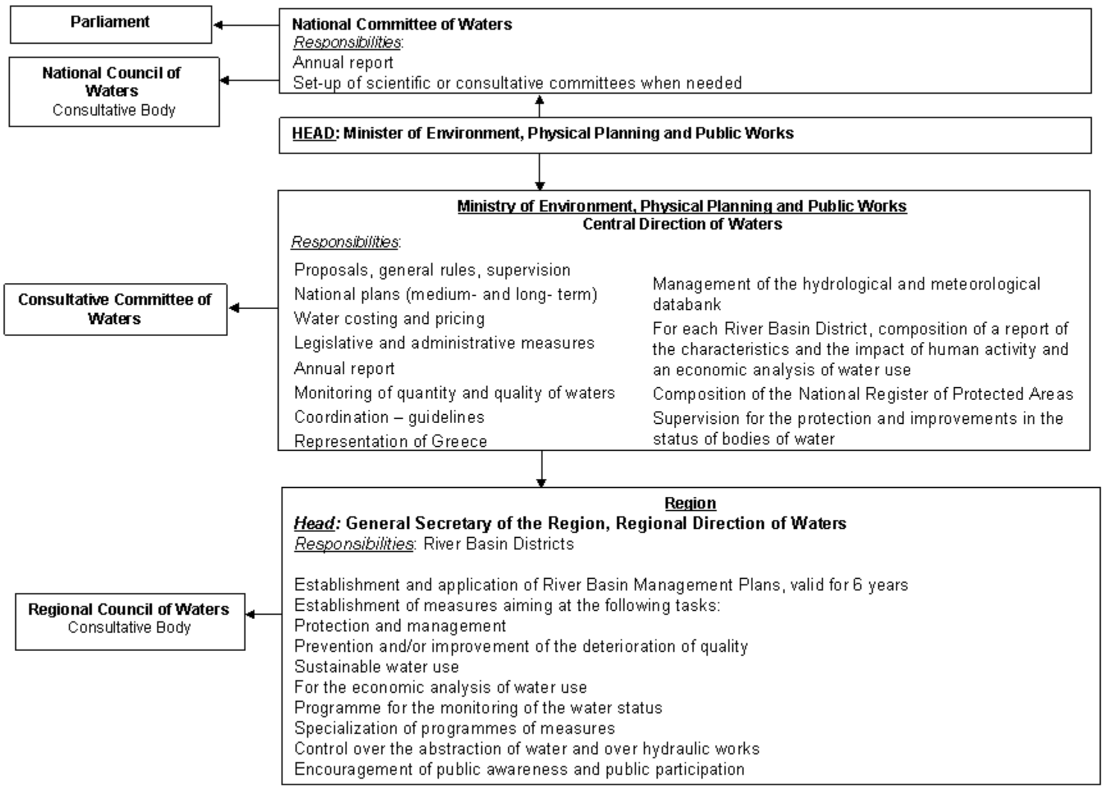


Fig. 4. Organisation chart of services concerning water resources management in Greece.

The River Basin District was first introduced in Law1739/87. Greece was divided into 14 river basin districts, including: West Peloponnesus, East Peloponnesus, North Peloponnesus, West Central Greece, Epirus, Attica, East Central Greece and Evia, Thessaly, West Macedonia, Central Macedonia, Thrace, Crete and Aegean Islands.

It is estimated that the existing river basin districts will be changed and limited in number. Within this concept, it is suggested to divide Greece into 7 to 9 river basin districts.

National Committee of Waters and National Council of Waters

A National Committee of Waters is constituted, chaired by the Minister of Environment, Physical Planning and Public Works. This Committee is responsible for: (i) planning of the policy for the protection and management of waters; (ii) supervision and control of the implementation of the aforementioned policy; and (iiI) approval of the national plans for the protection and management of the water potential of the Country.

Members of the National Committee of Waters are the Ministers of Economy and Finance, of Interior Affairs, Public Administration and Decentralisation, of Development, of Health and Welfare and of Agriculture. Other Ministers may participate when issues of their responsibilities are in the agenda. The Minister of Foreign Affairs participates when issues about international waters are discussed.

The National Committee of Waters may form consultative-scientific committees when needed. The National Committee of Waters submits an annual report to the Parliament and to the National Council of Waters.

A National Council of Waters is constituted, presided also by the Minister of Environment, Physical Planning and Public Works. Members of this Council are representatives of stakeholders, i.e. political parties represented in the Parliament, prefecture representatives, municipal unions and companies, unions of workers, scientific organisations and two non-governmental organisations. The National Council of Waters is a consultative body and reports to the National Committee of Waters.

Central Direction of Waters and Consultative Committee of Waters

A Central Direction of Waters is constituted as a unified administrative sector in the Ministry of Environment, Physical Planning and Public Works, having the following responsibilities:

(i) Working out of national medium –and long– term plans for the protection and management of waters.

(ii) Drawing up of the annual report mentioned above.

(iii) Coordination of the various state departments and public sectors and representation of Greece in the official bodies of the European Union.

(iv) Proposal of the general principles for water costing and pricing and supervision of their implementation.

(v) Proposal of legislative and administrative measures for the protection and management of water.

(vi) Management of the hydrological and meteorological database on a national level and care for updating.

The Central Direction of Waters is responsible for the economic analysis of the water use for each River Basin District, the composition of the National Register of Protected Areas, the surveillance for the protection, upgrade and restoration of surface, artificial or heavily modified water bodies, etc. In the Central Direction of Waters the Consultative Committee of Waters is constituted.

Regional Direction of Waters, Regional Council of Waters

Regions are responsible for the protection and management of each River Basin District. In each Region the Regional Direction of Waters is constituted, which has the following responsibilities:

(i) The specialisation of the appropriate measures that have to be taken for the integrated protection and management of the River Basin Districts.

(ii) The specialisation and application of medium- and long- term programs for the protection and management of the River Basin Districts.

(iii) The establishment of measures necessary for the economic analysis of water use.

(iv) The control over the abstraction of fresh surface water and groundwater and over hydraulic works developed for the exploitation of water.

(v) The establishment and application of River Basin Management Plans.

(vi) The encouragement of public participation.

In each Region, the Regional Council of Waters is constituted, presided by the General Secretary of the Region. This is a consultative body and acts as a link for the promotion of public involvement and participation in the protection and management of waters.

Methodological component: Drought characterisation and risk analysis

Intensity, frequency and duration of drought

Intensity, frequency and duration of drought were calculated for the Nestos and Mornos river Basins. Multiple indices were applied to estimate the optimal indicator to be used in a monitoring system. Two well-known indices, the Deciles and the Standardised Precipitation Index (SPI), and a new index, the Reconnaissance Drought Index (RDI), were evaluated. The results obtained by each index, as well as the correlations of the Deciles and SPI with the RDI are presented in Annex 1. The "run method" was applied to further characterise the statistical properties of drought.

Monthly precipitation data were collected at 10 stations across the Greek Nestos Basin with an average record length of 32 years (1964 to 1996), and at 8 stations across the Mornos Basin with an average record length of 39 years (1962 to 2001). The stations and periods used for the analysis are shown in Table 1.

Table 1. Meteorological stations in the Nestos and Mornos Basins

Sites in the Nestos Basin	Period	Sites in the Mornos Basin	Period
Achladia	1964 - 1996	Pyra	1962 - 2001
Chryssoupoli	1964 - 1996	Ath. Diakos	1962 - 2001
Kariofyto	1964 - 1996	Sykea	1962 - 2001
Kechrokampos	1964 - 1996	Koniakos	1962 - 2001
Mesochori	1964 - 1996	Pentagioi	1962 - 2001
Potami	1964 - 1996	Lidoriki	1962 - 2001
Prasinada	1964 - 1996	Karoutes	1962 - 2001
Ptelea	1964 - 1996	Malandrino	1962 - 2001
Semeli	1964 - 1996		
Sidironero	1964 - 1996		

The Nestos Basin

In general, all indices in all stations show a severe drought period during the years 1989-1993, a period that is documented as the most severe drought period over the last decades in Greece. The correlation among indices during this extreme drought period is high. Results show that the RDI is a very reliable index that could be more widely used than the other two indices tested, since it is correlated with both of them. The RDI has a mean correlation coefficient equal to 0.9509 when it is correlated to Deciles and a mean correlation coefficient equal to 0.9785 when it is correlated to SPI.

In order to characterise the statistical properties of drought, we considered the following parameters: duration, frequency and intensity. Drought frequency was estimated as the probability of non-exceedance for each precipitation station. We chose to calculate the probability of non-exceedance for the SPI, since its threshold is much more evident that the one of Deciles. We established a threshold of "severe drought" event when the SPI was equal or less than -1. Table 2 shows the frequencies calculated with this criterion. The intensity of the drought periods is also presented in Table 2. The intensity of each drought episode, calculated as the value of the SPI in each period is summarised in Table 3. Data in Table 2 show that apart from duration, the drought spell of 1989-93 was also relatively severe for almost all the stations of the Nestos Basin. Furthermore, the northern part of the basin (stations Mesochori, Potami, Prasinada) passed an important drought period during the hydrological year 1984-85.

Table 2. Frequencies of drought spells calculated when the SPI is equal or less than -1 and duration of drought spells in the Nestos Basin

Site	Number of droughts	Calculated return period (years)	Practical return period (years)	Drought periods (hydrological years)[†]
Achladia	8	4.05	4	1967 - 68 (1), 1973 - 74 (1), 1986 - 87 (1), 1988 - 90 (2), 1991 - 94 (3)
Chryssoupoli	7	4.75	5	1975 - 76 (1), 1984 - 85 (1), 1988 - 93 (5)
Kariofyto	4	7.11	7	1973 - 74 (1), 1988 - 89 (1), 1991 - 93 (2)
Kechrokampos	7	4.70	5	1965 - 66 (1), 1969 - 70 (1), 1973 - 74 (1), 1990 - 93 (3)
Mesochori	6	5.13	5	1984 - 85 (1), 1988 - 90 (2), 1991 - 94 (3)
Potami	5	6.17	6	1973 - 74 (1), 1984 - 85 (1), 1988 - 90 (2), 1993 - 94 (1)
Prasinada	4	7.45	7	1973 - 74 (1), 1984 - 85 (1), 1988 - 89 (1), 1992 - 93 (1)
Ptelea	6	4.98	5	1967 - 68 (1), 1984 - 85 (1), 1988 - 92 (4)
Semeli	6	5.01	5	1984 - 87 (3), 1989 - 90 (1), 1991 - 93 (2)
Sidironero	6	5.14	5	1975 - 78 (3), 1980 - 81 (1), 1984 - 85 (1), 1992 - 93 (1)

[†] (The number in the parentheses indicate the number of consecutive years of drought).

The threshold of the run method was calculated based on the Deciles index. As in many cases, the lowest 40% of the average precipitation occurrences was considered as the threshold in order to apply the run method.

Figure 5 shows for each Thiessen polygon, the diagram that describes the droughts identified on hydrological series and their characteristics. Figure 6 shows the diagram that sums up the influence of each polygon to the whole river basin throughout the hydrological time series. Table 4 summarises the characteristics of drought on each Thiessen polygon for the hydrological series that were studied.

The A_{crit} (critical area) is considered equal to 25% based upon the following reasoning. In the Greek part of the Nestos Basin, there are three dams. The sub-basin of the biggest one of them covers about 40-45% of the total Greek basin. We consider that having even 1/3 of the flow from the dams lost during a drought spell has undesirable results in agriculture, water supply and energy production. Therefore, it was considered that A_{crit} should be taken equal to the 25% of the basin. Based on the above, a diagram (Figure 6) that shows the water deficit along the entire river basin was produced, according to the theory of the runs.

Table 3. Drought periods and values of annual SPI for each period at the Nestos Basin

Site	Drought period 1 (SPI)	Drought period 2 (SPI)	Drought period 3 (SPI)	Drought period 4 (SPI)	Drought period 5 (SPI)
Achladia	1967 - 68 (-0.57)	1973 - 74 (-0.21)	1986 - 87 (-0.20)	1988 - 90 (-0.77)	1991 - 94 (-0.33)
Chryssoupoli	1975 - 76 (-0.60)	1984 - 85 (-0.56)	1988 - 93 (0.61)		
Kariofyto	1973 - 74 (-0.88)	1988 - 89 (-0.50)	1991 - 93 (-1.05)		
Kechrokampos	1965 - 66 (-0.31)	1969 - 70 (-0.01)	1973 - 74 (-0.28)	1990 - 93 (-0.56)	
Mesochori	1984 - 85 (-0.96)	1988 - 90 (-0.66)	1991 - 94 (-0.28)		
Potami	1973 - 74 (-0.66)	1984 - 85 (-1.51)	1988 - 90 (-0.45)	1993 - 94 (-0.23)	
Prasinada	1973 - 74 (-0.35)	1984 - 85 (-1.41)	1988 - 89 (-1.11)	1992 - 93 (-0.85)	
Ptelea	1967 - 68 (-0.28)	1984 - 85 (-0.39)	1988 - 92 (-0.67)		
Semeli	1984 - 87 (-0.43)	1989 - 90 (-0.19)	1991 - 93 (-0.58)		
Sidironero	1975 - 78 (-0.50)	1980 - 81 (-0.46)	1984 - 85 (-0.25)	1992 - 93 (-0.66)	

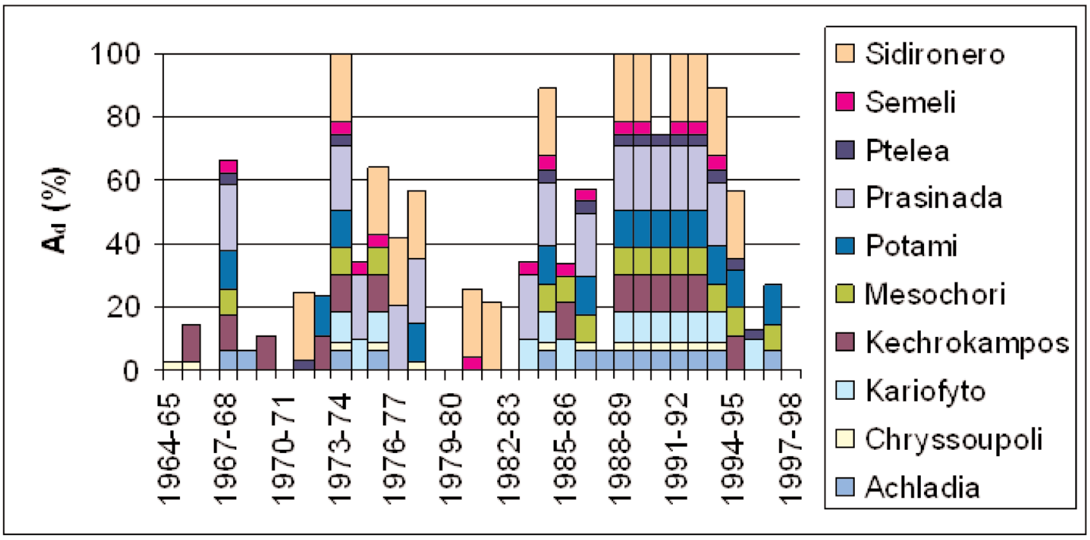


Fig. 5. Regional drought identification - influence of Thiessen polygons in the Nestos Basin. Ad: Affected area.

Table 4. Characteristics of drought spells among the Nestos Basin

	Duration (years)			Water deficit (mm)			Intensity of drought (mm/year)			Total number of droughts
	Min	Max	Average	Min	Max	Average	Min	Max	Average	
Achladia	1	8	2.33	12	952	239.59	12	128	84.07	14
Ptelea	1	8	2.17	9	948	235.47	9	158	90.19	13
Semele	1	4	2.33	56	538	294.21	56	156	118.89	14
Sidironero	1	4	2	3	363	131.80	3	121	56.02	14
Chrisoupoli	1	6	1.86	13	1137	263.41	13	211	121.34	13
Kariofyto	1	6	3.25	8	1068	453.19	8	178	107.88	13
Kehrokampos	1	5	1.63	11	894	193.69	11	179	90.62	13
Mesohori	1	7	2.6	7	680	172.85	7	97	47.96	13
Potami	1	7	2	4	703	203.66	4	262	104.15	14
Prasinada	1	6	2.33	3	712	226.21	3	155	80.21	14

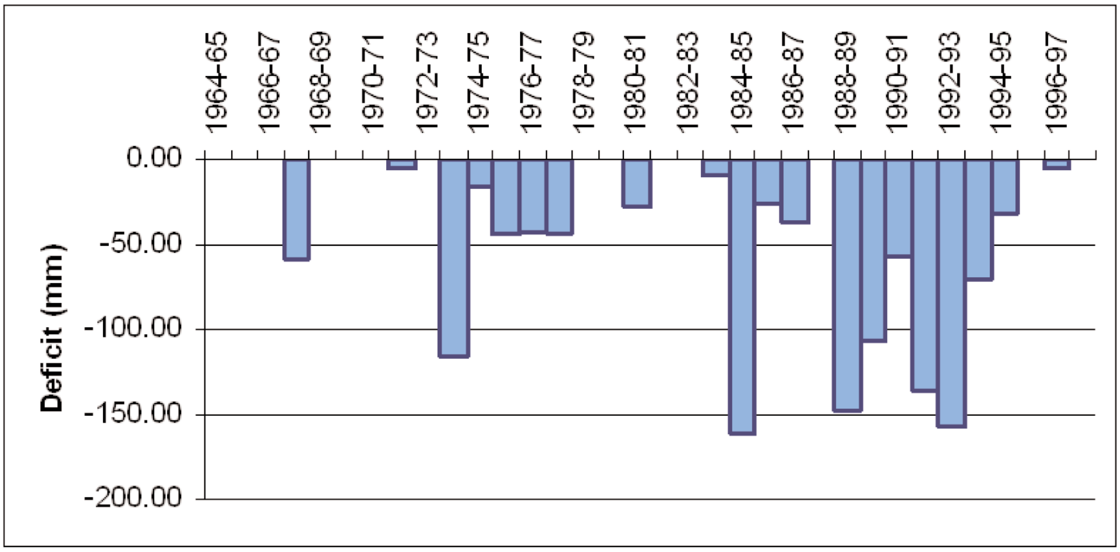


Fig. 6. Water deficit along the Nestos Basin.

The Mornos Basin

The analysis of the hydrologic regime of the Mornos Basin in Central Greece was conducted for 39 hydrological years. The main result is that drought is a recurrent phenomenon since 1987: in most of the years since then the Mornos watershed suffers from drought in almost every station.

The RDI correlates relatively well with the deciles and the SPI. It has a mean correlation coefficient equal to 0.8924, when correlated to Deciles and a mean correlation coefficient equal to 0.9812, when correlated to the SPI. In order to characterise drought and its statistical properties, we also considered the following parameters: duration, frequency and intensity. The results for the Mornos Basin are synopsised in Tables 5-7.

For the calculation of the frequency of drought, the probability of non-exceedence was calculated for each precipitation station. The probability of non-exceedence was calculated for the Standardised

Precipitation Index, because its threshold is much more evident that the one of Deciles. Therefore, the threshold to consider a severe drought event was considered equal to -1, and the following frequencies (summarised in Table 5) were computed.

For the drought periods presented in Table 6, the different intensities for each drought spell of all the meteorological stations were calculated. Table 7 summarises the characteristics of drought on each Thiessen polygon for the hydrological series that was studied.

Table 5. Frequencies of drought spells calculated when the SPI is equal or less than -1 and duration of drought spells in the Mornos Basin

Site	Number of droughts	Calculated return period (years)	Practical return period (years)	Drought periods (hydrological years)†
Pyra	6	6.50	7	1976 - 1977 (1), 1987 - 1988 (1), 1989 - 1990 (1), 1991 - 1992 (1), 1997 - 1998 (1), 2000 - 2001 (1)
Ath. Diakos	5	7.80	8	1975 - 1976 (1), 1982 - 1985 (3), 1991 - 1992 (1)
Sykea	5	7.80	8	1989 - 1990 (1), 1991 - 1993 (2), 1995 - 1996 (1), 2000 - 2001 (1)
Koniakos	4	9.75	10	1976 - 1977 (1), 1991 - 1993 (2), 2000 - 2001 (1)
Pentagioi	8	4.88	5	1982 - 1983 (1), 1987 - 1993 (6), 2000 - 2001 (1)
Lidoriki	6	6.50	7	1974 - 1976 (2), 1984 - 1985 (1), 1989 - 1990 (1), 1991 - 1992 (1), 1995 - 1996 (1)
Karoutes	4	9.75	10	1984 - 1985 (1), 1988 - 1990 (2), 1991 - 1992 (1)
Malandrino	6	6.50	7	1982 - 1983 (1), 1984 - 1985 (1), 1988 - 1990 (2), 1991 - 1993 (2)

† (The number in the parentheses indicate the number of consecutive years of drought).

Table 6. Drought periods and values of annual SPI for each period at the Mornos Basin

Site	Drought period 1 (SPI)	Drought period 2 (SPI)	Drought period 3 (SPI)	Drought period 4 (SPI)	Drought period 5 (SPI)	Drought period 6 (SPI)
Pyra	1976 - 1977 (-0.92)	1987 - 1988 (-0.08)	1989 - 1990 (-0.62)	1991 - 1992 (-0.63)	1997 - 1998 (-0.82)	2000 - 2001 (-0.52)
Ath. Diakos	1975 - 1976 (-0.29)	1982 - 1985 (-1.43)	1991 - 1992 (-0.55)			
Sykea	1989 - 1990 (-0.08)	1991 - 1993 (-1.13)	1995 - 1996 (-0.25)	2000 - 2001 (-0.84)		
Koniakos	1976 - 1977 (-0.17)	1991 - 1993 (-1.25)	2000 - 2001 (-0.71)			
Pentagioi	1982 - 1983 (-0.00)	1987 - 1993 (-0.62)	2000 - 2001 (-0.75)			
Lidoriki	1974 - 1976 (-0.34)	1984 - 1985 (-0.19)	1989 - 1990 (-0.56)	1991 - 1992 (-1.23)	1995 - 1996 (-0.59)	
Karoutes	1984 - 1985 (-0.02)	1988 - 1990 (-0.70)	1991 - 1992 (-1.82)			
Malandrino	1982 - 1983 (-1.02)	1984 - 1985 (-0.15)	1988 - 1990 (-0.24)	1991 - 1993 (-0.90)		

Table 7. Characteristics of drought spells among the Mornos Basin

	Duration (years)			Water deficit (mm)			Intensity of drought (mm/year)			Total number of droughts
	Min	Max	Average	Min	Max	Average	Min	Max	Average	
Pyra	1	3	1.77	29.1	457.6	245.57	29.0	325.0	150.99	16
Ath. Diakos	1	4	2.00	3.9	1801.8	432.88	3.9	450.4	157.63	16
Sykea	1	7	2.28	3.5	1512.7	345.5	3.5	224.6	112.71	16
Koniakos	1	2	1.77	0.2	1524.2	304.55	0.2	357.8	139.81	16
Pentagioi	1	8	3.16	105.7	3448.8	825.23	75.1	431.1	272.15	19
Lidoriki	1	3	1.33	1.8	418.6	138.69	1.8	260.9	100.65	16
Karoutes	1	4	2.00	8.4	576.2	259.83	8.4	286.8	116.14	16
Malandrino	1	3	1.60	25.7	475.7	158.14	12.8	252.9	101.72	16

The threshold of the run method was decided upon the deciles index. According to the deciles theory, a value equal to 4 may be considered as below normal. Therefore, the lowest 40% of the average precipitation occurrences was considered to be the threshold in order to apply the run method.

In Fig. 7, the diagram that describes the droughts identified on hydrological series and their characteristics for each Thiessen polygon is constructed. The diagram that sums up the influence of the polygons to the entire river basin through the hydrological time series is also presented in Fig. 8.

The A_{crit} (critical area) was considered equal to 25% of the basin, based upon the following theory. We consider that having even 1/4 of the area under drought and consequently 1/4 of the flow from the dam lost during a drought spell has undesirable results in water supply, agriculture, as well as in energy production. Therefore, it was considered that A_{crit} should be taken equal to 25% of the basin. Figure 8 shows the water deficit along the whole water basin, according to the theory of runs. During the most serious drought occurrence in Greece, throughout the period 1989 - 1993, the deficit stroke 400 mm of annual deficit out of a normal of 1245 mm per year. In August 1992, Mornos reservoir had water to supply to the Athens greater area only for 40 days.

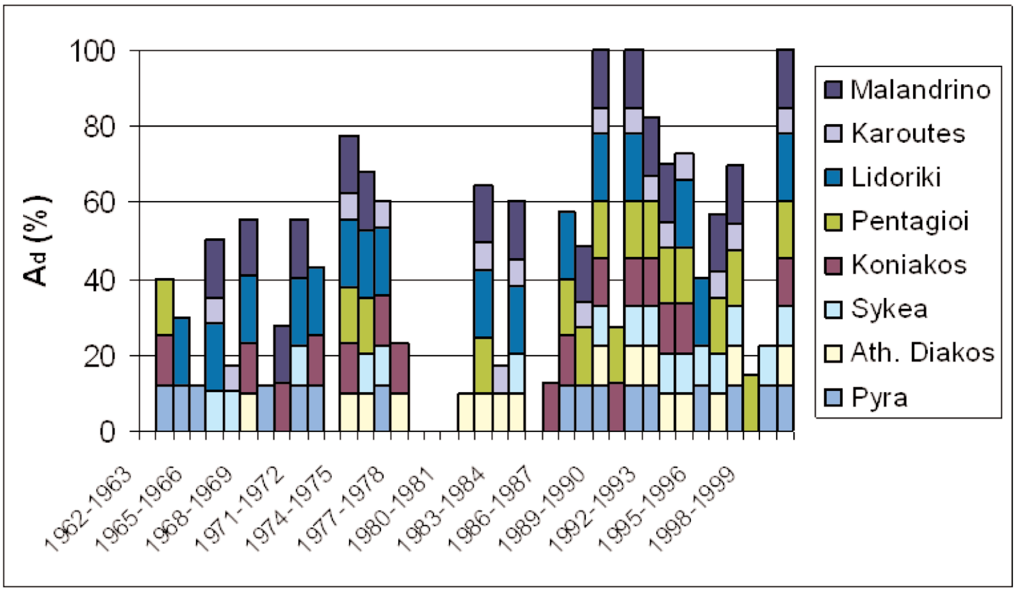


Fig. 7. Regional drought identification - influence of Thiessen polygons in the Mornos. Ad: Affected area.

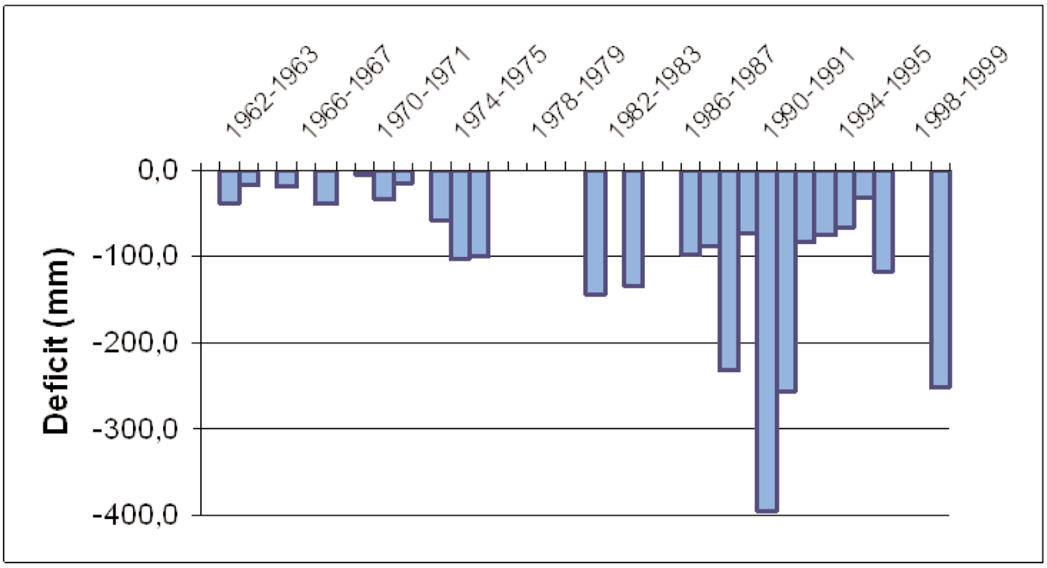


Fig. 8. Water deficit along the Mornos Basin.

Drought effects on runoff

Medbasin software was used for the assessment of the reduction of runoff for the two case studies. Medbasin was developed at the Laboratory of Reclamation Works & Water Resources Management and it includes two conceptual rainfall-runoff models, on daily and on monthly basis, respectively. Moreover, there are many additional tools, which can be used to simulate various conditions of the hydrological system. One of these tools was used in this study in order to simulate the several levels of drought and investigate the response of the system.

The methodology is based on the formulation of several climatic scenarios, derived from the alteration of the normal climatic conditions of the study area. For this task, a period of years with normal or near normal climatic conditions was defined (e.g. using a drought index). By applying the climatic scenarios for this period in the rainfall-runoff model, the percentage of the change of runoff compared to the normal value was estimated. It should be mentioned here, that the results of this method can be reliable only in annual or multi-year basis.

A detailed description of the Medbasin software and of the theoretical background is presented in the Chapter "Tools and models" of this publication.

The Nestos Basin

The selected area for the Nestos case study is a zone of 500 km^2 upstream of the river delta, between the hydrometric stations of Temenos and Paskhalia (Fig. 9). The geological structure of the part of Nestos valley from Temenos dam to Paskhalia is solid with a high runoff coefficient. The altitude varies from 100 to 1500m having a sharp terrain and a sparse hydrographical network. Data from four meteorological stations were used; three of them (Prasinada, Ptelea and Mesohori) are located within the study area, while Kariofyto station is outside the area, a few kilometres to the south (Fig. 9). Using the Thiessen polygons method, it was calculated that for the period of 1964-96 the mean annual precipitation is around 740 mm and the mean annual potential evapotranspiration is 710 mm (Fig. 10).

For the formulation of the climatic scenarios, the RDI was used in order to define the climatic conditions of the area (Fig. 11). A period of eight years (1971-1979) having near normal conditions was selected in order to run the rainfall-runoff simulation. Since only monthly data were available, the monthly rainfall-runoff model was used. The input data were the average precipitation and potential evapotranspiration of the area, while for the calibration of the model the measured runoff data at Temenos and Paskhalia stations were used.

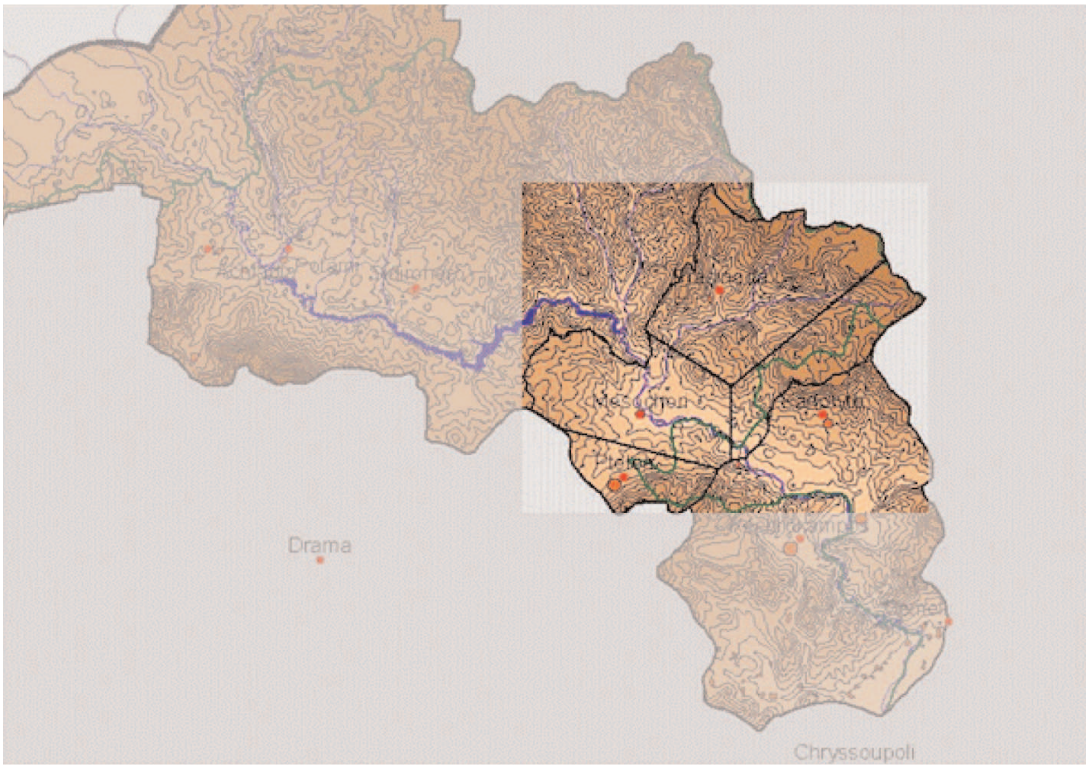


Fig. 9. Nestos Basin: Area of study.

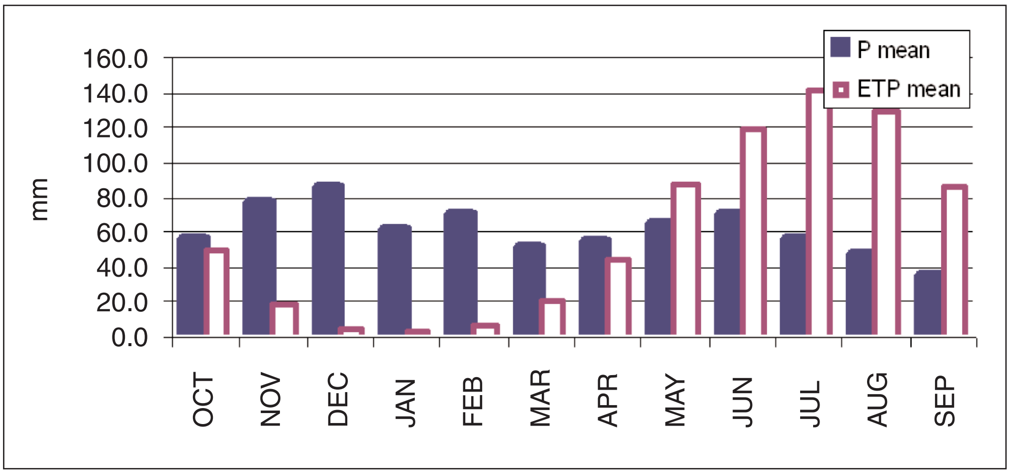


Fig. 10. Mean annual precipitation and potential evapotranspiration for the study area (period 1964-96).

About 120 climatic scenarios were created by altering the original precipitation and potential evapotranspiration data by different percentages up to -40% and +24%, respectively. The results of the rainfall-runoff simulation of these scenarios are presented graphically in Fig. 12 with two-dimensional and three-dimensional diagrams.

On the 2D diagram, some values of the RDI_{st} are presented together with the percentage of the runoff deviation from the normal value. As it can be shown, the runoff reduction is 20-35% for moderate drought conditions, 35-50% for severe droughts and it can be up to 65% for extreme drought conditions. In order to check the accuracy of these estimations, the actual values of runoff reduction for the dry period of 1990-95 were compared (Table 8). It can be observed that for the first

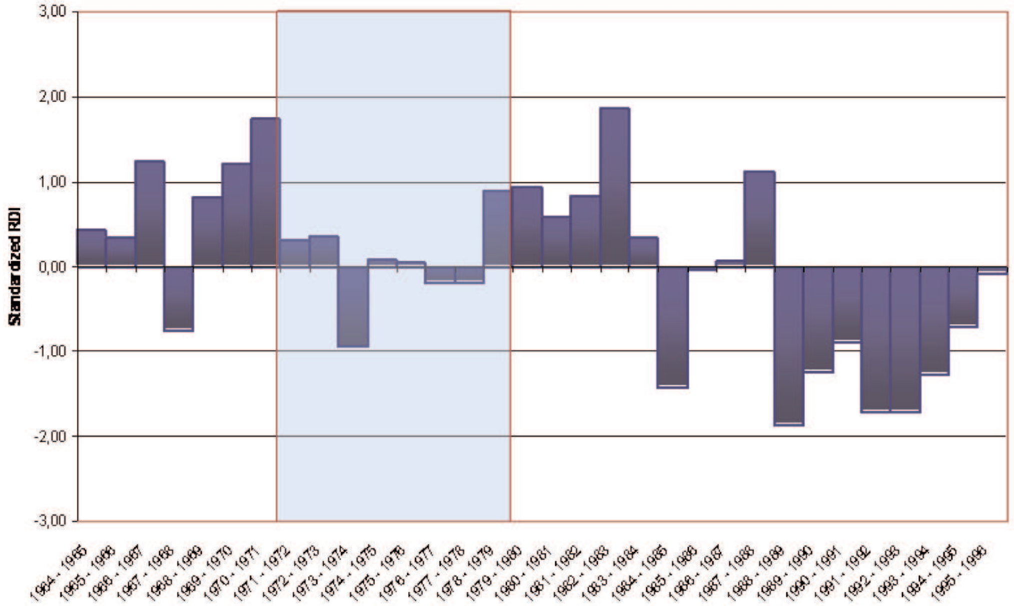


Fig. 11. Standardised RDI (RDIst) values for the study area of Nestos Basin. The period 1971-79 was selected for the rainfall-runoff simulation.

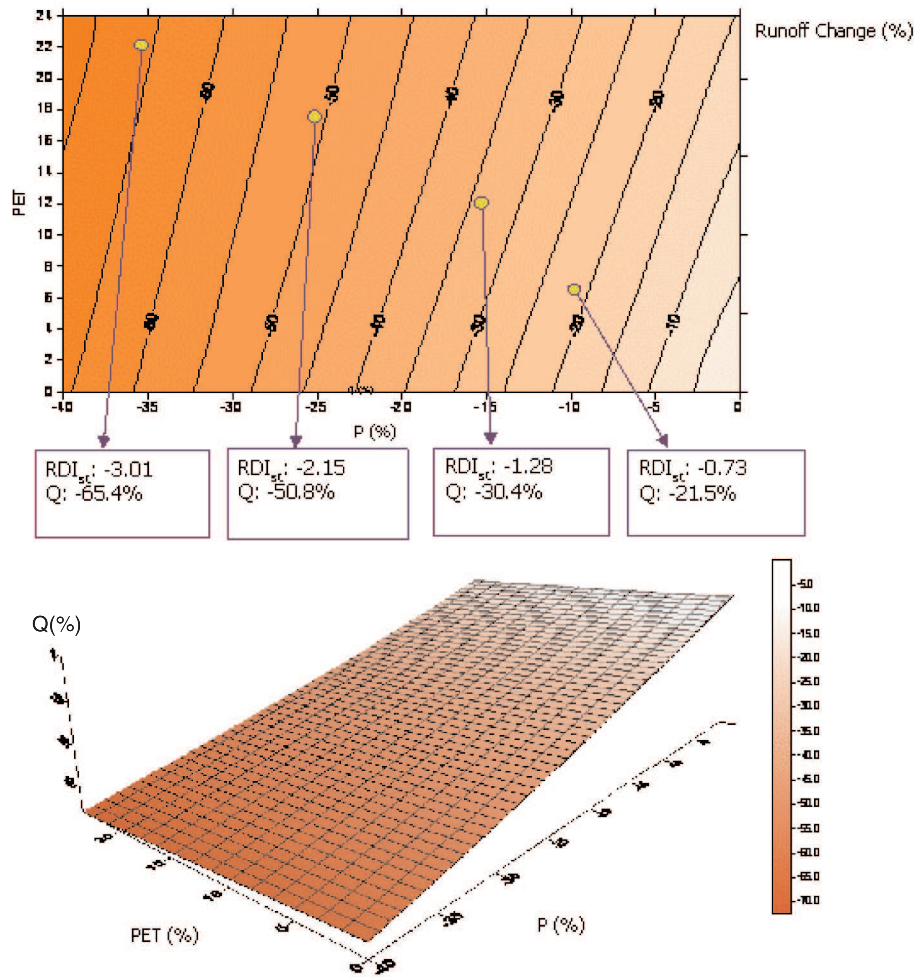


Fig. 12. Results of the rainfall-runoff simulation of the climatic scenarios for the Nestos study area. Q%: percentage of runoff change.

three years the estimation is good, while for the last two the actual runoff reduction is greater than the estimated. This may be caused by the cumulative effect of the sequence of the drought events, which is not taken into account in this approach.

Table 8. Actual and estimated runoff reduction for a period of 5 dry years in the Nestos Basin

Hydrological year	RDIst	Actual runoff reduction (%)	Estimated runoff reduction (%)
1990-91	-0.89	19.2	23.0
1991-92	-1.72	45.1	47.7
1992-93	-1.71	52.8	47.6
1993-94	-1.27	53.4	33.3
1994-95	-0.72	39.6	22.5

The Mornos Basin

The applied methodology for the Mornos case study is similar to the Nestos case. Eight years were selected for the rainfall-runoff simulation (1967-1975, Fig. 13). For this case daily data were also available, therefore the daily and the monthly model were both utilised. For this analysis, which is based on annual values, the results of the monthly model are similar to the daily one.

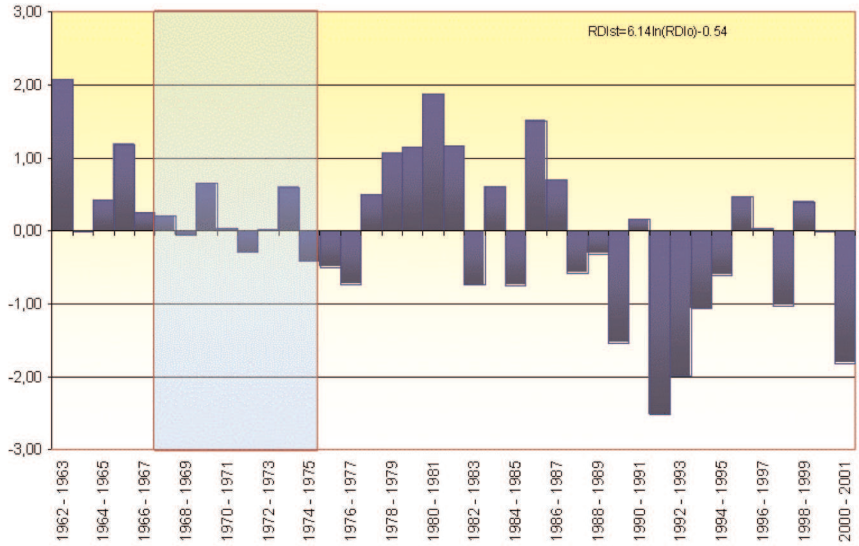


Fig. 13. Standardised RDI values for the study area of Mornos Basin. Years 1967 to 1975 were selected for the rainfall-runoff simulation.

The climatic scenarios were formulated by altering the original data of precipitation and potential evapotranspiration by various percentages up to -40 and +14%, respectively. About 170 scenarios were simulated and the results are presented in Fig. 14. The comparison of the results with RDI_{st} shows that the reduction of runoff for moderate drought conditions is 8-20%, for severe droughts from 20-30% and for extreme droughts can be up to 50%.

Potential impacts of drought

The potential impacts of drought in the Nestos and Mornos Basins are summarised in Table 9. The importance of each impact represent the responses to the interviews of major stakeholders in drought and water management in the basins. The full responses are included in Annex 3.

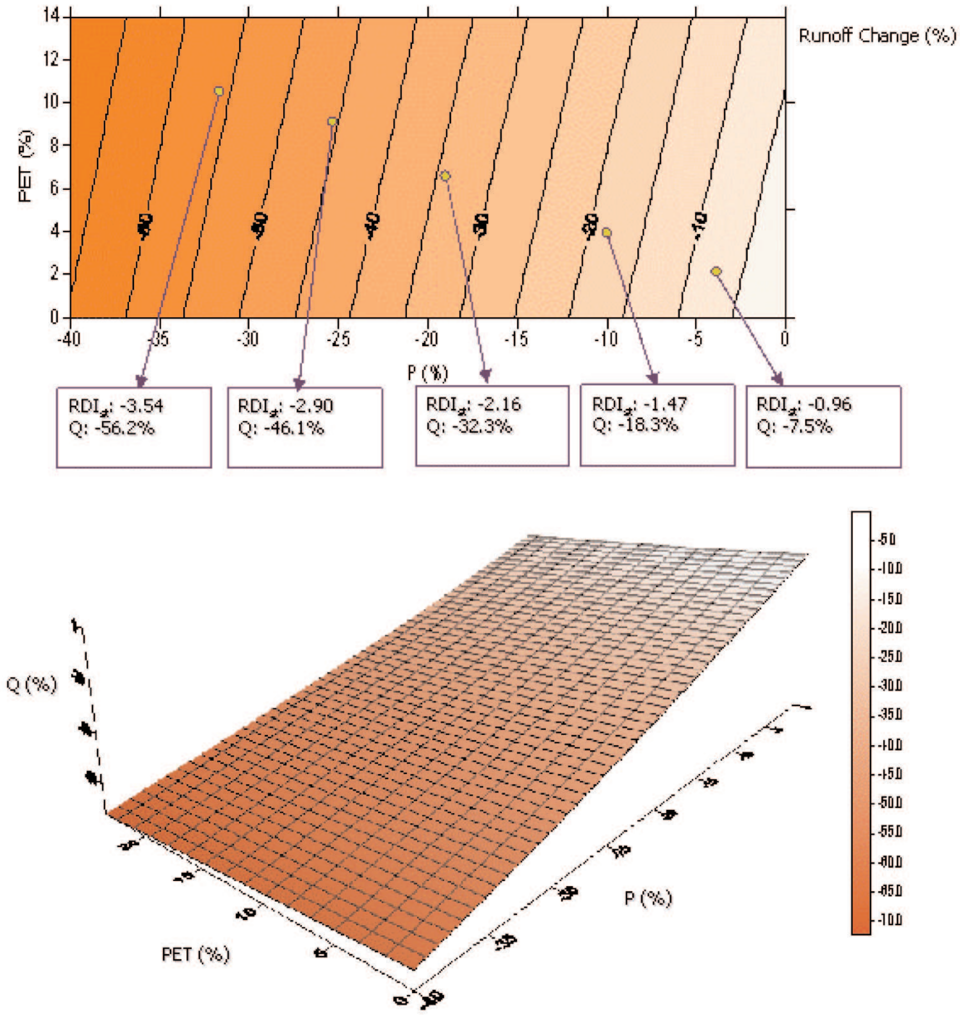


Fig. 14. Results of the rainfall - runoff simulation of the climatic scenarios for the Mornos Basin. Q%: percentage of runoff change.

In general, the most significant impacts of drought in the Nestos and Mornos Basins refer to runoff reduction and reduction in agricultural production. In addition, in the Nestos water basin it is important the wetland ecosystem affection and biodiversity loss. In the Mornos water basin the pressure on water supply system of the city of Athens (capital of Greece) and the tensions to government are key issues.

Operational component

Combining the above reported procedures and the lessons learned from previous actions at the national, regional and local level during significant drought events of the past, a set of actions was devised. In the case of drought, the experience from the past, regarding the Greek area, was mainly attained through two periods of extreme drought that stressed the metropolitan area of Athens. The urban water supply system, which was used in this study along with the drought events considered, and the actions that were taken, regardless of their success, are presented below.

Lessons learned from the Athens urban water supply system study, mainly focus in drought mitigation actions and plans. The success of these actions and plans will be enhanced with the use of a monitoring system that will give us information on when and where various measures should be applied. Since a monitoring system is essential for the success of the measures, a brief introduction on how a monitoring system can be of assistance is also presented.

Table 9. Summary of the potential impacts of drought in the Nestos and Mornos Basins based on responses of stakeholders

Impact	Nestos Basin	Mornos Basin
Increase of farm subsidies	Very important	Very important
Conflict appearance in water use	Very important	Very important
Increase in number and severity of fires	Very important	Important
Decreased crop production	Very important	Not very important
Increase in crop imports	Very important	Not very important
Increased soil erosion	Important	Very important
Conflict appearance in political decisions	Important	Very important
Public dissatisfaction with government regarding drought response	Important	Very important
Decreased water in farm ponds for irrigation	Important	Important
Increase in insects, pests, and crop diseases	Important	Important
Loss of farm income	Important	Important
Biodiversity loss in ecosystems associated with water	Important	Important
Increased cost of ground water extraction	Important	Not very important
Decrease in farm income	Important	Not very important
Decrease of agricultural labour	Important	Not very important
Increase in food prices	Important	Not very important
Increased unemployment of the agricultural sector	Important	Not very important
Increased stress to endangered species	Important	Not very important
Conflict appearance in management	Important	Not very important
Decrease in hydroelectric power generation	Important	Not very important
Additional cost of water transport or transfer	Important	Not very important
Increase in water tariffs	Not very important	Important
Decreased crop quality	Not very important	Important
Additional cost of supplemental water infrastructures	Not very important	Very important
Decreased revenues of water supply firms	Not very important	Very important
Decrease in reservoir and lake levels	Not very important	Important

In order to mitigate the drought consequences there are two major axes that should be followed. These two axes refer to the long term and the short term actions that have to be taken. In the long term, a preparedness master plan should be deployed and applied, while in the actions in the short term, predetermined actions could be devised and implemented. Table 10 summarises the operational actions.

Preparedness master plan

Regarding the preparedness plan, four are the main aspects that have to be considered along with other aspects of less importance or ones that are applied according to the local conditions of the application areas. These main aspects are:

The *technocratic perception* (refers to the knowledge on what should be done and of course in what time). This knowledge should be concrete and widely respected since there is no space for experiments during the implementation. Though a drought monitoring system can help in identifying the correct time of actions implementation, thresholds between the different levels of drought severity should be clarified and accepted for local conditions, so all the authorities involved in the implementation of the plans will act accordingly. Measures that should be taken shall be concordant with the international practice, though local deviations should also be considered.

The *administrative and organisational matters*. It should be clear who is responsible for every action that should be taken. Organisational disorders can lead to devastation. Certain control centres that may not decide upon an action, in the thought that it is not their responsibility, may affect the entire plan implementation. Though it seems that this is an aspect of minor importance, this step has to be planned in advance and given the respective credit. It is a known fact (at least in Greece) that

Table 10. Summary of the components of the drought planning and operational actions to manage drought in Greece

Component of drought planning	Operational actions
Preparedness master plan (ongoing)	1. Ongoing based on monitoring and early warning 2. Definition of the responsible officials for the action to be taken 3. Definition of the time to implement the action 4. Ensure laws are in place to take action 5. Ensure public participation
Actions in the short term (actions taken when drought is occurring)	1. Reduction of water demand – prohibition of use – pricing (not effective) – incentives to save water – advertising to raise public awareness – agricultural practices that save water 2. Increment of water supply 3. Monitoring
Practical examples	1. Improvement of the operational management of the water system 2. Use of emergency and auxiliary water resources 3. Emergency water transfers 4. Changes in rights of water use 5. Monitoring 6. Concrete applications in the city of Athens and in the Mornos Basin

when a situation is dealt successfully, all authorities involved are trying to gain the credit of this success, while no one accepts the responsibility when something goes wrong.

Time and space actions. The time sequence of the actions as well as the spatial scale of the plan should be carefully scheduled. If the actions are not applied in the right order a prominent loss of resources may occur. This step focuses mainly in planning the actions in advance, in an acceptable detail level, regardless of the final implementation.

Public awareness and participation. Public has to be involved in the plan. Not only because the citizens will be the receivers of the actions but because they have to be fully aware of what is going to happen. This will help the smoother implementation of the plan and will give the civilians the potentiality of making the appropriate proposals for changes in the plan in order to be more adaptive to them. Non governmental organisations (NGOs) have to play an important role in the interaction between the public and the authorities. Since their communication with the citizens is guaranteed and most of the times they are spread among different community levels they can reassure an important feedback to the stakeholders.

Actions in the short term

Two directions can be followed: Reduction of the water demand and increment of the water supply. In an urban environment, this may be achieved through the administrative actions along with new and sometimes even strict laws and essentially through the stimulation of public awareness. Specific acts of this type are for example the prohibition of excessive use together with a legal framework for a more rational water use. Pricing policy regarding higher costs per unit for higher water consumptions may be also applied. In European countries, though, this measure was used in the past and was not very successful.

A more successful measure could be the use of economic incentives from the water companies in order to lead the people in less water consumptions. Advertising and other means of public announcement is always essential in not only informing the people for the water shortage situation but also helping them to consume water in a more rational way in the long term. Public awareness information may be diffused through mass media or leaflets distributed to the citizens, but an important aspect is to pass this information to young people through schools (or any kind of educational campaigns), in order to shape a life style that includes rationality in water use. Regarding the rural environment, changes in agriculture will mainly lead to the desired results. Such changes may be the selection of less water consuming crop varieties, the control of evapotranspiration by artificial means, the optimisation of agronomic techniques and actions that are even more complicated (e.g. the soil enhancement).

Emergency water transfers and diversions is another auxiliary solution from the same point of view, with the advantage that the source will not remain connected to the supply network after the crisis and the disadvantage of being a more expensive solution since appropriate infrastructure should be constructed just for a short period of time.

Diversions between different purposes of water consumption that should be listed hierarchically in advance may be also implemented during an emergency situation.

Measures and actions to minimise the impacts of drought should be also considered. Minimisation of water supply impacts should be made through water supply system adjustments. The same implies for the agricultural sector, while in the economic sector impacts may be minimised with direct and indirect public aid and the use of insurance policies.

Monitoring systems

The actions planed for drought mitigation will not be very efficient unless information on drought incidents in temporal and spatial scale are available or can be acquired. Such information can be obtained from monitoring systems. In brief, a monitor system can give information of when a drought period started, how long it lasted, how severe it was and which were its spatial limits. Moreover, a monitoring system applied on historical data series can give us the opportunity to identify drought prone areas. Identification of drought prone areas helps in a more efficient application of drought mitigation plans, since areas that are affected by drought more frequently than their surroundings should be monitored in detail and the authorities should respond faster in the mitigation of an extreme situation. Monitoring systems though, can mainly supply information on past events. A warning system of extreme situations is a more useful tool, since it can provide the authorities with enough time in order to apply measures to prevent the situation. A warning system can be the result of a combination between a monitoring system and a weather prediction system and it is obvious that its accuracy is based on meteorological predictions.

Operational monitoring in the Mornos Basin and the Athens water supply system

The best practices for drought mitigation that are presented in this study are mainly derived from what we have learned from past actions and mainly from the measures that were taken during drought events in the one of the most important water supply networks of Greece, the Athens metropolitan water supply network. This network is important not only because it supplies an urban area with almost half the population of the whole country but, as shown in Fig.15, because it comprises a number of rivers, artificial lakes, reservoirs, pipelines and other infrastructures that covers about one fifth of the whole area of Greece.

There are two main historical droughts, which occurred in the past, which affected Athens and consequently the water supply system and all the areas that are connected to this system. The first drought took place during the years 1976 to 1977 and led to a significant urban water shortage. Though there are not detailed data available from this period regarding the incident and the solution applied, it is known that the pressure for water was so high that even brackish water was used to cover part of the needs. It is important that this specific drought and its consequences led the authorities in an extension of the water supply system with the addition of the Mornos reservoir.

The Mornos dam (which can be shown in the left part of Fig. 15) was finally constructed in 1980 and it is a part of the metropolitan water supply system since then. The second major drought took place in the years 1989 to 1993. The pressure on the urban water supply system was again extremely significant even though new reservoirs were already added to the system. It should be mentioned that the reservoir levels were low and that the prediction of water availability, even with the measures applied, was that the stored water would cover the needs only for the remaining 33 days.

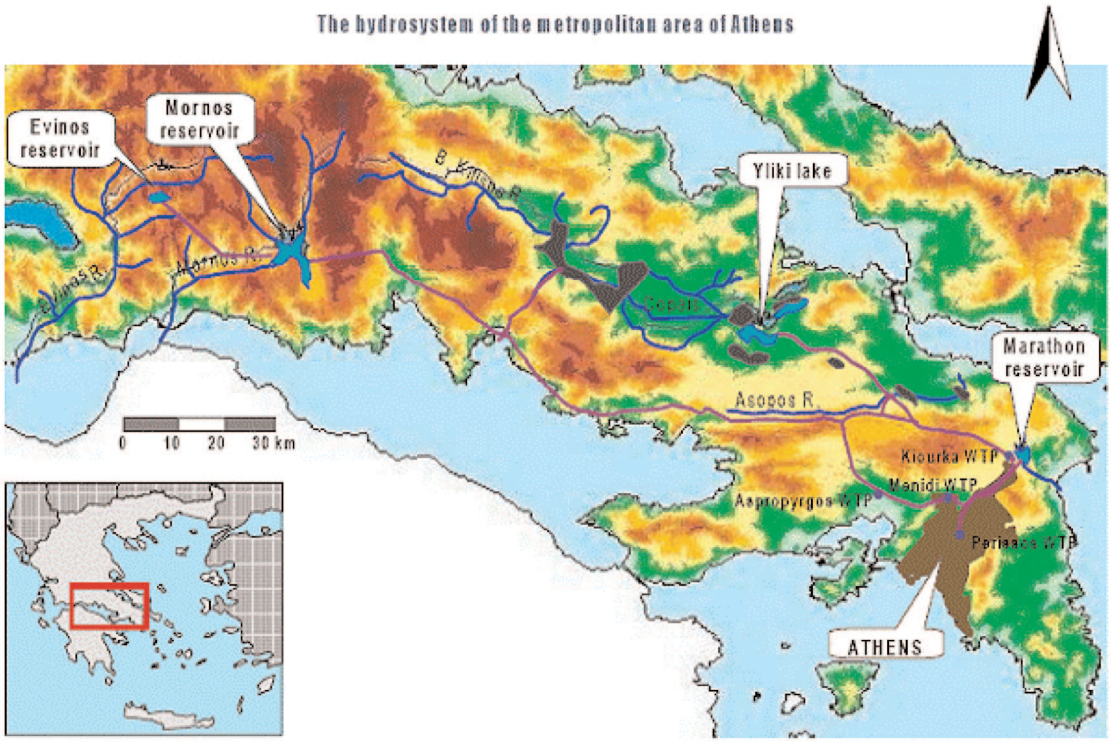


Fig. 15. Water supply network of Athens.

Another important issue, from an environmental point of view, was that the specific drought affected the rural areas, which support the system. The Kopais valley (in the centre of Fig. 15), which is one of the main agricultural sites in the outskirts of Athens, suffered a major problem regarding irrigation water scarcity, since the Yliki Lake, which provides water for irrigation in the area, was used to cover the urban needs of the metropolitan area. In order to solve this problem, the authorities agreed to provide the farmers with a certain amount of water for irrigation regardless of their real needs. This example shows, not only the pressure of drought in all the areas that are involved in the water supply network of Athens, but also an involvement of politicians in the situation providing non scientifically based solutions. The lack of systematic plans for extreme events mitigation led to the use of actions that were not sustainable and viable and could produce even larger problems in the future.

A number of actions were proposed during the second drought period. Some of them were finally implemented, though a lot of them were rejected on a second thought. An example of a rejected action was the water transport with tankers. It was a rather expensive solution that proposed the transport of water from a remote site, without taking into account the capability of this area in providing the specific amount of water. The addition of new resources to the system was another rejected solution. According to this proposal, Trihonis Lake, a natural lake at the west of the Evinos River was examined to reinforce the water system. Of course, adding new resources every time a problem occurs has nothing to do with a systems stability and moreover with any sense of sustainability. The proposal for new infrastructure was also rejected as an expensive and unsustainable solution.

Actions that were finally taken marginally assisted in overcoming the difficult situation, though some of them are not considered useful worldwide nowadays. Water supply cut-offs according to a schedule was one of them. Since water was not available for all the sections of the metropolitan area, a scheduled distribution was designed. Water was distributed to different sections for only a few hours each day according to a time table that was publicised through mass media. Citizens had to schedule their own activities according to a broadcasted time table or they had to collect water in small reservoirs at their house for daily use.

Pricing policy was used along with the cut-offs. The pricing policy was mainly based in the set up of high penalties for high consumptions in order to force citizens to consume only the necessary amount of water. Though this measure may have led to social inequality forcing poor people to lower consumptions, it was a useful solution in the water supply system of Athens during the past droughts.

Public information mainly through mass media campaigns has also been used during past droughts successfully. Citizens were informed about the water storages, the distribution schedules and they adopted the measures proposed by the authorities in a very rational way.

Finally, an important measure taken from the authorities was the irrigation water reduction from Yliki reservoir to over 50%. This measure helped in gaining water for urban use, which was considered at the time as more important, but created a significant problem in the irrigated areas since the reduction was not based in a schedule and it could not be easily adopted by the farmers.

Proactive and reactive plans and actions

The most recent regional drought episode in Greece was experienced during the period 1989-1993. According to the data of that period, this multiple-year drought had caused severe problems in most areas of Greece. The situation was so difficult that for the last six months of the drought period, several non-conventional scenario and solutions were proposed for securing water supply for domestic use in the major cities of the country. The most characteristic case was the case of the municipality of Athens, which derives its water from Mornos River as well as Yliki and Marathon Lakes, and a battery of boreholes from Viotikos Kifissos basin. (Recently Evinos River is also one of the contributors for fulfilling the water resources demands of Athens).

Some of these scenarios referred to massive transport of water by vessels from various areas, the construction of a new aqueduct connecting Trichonis Lake with Mornos reservoir, construction of water supply networks from other areas of Sterea Hellas and Peloponnese.

The most amazing of all was that Athens, at the end of September 1993, had water only for one more month. The solution which was at that time decided was given by applying demand reduction measures, which were assisted by the change of the climatic conditions soon after.

Gradually after October 1993, the reservoirs of the system started to be filled and after a lag of three years, the situation was again normalised.

Within this Plan, the institutional and legal measures related to water resources and more specifically the mitigation of drought, are covered by the EU Directive 2000/60 and the Law 3199/2003. Particularly, measures taken or planned that are compatible with the NAP are:

The implementation of the plans for developing water resources at all levels, the establishment and operation of the regional water management services, the issue of regulation decisions by prefectures to protect water resources per river basin and the exertion of effective checking on infringement of the law and infliction of the respective penalties are ensured by the respective laws, and the support for more efficient operation of Local Land Reclamation Organisations.

The reparation and renovation of the irrigation networks, the application of integrated irrigation systems, the water recycling and re-usage is implemented through the plans of the Land Reclamation Directorate for facing drought as well as the Local Land Reclamation Organisations.

The actions for combating drought are being realised by the construction of dams and off-stream reservoirs in drought prone areas. So far, twenty dams and twenty-nine reservoirs have been constructed. Also, technical studies for eleven dams and four water reservoirs have been prepared. Both the Greek government and the European Union fund the plans. Additionally, the Ministry of Agriculture has continued an activity initiated in 1994 for facing the drought problem, by funding works like drilling (where sufficient ground water resources exist), harvesting of spring waters, repairing the irrigation networks and other land reclamation projects. Recycled water has been used, at a relatively small scale, to satisfy irrigation needs. Other actions include: The refilling of artificially drained lakes and the planned diversion of the Acheloos River towards the Thessaly plain, which is threatened by desertification; The development and expansion of the National Data Bank of Hydrological and Meteorological Information; and The support of research for increasing available water supply. Several reports are being prepared for the support and pilot application of the EU Directive.

Given that agriculture uses 84% of the water resources of Greece, most pro-active and reactive plans and actions concerning the effects of droughts were taken in the past by the Ministry of Agriculture.

Proactive actions

The most relevant proactive actions in Greece include: Small earth dams for collection of rainwater, canal rectification to reduce water losses, and modernisation and improvements of irrigation networks.

In more detail, all proactive measures have the same aim to enhance the storage, the conveyance and distribution of water. In this context, it should be mentioned that important contribution to water saving is the gradual change from conventional surface irrigation systems to modern sprinkler and trickle irrigation systems. Therefore, application efficiency is enhanced if farmers follow this tendency.

Reactive actions

The most relevant reactive actions in Greece include: Constraints in water consumption, intensification of the use of groundwater resources, reallocation of water resources, use of saline and brackish waters, and Water transfer.

During drought, the reactive actions follow two categories of measures: the allocation of new sources of water, such as saline and brackish waters and also intensive pumping of existing ground waters. In some cases, water is also transferred from agricultural users to the towns and cities for municipal consumption. If possible, in some cases, water transfers and reallocation of water resources is attempted. The reallocation of water resources of Viotikos Kifissos from the irrigation area of Viotia, in order to serve the Athens greater area during the drought 1989-1993 is the most profound example of this category of reactive actions. In the future, pro-active and reactive plans and actions for drought mitigation will be based on the Law 3199/2003.

During this period, several Water Resources Management Studies are prepared for most regions of the country under the supervision of the Ministry of Development. Although these studies have their roots on the previous legal system (Law 1739/87) by which the coordination of water resources management was responsibility of the Ministry of Development, they can produce important results for the implementation of the Law 3199/2003.

It is expected that these studies will organise the hydrological and other data in a systematic way and they will provide useful information about the drought-prone areas of the country. However, it should not be anticipated that these studies will produce proactive or even reactive plans to combat drought. According to the Law 3199/2003, proactive and reactive plans related to the mitigation of drought will be adopted by the Central Direction of Waters (proposals, general rules, medium-term and long-term national plans) and by the Regional Direction of Waters for each River Basin District.

Although reallocation strategies seem to be a very effective measure to combat drought in the agricultural sector, very little work has been done at operational scale. It is expected that at least in some areas prone to drought experimental studies on changes of cropping patterns will be applied. For example, Thessaly plain has been proposed for these cropping pattern changes, where one of the major crops is cotton.

During the period of 1989-1993, several measures for the confrontation of drought were taken by the ministries involved and the perfectural and municipal services. Most of these measures, which have been presented elsewhere in this text, were taken with little co-operation and co-ordination. However, in most of the cases (and although there are some conflicts reported) the results were in the same direction, namely the reduction in water consumption and the use of some extra water resources wherever possible. Conclusively, it should be said that during the last drought there was no systematic approach and sufficient co-ordination.

Stakeholder analysis

The Public Power Corporation S.A. (Hydroelectric Power Plants Operations Department)

Public Power Corporation (PPC) supplies Greece with electric energy. A percentage of 6% of the total energy is supplied by hydroelectric plants. The dams of PPC form reservoirs-artificial lakes that are used for power production irrigation and water supply purposes.

The interviewee –director of the sector of exploitation of hydro-electrical stations– perceives drought as a comparison between the mean value of precipitations during a long time series and the mean value of precipitations of the current year. He also believes that mankind cannot easily control but only influence drought, because this is related to the quantity of precipitations. Agriculture is the most sensitive sector affected by drought (80% of the total water consumption is used in agriculture), while tourism seems to be the most insensitive sector.

Ordering the factors of uncertainty, which affect irrigation farmers, the climate may be considered as having the highest level of uncertainty, because in the interviewee's opinion it is not influenced by man. In a second rang, the economic value of agricultural products should also be considered, because they are related to the climatic conditions. On the other hand, in the interviewee's opinion, agricultural policies are rather insensitive to uncertainty.

The interviewee believes that only a small part of users is holding a water permit in Greece. The whole issue is complicated and has many aspects: financial, social, developmental and legal. According to the Law 3199/2003, many sectors are represented and participate in organisations/committees that are responsible for the definition of water allowance during drought periods. The problem focuses in the fact that such numerous bodies do not easily make decisions.

The number of users related to a certain water allowance influences decisions, due to the political power of the vote. There is also greater ability to make decisions concerning the definition of water allowance for representatives of the public sector (ministries, etc.).

There is no formal procedure to declare a "drought situation". As far as the management of inflows in reservoirs of hydroelectric plants is concerned, the "drought situation" is considered by taking into account the current meteorological and hydrological information, in comparison with previous conditions, the volume of the reservoirs, the snows existing in the basin district, etc.

According to the interviewee, in the case of drought, highest priority for the water supply should be given obviously to the domestic use of water and lowest priority to tourism, with the exception of the Aegean islands. These priorities correspond also to the priorities that the administration should defend.

The Public Power Corporation does not have a specific policy that is followed in the case of drought. Nevertheless, during past periods of water scarcity, pressure has been applied on farmers for the reduction of the quantity of water used for irrigation (informal measure) and a report has been sent to the prime minister. In drought periods, a pro-active measure adopted by the Public Power Corporation is the construction of reservoirs managed by the Corporation itself and which are multi-purpose projects.

A reactive measure taken by the Public Power Corporation, related with the drought management, is the appropriate management of water outflows from the reservoirs for domestic use and irrigation purposes, in addition to the energy production. According to the interviewee, creation of reservoirs may be considered as the most important measure to be carried out for the management of drought, because rainfalls are few in Greece and unevenly distributed during the year. Desalinisation of water is considered to be an expensive way for water supply. Measures should be adopted separately for the various districts of the Country because they have different weighting conditions of water use.

The interviewee considers as measures not accepted by the public: The substitution of high water-demanding crops with low water-demanding crops, the reallocation of water, the inter-basins transfers, and the conversion of some irrigation surfaces to dry farming.

The interviewee expresses the opinion that water cannot be treated in a way similar to other natural resources (oil, gas, etc.) because the property of water cannot be easily controlled, i.e. who the owner of water is and how the water will be sold. The water management should be carried out by public organisations and the users should pay the cost according to social criteria.

There are two distinct parts in Greece: (i) The Eastern part and the Aegean islands, characterised by water scarcity and consequently a considerable number of users that would probably buy water; and (ii) the western part, with adequate quantities of water and, therefore, less inclined to buy water.

Water is a good of first priority, essential for the human life. Buying and selling water would result in the interest of some people or companies dealing with the water marketing and a high cost for the water itself. The establishment of institutions, which would deal with water buying and selling seems to be unfeasible for the time being.

The Greek National Committee for Combating Desertification

The interviewee –president of the Committee– perceives drought as a naturally occurring phenomenon that takes place when precipitations have been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems. He also believes that agriculture is the most sensitive sector affected by drought (80% of the total water consumption is used in agriculture), while tourism seems to be rather insensitive.

According to the interviewee, the agriculture sector is the major consumer in Greece and therefore this is the one whose responsibility is to cope with the effects of drought.

Ordering the factors of uncertainty that affect irrigation farmers, climate may be considered as having the highest level of uncertainty, as it is often related with severe consequences. On the other hand, in the interviewee's opinion the work market is rather insensitive to uncertainty.

According to the interviewee, in the case of drought, the highest priority for water supply should be given obviously to the domestic use of water and second to agriculture. The lowest priority should be given to the recreational use of water. These priorities correspond also to the priorities that the administration should defend.

The Committee's proposal with regard to proactive measures generally adopted in drought periods includes the construction of reservoirs, the enforcement of the artificial groundwater recharge and the improvement and repair of the water supply systems. Concerning the reactive measures generally adopted in drought periods, it is suggested to discourage wasteful use of irrigation water and to use agricultural methods limiting evapotranspiration.

According to the interviewee, increase in the regulation capacity for irrigation purposes and creation of reservoirs may be considered as the most important measures to be carried out for the management of drought (management of supply). Inter-basin transfers of water and use of brackish water are considered by the interviewee as being of lowest priority measures for water supply (least important).

The interviewee expresses the opinion that it is possible to treat water in a way similar to other natural resources (oil, gas, etc.) but at the same time, there should exist an intervening state policy to preserve public interest. The option to buy and sell water would possibly involve users from the whole country.

The interviewee considers as possible negative effects of buying and selling water, the increase of the price of water, the profits without control to companies selling water and the various environmental consequences of such a policy. Simultaneously with the creation of water banks, controls for the protection of the public interest should exist.

Ministry of Agriculture - Hellenic Agricultural Insurances

The interviewee –director of the branch of Patras– perceives drought as an extended deficiency in water caused by lack of precipitation in a particular area. The interviewee believes that man can significantly limit the consequences of drought by applying an appropriate planning, organisation and a national policy of drought confrontation that will control the malign consequences.

The interviewee believes that the agricultural production of non-irrigated crops is exclusively dependent of precipitation. For the irrigated crops, any pause of irrigation can be disastrous. Therefore, he considers that the domain most affected by drought is agriculture, whereas domestic use is not that sensitive as a provision for water reserves is often ensured. It is evident though, that the domain responsible to confront the drought consequences is the agriculture domain.

Sorting the factors of uncertainty that affect irrigation farmers, climate may be considered as having the highest level of uncertainty, since it cannot be controlled. On the other hand, the interviewee believes that the work market is rather insensitive to uncertainty.

The interviewee believes that the current legal framework defines clearly the rights of the water permit holders, but that compensations due to users are not clearly defined in the current legal framework.

The interviewee expressed the opinion that the agriculture sector should be better represented in the legal framework and that the groups that have the greater ability to make or influence decisions concerning the definition of water allowances are mainly the different Scientific and Technical Chambers. According to the interviewee, a "drought situation" is undefined as far as time is concerned; however, it could be related to the end of the last rainfall.

In the case of drought, the highest priority for water supply should be given to agriculture, because it is the domain most affected and also affects every other activity. The lowest priority should be given to recreational use of water. However, those priorities do not correspond to the priorities that the administration defends, as the current legal framework does not prescribes this strategy.

In previous drought situations, the Department followed a pilot programme of precipitation increase in the highlands of Central Greece with the method of seeding clouds with hygroscopic substances. Unfortunately, the programme was not accepted by the government. Emphasis should be given in the fact that no proactive neither reactive measures are taken by this department in order to combat drought.

The interviewee believes that the most important measure to be taken is the creation of reservoirs in order to ensure the water sufficiency. He also considers an increase in the regulation capacity for irrigation purposes as an important measure to be followed, as well as the improvement of irrigation efficiency. He regards the reallocation of water from irrigation to urban uses as an unnecessary measure as it will induce social problems.

The interviewee believes that measures acceptable by the public are the creation of reservoirs, the regulation capacity for irrigation purposes and the improvement of irrigation efficiency, whereas a measure not acceptable by the public is the reallocation of water from irrigation to urban uses. In general, more accepted are the measures concerning the creation of infrastructure and sound management principles, while less acceptable are considered the measures concerning modification in agricultural uses.

The interviewee expressed the opinion that it is possible to treat water in a way similar to other natural resources (oil, gas, etc.) under the condition that the utilisation cost will be limited to low levels and will be spread according to the user's intentions. Water metering would involve a considerable number of users and could possibly reduce the total consumption.

A negative effect for buying and selling water is that the consumption would be disproportional to the real needs of each user, and that the users to be aggrieved would be the ones whose needs would be the greater, and in particulate the irrigation farmers. The establishment of water banks is considered to be a necessary measure, but it should be governed by a well-planned Water Management and Utilisation Rule and its application should be very well monitored.

Strengths and weaknesses of the current structure

It is understandable that the interviewees face the drought phenomenon and the corresponding results from their interest and the interest of the people they represent. Obviously, the big majority of people agree that recreational uses (e.g. pools, fountains, etc.) have the last position hierarchically in the list of uses. However, according to the Law 3199/2003, municipal water consumption is considered as the first priority. Regarding the other uses, there are specific interests in each area, which to some extent define the priorities.

The main strengths of the Greek institutional framework that stand out from the above analyses are:

(i) A National Data Bank of Hydrological and Meteorological Information (NDBHMI) has been established. Various software applications are linked to the central database of the NDNHMI supporting the analysis and synthesis of the data and the elaboration of secondary information. A GIS subsystem was developed to support the spatial analysis of hydrological data.

(ii) There are sufficient socio-economic data concerning water users, with the exception of incomplete information on farmers and irrigation water.

(iii) According to the existing situation, all institutions involved in drought preparedness and mitigation, have a good experience concerning recent drought episodes. Although there are no specific plans for drought mitigation in Greece, many governmental institutions and other institutions are dealing with the effects of drought in a case to case basis.

(iv) There is a sufficient number of reservoirs that are being used in drought situations and therefore the water reserves of the country are well managed.

(v) The domain of agriculture seems to have enough influence with the government and whenever irrigation farmers are affected by drought, the pressure exercised on the authorities has good results in order to combat drought.

(vi) The Law 3199/2003 has been recently adopted. According to this law, all sectors affected by drought are represented in the National Council of Waters and the Consultative Committee of Waters.

The main weaknesses of the Greek institutional framework that stand out from the above analyses are:

(i) Up to now there is neither insurance nor compensation policy provided by the legal framework for the rainfed or irrigated agriculture.

(ii) No systematic monitoring of drought occurrence and regional extent has existed in Greece in the past. This work will be hopefully carried out by the commissions instituted according to the law 3199/2003 on Water Resources Management.

(iii) In the past, decisions concerning droughts were taken in a case to case basis. This approach is considered unsatisfactory and it is therefore necessary to elaborate a plan for drought mitigation, based on the structures described in the law 3199/2003 on Water Resources Management. The only positive conclusion regarding the case by case action against drought is that it is an indication of local creativity and the readiness of the local organisation to act independently and find quick and acceptable solutions.

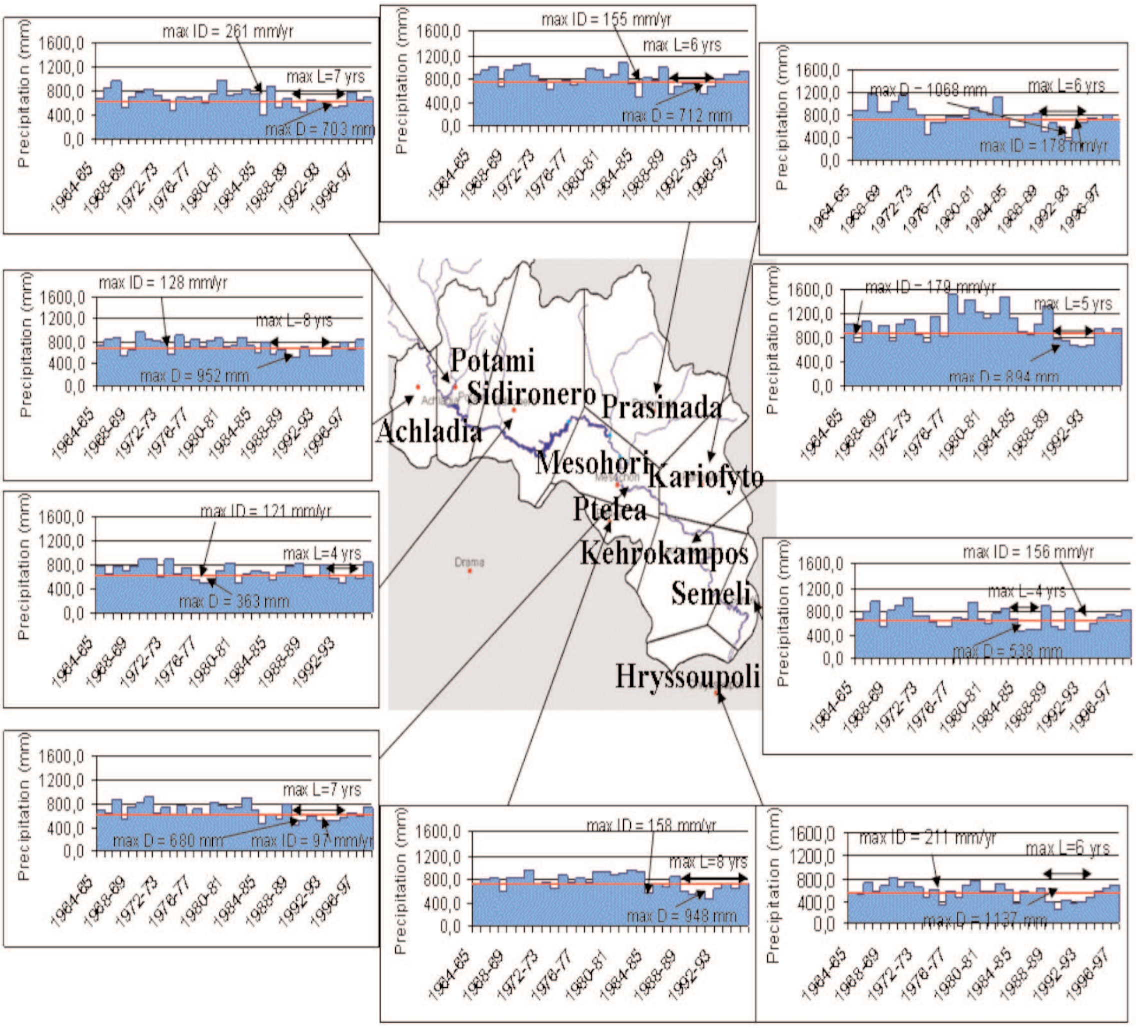
(iv) Up to now, there is a lack of information concerning the consumption of irrigation water by individual farmers. Although there are institutions and organisations with experience on the subject, there is no coordination among them and there is no managerial policy in a higher level from a central administration.

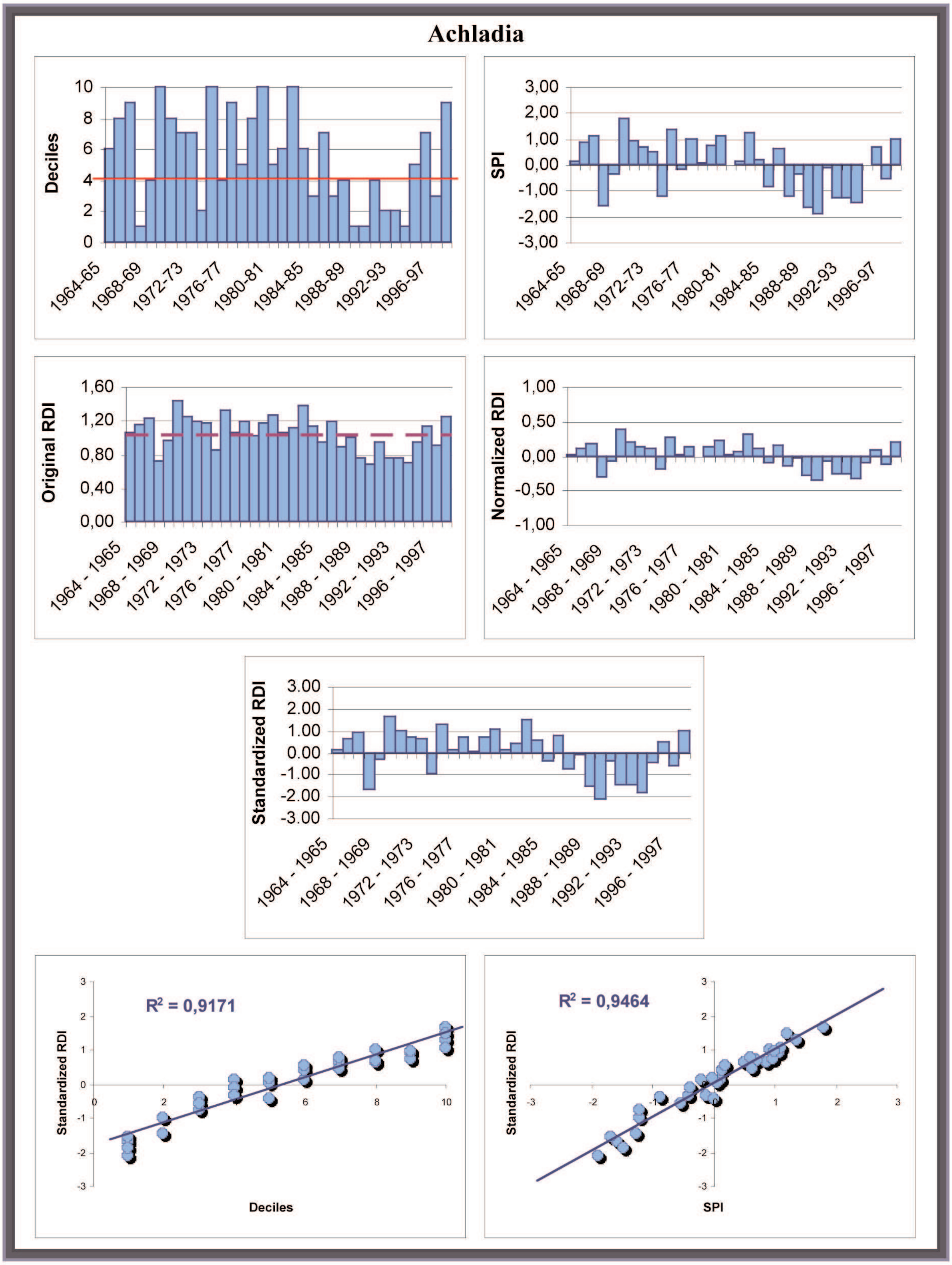
(v) In Greece, little research was carried out in the past for defining droughts for different sectors of the economy, i.e. agriculture, power production, domestic use, etc. Similarly, drought indicators have not been examined with respect to their feasibility on Greek conditions.

(vi) There are no drought indicators or any other scientific objective indices used in order to detect crisis situations.

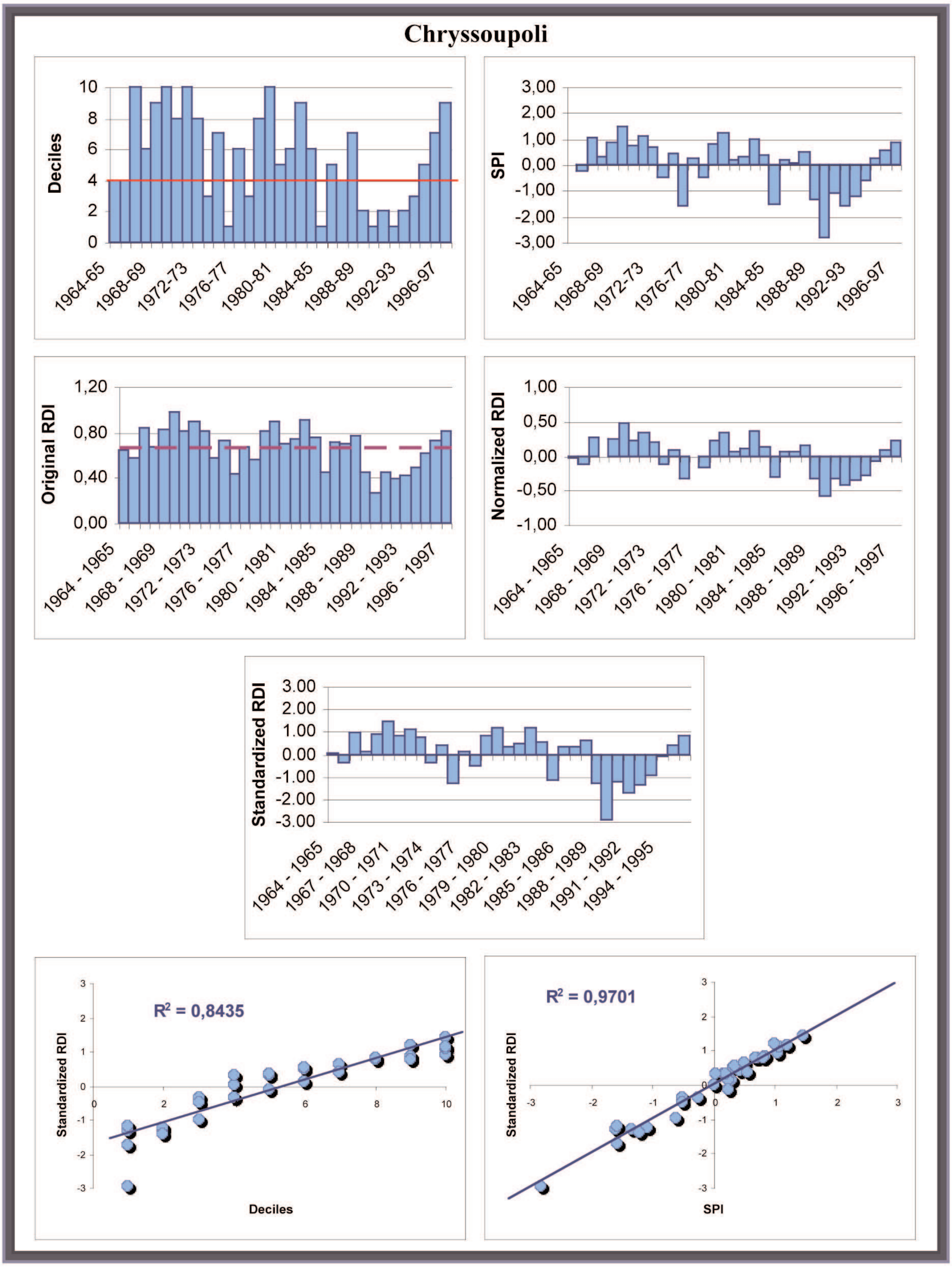
Annex 1. Drought characterisation

Nestos River Basin

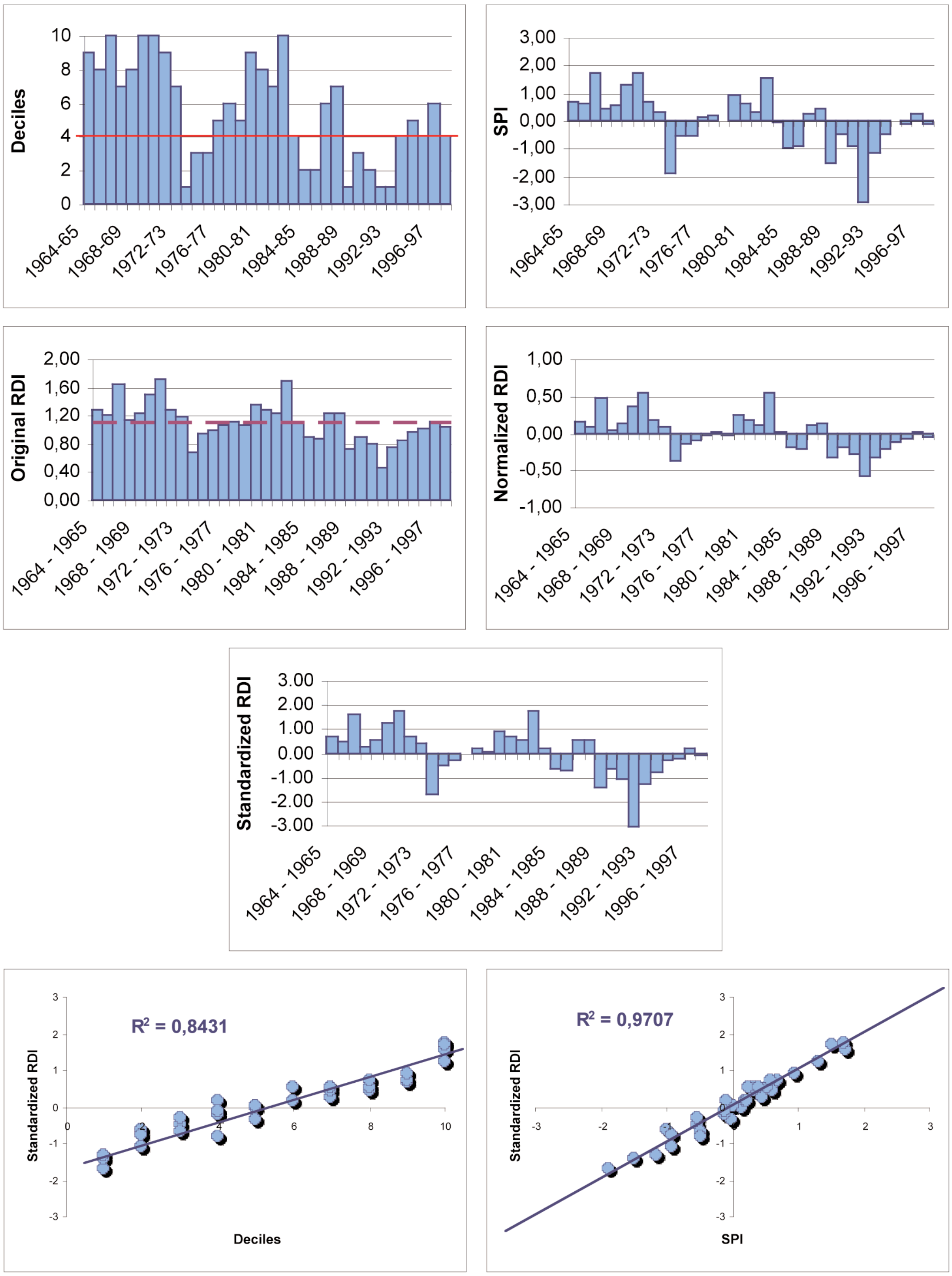


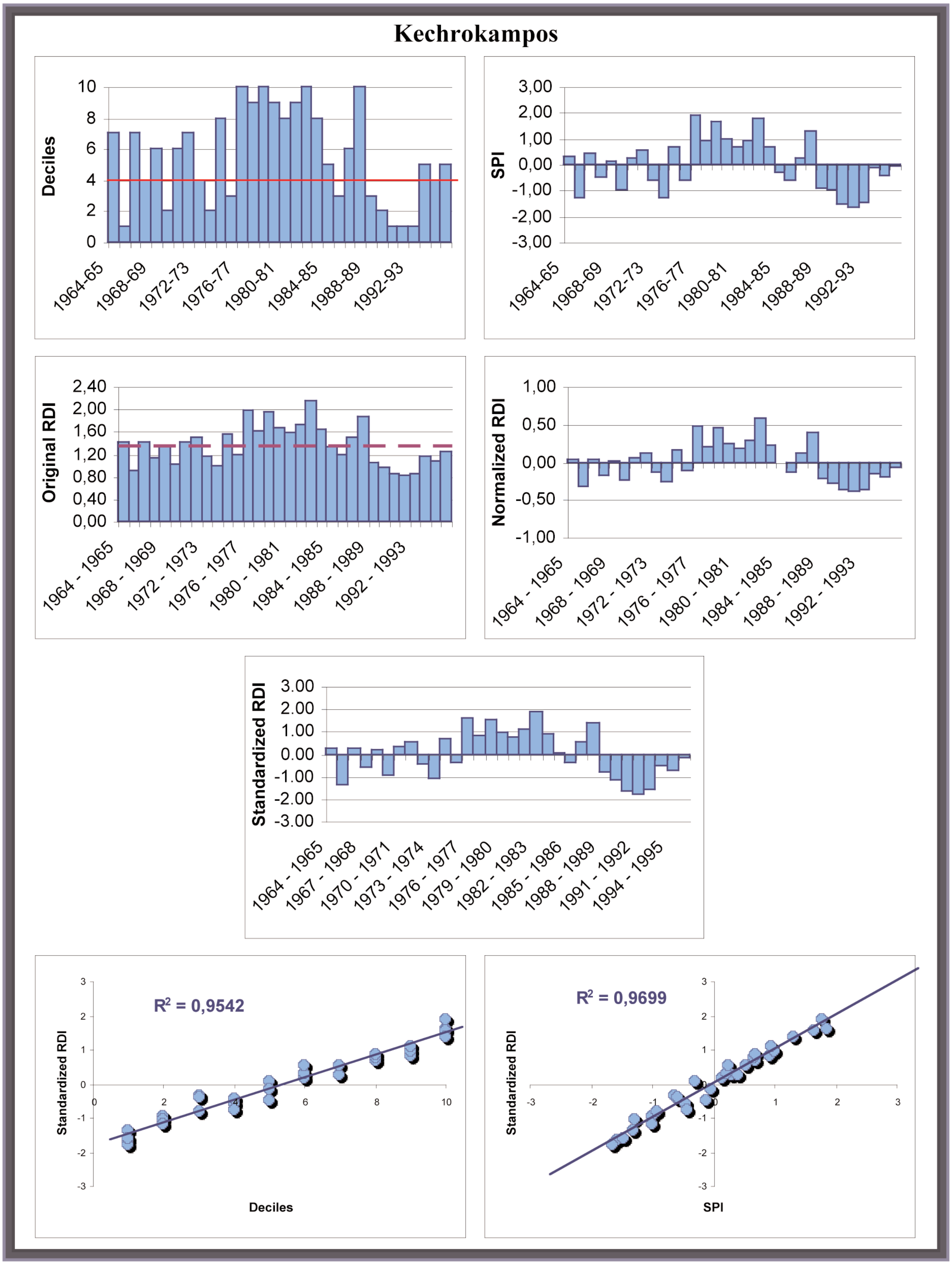


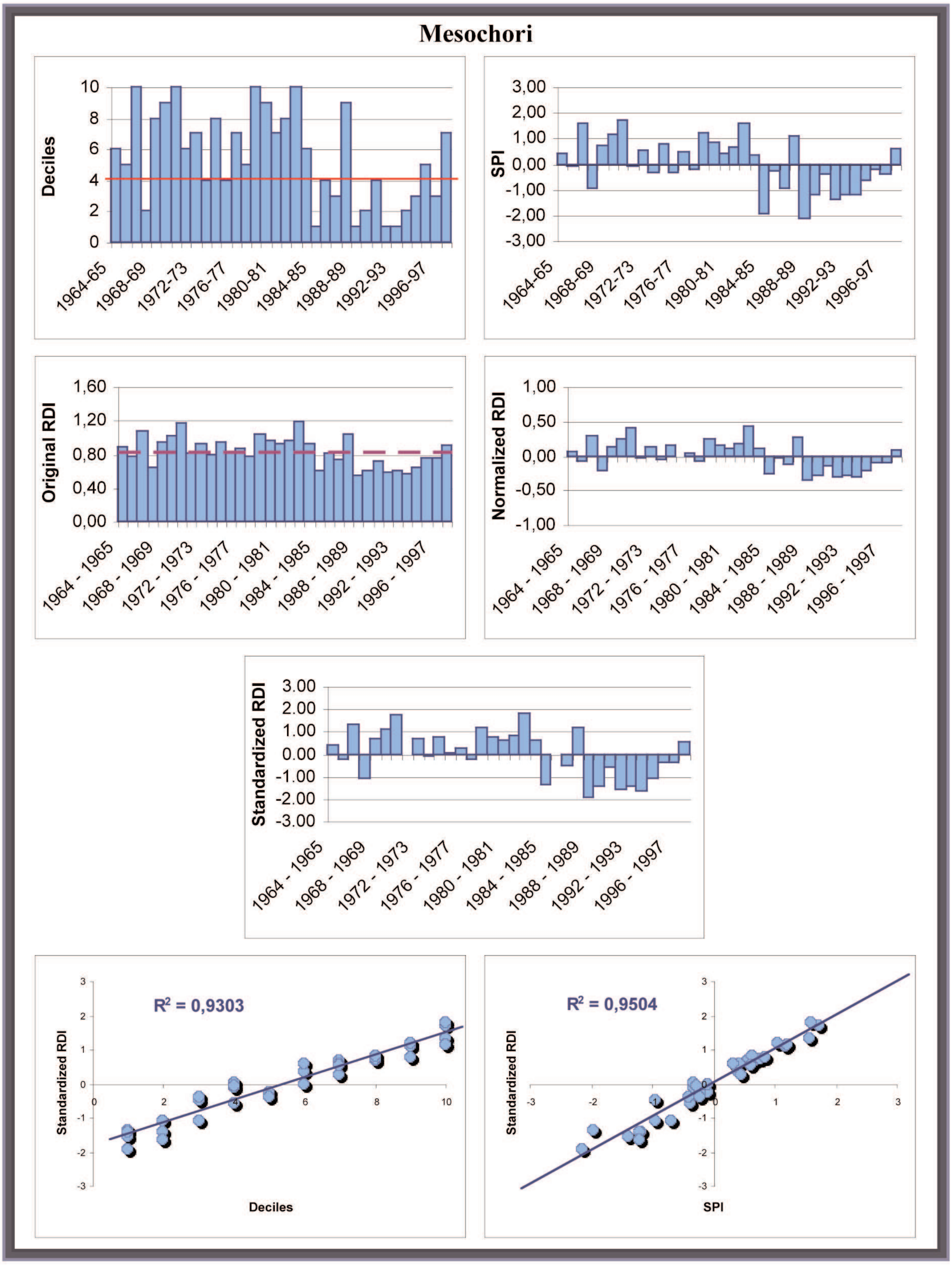
Achladia
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
R² = 0,9171
R² = 0,9464
Deciles
SPI


Chryssoupoli
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
R² = 0,8435
R² = 0,9701
Deciles
SPI

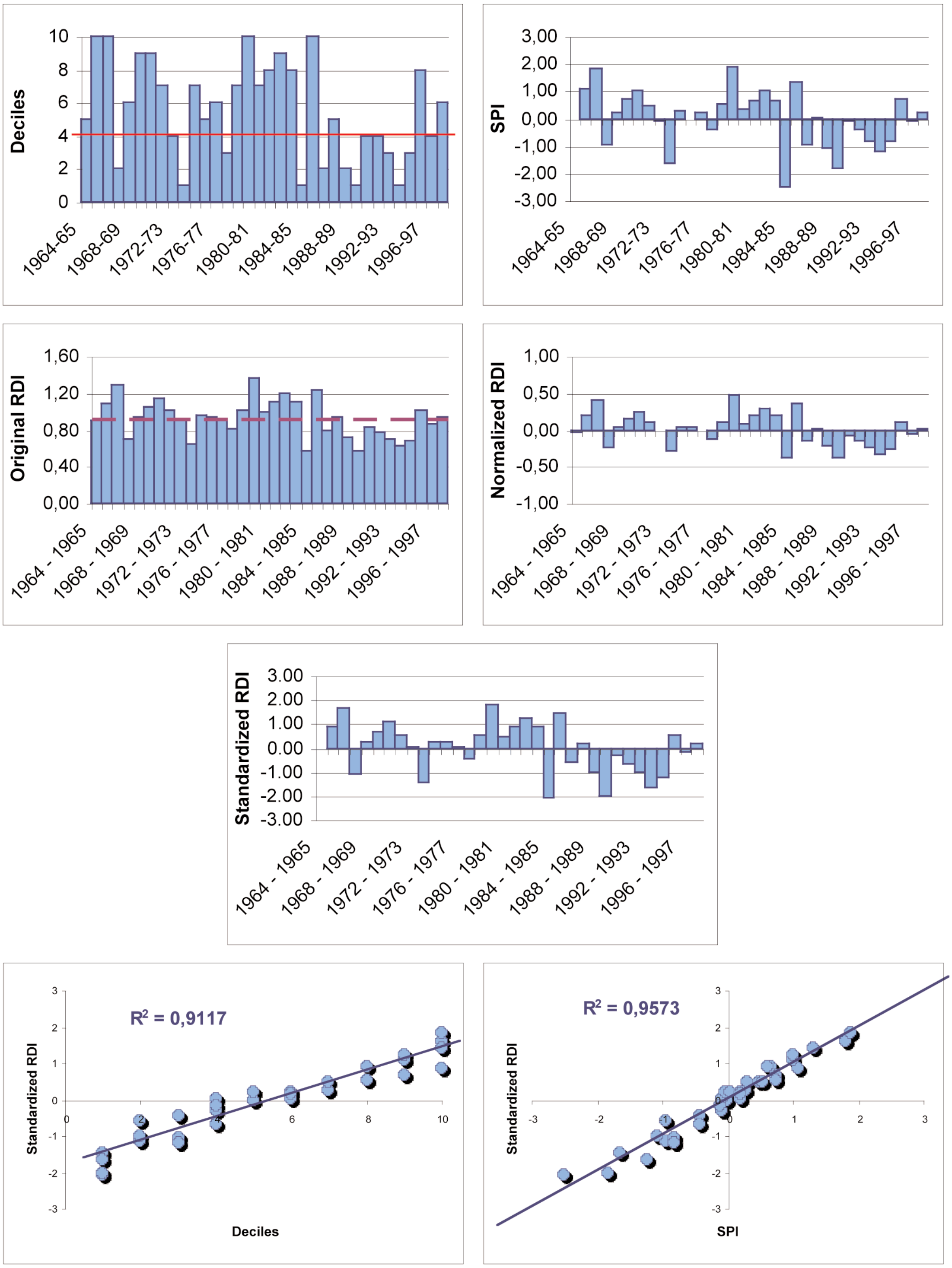
Kariofyto


Deciles
1964-65
1968-69
1972-73
1976-77
1980-81
1984-85
1988-89
1992-93
1996-97
SPI
Original RDI
Normalized RDI
Standardized RDI
1964 - 1965
1968 - 1969
1972 - 1973
1976 - 1977
1980 - 1981
1984 - 1985
1988 - 1989
1992 - 1993
1996 - 1997
R² = 0,8431
R² = 0,9707

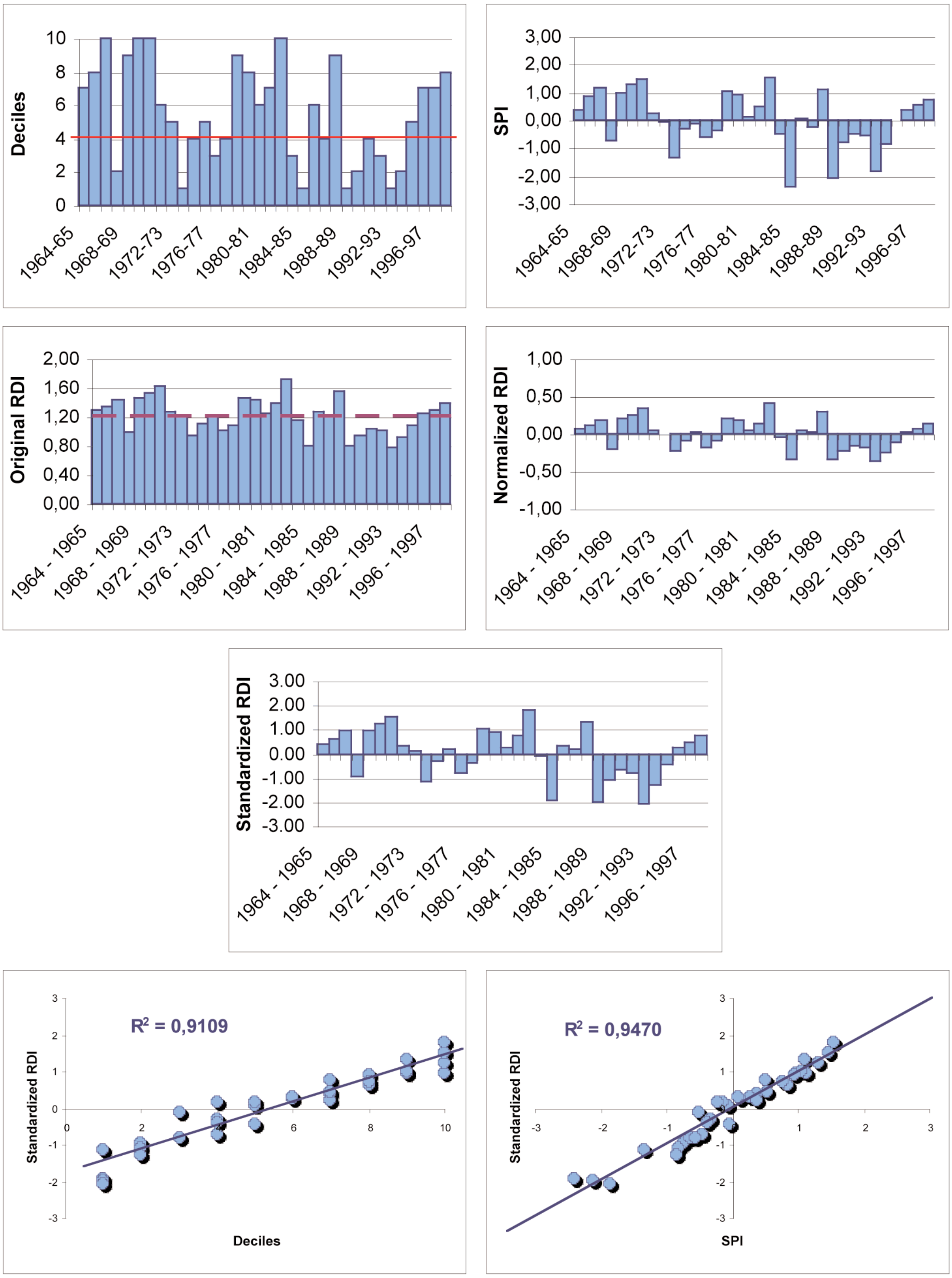

Kechrokampos
Deciles
10
8
6
4
2
0
1964-65
1968-69
1972-73
1976-77
1980-81
1984-85
1988-89
1992-93
SPI
3,00
2,00
1,00
0,00
-1,00
-2,00
-3,00
1964-65
1968-69
1972-73
1976-77
1980-81
1984-85
1988-89
1992-93
Original RDI
2,40
2,00
1,60
1,20
0,80
0,40
0,00
1964 - 1965
1968 - 1969
1972 - 1973
1976 - 1977
1980 - 1981
1984 - 1985
1988 - 1989
1992 - 1993
Normalized RDI
1,00
0,50
0,00
-0,50
-1,00
1964 - 1965
1968 - 1969
1972 - 1973
1976 - 1977
1980 - 1981
1984 - 1985
1988 - 1989
1992 - 1993
Standardized RDI
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
1964 - 1965
1967 - 1968
1970 - 1971
1973 - 1974
1976 - 1977
1979 - 1980
1982 - 1983
1985 - 1986
1988 - 1989
1991 - 1992
1994 - 1995
R² = 0,9542
Standardized RDI
Deciles
R² = 0,9699
Standardized RDI
SPI


Mesochori
Deciles
1964-65
1968-69
1972-73
1976-77
1980-81
1984-85
1988-89
1992-93
1996-97
SPI
Original RDI
Normalized RDI
Standardized RDI
1964 - 1965
1968 - 1969
1972 - 1973
1976 - 1977
1980 - 1981
1984 - 1985
1988 - 1989
1992 - 1993
1996 - 1997
R² = 0,9303
R² = 0,9504
Deciles
SPI

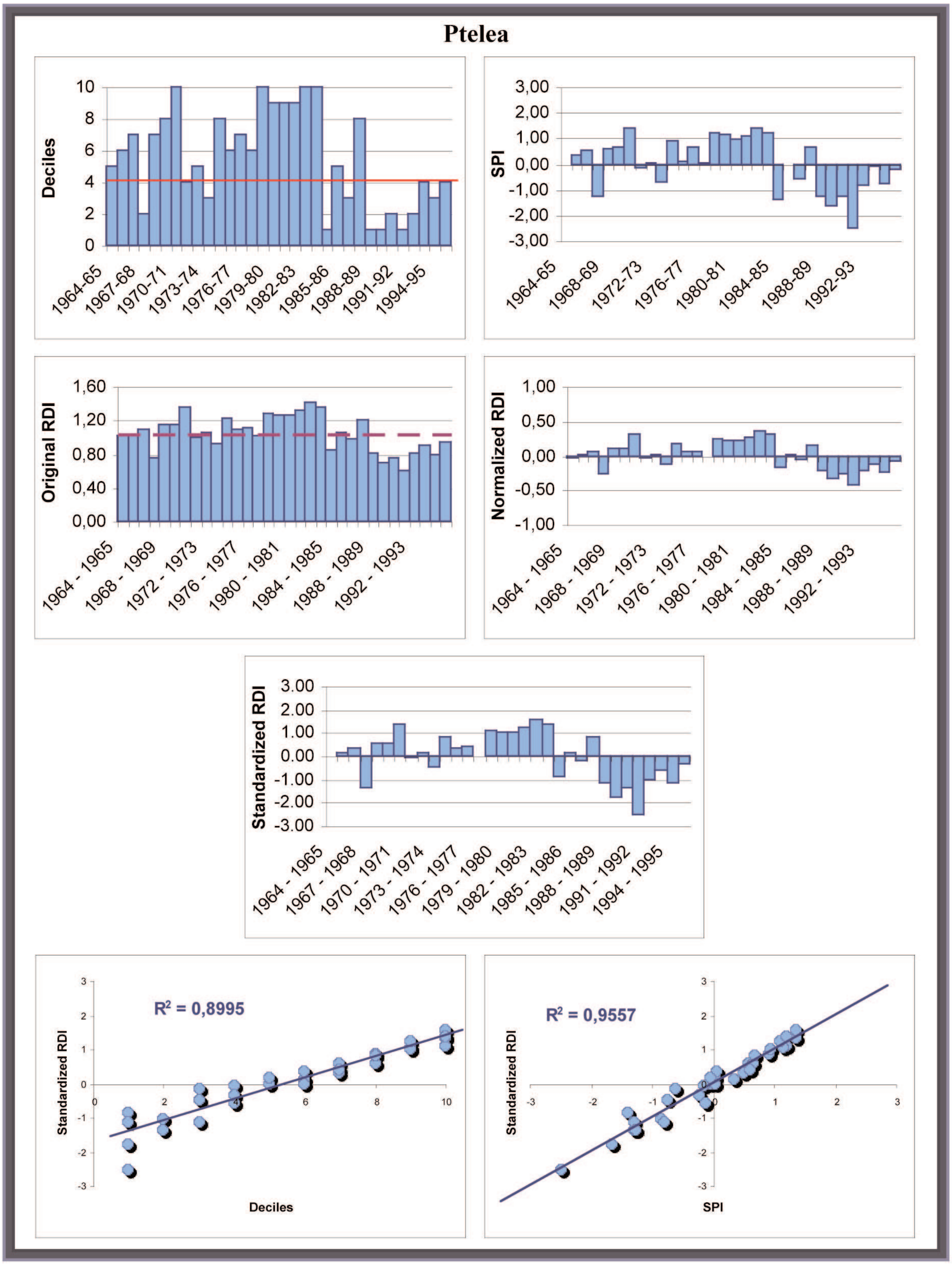
Potami

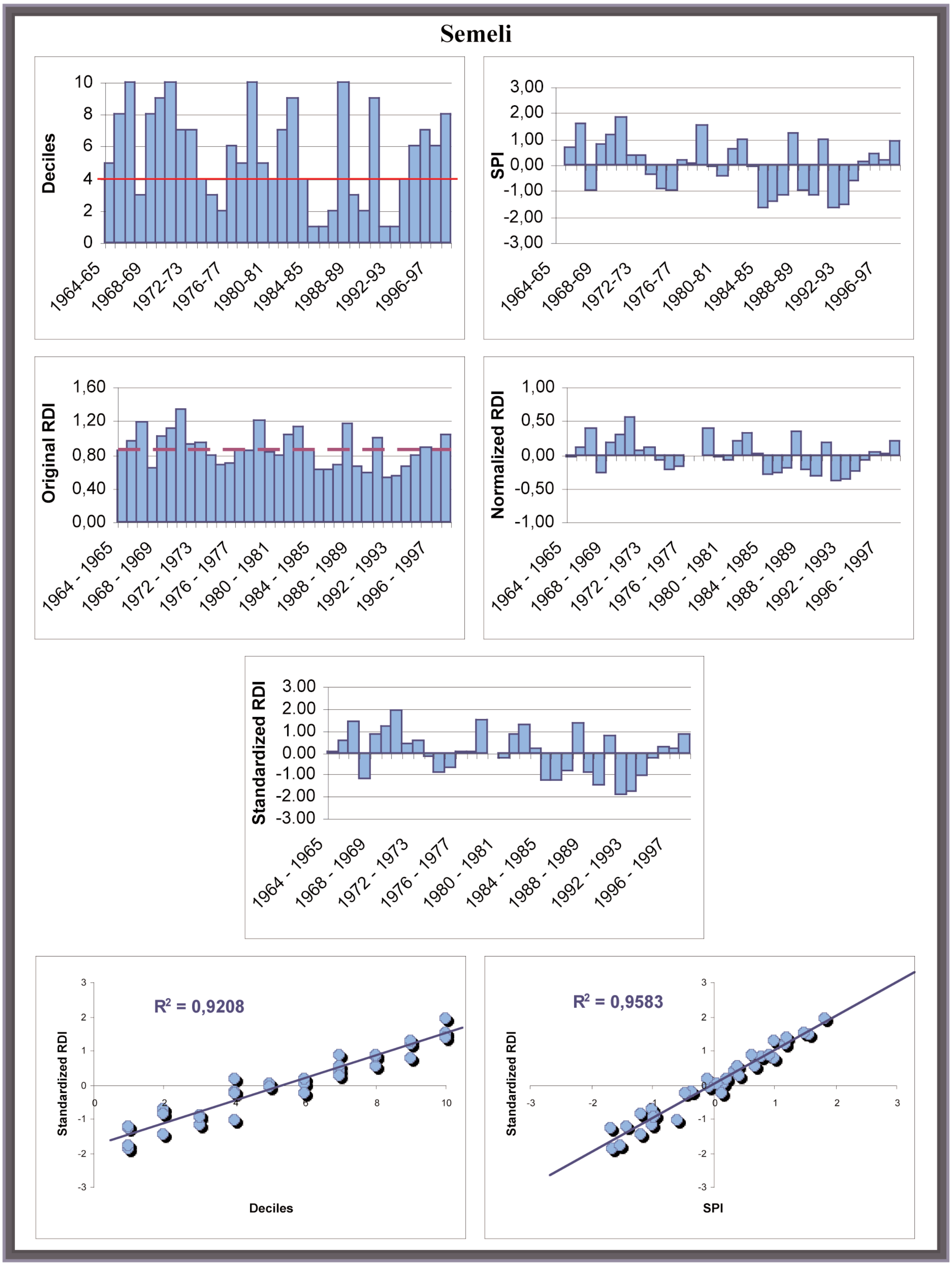

Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
1964-65
1968-69
1972-73
1976-77
1980-81
1984-85
1988-89
1992-93
1996-97
1964 - 1965
1968 - 1969
1972 - 1973
1976 - 1977
1980 - 1981
1984 - 1985
1988 - 1989
1992 - 1993
1996 - 1997
R² = 0,9117
R² = 0,9573
Deciles
SPI
Standardized RDI

Prasinada

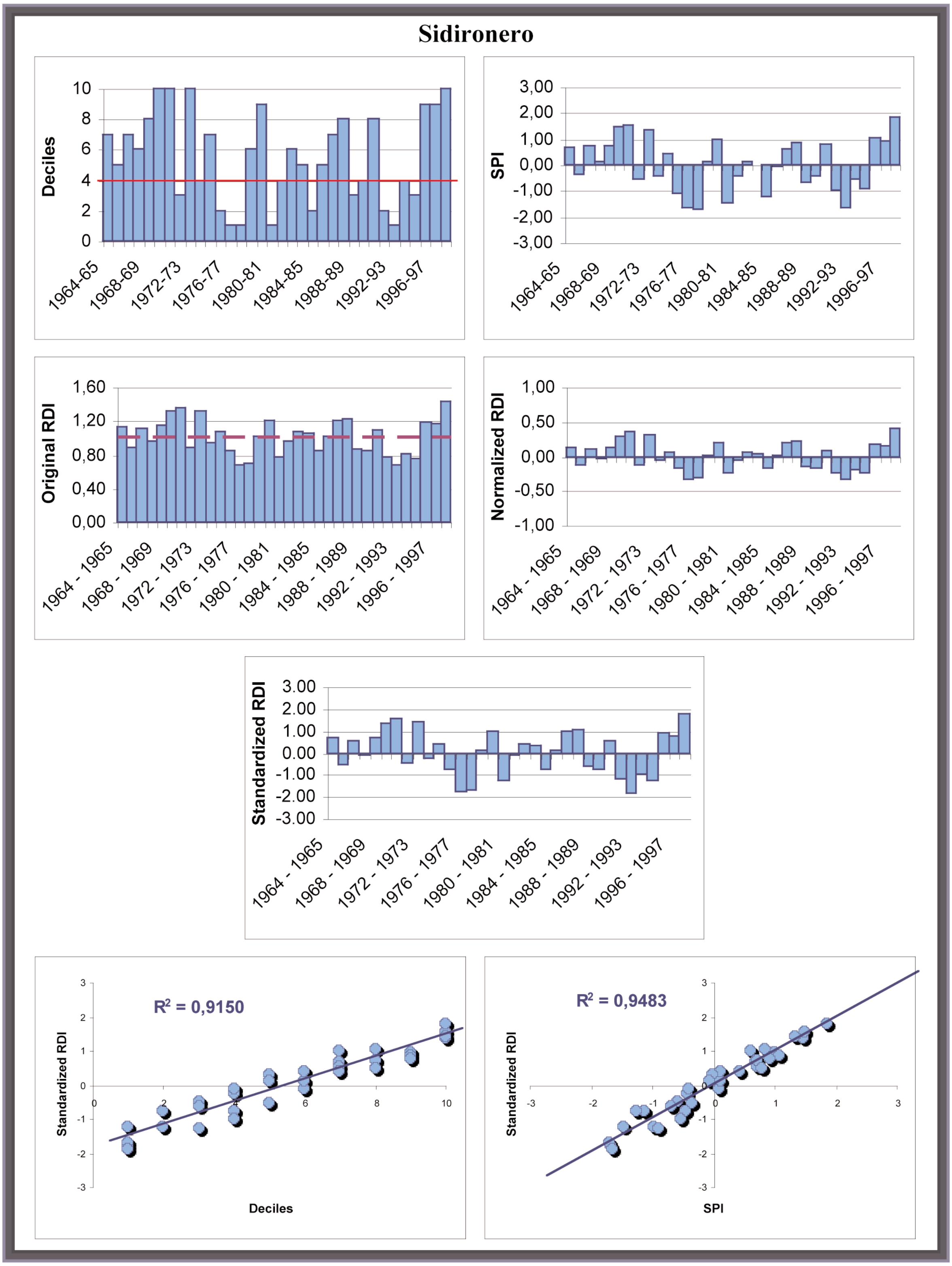


Deciles
1964-65
1968-69
1972-73
1976-77
1980-81
1984-85
1988-89
1992-93
1996-97
SPI
Original RDI
Normalized RDI
Standardized RDI
1964 - 1965
1968 - 1969
1972 - 1973
1976 - 1977
1980 - 1981
1984 - 1985
1988 - 1989
1992 - 1993
1996 - 1997
R² = 0,9109
R² = 0,9470

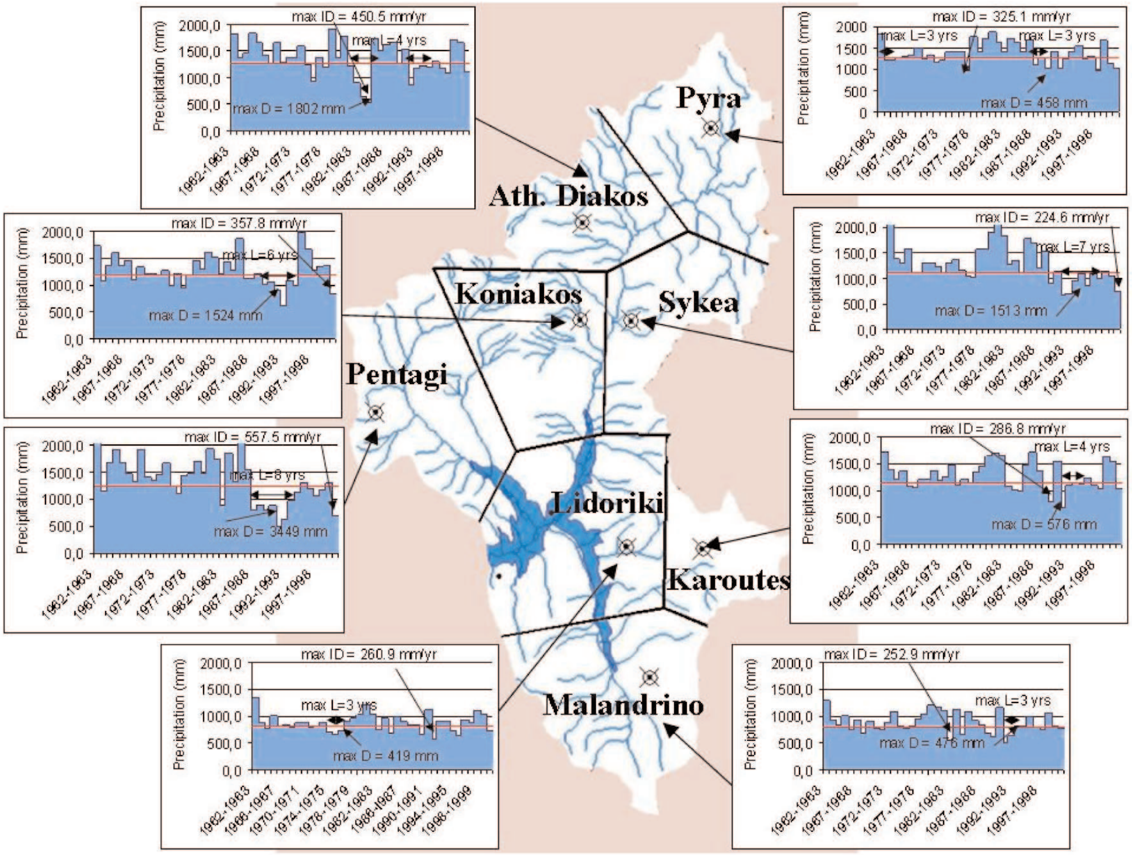

Ptelea
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
R² = 0,8995
R² = 0,9557
Deciles
SPI

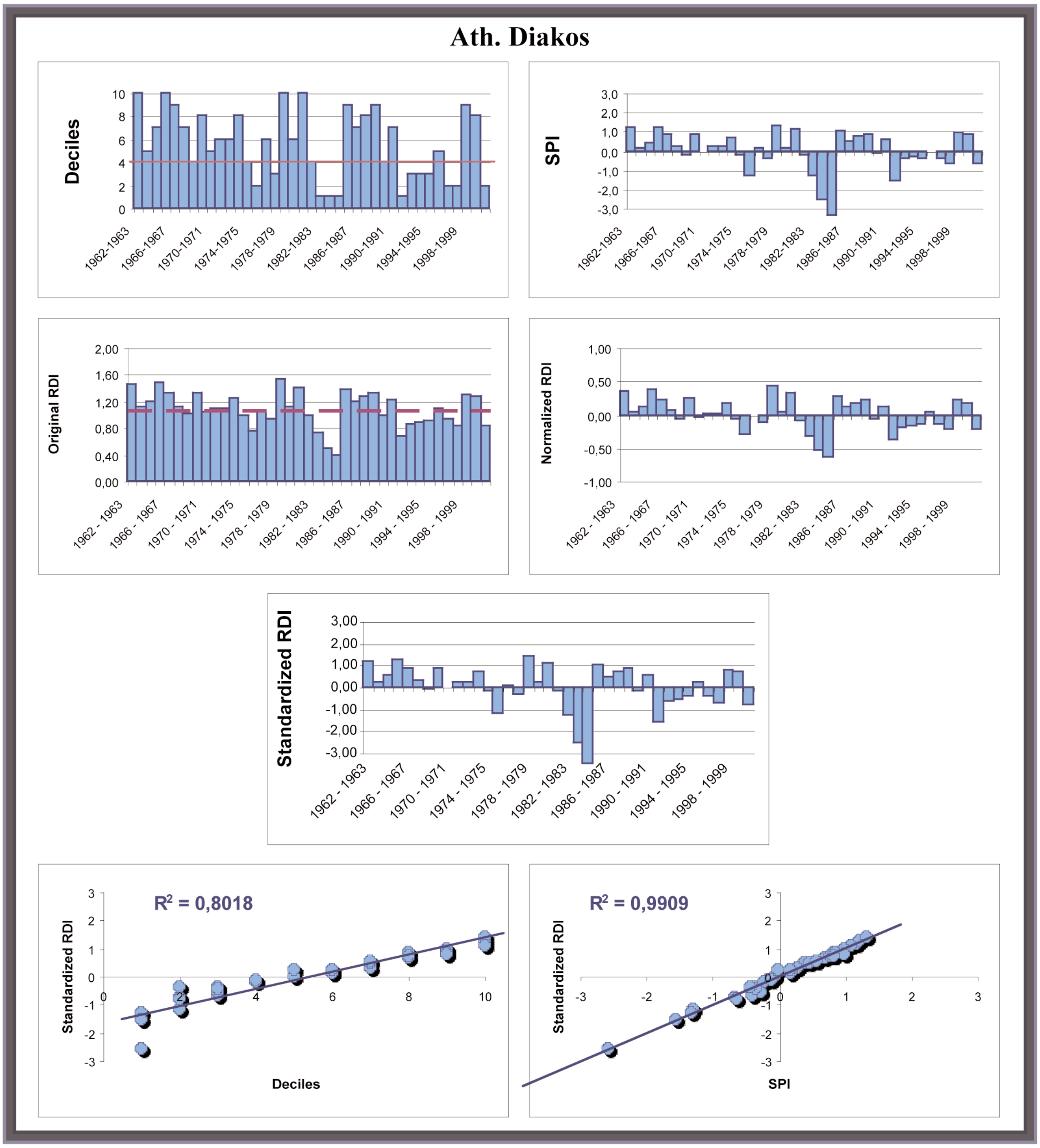


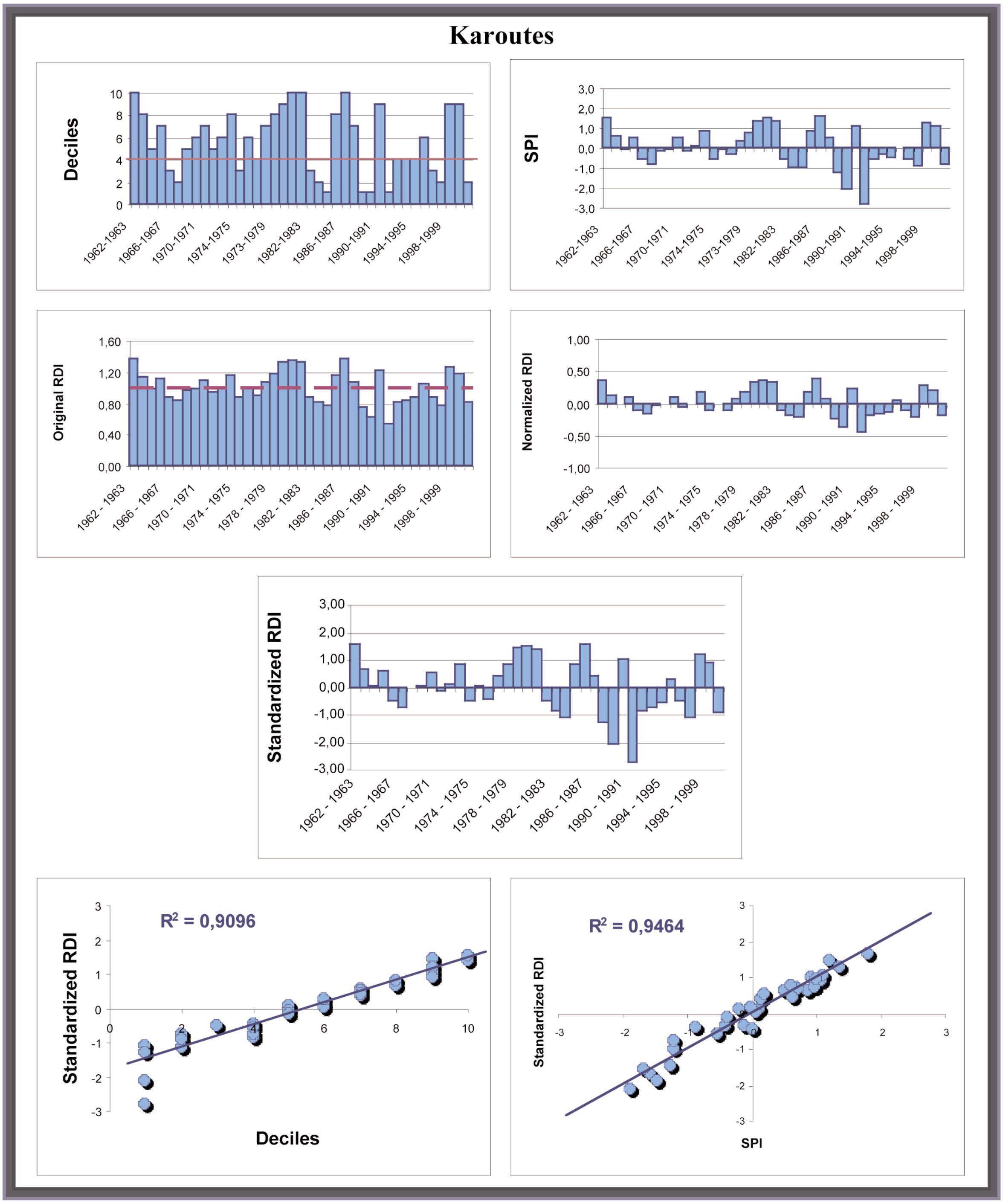
Semeli
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
1964-65
1968-69
1972-73
1976-77
1980-81
1984-85
1988-89
1992-93
1996-97
1964 - 1965
1968 - 1969
1972 - 1973
1976 - 1977
1980 - 1981
1984 - 1985
1988 - 1989
1992 - 1993
1996 - 1997
R² = 0,9208
R² = 0,9583
Deciles
SPI

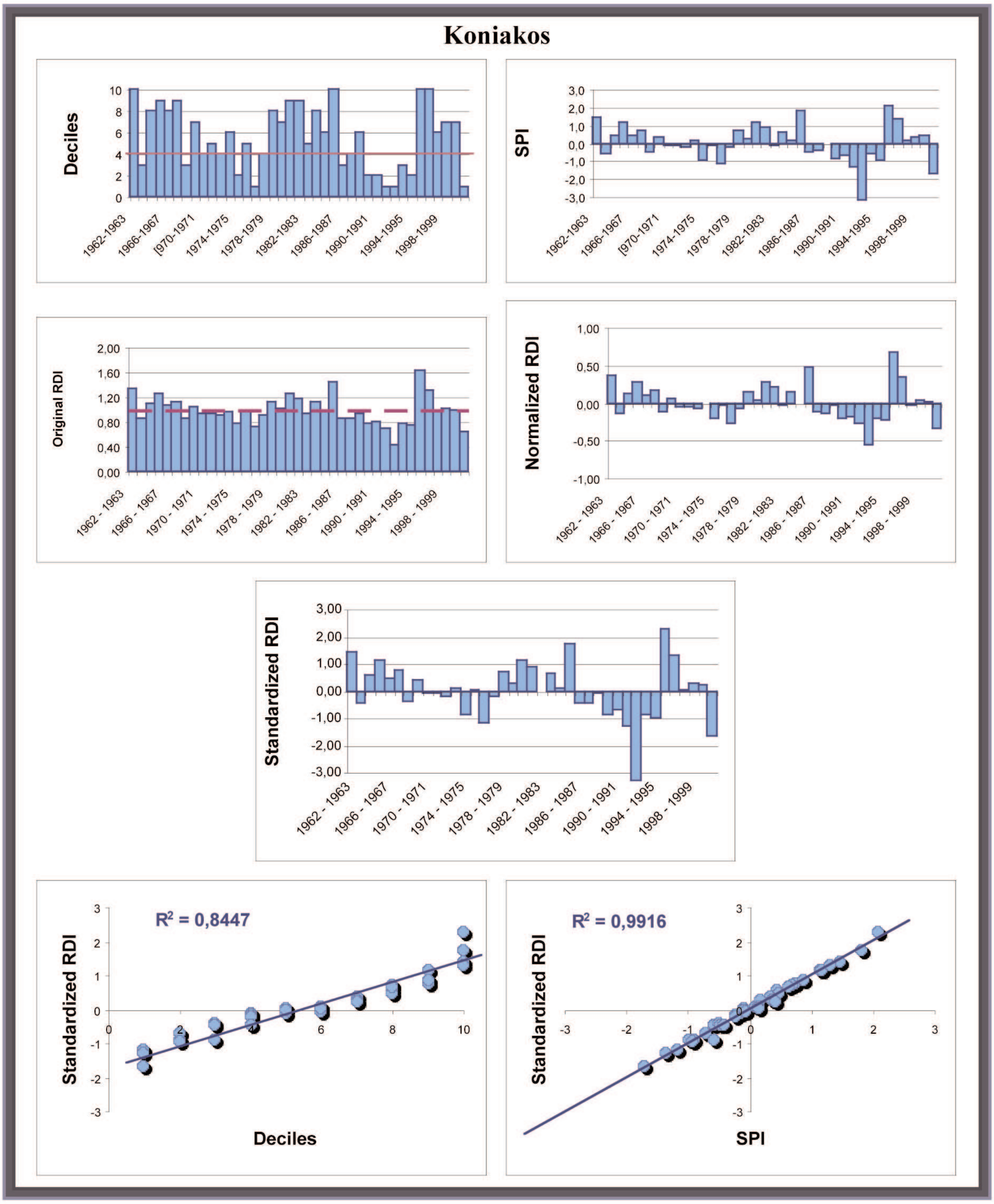

Sidironero
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
R² = 0,9150
R² = 0,9483
Deciles
SPI

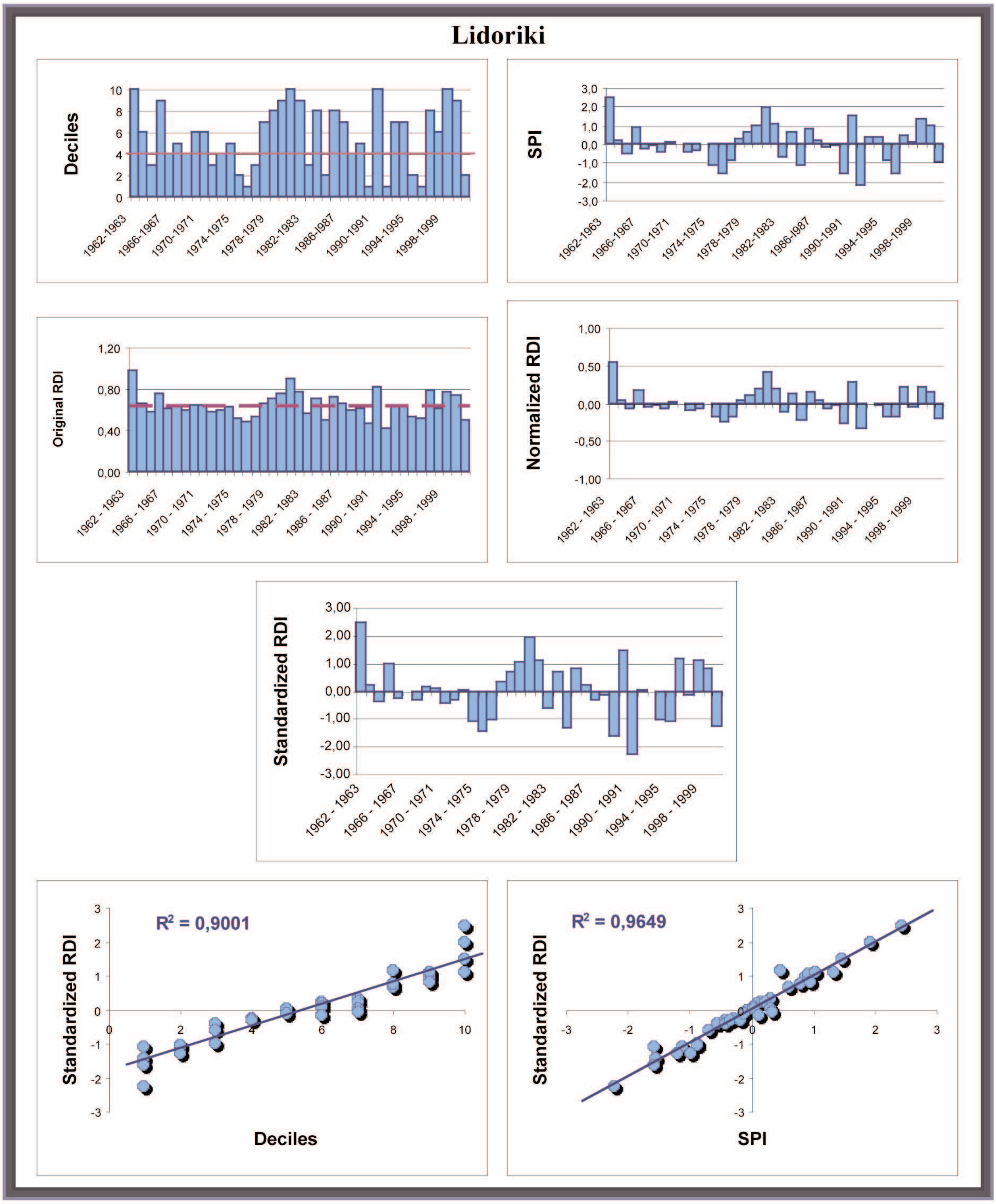
Mornos River Basin



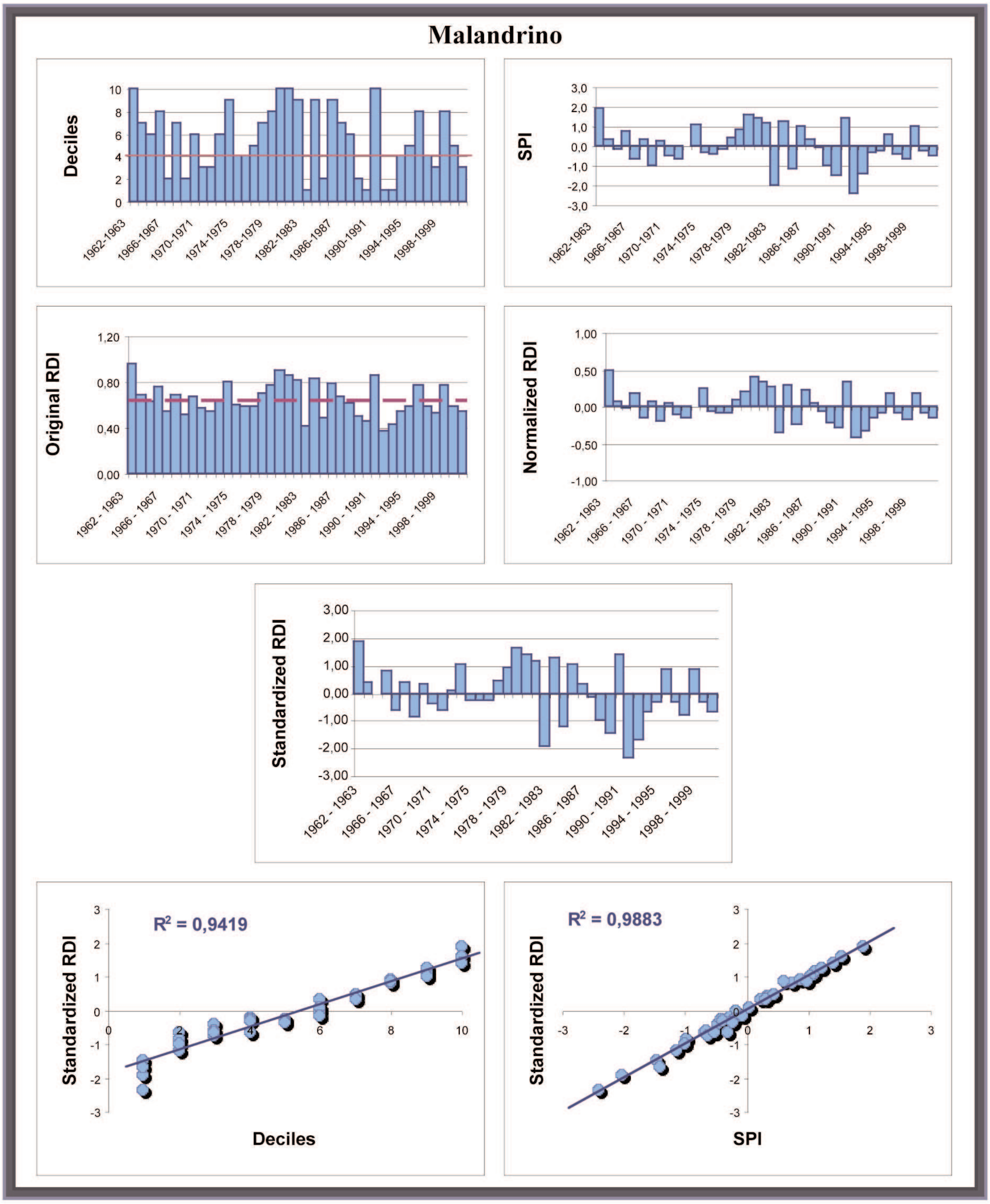

Ath. Diakos
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
R^2 = 0,8018
R^2 = 0,9909
Standardized RDI
Deciles
SPI

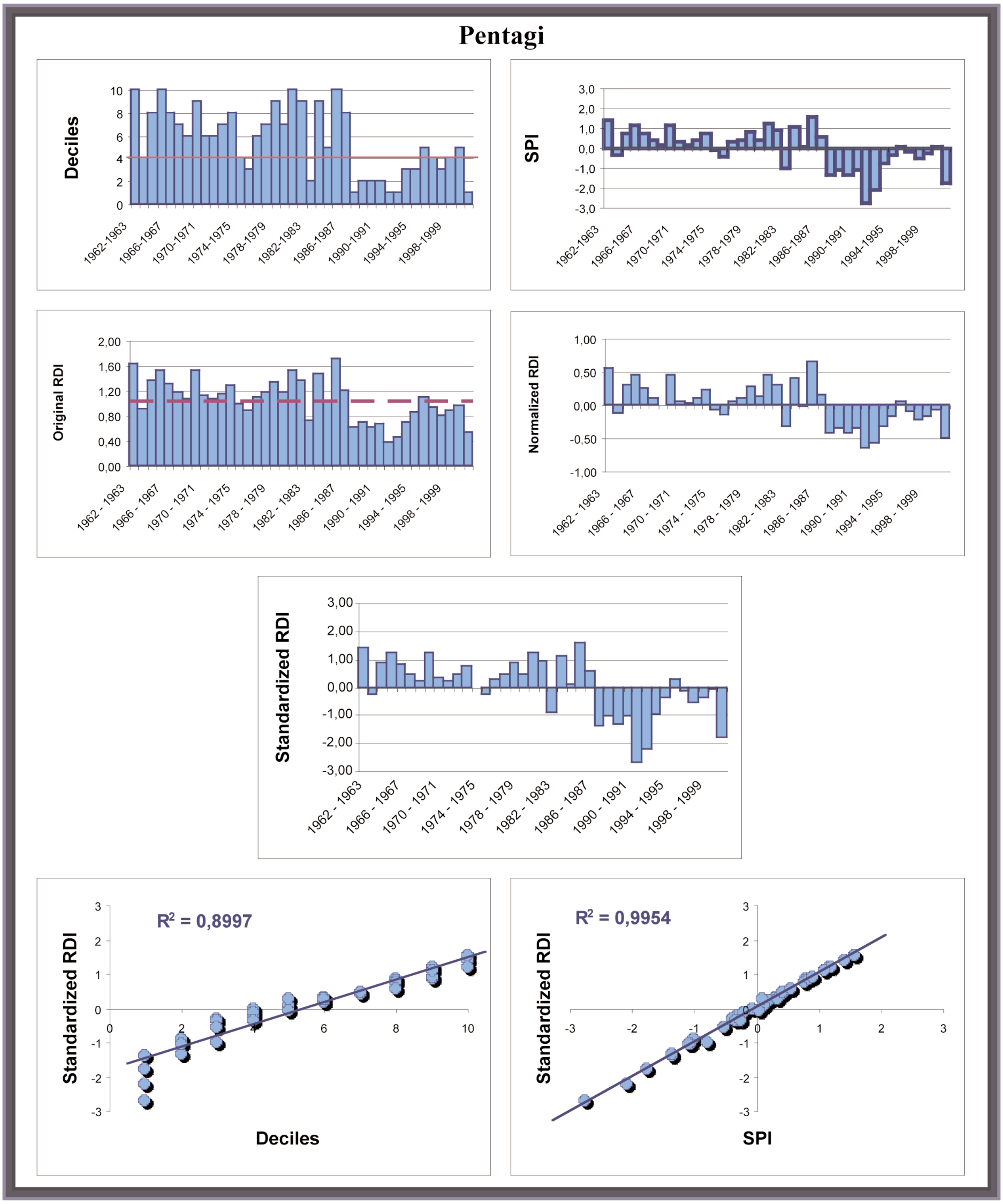

Karoutes
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
R² = 0,9096
Standardized RDI
Deciles
R² = 0,9464
Standardized RDI
SPI

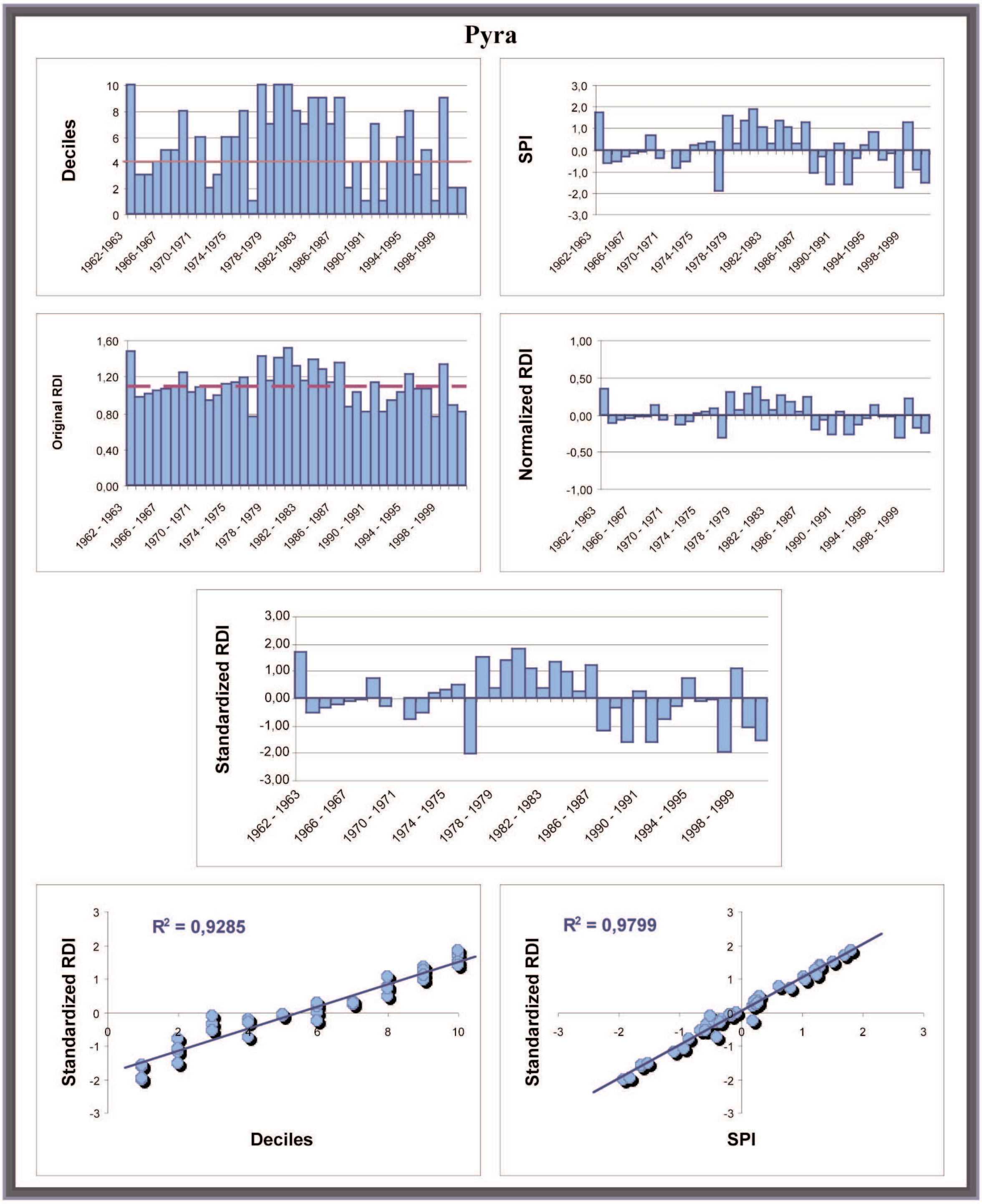

Koniakos
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
R² = 0,8447
R² = 0,9916
Deciles
SPI

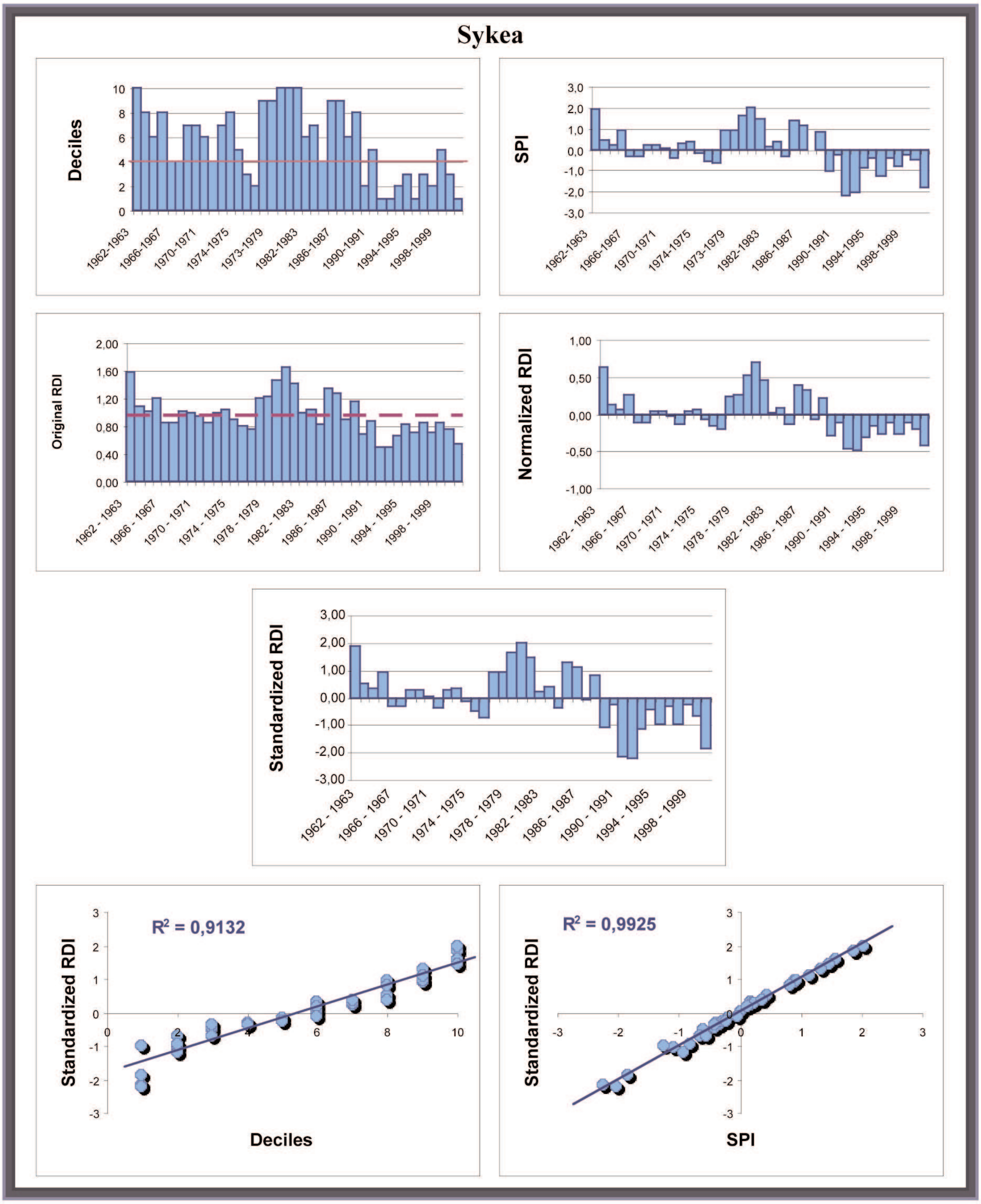


Lidoriki
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
R² = 0,9001
R² = 0,9649
Deciles
SPI


Malandrino
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
1962-1963
1966-1967
1970-1971
1974-1975
1978-1979
1982-1983
1986-1987
1990-1991
1994-1995
1998-1999
R² = 0,9419
R² = 0,9883
Standardized RDI
Deciles
SPI


Pentagi
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
1962-1963
1966-1967
1970-1971
1974-1975
1978-1979
1982-1983
1986-1987
1990-1991
1994-1995
1998-1999
R² = 0,8997
R² = 0,9954
Standardized RDI
Deciles
SPI


Pyra
Deciles
SPI
Original RDI
Normalized RDI
Standardized RDI
R^2 = 0,9285
R^2 = 0,9799



Sykea
Deciles
1962-1963
1966-1967
1970-1971
1974-1975
1973-1979
1982-1983
1986-1987
1990-1991
1994-1995
1998-1999
SPI
Original RDI
Normalized RDI
Standardized RDI
R² = 0,9132
R² = 0,9925
Standardized RDI
Deciles
SPI

Annex 2. Data and information systems

The Institutions that collect, record and process data that provide a representation of natural processes and socio-economic patterns directly or indirectly related to droughts are outlined in Table 1.

Table 1. Summary of institutions that collect and process data related to drought in Greece

Institution	Type of Data
The Ministry of Environment	Water quality, Water use, Geographical data, Land use
The National Meteorological Service	Meteorological data
The Public Power Corporation	Energy consumption
The Ministry of Agriculture	Meteorological data, Water quality, Water use, agricultural census
The Ministry of Interior	Municipal water consumption
The Ministry of Development	Land use, Populations, Groundwater
The National Observatory of Athens	Meteorological data
The Water Supply Companies	Water quality, Water use
The Army	Geographical Agency Maps, Topography, Land use, GIS
The Centre of Planning and Economic Research	Socio-economic indicators
The Institute of Geology & Mineral Exploration	Groundwater, Land use, Geology
The National Statistical Service	Statistics, Macroeconomic indicators

The major institutions, which play a role in combating drought are the three ministries:

(i) The Ministry of Agriculture, the Ministry of Interior and the Ministry of Environment. These Ministries are responsible for the use of water in Agriculture, in Municipalities and in the Industry domain.

(ii) The National Data Bank of Hydrological and Meteorological Information (NDBHMI), which has been established using information provided by the first six Institutions mentioned in Table 1, contains hydro-meteorological and hydro-geological data covering the entire country. Up to now, only the institutions that have contributed in the creation of this data bank have access to the data, but soon the data will be also accessible to other institutions and research organisations. The NDBHMI provides the required infrastructure for the implementation of the EU Water Framework Directive for the protection, rational management and exploitation of the water resources at the national level.

(iii) Various software applications are linked to the central Database of the NDNHMI supporting the analysis and synthesis of the data and the elaboration of secondary information. The distributed form of the database allows a continuous online operation and exchange of data between the participating organisations.

(iv) A GIS subsystem was developed to support the spatial analysis of hydrological data. The GIS applications were designed and implemented in such a way to allow both independent processing of data as well as interaction with the database and the different software packages.

(v) Given the large number of organisations measuring rainfall in Greece, a rationalisation plan was devised, creating a unified meteorological network.

(vi) Together with the National Network of Gauging Stations, the project team studied the development of network of 15 high resolution gauging stations in Attica, the greater area of Athens. These stations will automatically transfer data to the main database of NDBHMI at programmed intervals. The selection of the location of the stations was made, taking into account the geographical distribution as well as the security of each location. The main equipment in these stations consists of the following: Auto-recording meteorological stations Data - transfer equipment Customised software for the automatic transferring of recordings to the database This network will work in parallel with meteorological radars that the National Technical University of Athens (NTUA) is in the process of buying. This system will constitute an integrated storm prediction system in the wider area of Athens.

Annex 3. Potential impacts of drought

Table 1. Summary of the potential impacts of drought in the Nestos and Mornos Basins based on responses of stakeholders. Impact range from 0 (not important) to 5 (most important)

Impact	Nestos Basin rank	Mornos Basin rank
ECONOMIC: WATER SUPPLY		
Additional cost of supplemental water infrastructures	2	5
Additional cost of water transport or transfer	4	0
Decrease in hydroelectric power generation	4	2
Decreased revenues of water supply firms	2	5
Increase in water tariffs	3	4
Increase in water treatment costs	3	3
Increased cost of ground water extraction	4	3
Reduced service quality	3	3
Other (please specify)		
ECONOMIC: AGRICULTURE		
Decrease in farm income	4	3
Decrease in land prices	2	2
Decrease in livestock feed quantity and quality	3	2
Decrease in rangeland and pasture production	3	3
Decrease of agricultural labour	4	3
Decreased crop production	5	3
Decreased crop quality	3	4
Decreased water in farm ponds for irrigation	4	4
Increase in consumer credits in rural areas	3	3
Increase in crop imports	5	2
Increase in food prices	4	3
Increase in insects, pests, and crop diseases	4	4
Increase in livestock diseases	3	2
Increase of farm subsidies	5	5
Increased crop insurance premia	3	3
Increased soil erosion	4	5
Increased unemployment of the agricultural sector	4	3
Livestock production: water quality and quantity	3	3
Loss of farm income	4	4
Loss of income of industries dependent on agriculture	3	3
Losses in financial institutions related to agricultural activities (e.g., credit risks)	2	1
Revenue losses to state and local governments (from reduced tax base to farmers)	2	3
Other (please specify)		
ECONOMIC: FISHERIES		
Decrease production of fishery	1	0
Other (please specify)		
ECONOMIC: FORESTRY		
Decreased production of forests	2	2
Other (please specify)		

ECONOMIC: INDUSTRY		
Changes in the energy cost (e.g., due to changes in hydroelectric by oil)	1	0
Electric power unbalance (Increased energy demand and reduced supply)	3	2
Income loss of manufacturers and sellers of recreational equipment	0	0
Other (please specify)		
ENVIRONMENTAL		
Biodiversity loss in ecosystems associated with water	4	4
Biodiversity loss in land based ecosystems	2	2
Changes in estuarine areas (e.g., salinity levels)	3	2
Changes in the migration and concentration of animal species (loss of wildlife in some areas and too many species in others)	3	2
Decrease in reservoir and lake levels	2	4
Deterioration of visual and landscape quality (e.g., dust, vegetative cover, etc.)	1	2
Deterioration of air quality (e.g., dust, pollutants)	1	1
Ground water depletion and land subsidence	3	2
Increase erosion of soils by wind and water	2	2
Increase in diseases in animals (e.g., due to low quality of water or poor feed)	3	2
Increase in diseases in plants (e.g., due to low quality of water)	3	3
Increase in invasive weeds and algae	3	3
Increase in number and severity of fires	5	4
Increased stress to endangered species	4	3
Reduction of the wetland areas	3	2
Water quality effects (e.g., salt concentration, increased water temperature, pH, dissolved oxygen, turbidity)	3	2
Other (please specify)		
SOCIAL		
Appearance of human health related problems (from water and air quality deteriorations)	2	2
Conflict appearance in management	4	3
Conflict appearance in media or science	3	3
Conflict appearance in political decisions	4	5
Conflict appearance in water use	5	5
Damage in cultural heritage sites	1	2
Danger to public safety from forest and range fires	3	3
Decrease in the visits to a recreational area	2	2
Decreased nutrition quality in subsistence farm areas	2	2
Deterioration of aesthetic values	2	2
Increase in the poverty level in rural areas	3	3
Increased migration to urban areas form agricultural areas	3	2
Public dissatisfaction with government regarding drought response	4	5
Other (please specify)		