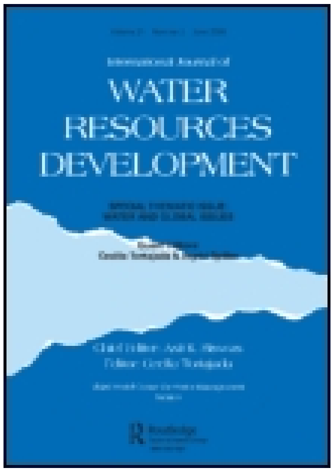

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E. A. Baltas [a]

[a] Department of Hydraulics , Soil Science and Agricultural Engineering, School of Agriculture, Aristotle University of Thessaloniki , Greece

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Climatic Conditions and Availability of Water Resources in Greece

E. A. BALTAS
Department of Hydraulics, Soil Science and Agricultural Engineering, School of Agriculture, Aristotle University of Thessaloniki, Greece

ABSTRACT *Greece is characterized by a special geomorphologic structure, the result of which is a variety of climatic conditions and the division of the area into a plethora of basins and a number of water districts. This study aims to analyze the climatic conditions, as well as of the availability of water resources across the country. The air temperature and rainfall data of the time period 1965–95 were acquired from 40 meteorological stations and processed on a monthly and annual basis. The spatial distribution of the aforementioned climatic variables, as well as of the climatic indices of Johansson Continentality and De Martonne Aridity was derived. The results show that the Pindos mountain range is a major contributing factor in the climatic variety, dividing the country into windward, high precipitation western areas and leeward, low precipitation eastern areas. This precipitation pattern affects directly the availability of water resources, which was briefly analyzed in each water district.*

Introduction

Greece is a country with an area of 132 000 km^2 with intense ground relief, limited back land and a great extent of coasts. The result of that special geomorphologic structure is a variety of climatic conditions, the division of the country into a plethora of basins and a large number of water districts (14) (Ministry of Development, 1987). The classification of a region's climate constitutes an important characteristic for the evaluation of its hydrologic identity.

The aim of the present study is to provide descriptions, first of the climatic conditions and second of the availability of water resources in the 14 water districts of Greece. The climatic conditions are described through the spatial distribution of the variables of precipitation and air temperature, as well as via two climatic indices; the Johansson Continentality and the De Martonne Aridity. Temperature-precipitation diagrams representing the mean monthly values of precipitation and air temperature were also derived for all the meteorological stations. These diagrams allow the distinction between markedly different climatic types, but they are not an efficient method of detecting climatic gradients (Mazzoleni *et al.*, 1992).

Correspondence Address: E. A. Baltas, Department of Hydraulics, Soil Science and Agricultural Engineering, School of Agriculture, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece. Email: baltas@agro.auth.gr

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The index of De Martonne belongs in the category of aridity-humidity indices and was selected for the derivation of the aridity map of the country. Aridity is the degree to which a climate lacks effective, life-promoting moisture, the opposite of humidity, in the climate sense of the term (American Meteorological Society [online]). The Johansson Continentality Index was selected for the basic distinction between continentality and oceanity of a region. There are many methods to determine the Index of Continentality of a region, but this index is the one used most frequently in many studies (Sjögersten & Wookey, 2004; Filatov *et al.*, 2005). The two indices constitute a mean for the surface representation of climatic conditions and are indirectly related to water resources. The values of the two indices are calculated using the variables of precipitation and air temperature. The parameter of precipitation is basic in water balance equations for the management of water resources on the basis of drainage basin area. The mean hyper-annual surface precipitation constitutes an important characteristic for the evaluation of a region's hydrologic identity and response, so its examination provides reliable results on the hydrologic status of each water district. The parameter of temperature is indirectly related with water resources through the process of evapotranspiration. High evapotranspiration may gradually lead to the reduction of the available water reserves. This situation may worsen through the expected climate change.

The spatial distribution of the water resources is not uniform. In Greece, there are regions with large water reserves and others with intense deficiencies (Sofios *et al.*, 2007). With regard to the water quality, in general terms the quality of the surface and underground water resources is at a level that permits the use of water for various purposes, including potable water, in the majority of the regions. However, the quality of the surface and underground water has been downgraded near industrial zones and especially near coastal areas, where the over-exploitation has led to the intrusion of seawater. The intense fertilization of crops in some regions has also downgraded the quality of the aquifers in the interior.

The intense geomorphology of the country results in a large number of drainage basins and water districts. This means that the implementation of the Directive of the European Parliament and of the Council 2000/60 for the sustainable management of water resources on the basis of drainage basin area would encounter great difficulties (Baltas & Mimikou, 2006). In particular, the most important problems that could be highlighted relating to the state of water resources are:

- the deficiencies and difficulties in the alignment of independent hydrogeological basins inside the boundaries of each water district;
- the occasional and uncontrolled exploitation of specific water resources beyond the boundaries of one water district, without established knowledge of its capabilities, which leads to the gradual degradation of quality and quantity;
- the difficulty or non-existence of a total encounter of problems relating to the plan and management of water resources;
- the difficulty coordinating the authorities at a national and peripheral level regarding studies and research on the infrastructure relating to the water resources;
- the need for assuring the rational management of the transnational water resources and their common utilization based on the needs for water of the involved countries;

- the lack of a single management authority in the water sector;
- the interaction between coastal waters due to nearby streams or rivers that flow into the sea; and
- the difficulty in making long-term predictions about hydrologic, population, economic trends, production sectors etc. in the frame of the developing programme in order that corresponding predictions about utilization structures could be made.

Study Area

Greece is between the 34th and 42nd parallel of the northern hemisphere and is located in the eastern part of the Mediterranean Sea. The climate is typical Mediterranean with mild and humid winters, warm and dry summers and generally, long periods of sunshine throughout the year. From the climatic point of view, the year is mainly divided into two seasons: the cold and rainy winter period that lasts from mid-October until the end of March and the warm and dry period that lasts from April until October. The colder months of the first period are January and February, during which the mean minimum temperature varies between 5–10°C in the coastal regions, from 0–5°C in the continental regions and reaches negative values in the northern regions. The warmer period occurs in the last 10 days of July and the first week of August, when the mean maximum temperature varies between 29–35°C. During the warm period the high temperatures are moderated by the cool sea breeze in the coastal areas and by the northern winds (Etesians) that blow mainly at the Aegean Sea (Hellenic National Meteorological Service, http://www.hnms.gr, 20/12/2007).

The most intense rainstorms are produced by the passage of depressions, usually accompanied by cold fronts (and rarely by warm fronts) approaching from the west, south-west or north-west. Frequent and rapid changes in weather are caused by frontal air mass activity, resulting in regular flash floods. A convectional weather type (characterized by a cold upper air mass that produces dynamic instability) is also responsible for many intense storms, especially in the summer (Kurz & Fontana, 2004).

A great variety of climatic types, in the frame of the Mediterranean climate, can be observed in nearby areas. The topography of the Pindos mountain range plays an important role in precipitation and runoff regimes in Greece. The Pindos mountain range extends north-south to the movement of weather systems, causing air masses to ascend, their condensation leading to rainfall events. The climate varies from humid in the north-western regions to dry in the eastern regions of the country. The availability of water resources is proportional to the general precipitation pattern.

Data Analysis

The daily time step data of precipitation and air temperature with regard to the 30-year time period (1965–95) were acquired from 40 meteorological stations across Greece. More recent data were not obtained for reasons of data availability. The data from each station were analyzed and processed in order to calculate the mean monthly and annual values that were necessary for the derivation of the temperature-precipitation diagram at each station, as well as for the calculation of the indices of Johansson and De Martonne.

The Johansson Continentality Index is used for the climatic classification between continental and oceanic climates. The index is calculated by the following formula (Flocas, 1994; Chronopoulou–Sereli, 1996):

$$k = \frac{1.7E}{\sin f} - 20.4 \tag{1}$$

where E (in°C) is the annual range of mean monthly air temperatures and f is the geographical latitude of the station. The climate is characterized as marine when k varies between 0 and 33, as continental when k varies between 34 and 66 and as exceptionally continental when k varies between 67 and 100.

A measure of aridity of a region, applicable only at a local level, is proposed by De Martonne (1925) and is given by the following relationship:

$$I_{DM} = \frac{P}{T + 10} \tag{2}$$

where P is the mean annual precipitation (mm) and T (°C) the mean annual air temperature. The De Martonne Index climatic classification consists of six climate categories, from dry to very humid (Table 1), based on the values of I_{DM} and P.

Surface Representation of Climatic Variables and Indices Using GIS Techniques

The surface representation of the climatic variables and indices was performed using GIS techniques. The spatial integration of the stations' point values followed after the calculation of the mean annual values of precipitation and air temperature and of the aforementioned indices at each of the 40 meteorological stations. ESRI's ArcGIS Desktop-ArcInfo software was used for that purpose. The raster files of the variables and indices were developed via the 'Interpolation to Raster' Inverse Distance Weighted function (IDW), included in the Spatial Analyst extension of ArcMap. The cell size of the output rasters was set to 1000 m.

Interpolation predicts values for cells in a raster from a limited number of sample data points and can be used to predict unknown values for any geographic point data. The IDW method estimates cell values by averaging the values of sample data points in the vicinity of each cell. The closer a point is to the centre of the cell being estimated, the more influence, or weight, it has in the averaging process. This method assumes that the variable being mapped decreases in influence with distance from its sampled location (McCoy & Johnston, 2001).

Table 1. De Martonne Index climatic classification

Climate	Values of I_{DM}	Values of P(mm)
Dry	$I_{DM} < 10$	$P < 200$
Semi-dry	$10 \leq I_{DM} \leq 20$	$200 \leq P < 400$
Mediterranean	$20 \leq I_{DM} < 24$	$400 \leq P < 500$
Semi-humid	$24 \leq I_{DM} < 28$	$500 \leq P < 600$
Humid	$28 \leq I_{DM} < 35$	$600 \leq P < 700$
Very humid	a.$35 \leq I_{DM} \leq 55$	$700 \leq P < 800$
	b.$I_{DM} > 55$	$P > 800$

Two parameters of the IDW method were defined: Power and Search Radius Type. By defining a high power, more emphasis is placed on the nearest points, and the resulting surface will have more detail (i.e. be less smooth). Specifying a lower power will give more influence to the points that are further away, resulting in a smoother surface. A power of 2 is most commonly used. With regard to the search radius type, there are two options: fixed and variable. In the present case, the variable search radius type was selected. With a variable search radius, the number of points used in calculating the value of the interpolated cell is specified, which makes the radius distance vary for each interpolated cell, depending on how far it has to search around each interpolated cell to reach the specified number of input points (ArcMap Help Menu). The specified number of points was 12 and no maximum distance was defined.

Finally, the function CONTOUR included in the 'Surface Analysis' toolset of the Spatial Analyst extension was used for the development of the final contour map of each climatic variable and index.

Results

Climatic Conditions

Variables of precipitation and air temperature. The mean annual areal precipitation of the 30-year period (1965–95) is depicted in Figure 1. A high variability of precipitation can be observed, varying from 1150 mm in the high precipitation north-western part of the country to 350 mm in the eastern part. This is attributed to the Pindos mountain range, which interrupts the prevailing eastern movement of weather systems, thus dividing the country into two major parts: the windward, high precipitation western areas and the leeward, low precipitation eastern areas. The western air masses, rich in moisture from the evaporation above the Ionian Sea, ascend the windward side of the Pindos mountains, cool and lose most of their moisture, resulting in intense and frequent rainstorms. When they descend the other side, they are warmed by adiabatic sinking.

At a local level, the geomorphology combined with the direction of air masses results in an exception to the above spatial distribution of precipitation, e.g. the nearby regions of Attica and Kimi that are located in the eastern part of Greece, away from the Pindos mountain range. The region of Kimi has the greatest mean annual precipitation (1155 mm) in the entire country. On the contrary, Attica is characterized by low rainfall. This is attributed to the intense topography of Kimi together with the movement of north-eastern air masses. These air masses, rich in moisture due to the evaporation above the Aegean Sea, ascend the Kimi Mountain and lead to intense rainstorms.

With regard to the spatial distribution of the mean annual air temperature, it is affected by the direction of the Pindos mountain range, parallel to the direction of the coastline (Zambakas, 1992). During the winter months, the Pindos mountain range protects the western areas of Greece from the north-eastern cold air masses and that, in conjunction with the region's proximity to the sea, contributes to their higher mean temperatures. The mean temperatures are generally lower at the northern part of the country. The minimum mean annual values are observed in Florina (12.1°C) and Kozani (12.7°C) located in the northern mountainous areas. On the contrary, the maximum values are observed in the most southern parts of Greece, in the islands of Crete (Ierapetra 19.5°C) and Rhodes (18.9°C). A downward tendency of the mean annual temperature is also observed with the increase in altitude.

Other factors affecting the spatial distribution of air temperature are the local conditions, such as the urbanization of a region (e.g. Attica), which formulates a local micro-climate.

The temperature-precipitation diagram for each meteorological station was also derived. These diagrams depict the monthly mean values of precipitation and air temperature for the study period 1965–95. Figure 2 depicts the diagrams for the stations at Arta and Athens. The station at Arta is typical of the high precipitation that characterizes the north-western part of Greece. The mean annual precipitation at this station is 1063 mm, while the mean annual air temperature is 17°C. The National Observatory in Athens is located in the central-eastern part of the country, which is typical of the drier conditions prevailing in the eastern part of the country. The corresponding values are 377 mm and 17.9°C.

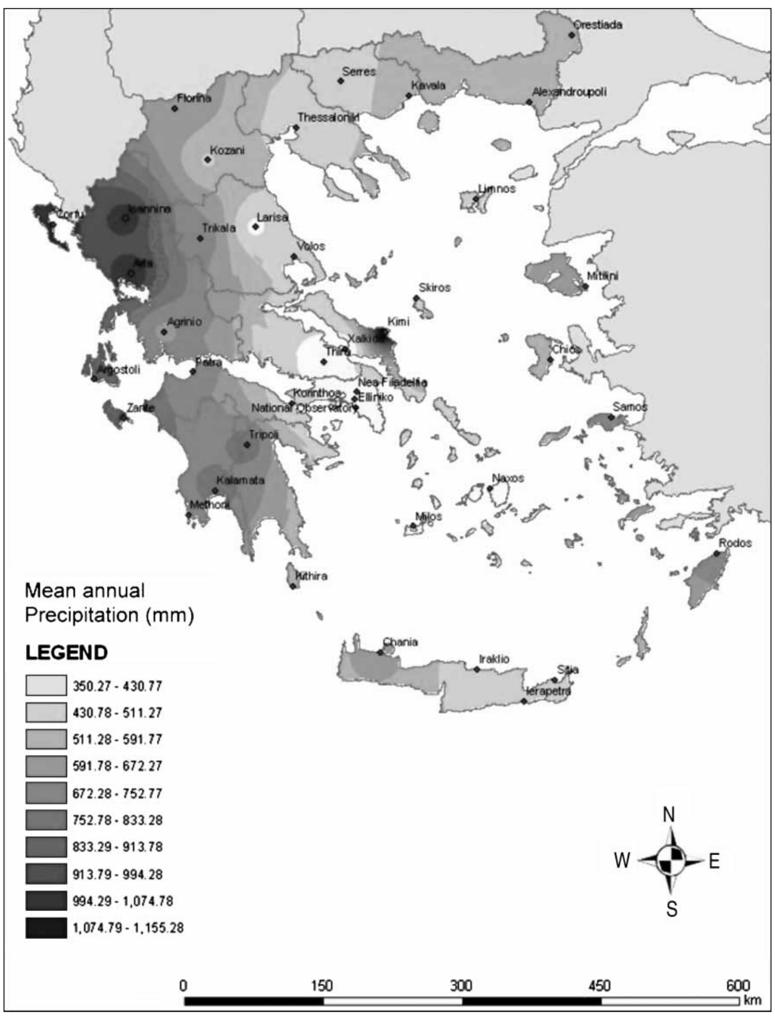

Figure 1. The mean annual areal precipitation (mm) (1965–95)

Climatic indices. The spatial distribution of Johansson Continentality Index is depicted in Figure 3. The index values vary between 15 and 38 in the entire study area. At 11 of the 40 stations the index value was higher than or equal to 33 (limit), denoting continental climate. These stations are mainly located in the northern part of the country and are affected either by their proximity to the mountains or by the climatic conditions of the continental part of Europe. A marine climate type characterizes the rest of the country.

Figure 4 depicts the De Martonne Aridity Index, whose values range from 12.59 (Xalkida), denoting a semi-dry climate to 45.43 (Kimi), denoting a very humid climate. The values of the index gradually increase from the eastern to the western parts of Greece, covering almost the entire range of the classification's climate categories, from dry to very humid. The spatial distribution of the index is in agreement with that of the mean annual precipitation. At the stations in Kimi, Ioannina, Arta and Corfu, the values of the index were higher than 35, implying very humid conditions. These stations, except for Kimi, are located in the north-western part of Greece, where the mean annual precipitation is the highest in the country and exceeds 1000 mm. On the eastern coast, including the region of Attica where the majority of the country's population lives, the index values range from 12.6 to 19, implying semi-dry conditions.

Availability of Water Resources in Greece

In the following, the water districts have been grouped into four main areas of the country. More specifically, they are the northern area, characterized by the transnational water resources, the central area, where there are great discrepancies in the water potential between eastern and western regions, the southern area that consists of Peloponnesus, and finally the fourth area that consists of all the islands.

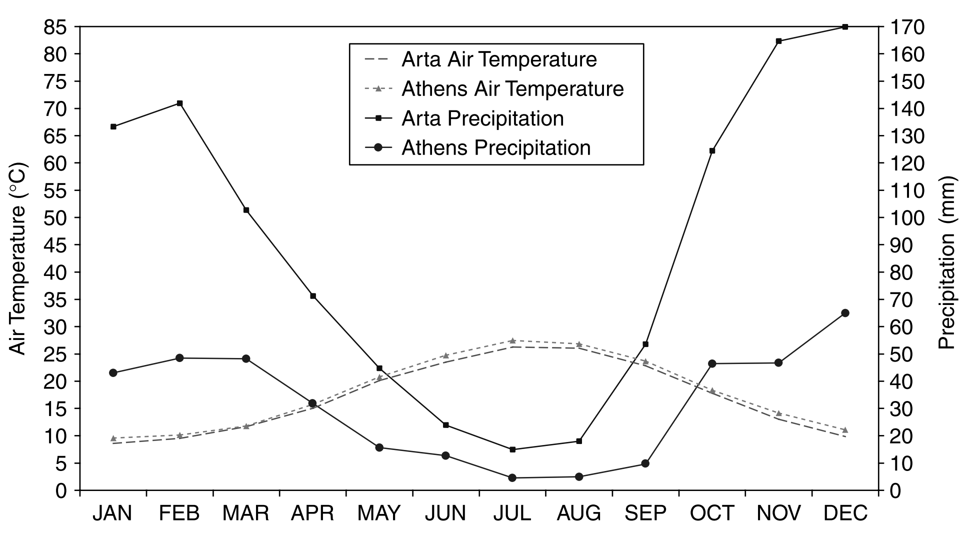

Figure 2. Temperature: precipitation diagram of the stations of Arta and National Observatory of Athens

Northern area. The northern area of the country consists of the water districts of Western Macedonia (09), Central Macedonia (10), Eastern Macedonia (11) and Thrace (12) (the number in parentheses denotes the location of each district in Figure 5). The common feature of these water districts is that they include transnational water resources, the management of which is valuable for the fulfilment of basic needs. The transnational water resources of the country, according to the Directive 2000/60, require a single and special treatment for the implementation of the most rational management policy, in order that their best utilization inside the national boundaries is achieved, and that the disruption of relationships with neighbouring countries is prevented. These water resources are the Big Prespa Lake with FYROM and Albania and the Small Prespa Lake with Albania in the water district of Western Macedonia, the River Axios and Doirani Lake with FYROM in

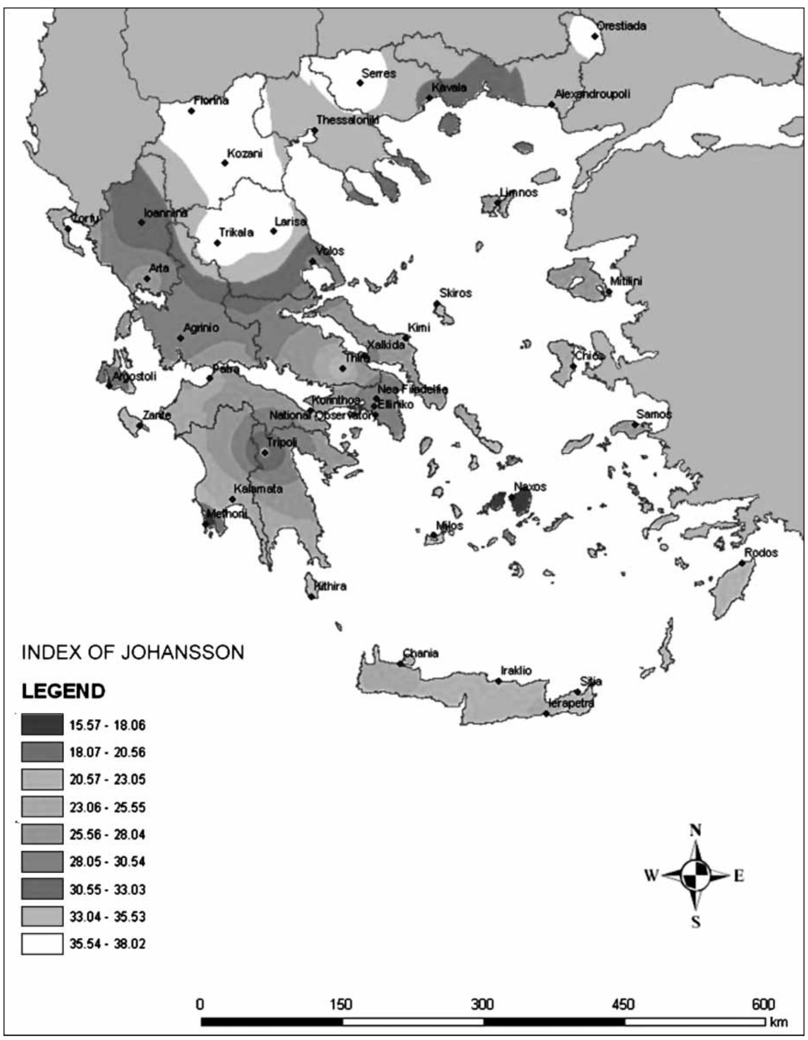

Figure 3. The Johansson Continentality Index

the water district of Central Macedonia, the River Strimonas with Bulgaria in the water district of Eastern Macedonia, the River Nestos with Bulgaria and the River Evros with Bulgaria and Turkey in the water district of Thrace.

The water district of Western Macedonia (13 624 km^2) is characterized by intense ground relief and small plains. The climate is continental with harsh winters and snowfalls and the mean annual temperature is 13°C. The mean annual rainfall is 640 mm. This district has a sufficiency in water. A great part of the water demand is supplied by the transnational Small Lake and Big Prespa Lake, while the River Aliakmonas is used for the water supply of the city of Thessaloniki. The river basin of Aliakmonas has the largest area in the district (8847 km^2 or

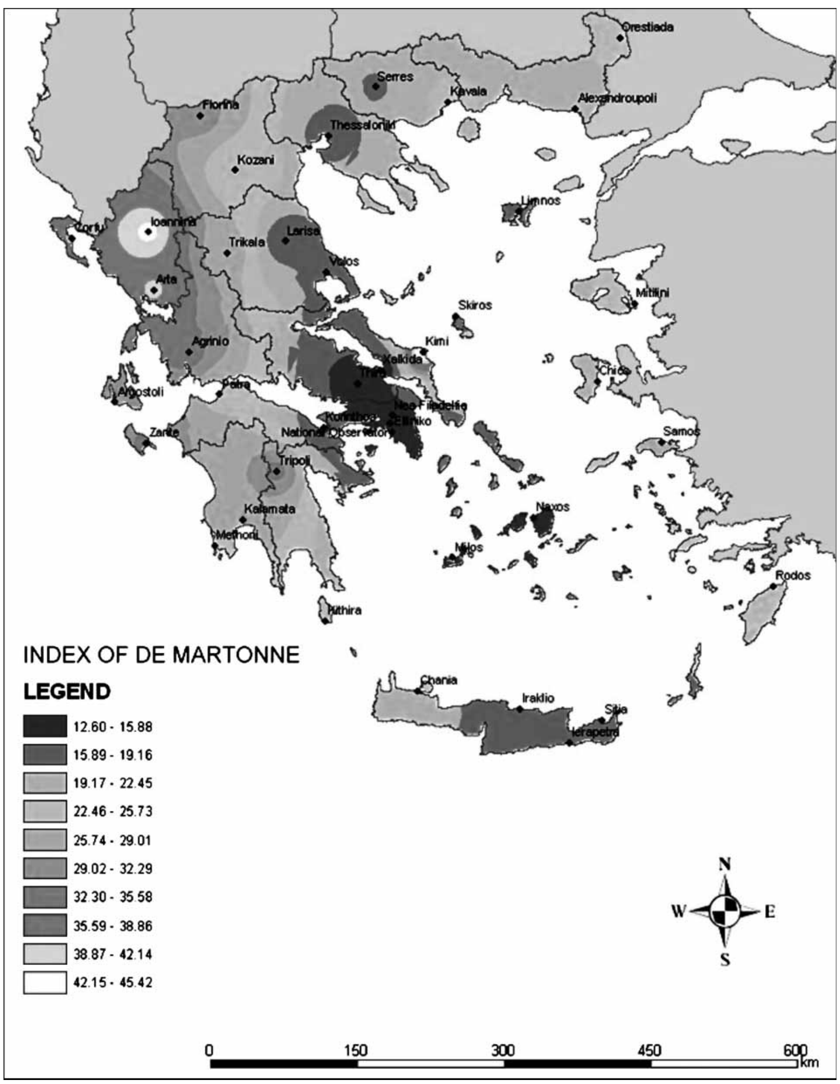

Figure 4. The De Martonne Aridity Index

65% of total) and the river is 93 km in length. Twenty-eight per cent of the total area consists of small watersheds. These watersheds, with an area that is less than 40 km^2, drain directly to the sea. They are characterized by ephemeral low flow and do not contribute to the water potential of the district. Another remarkable feature of this district is the production of hydroelectric energy from the utilization of the water potential of the River Aliakmonas.

The water district of Central Macedonia (10 171 km^2) has a deficiency in water resources; it has the second poorest water resources, the district of Attica having the worst. The mean annual temperature is 14°C and the mean annual rainfall is 577 mm. The demand for water in urban and agricultural usage is high because the city of Thessaloniki is the second most important centre of industrial development after Athens, and the crop productivity of the district is high, the second in the country after Thessaly. The demand for water is mainly supplied by the adjacent Aliakmonas river basin, as well as from transnational water resources, the River Axios and Doirani Lake. The Axios river basin covers an area of 1644 km^2 and the river is 100 km long within the Greek boundaries. Other river basins with an area greater than 1000 km^2 are those of Loudias and Gallikos. These basins cover 38% of the total area of the district. Small watersheds also account for 38% of the area.

The water district of Eastern Macedonia (7323 km^2) is characterized by low ground relief with wide plains and a sufficiency in water resources. This region presents a major development in the agricultural sector. The mean annual rainfall is 609 mm. The river basin of Strimonas, which is a transnational river, covers 5925 km^2 or 81% of the total area. The river is 105 km long within the Greek boundaries. The remaining 19% of the total area does not contribute to the water resources of the district because it consists of small watersheds.

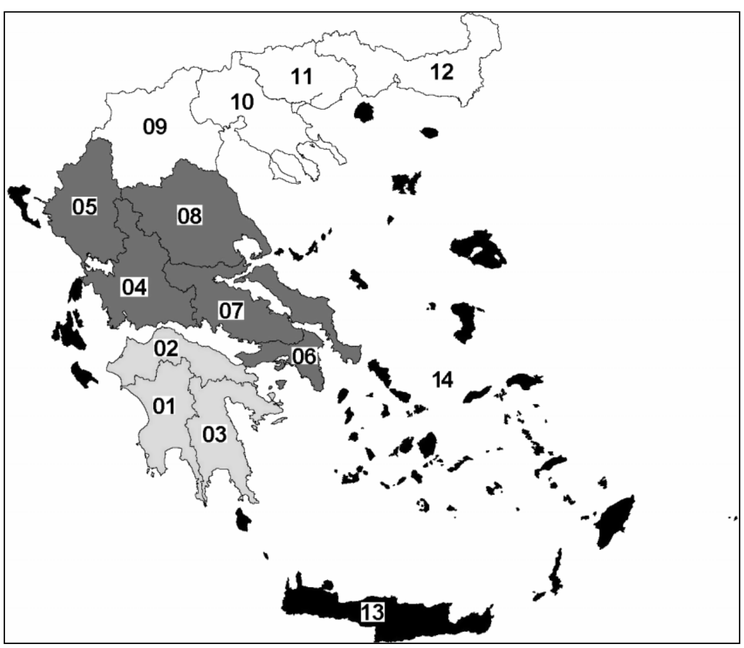

Figure 5. The 14 water districts of Greece and the proposed four water districts (in grey tones)

The water district of Thrace (11 117 km^2) is characterized by remarkable crop productivity and a sufficiency in water resources. The transnational Rivers Evros and Nestos are valuable for the fulfillment of the demand for irrigation water. The mean annual temperature varies between 14.5 and 16.5°C. The mean annual rainfall is 694 mm, ranging between 500 and 600 mm in the coastal areas and exceeds 1000 mm towards the northern mountainous areas. The mean annual volume of surface runoff is assessed at $10.2 \times 10^9\ m^3$, while the contribution from the Greek part is about $2.7 \times 10^9\ m^3$ (Ministry of Development, 1997).

Central area. The central part of the country consists of the water districts of Western Sterea (04), Epirus (05), Eastern Sterea (07), Thessaly (08) and Attica (06).

The water district of Western Sterea (10 199 km^2) is located in the western, high precipitation part of the country. The mean annual rainfall is approximately 800–1000 mm in the coastal areas, 1400 mm in the mountainous areas and exceeds 1800 mm in high altitude areas. The Rivers Acheloos, Evinos and Mornos and Lake Trichonida constitute the major surface water resources of the district, in addition to the underground water resources, which are generally not utilized. The river basins with an area greater than 1000 km^2 are Acheloos (5635 km^2) and Evinos (1093 km^2), which cover 65% of the total area of the district. Small watersheds cover 23% of the area. The surface runoff is assessed at $5.3 \times 10^9\ m^3$ (Ministry of Development, 1997). The large water potential that remains unutilized should be integrated into a common management plan for the rational fulfillment of the needs inside the boundaries of the water district, but also in order to increase the water potential of the eastern part of the country, where the natural supply is insufficient to supply the growing demand. At present, part (8.6%) of the district's water potential, from the river basins of Evinos and Mornos, is used to supply water to the capital, Athens. A small part of the supply is also transferred to Thessaly via Plastiras Lake. In addition, four hydroelectric plants in the Acheloos river basin have been constructed for the production of electric power. In the coastal areas (e.g. Gulf of Ambrakikos, Arta), the waters have been qualitatively downgraded due to the fertilization of crops.

The water district of Epirus (10 026 km^2) is located in the north-western part of the country, which has the highest precipitation and is characterized by a surplus of water. The mean annual rainfall ranges from 1000–1200 mm in the coastal areas to 2000 mm in the mountainous areas. The river basins with an area greater than 1000 km^2 are those of Aoos, Arachthos and Kalamas, covering approximately 58% of the total area of the district. The River Aoos flows towards the Albanian territory. The Aoos river basin has an area of 2083 km^2 and the river is 96 km long within the Greek boundaries. The River Arachthos is the longest, with a length of 146 km. The volume of surface runoff is assessed to be $5.5 \times 10^9\ m^3$. Small watersheds cover 22% of the total area of the district.

In the water district of Eastern Sterea (12 321 km^2) the water resources are sufficient to supply the demand. The mean annual rainfall varies from 500 mm on the plains to 1200 mm in the mountainous areas (Kimi) of Evias. The Boiotikos Kifisos (1914 km^2) and Sperchios (1650 km^2) river basins cover 29% of the total area of the district. A large percentage (43%) of the total area consists of small watersheds. The surface runoff of the district is assessed at $2.5 \times 10^9\ m^3$. Lakes Iliki and Paralimni contribute to the water supply of the capital of Athens. With regard to water quality, the River Asopos, 22.6 km in length and a basin area of 715 km^2, is an example of the degradation of water quality due to the uncontrolled development of the industrial zone located near the capital. This degradation has been expanded to the underground water resources and measures have been taken in order to control and eliminate the sources of pollution.

The water district of Attica (3207 km^2) has the poorest water resources. The mean annual temperature varies between 16–18°C, depending on the altitude and the distance from the sea. The mean annual rainfall is 512 mm, ranging from 350 mm on the plains to 1000 mm in the mountainous areas. The Kifisos river basin has the largest area (332 km^2). A large percentage (58%) of the total area consists of small watersheds. The surface runoff of the district is assessed at $251 \times 10^6\,m^3$. The high demand for water by the capital, Athens, is supplied through the conveyance of capacities from the districts of Western and Eastern Sterea.

The water district of Thessaly (13 377 km^2) includes the largest plains in the entire country and is distinguished by its high crop productivity. The mean annual temperature varies between 16–17°C. The rainfall is greatest in the western part of the district, while it decreases on the plains and increases in the eastern mountainous areas. The mean annual rainfall is 858 mm. The Pinios river basin (10 628 km^2) is the largest in the country and covers 81% of the total area of the district. The river is 255 km long. The surface runoff of the district is assessed at $3.2 \times 10^9\,m^3$ (Ministry of Development, 1997). There is a dearth of water resources in the district and the demand for irrigation water is not covered by the water available. Over-exploitation of the aquifers has led to a considerable fall in the level of the groundwater. Therefore, a special management policy needs to be applied in order to reinforce the water potential through the rational use of the water resources (extension and modernization of the irrigation network), as well as through the conveyance of water capacities from other water districts.

Southern area. Peloponnesus consists of the water districts of Western Peloponnesus (01), Eastern Peloponnesus (03) and Northern Peloponnesus (02).

The water district of Western Peloponnesus (7301 km^2) is rich in surface and underground water resources. The mean annual rainfall is 1100 mm, ranging from 800 mm on the plains to 1600 mm in the mountainous areas. The naturally available water potential (surface and underground) is assessed at $4.4 \times 10^9\,m^3$ per year (Ministry of Development, 1997). The Alfios river basin has the greatest area (3561 km^2 or 49% of the total area) and the river length is 60 km, while 19% of the total area of the district consists of small watersheds.

In the water district of Eastern Peloponnesus (8423 km^2) the mean annual rainfall is 808 mm, ranging from 600 mm on the plains to 850 mm in the mountainous areas. The Evrotas river basin has the largest area (1765 km^2 or 20% of the total area) and the river length is 56 km, while 51% of the total area of the district consists of small watersheds. The groundwater has been downgraded in many coastal areas, due to the over-exploitation of the aquifers.

The water district of Northern Peloponnesus (7310 km^2) is characterized by a plethora of watersheds due to the intense ground relief. The water resources are sufficient to supply the demand, 90% of which is for irrigation purposes. The mean annual rainfall is 680 mm, ranging from 500 mm on the plains to 1200 mm in the mountainous areas. The Pinios (Ilias) river basin covers the largest area (960 km^2 or 13% of the total area) and the river length is 84 km, while 46% of the total area of the district consists of small watersheds.

Islands. The fourth area, comprising all the islands, consists of the water district of Crete (13), the water district of the Aegean Sea islands (14) and the islands of the Ionian Sea. The features that characterize the development identity of the islands are the limited natural supply of water and the increased seasonal demand. The problem is not intense during the winter months, but it becomes serious in summer.

In the water district of Crete (8336 km^2) the mean annual temperature varies between 18.5°C in the western area and 20°C in the southern area. The southern and south-east coasts of Crete are among the warmest regions of the country. The duration of the warm period exceeds six months. The mean annual rainfall is 900 mm, while in the western part (White Mountains) the annual rainfall reaches 1700 mm. The surface runoff is assessed at 1.5×10^9 m^3 (Ministry of Development, 1997). The island is rich in water resources that could satisfy the growing demand. The greatest problem is their spatial distribution in relation to the needs. More specifically, the western part is rich in surface and underground water resources. However, the rainfall decreases towards the eastern side of the island and combined with the salinity of groundwater, it leads to a deficit in the supply-demand balance, posing problems even for the requirement of the water supply (e.g. Iraklio).

The Water district of Aegean Sea Islands (9104 km^2) consists of the islands of Cyclades and Dodekanisa, and also Lesvos, Chios and Samos. The climate is mild Mediterranean with the mean annual temperature ranging from 16.9 to 19.9°C. The annual rainfall ranges from 350 to 818 mm and is greater in the islands of the eastern Aegean. The water resources are not sufficient to cover the demand for water, neither for irrigation purposes, nor for residential use.

Demand for Water

With regard to the demand for water, in the past there was no systematic recording of the water consumption per use. This is due to the fact that the policy on water had set priority on the research and utilization of new water resources. During recent years, a considerable effort has been made to determine the precise water quantities consumed per use in each water district. The current annual demand for water (in million cubic metres (MCM)) in each water district is shown in Table 2. As shown, the total annual demand for water under the present conditions in all water districts is estimated to be 8184.3 MCM. Of this, 84% are allocated for irrigation purposes, 12% for potable water, 3% for industrial and energy purposes and 1% for livestock (NTUA, 2008). The water allocated for the energy sector is used only for cooling purposes by the thermal electrical energy stations.

Table 2. Demand for water (in MCM) in the 14 water districts of Greece

Water district	Irrigation	Potable water	Livestock	Industry	Energy	Total
Western Peloponnesus	201.0	23.0	5.0	3.0	20.0	252.0
Northern Peloponnesus	401.5	41.7	6.6	3.0		452.8
Eastern Peloponnesus	324.9	22.1	4.7			351.7
Western Sterea	366.5	22.4	9.0			397.9
Epirus	153.5	33.9	10.3	4.3		202.0
Attica	99.0	420.0	2.5	17.5		539.0
Eastern Sterea	773.7	41.6	9.9	12.6		837.8
Thessaly	1550.0	69.0	13.0			1632.0
Western Macedonia	609.4	43.7	7.9	30.0	80.0	771.0
Central Macedonia	527.6	99.8	8.0	80.0		715.4
Eastern Macedonia	627.0	32.0	5.8			664.8
Thrace	825.2	27.9	7.1	11.0		871.2
Crete	320.0	42.3	10.2			372.5
Aegean Sea islands	80.2	37.2	6.8			124.2
Total	6859.5	956.6	106.8	161.4	100.0	8184.3

Source: National Technical University of Athens (2008).

Conclusions

The present study shows that the geomorphologic structure of the Greek peninsula, characterized by the intense ground relief, contributes to a wide diversity of climatic conditions, even within short distances, something that occurs in few places in the world. The north-south direction of the Pindos mountain range, parallel to the coastline, constitutes a major contributing factor to the climatic variety across the country. Extending north-south to the prevailing western air masses, the mountain range divides the country into western high and eastern low precipitation areas. The climate at each of the 40 meteorological stations was classified into continental and marine, based on Johansson Continentality Index. The climate at 11 of the 40 stations is classified as continental. These stations are located in the northern part of the country and are affected either by their proximity to the mountains or by the climatic conditions of the continental part of Europe. In addition, the climate at each station was classified into categories ranging between dry and humid based on the De Martonne Aridity Index. The spatial distribution of this index was similar to that of the general precipitation pattern of the country.

The availability of water resources in each water district was also analyzed. The rational management of water resources needs to be planned, taking into account the non-uniform spatial distribution of the water reserves. A smaller number of water districts that accord entirely with the Directive would be easier to organize and study, as well as give more systematic control, supervision and management. The four parts of the country, northern, central, southern and all islands present common features concerning the management policy and should be the basis for the development of four water districts. The northern part comprises water districts that include transnational water resources, the management of which should be made from a single authority. Eastern and western districts of the central part should be merged into one district for the implementation of a single management plan. This action would allow the utilization of water resources from the areas that are sufficient in water to benefit the areas that present a deficiency in water resources. The same applies to the southern part (Peloponnesus). The islands constitute another part that is characterized by increased seasonal demand. A structure with fewer water districts is critical for the intense water management problems that are expected to be encountered in the future. This reconstruction should be made in cooperation with the local authorities, making all the people involved in the plan work together in an organized way.

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