Irrigated crops' water needs in Magnesia region, Greece

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Abstract
Demand for irrigation water is estimated to be increased by 14% till year 2025, while water that is intended for use in the agricultural sector is estimated to be reduced by 8-15%. Therefore, it is mandatory that measures should be taken in order to rationalize the use of irrigation water. The aim of this study was to define the water needs of the most cultivated and irrigated annual crops, in the region of Magnesia, Greece. Estimating the crop water needs could provide help to the authorities to properly manage the restructuring of crops. The project was divided in three stages. During the first stage, current and historical data concerning regional climate, cultivated plant species, cultivated areas, geographical and other statistical information were collected. During the second stage, all the collected data were firstly digitized and archived, while afterwards data were statistically processed. The final stage included the creation of geographical information maps and the calculation of crops' water needs.

Keywords: *irrigation; water needs; irrigated crops.*

1. INTRODUCTION

Irrigation, internationally, consumes more water compared to other uses and ranges from 70-80%. Irrigated areas of the planet, although occupying about 17% of the cultivated land, consume about 70% of the global water reserves [1,2]. This percentage is reduced to around 40% in food-importing countries with well-developed economies, while it climbs above 95% in countries having agriculture as the main economic activity [2].

Water is a limiting factor for economic growth and living standards in the Mediterranean countries. However, the lack of water resources is not always the cause. The big fluctuations in water demand and availability are most often the main reason for the lack of water [3]. The water resources in the area are in critical condition and improving the water use efficiency (WUE) is imperative [4]. Improvement of water efficiency can save between 15 and 60% of total water use, as stated in a report of the European Union (EU) on the identification of water-saving potential in EU [5].

Greece is considered a rich country in water, with an average annual rainfall of 700 mm, equivalent to 115 billion m^3. Of these, 50% is lost due to evapotranspiration and 30% (about 35 billion m^3) due to surface drainage end up in the sea [6]. The uneven distribution of rainfall, extreme weather events and anthropogenic interferences result in water scarcity occurring in some parts of the country [7].

Proceedings of the Seventh International Conference on Environmental Management, Engineering, Planning & Economics
Mykonos Island, Greece, May 19-24, 2019
ISBN: 978-618-5271-73-2

The intensification of agriculture in recent decades in Greece has been based on the large increase in irrigated land. One of the most important changes that took place was the extension of irrigation to arable crops (e.g. corn, sugar beet, alfalfa, cotton). Thus, while in 1961 irrigated land accounted for 13.3% of agricultural land, in 1998 it reached 36% [8]. Regarding the geographic diversification of demand for irrigation water in Greece, the highest demand is presented in Thessaly (1550 hm^3/year), followed by Northern and Central Greece, and Thrace [9].

Nowadays, the main objective, supported by the European Union and international organizations in the development and management of water resources, is that any intervention or planning should ensure the viability and sustainability of the system [9]. It is therefore necessary for a water resource management policy to be applied in Greece in order to satisfy the water needs of irrigation, drinking supply, industry and energy and to manage restructuring of the crops. This will result in the preservation of the quality of water resources and the natural environment in good condition.

Considering the above mentioned, the aim of this study was to define the water needs of the most cultivated annual crops that are irrigated, in the region of Magnesia, Greece. Estimating the crop water needs can help saving irrigation water by defining the suitable irrigation dose and the right application time, but also can provide crucial help to the authorities to properly manage the restructuring of crops.

2. MATERIALS AND METHODS

The water requirements estimation was based on the calculation of the reference evapotranspiration (ETo) and the crop coefficient procedure. The most reliable method for these calculations is the modified Penman-Monteith equation, as described in the FAO-56 paper [11]. In this method, the evapotranspiration of the crop (ETc), expressed in mm/d, is calculated as shown in Equation 1:

$$ETc = ETo * Kc \quad (1)$$

where ETo is the reference evapotranspiration (mm/d), and Kc is the crop's coefficient which varies according to the development of the crop.

The estimation of the reference evapotranspiration (ETo), expressed in mm/d, is calculated as shown in Equation 2:

$$ETo = [0.408\Delta(Rn\text{-}G)+ \gamma u_2(e_s\text{-}e_a)/(T+273)]/[\Delta+\gamma(1+0.34u_2)] \quad (2)$$

where Rn is the net radiation at the crop surface (MJ/m^2/day), G is the soil heat flux density (MJ/m^2/day), T is the mean daily air temperature at 2 m height (°C), u_2 is the wind speed at 2 m height (m/s), e_s is the saturation vapour pressure (kPa), e_a is the actual vapour pressure (kPa), e_s-e_a is the saturation vapour pressure deficit (kPa), Δ is the slope vapour pressure curve (kPa/ °C), and γ is a psychrometric constant (kPa/ °C).

For the estimation of the daily reference evapotranspiration for each month of the year, the historical weather data of thirteen meteorological stations, that are located inside and near the region of Magnesia, were used. Nine meteorological stations belong to the National Observatory of Athens, three belong to the Hellenic National Meteorological Service, while the other one is placed in the experimental farm of the University of Thessaly, which is located in Velestino. These stations have the ability to continuously record weather variables and generate the daily low, high and mean air

ISBN: 978-618-5271-73-2

temperature, the daily minimum and maximum air's relative humidity, the daily precipitation and the average wind speed. These variables are essential for the calculation of the reference evapotranspiration in each station.

The calculated values of the reference evapotranspiration for the last five years along with weather data and the geolocation of each meteorological station were entered in a Geographical Information System. After interpolating the data using the Inverse Distance Weighted method, the reference evapotranspiration and weather info (e.g. precipitation) of each month was depicted in GIS maps.

Thereafter, current and historical data concerning cultivated plant species, cultivated areas, geographical and other statistical information were collected with the help of Hellenic Statistical Authority and by local authorities that keep that kind of data. In order to provide help to restructuring of the crops, only the irrigated crops that could be restructured were selected for further calculations. Thus, perennial crops, trees, and crops that do not cover significant area, were excluded.

The Equation 1 was used afterwards in order to calculate the crop evapotranspiration for each crop in every municipal district within Magnesia. The Kc coefficient values and the length of growth stages for each crop were derived from the FAO-56 paper [11]. In order to estimate the water requirements for each crop, the effective precipitation was subtracted from the crop's evapotranspiration.

Finally, the water needs for each crop were calculated for each municipal district and for the whole region, according to the cultivated area of each crop.

3. RESULTS AND DISCUSSION

The contour maps of average reference evapotranspiration for each month, during irrigation season, are shown below in Figures 1-5.

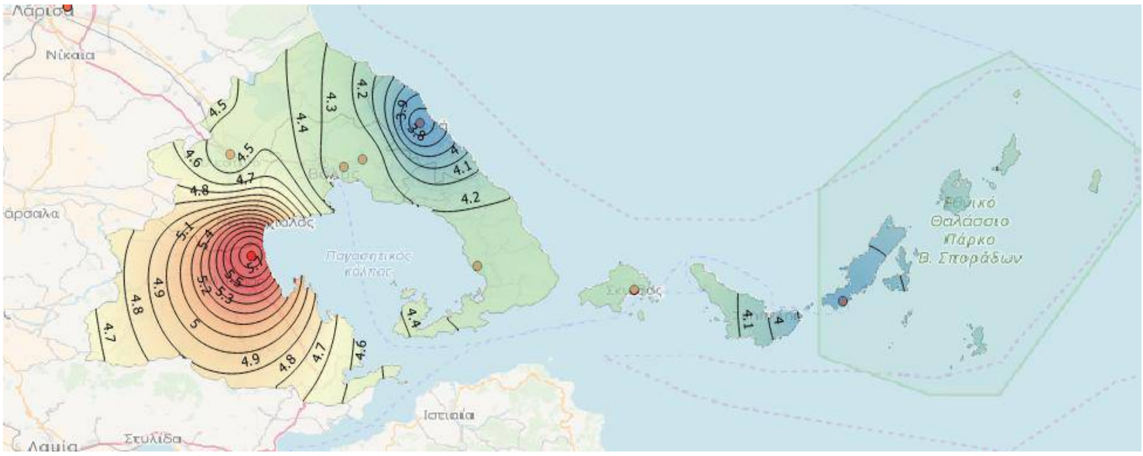

Figure 1. Contour map of reference evapotranspiration for month April (five year average).

ISBN: 978-618-5271-73-2

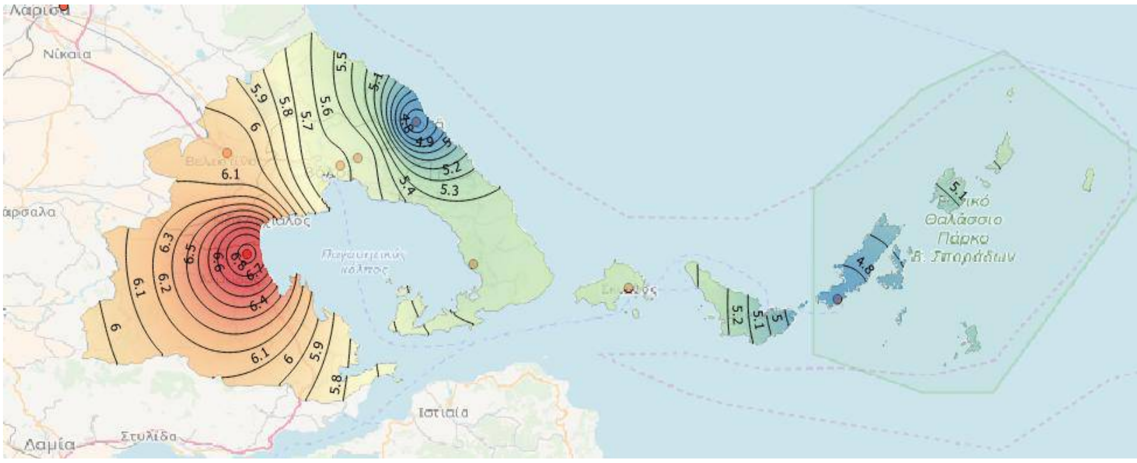

Figure 2. Contour map of reference evapotranspiration for month May (five year average).

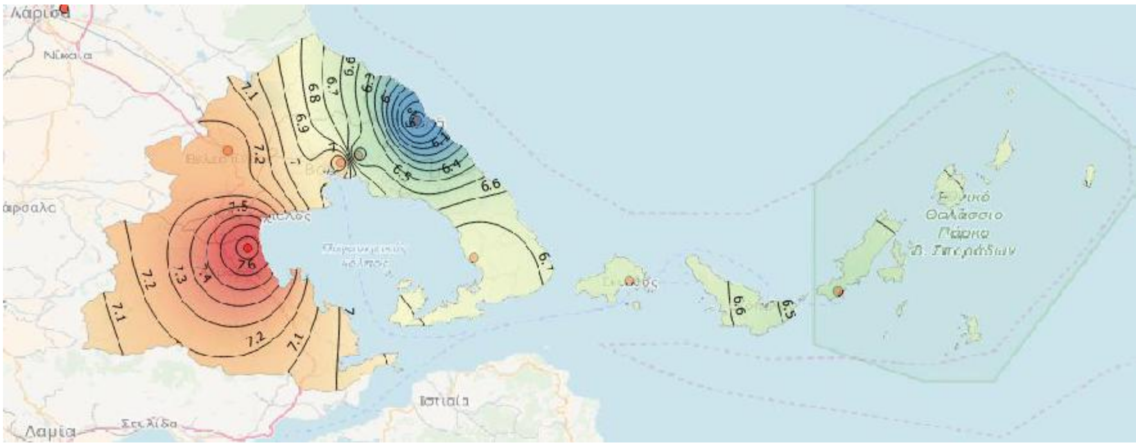

Figure 3. Contour map of reference evapotranspiration for month June (five year average).

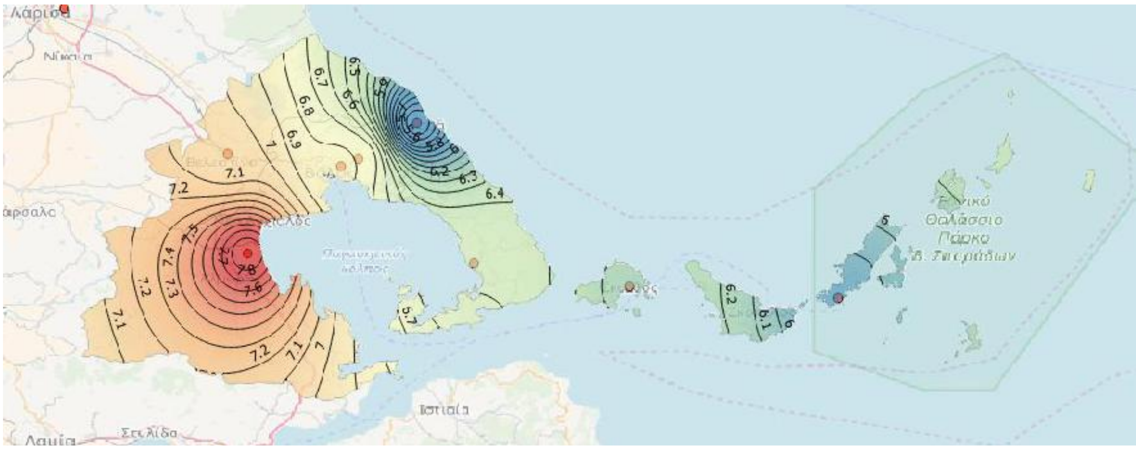

Figure 4. Contour map of reference evapotranspiration for month August (five year average).

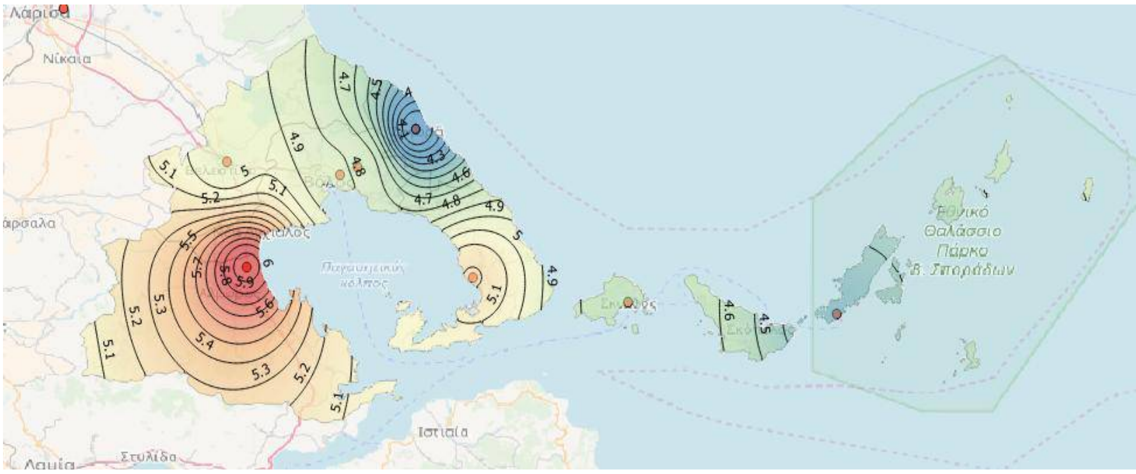

Figure 5. Contour map of reference evapotranspiration for month September (five year average).

As shown in Figures 1-5, the five year average of the reference evapotranspiration ranged from 3.7 to 5.9 mm/day for the month April, and from 4.5 to 6.9 mm/day for May. For June, the five year average reference evapotranspiration ranged from 5.7 to 7.7 mm/day. July had the highest evapotranspiration that was found to be at 8 mm/day, while the minimum was found at 5.2 mm/day. For August, the five year average of the reference evapotranspiration ranged from 4.7 to 7.5 mm/day, while for September it ranged from 3.8 to 6.1 mm/day.

Average crop water requirements for the season that irrigation is required (usually from April to September) are presented in Table 1. As shown in Table 1, the most water consuming crop is alfalfa with tomato for canning and sugar beet to follow.

Table 1. Crop water requirements per irrigation season (five year average)

Crop water requirements (mm)				
Cotton	**Maize**	**Alfalfa**	**Tomato (for canning)**	**Sugar beet**
361	373	705	574	562

Seasonal water needs of the most cultivated irrigated annual crops for the region of Magnesia (five year average) are presented below in Figure 6.

As shown in Figure 6, the crop that has the highest regional demands in Magnesia is cotton, with alfalfa and maize to follow.

ISBN: 978-618-5271-73-2

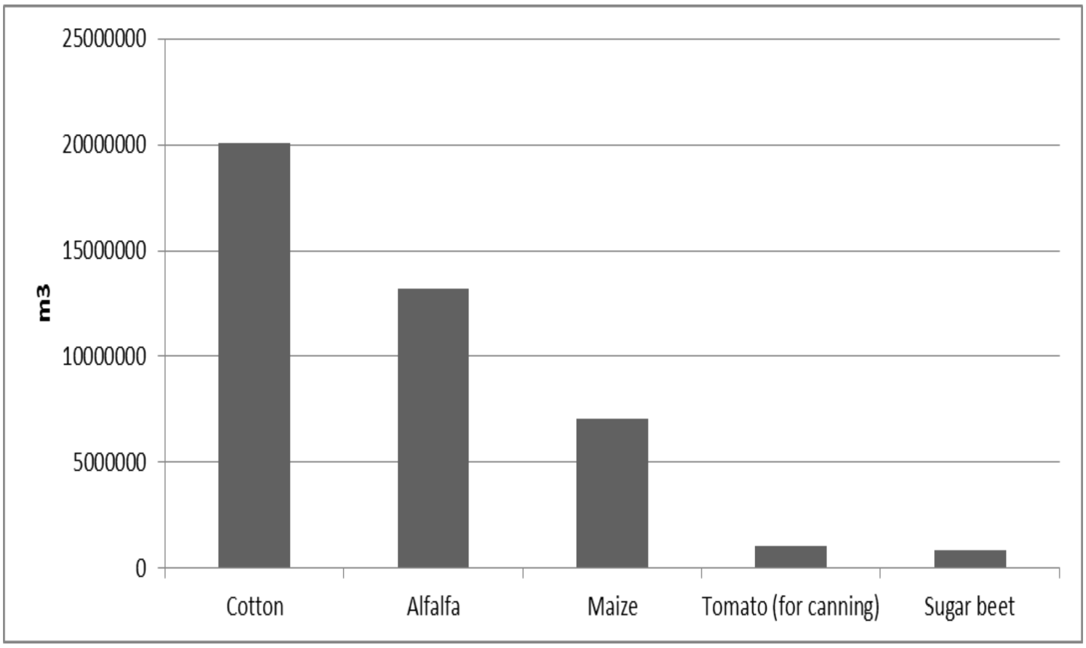

Figure 6. Seasonal water needs of the most cultivated irrigated annual crops for the region of Magnesia (five year average).

4. CONCLUSIONS

Proper planning of irrigation can ensure the viability and sustainability of water resources management. It is necessary for a water resource management authority to have the knowledge of the water needs of irrigation in order to satisfy the water demand. Thus, it is mandatory to estimate the crop water needs. The estimation of crop water needs can also assist the authorities in order to properly manage the restructuring of the crops within a region and provide crucial information to the stakeholders (ie farmers). In the region of Magnesia, the most water consuming crops have been found to be alfalfa, tomato for canning and sugar beet, with maize and cotton to follow. However, according to the cultivated area that each crop covers, the most water demanding crops in the region of Magnesia are cotton, alfalfa and maize, with tomato for canning and sugar beet to follow.

Acknowledgments

This research is co-financed by Greece and the European Union through the Operational Program «Human Resources Development, Education and Lifelong Learning 2014-2020» (MIS 5004156).

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ISBN: 978-618-5271-73-2